HEVEA BRASILIENSIS

OR

PARA RUBBER

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PARA RUBBER.

PREFACE TO THE FOURTH EDITION.

While writing this edition I have been greatly impressed by the changes which, in quite recent times, have come over the plantation and crude rubber industry. At the time of writing the previous editions in 1905, 1906, and 1908 respectively, I had the impression that the development of plantations was, in many details, in quite an experimental phase. To-day this idea must be almost entirely abandoned. The cultivation of rubber trees has proved itself to be equal to, if not more important than, that of any other plant grown in the tropical zone. *Hevea brasiliensis* has now been successfully grown throughout the Indo-Malayan region, in tropical America (including the West Indies) and tropical Africa. It flourishes on rocky hillsides, flat alluvial plains, wet soil, and dry land, at all altitudes from sea-level to 3,000 feet, and is now recognised as the most hardy and profitable rubber-yielding species under cultivation. It has continued to grow for over one-third of a century in Ceylon and Malaya and one of the oldest specimens recently yielded 160 lb. of dry rubber in two years. The crops from cultivated trees and the anticipated yields have so impressed various governments that many of them have decided to effect a radical change in their agricultural policy. Those Governments, which for many years have relied upon large revenues from Brazilian and African forests have, though at a very late hour, seen the necessity of lowering export duties, subsidising plantation developments, and encouraging the use of scientific methods and up-to-date machinery in the collection and preparation of raw rubber. This of course means a continuation of supplies and keener competition at some future period. While the growth of the Eastern plantation industry has led countries, previously dependent upon wild rubber, to protect old and foster new sources of supply, other countries, especially Ceylon, Borneo, the Federated Malay States and the Straits Settlements, have already reaped considerable financial benefit from the sale of land and new taxation. The new industry has not only changed the agricultural policies of foreign governments and general trading relationships, but it has also resulted in the opening up of land and the distribution and employment of large native populations in vast forest areas previously of no importance to the commercial world. What, in point of productivity, the planting of one million acres of rubber trees will mean, can only be manifest some six years hence, but there is ample evidence that it will materially affect many departments of commerce except some unforeseen disaster overtakes plantations. An annual yield of 100,000 tons from Eastern plantations will assuredly have its influence in many directions.

Another feature, of more than passing importance, is the wide-spread recognition gained by this new agricultural development during the last few years. The plantations in the East alone have even now drawn approximately £100,000,000 from the financial houses of Europe, and already there are signs of changes in the centres of distribution of crude rubber, which will become better defined as new supplies from the various Eastern ports increase. The security presented in well-managed plantations has drawn into the investor's list individuals from every class, from royal blood to the peasant. The press has, in almost every civilised country, recognized the commercial aspect; newspapers, magazines, and technical journals have found it advisable to chronicle the trend of events in relation to the raw and manufactured product.

Even our learned societies, colleges, and universities have realized that in this new line of tropical agriculture there is something worthy of being not only recognized, but maintained and protected. The enterprise, being largely British, means a great deal to this country; considerably more than half the world's total planted acreage is in British possessions. Our universities recognise that the success of every tropical cultivation is dependent, in the long run, on the relative immunity from diseases and pests which the plants enjoy; they also know that extensive and contiguous areas under the same species present ideal conditions for the spread of menacing epidemics among plants. The active steps taken by the Imperial College of Science and Technology in creating a chair of plant pathology, in order that men may be thoroughly trained in all that pertains to plant diseases in the tropics and elsewhere, is admittedly one of prime importance. That the rubber plantation industry should have played a part in encouraging its immediate inauguration should give satisfaction to all who have the permanency of plantations in view. Already trained mycologists and chemists have been sent to the East to render every possible assistance to planters on the spot. Diseases and pests will, like labour troubles, always be with us; they can, however, be kept in check if trained men are available and every effort is made to promptly deal with them immediately they make their appearance. It must be admitted that to the government of this country our thanks are due for having secured, on their own initiative, the original supplies of rubber plants from tropical America; it is, perhaps, not too much to hope that they will now spare no efforts to protect an industry which affects thousands of their people, and on which commerce in every civilised land is, to a small or large extent, dependent.

As far as the estates are concerned there has, in the past few years, been marked progress in the methods of tapping, coagulating, washing, drying, and packing of rubber. While some departments of estate work are still, in part, of an experimental nature, improvements have been, and are still being, effected. The greatest progress has, I think, been in the systems of tapping and in the yields obtained. When this edition was decided upon I issued printed forms to all managers of Hevea plantations, and directors of rubber companies, soliciting definite statements regarding the methods of tapping trees of various ages, the thickness of bark shavings, the kind of knife preferred and the yields from trees varying in age from three to twenty-five years. It is owing to the very willing help rendered by the responsible officers of the various estates and companies in Ceylon, Malaya, and the Dutch East Indies that the chapters dealing with these subjects have been written.

I hope that the low average yield obtained on some estates and in certain countries will lead to a much closer investigation as to the causes. Poor soil, overcrowding of the plantation and weeds are largely responsible for the low average yields herein quoted from particular countries or estates; the first can be remedied by proper tillage and manuring, the others by better financial and estate management. It must also be borne in mind that low average yields may, to a very large extent, be compensated for by the excellence of the management; the countries of highest average yield per tree are those where labour and staff expenses are comparatively high.

In the length of time allowed for renewal of bark there has been very little change, though there is still a widespread desire to tap the newly-formed tissue as soon as its thickness is equal to that of the old bark, and consequently a tendency to adopt a three-year cycle instead of one of four years. Though much depends upon the rate of growth, I am, in general, inclined to the view that it would be wiser to lengthen rather than shorten the four-year interval which I have up to the present advocated.

It has been found impossible to keep to the plan adopted in previous editions; the growth of the industry and the estate improvements effected have necessitated my taking a much wider view of the whole subject, and in fact re-writing original chapters and adding many new ones. My information has been drawn from numerous sources, including estate documents connected with companies in which I am particularly interested, and general literature on the subject. I have not hesitated to use matter appearing in the India-Rubber Journal, and my other books bearing on rubber cultivation.

In the preparation of this edition I have received valuable assistance from many friends. Above all, I must acknowledge Mr. W. T. Gibson, A.R.C.Sc., for his valuable assistance from the beginning to the end of this work, and especially for the

various statistics and the detailed index he has compiled. Had I not been able to obtain his services I fear that the publication of this edition would have been long delayed. I have also to thank Dr. P. Schidrowitz for suggestions incorporated in the chapter dealing with the chemistry and testing of rubber ; Dr. D. Spence for his notes on proteins ; Mr. Tabor for the drawings showing the anatomy of the stem of *Hevea brasiliensis* ; Mr. Kurt Pfleiderer for reading the manuscript of the chapter on washing of rubber ; the managers, directors, and secretaries of plantation companies for furnishing me with up-to-date information ; and the numerous firms who have so generously supplied me with illustrations.

H.W.

March 8th, 1912.

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THE HISTORY OF PARA RUBBER.

It is natural that Christopher Columbus should be associated with our product. History relates that on his second voyage to America (1493-1496) he saw the natives of Haiti playing with balls of *gum*. Further references in 1525 were made to this substance by d'Anghiera, and to trees in Mexico by Torquemada in 1615. These and many other historical facts refer, in all probability, to rubbers from trees other than Hevea.

Priestley, in 1772, by pointing out that the substance from the trees had the power of removing pencil marks from paper, was responsible for the name *indiarubber* by which the product is likely to be known to the English for all time.

It was not until Charles Goodyear and Thomas Hancock pointed out, in 1842 and 1843, the changes consequent on applying heat to raw rubber with which sulphur was mixed, that this substance took its place as one of the most important commercial products with which plants can be associated.

Probably the first account of species of Hevea was that made by Condamine, who, in 1773, was sent to measure an arc of the meridian near Quito (Kew Bull., 1906). The tree yielding rubber in the Andean region was named *Heve* or *Jeve*; in the Amazon valley it was called *Cahuchu*—a word which suggests similarity to the German *Kautschuk* (*caoutchouc*). In Brazil the Portuguese generally call the rubber *Seringa*, the native collectors *Seringueiros*, and the tree *Pao de Seringa*. In the Kew Bulletin, 1906, it is stated that "these names suggest that the syringe was one of the earliest uses to which indiarubber was locally applied."

Various Rubbers from Hevea and other Species.

The position now occupied by species of Hevea as sources of rubber is indicated by the following table (Spence, Lectures on Indiarubber):—

Trade Name.	Geographical Origin.	Chief Export Centres.	Botanical Origin.
1.—Para, fine Island, soft cure. 2.—Para entrefine, Islands entrefine. 3.—Negroheads or Islands coarse, Sernamby.	Brazil, the islands of the lower Amazon and its delta, also other parts of the State of Para.	Para	*Hevea brasiliensis*, Muell. Arg. *Hevea* sp. "*Itauba*," Ule. *Hevea Spruceana*, Muell. Arg. *Sapium taburu*, Ule.

Trade Name	Geographical Origin.	Chief Export Centres.	Botanical Origin.
4.—Fine Para, upriver, hard cure 5.—Upriver entrefine, hard entrefine. 6.—Upriver coarse or Manaos Scrappy Negroheads.	The district lying on both sides of the Amazon and some distance up. Also the district drained by its large tributaries, the Jurua, Madeira, Rio Negro, etc.	Manaos, Para. Iquitos, Serpa.	*Hevea brasiliensis*, Muell. Arg. *Hevea* sp. '*Itauba*' Ule *Hevea discolor*, Muell. Arg. *Hevea* sp. from Rio Negro. *Hevea similis*, Hemsl. *Hevea biglandulosum*, Ule. *Micrandra syphon oides*, Benth.
7.—Cameta Negroheads.	South Western Para.	River Harbour, Cameta.	*Hevea brasiliensis*, Muell. Arg. *Hevea Spruceana*, Muell. Arg. *Sapium tabura*, Ule.
8.—Caucho Balls. (Also Peruvian) 9.—Caucho Slabs and Strips. (Also Peruvian)	Amazon district and its southern tributaries also yielding Para.	Manaos, Para, Iquitos, Serpa.	*Hevea brasiliensis* and other Hevea species. Various species of Sapium for Caucho blanco and *Castilla Ulei*, Warb., for Caucho-negro.
10.—Matto-Grosso, fine and entrefine.	Province of Matto-Grosso, Brazil.	Montevideo. Rio de Janeiro.	*Hevea*, probably *brasiliensis*, and others.
11.—Matto - Grosso, Virgin Sheets, White Para.	do.		
12 —Matto-Grosso, Negroheads.	do.		
13.—Bolivian, fine medium.	Bolivia.	Manaos, Mollendo, Arica, & various Peruvian & La Plata Ports.	Various species of Hevea.
14.—Virgin, coarse, entrefine.	do.		
15.—Uncut Bolivian.	do.		
16.—Mollendo, fine, medium and coarse.	South Bolivia, and small lots from Peru.	Mollendo.	Various species of Hevea.
17.—Peruvian, fine, medium and scrappy. Peruvian Balls (also Caucho).	Peru.	Iquitos. Manaos. Mollendo.	*Hevea brasiliensis*, Muell. Arg. *Hevea* sp. "*Itauba*," Ule.
18.—Orinoco, also Angostura or Ciudad Bolivar.	Venezuela.	Ciudad Bolivar.	*Hevea Knuthiana*, Hub.

History of Para Rubber Exports.

The history of Para rubber exports furnishes one of the most instructive lessons in economic botany. The most interesting development has yet to be witnessed when the product from plantations established prior to and since 1906 is placed upon the world's market to compete with material derived from the same species in Brazil.

Brazil exported only 31 tons of rubber in 1827—twenty years later 624 tons; in 1867 she exported 5,826 tons; and it was not until an interval of over fifty years had elapsed that a total of 10,000 tons was obtained in one year from the whole of Brazil. The following figures (I.R.J., Sept. 7th, 1908) will serve to illustrate the slow development of raw rubber supplies from 1827 to 1910:—

Exports of Para Grades (and Caucho) from Brazil.

1827 to 1852.

Year.	Metric tons (approximate).	Year.	Metric tons.
1827	31	1843	340
1828	50	1844	451
1829	91	1845	561
1830	156	1846	673
1836	189	1847	624
1837	283	1848	901
1838	243	1849	978
1839	391	1850	1,466
1840	388	1851	1,582
1841	339	1852	1,632
1842	270		

1853 to 1910.

Year.	Amazonas. tons.	Para. tons.	Total. tons.
1853	1	2,365	2,366
1854	33	2,682	2,715
1855	85	2,111	2,196
1856	239	1,665	1,904
1857	212	1,596	1,808
1858	—	1,745	—
1859	116	2,557	2,673
1860	208	2,463	2,671
1861	251	2,262	2,513
1862	294	3,060	3,354
1863	550	3,484	4,034
1864	52	3,413	3,465
1865	—	3,545	—
1866	624	4,810	5,434
1867	870	4,956	5,826
1868	990	4,661	5,651
1869	1,096	4,779	5,875
1870	1,360	5,241	6,601
1871	1,370	5,394	6,764
1872	2,011	6,206	8,217
1873	1,906	6,384	8,290
1874	2,193	5,522	7,715
1875	2,164	5,565	7,729
1876	1,733	6,175	7,908

Year.	Amazonas. tons.	Para. tons	Total tons.
1877	2,573	6,641	9,214
1878	2,773	4,038	6,811
1879	3,246	6,889	10,135
1880	3,362	5,317	8,679
1881	3,385	5,317	8,702
1882	4,358	5,713	10,071
1883	2,349	5,470	7,819
1884	5,547	5,610	11,157
1885	5,508	6,273	11,781
1886	6,177	6,512	12,689
1887	6,744	6,645	13,389
1888	8,011	7,678	15,699
1889	7,818	8,171	15,988
1890	10,710	4,644	15,354
1891	9,345	7,304	16,649
1892	11,775	6,474	18,249
1893	10,809	8,240	19,049
1894	11,661	8,048	19,709
1895	11,100	8,209	19,309
1896	12,385	8,870	21,255
1897	12,905	9,834	22,739
1898	12,596	9,312	21,908
1899	—	9,736	—
1900	—	9,954	—
1901	15,694	13,467	28,161
1902	13,711	13,406	27,117
1903	16,509	12,559	29,068
1904	15,334	13,171	28,505
1905	15,253	16,221	31,474
1906			34,220
1907			36,921
1908			36,991
1909			39,112
1910			38,200

The figures for 1906 to 1910 are those given by the British Consul at Para, and refer to the exports (including caucho) from Para, Manaos, etc. Messrs. Samuel Figgis and Co., London, give the following statistics of crop in their annual report for 1911 :—

	1911. tons.	1910. tons.	1909. tons.	1908. tons.
Brazil, Peru, and Bolivia	37,730	38,200	39,050	38,160
Including Peruvian and Caucho	6,440	8,160	8,250	7,460

African Crops.

It is interesting to note the progress of African crops, as compiled by Messrs. Samuel Figgis & Co. The following figures are given :—

	1911. tons.	1910. tons.	1909. tons.	1906. tons.
West Coast African (total about)	15,000	14,800	15,500	17,200
including Benguela and Mossamedes	1,900	1,600	1,920	1,450
Loanda	430	800	950	700
Congo, French Congo and Soudan	6,200	6,000	6,300	5,900

A more complete set of statistics (I.R.J., Dec. 30th, 1911), is now available, showing the output for practically the whole of rubber-producing Africa:—

	1909. tons.	1910 tons.
French Colonies	6,647	7,340
Congo Free State	5,217	5,000
Portuguese Possessions	3,161	3,504
British Colonies	1,974	2,818
German Colonies	2,114	2,800
	19,113	21,462

The production of some parts of Africa not included in the above table would probably bring the figures up to 22,000 tons or thereabouts in 1910.

The foregoing details give us some idea of the progress of wild rubber supplies from the two principal continents—tropical America and Africa. It is now necessary to study more closely the conditions prevailing where these huge quantities of rubber have been harvested, and to detail the changes likely to occur in consequence of plantations having been established in other parts of the world.

Wild Rubber Developments.

Hitherto wild rubber has been obtained from forest trees or vines indigenous in local areas, and has been collected mainly by native labourers who have bargained their harvests for articles of food, etc., and who in their work have frequently adopted methods requiring the minimum skill and involving the destruction of the plants. To-day, the business of rubber exploiting in tropical America and Africa is being supervised by companies which are aiming at the preservation of the original wild plant, and in some cases the reafforestation of areas poorly represented in wild rubber species by indigenous or introduced rubber-yielding trees of known value. The terms under which much land has been leased in Brazil and the Congo provide that a definite acreage shall be planted each year, thus ensuring that the sources of supply shall, if possible, be maintained.

Importance of Wild Rubber Supplies.

The sources of wild rubber are receiving much more consideration and care than was the case a few years ago, and may for many years to come be expected to annually supply large quantities of the raw material. Rubber manufacturers have hitherto been dependent, almost entirely, on wild rubber; and it seems illogical to suggest that the rubber forests on which so much new capital and enterprise have been recently expended, and in which prominent scientific and business men are concerned, will be unable to satisfy, in part, the increased demand expected in the next few years.

Though the extraction of rubber from indigenous trees, vines, and shrubs in African and American forests has been hitherto mainly carried out at the sacrifice of the plants yielding caoutchouc, it must not be surmised that this practice is always adopted. In only one case—guayule—does destruction of the plant appear necessary. Most of the companies of recent birth, formed for the exploitation of rubber from wild sources, are paying attention to the planting of ordinary jungle or areas which already possess a fair proportion of rubber trees, and are carefully supervising collecting operations wherever possible.

Change in Wild Rubber Grades.

The material exported from the wild rubber areas in America will probably retain much of its present character, whereas that from tropical Africa may show considerable changes in the future and tend to become somewhat similar to that from America. This is suggested from a study of the developments which are now going on in both countries. In American areas attention is mainly directed to the cultivation and exploitation of species indigenous there, and though a few species of Landolphia, Funtumia, and Ficus from Africa and the Indo-Malayan region have been tried, they do not appear to give very satisfactory results. On the other hand, nearly every part of tropical Africa is carrying out extensive experiments with Hevea and Manihot species from America, and in consequence of the success which has already been achieved, one, if not more, of the three American genera is likely to be largely adopted. The cultivation of climbing plants and of root rubbers is generally more difficult and expensive than that of arborescent forms, and it appears probable that the produce of the latter will largely increase, and that of the former decrease in quantity. Judging from results obtained, it appears to me that the cultivation of species of Hevea, Castilloa, Funtumia, Manihot, Sapium, and arborescent forms similar to them, will predominate in the future, and that of species of Landolphia, Cryptostegia, Clitandra, Carpodinus, and Willughbeia, etc., gradually become relatively insignificant. Plants of the former group require less supervision, they attain maturity at an earlier age, they allow of continuous tapping operations for several years on the same tree, and under certain conditions yield rubber in larger quantity and of better quality than do those of the latter class.

In the Indo-Malayan region, the indigenous species of Cryptostegia, Leuconotis, Parameria, Rhynchodia, etc., and even of Ficus and Sapium, are gradually being neglected in preference to those from tropical America. Species of Manihot, Ficus, and Castilloa do not appear to give as favourable results as *Hevea brasiliensis*, and before very long that area will stand out remarkably for the uniformity of the greater part of its exported rubber. *Hevea brasiliensis* appears to have been taken up in the East almost to the exclusion of all other rubber-yielding plants, and even the coconut palm has been felled in order to make room for this favourite species. It is very rare in Ceylon or Malaya that one meets with plantations of Castilloa, such as those in Mexico, or of Manihot, as in parts of Bahia and East Africa.

DIFFERENCES BETWEEN WILD AND PLANTATION AREAS.

Eastern rubber estates are nearly all planted with tree forms; only a few possess indigenous trees or climbers, and the waiting period is consequently very long. Properties in Malaya, possessing trees of the indigenous *Ficus elastica*, have nearly all been regularly and systematically planted with seedlings reared in the nursery, and in this feature differ from the wild or pseudo-wild areas.

Again, it may be stated, with some degree of accuracy, that the rubber output from most parts of tropical America and Africa is dependent upon native efforts; there the amount of skilled supervision is small compared with that on planted estates in the East. I have been informed by residents in prominent wild-rubber areas that they have only a few practical men of repute. In Ceylon, Southern India, Sumatra, Java, Borneo, Federated Malay States, Straits Settlements, etc., the estates are managed by Europeans having considerable tropical experience, and their system of keeping records and accounts, and their knowledge of engineering, surveying, languages, etc.—all of which play a very important part in the ultimate success of any rubber plantation—are such as to command complete confidence. The number of planters drawn from Ceylon to engage in the rubber industries of the Malay Archipelago is very large, and from a few years' experience in that island I anticipate that good work will be done.

It is now generally admitted that *Hevea brasiliensis* has, on Eastern plantations, been proved to give excellent results, and to stand tapping operations even of a very drastic nature. This cannot yet be asserted for many Castilloa plantations in Mexico and Central America, or even for those of Manihot (Ceara) in Brazil, or Landolphia and Funtumia in Africa, though favourable results from many of these are expected.

Plantations of rubber trees are capable of being worked more economically than forests of mixed plants; the number of rubber trees is generally accurately recorded, they are capable of being minutely inspected daily, and there are often more rubber trees in one acre of an Eastern plantation than in several square miles of American and African forest. Of course, it is possible to plant in any country, but the abundance and cheapness of the Indian, Javanese, Chinese, and Malay labour make it possible to do planting work cheaper in the East than in most parts of the tropics.

It is asserted by many that tropical plants will thrive best in their native habitats; this statement can be seriously contested, and is often contradicted by the results obtained from introduced plants in the tropics. True, the indigenous rubber-producing plants in the American and African forests represent types which, in their native countries, have survived in the struggle for existence, and have often successfully contested certain pests. But it is well known that a change of climate is sometimes beneficial to the plants, and that under cultivation they may yield far larger crops than in their wild native state.

Future Supplies from Brazil.

The foregoing remarks must not be taken to suggest that the sources of wild rubber are going to be completely obliterated when supplies from plantations are forthcoming in large quantities. I believe that plantations will more severely affect the inferior wild rubbers from Africa than the first-quality grades from Brazil. Furthermore, the effect on the latter will only be one of curtailment and not entire obliteration. It has been the same in the history of many other tropical products. It should never be forgotten that Brazil lives on its rubber and is not likely to allow such a source of revenue to be entirely destroyed; a large number of the natives have no other means of making a living other than by collecting rubber. Witt (Lectures on Indiarubber) assures us that "it is not at all unlikely that even at low prices people in Brazil will be able to compete very well with the East . . . . Should rubber prices ever go very low it is not to be supposed that the Governments . . . . would keep up the heavy taxation of rubber . . . . There is a very big margin left should prices ever drop, say to 2s. per lb." Other tropical industries could be mentioned which are kept alive, by native labour, when Europeans find it unprofitable to engage in them.

Vasconcellos, the Commissioner for the Federal Government of Brazil, reminded us quite recently, that Brazil was the habitat of rubber and that the Government were quite aware of the competition ahead. Speaking of Brazil he said, "It is awake also to the necessity for arming itself with instruments equal to those of its competitors, so that it may obtain its due; not privileges, but fairness and justice. It is only right that you should know that my Government is paying great attention to the necessity of ameliorating the rubber situation in the country by removing the two obstacles which exist at present, want of labour organisation and excessive taxation." It is quite clear that Brazil is fully alive to the necessity of protecting its main source of revenue.

Sandmann is of the opinion that the living expenses of the seringueiro, now the equivalent of 1s. 10d. per day, are very high on account of the absurd prices of food stuffs. These can be reduced by more efficient organization, and by opening up the land for the cultivation of food crops. In this way there appears to be a possibility of reducing the average daily cost to about 6d., which, if accompanied by the abolition of taxes, would enable supplies of rubber to be shipped from Brazil for some time to come.

Government encouraging Plantations in Brazil.

The respective Governments in Brazil have recognised the change which is likely to take place in the raw rubber industry in consequence of the development of plantations in the East.

The Governor of the State of Para, in his annual message (I.R.J., November 14th, 1910), warned the producing interests of the State against the error of supposing that South America was the only rubber-producing country of importance. He drew attention to the growing importance of rubber planting in the British Colonies. History had shown that careful and scientific culture competed on favourable terms with wild extractive industries. It was not that he did not have confidence in the industrial and commercial future of Para. But he warned them against prodigality during periods of abundance, and urged the necessity of forming plantations. He did not despair of Para holding its own if these recommendations were adopted, and provided that production was at least doubled.

Two years ago I pointed out (I.R.J., December 13th, 1909,) that the Brazilian Federal Government was about to make a move in the systematic planting of rubber. It was proposed to offer those who would undertake to plant a million trees or so, free land and total exemption from duties on exports of rubber for a long term of years, with possible participation by Government in profits.

According to the Consular Report for 1909 it is owing to the defective methods of tapping and coagulating in Brazil that only 45 per cent. of the rubber collected is "Fine," the rest being of the inferior grades fetching often only half the price of "Fine" rubber. During 1909 a process was invented by Dr. Pinto for preparing crude rubber, and to test the value of this preparation, a ton of Hevea and a ton of Caucho prepared by this system were to be sold on the open market in New York. Dr. Pinto received a premium of £2,500 from the Federal Government for his invention.

Supervision and Protection of Trees in Brazil.

While it is admitted that the Brazilian Government has recommended measures to stimulate plantation work, but little appears to have been done in the way of protecting the forests from which the States of Para and Amazonas draw some 70 per cent. of their revenues. The difficulty of supervising rubber trees in the forest areas is general throughout Brazil, though the plantations do not suffer in the same way.

The Brazilian Position in 1910.

At the end of 1910 I was able to report that the schemes for fostering Hevea rubber cultivation in Acre, and proposals having reference to the State of Para and the Municipality of Anajas, had progressed satisfactorily. The State of Para has modified the taxes on rubber from plantations, charges on rubber going outwards have been lowered, and free transport has been conceded on machinery, seeds, etc. Furthermore, the authorities have come to the financial assistance of people prepared to carry out plantation work on a large scale. Companies thus deriving financial assistance from Government have to undertake to plant several thousand seeds annually, and to observe the instructions of the Agricultural Department; they have also to maintain schools and to train men for agricultural work on estates. In the event of the regulations of the Government not being complied with, the concessions leased to private individuals revert to the State. The Municipality of Anajas offered substantial bonuses for every 500 trees properly planted. In this way the Government are practically determining the future of the industry. The Peruvian Government has not lost sight of the importance of plantations, and has agreed to pay, in cash, a premium for every rubber tree of three years old grown on a plantation; this is equivalent to giving a government guarantee on capital thus invested.

In 1910, Dr. Huber, of Para, wrote that the premium had already been paid upon over 4½ million trees in Para.

Proposals from Acre.

In August, 1909, a congress of proprietors of rubber estates was held in the Acre territory to discuss the best means of maintaining prices and developing the rubber industry. The message which the Congress, on the conclusion of the sittings, forwarded to the President of the Republic, states the chief difficulties under which the rubber industry labours not only in the Acre, but throughout the Republic. The remedies they proposed included: Legislation to confirm actual proprietors of estates in their possession; establishment of roads; development of railway; subventions to steamships; further Government aids to colonisation; the appointment of a commission to study rubber plantations in Ceylon, etc., and reduction of taxation, especially of export taxes. Action upon these lines would certainly improve the prospects of wild rubber from this area.

When such developments by the various governments are considered in conjunction with the many improvements in the way of machinery for turning out better-grade rubber, it is quite apparent that though in the future the supplies from these countries may be curtailed, we shall always be able to rely upon considerable quantities being annually harvested. We have, however, some doubts as to whether the various Governments in Brazil, acting through their Agricultural Departments, will be able to control the proper planting and cultivation of subsidised estates. Experience in the Congo, where perhaps conditions have not been so favourable, does not inspire us with confidence in this work. Nevertheless, we firmly believe that some progress will be reported within a few years as the result of the wise measures adopted by Government Departments in Brazil.

Recommendations by the Manaos Rubber Congress.

The Congresso Commercial Industrial e Agricola, organised by the Commercial Association of Amazonas, with the support of the State Government, was recently held at Manaos, and decided to recommend to the public authorities of the countries and states represented in the Congress the re-modelling of the existing rates for freightage, especially those relating to food supplies requisite for the maintenance of workers in the rubber-extracting industry. They emphasised the urgency of ameliorating labour conditions in the rubber-extracting industry. They recommended the public authorities of the State to improve the means of communication for the municipalities of Barcellos and Sao Gabriel, on the river Negro where the defective navigation is the cause of a great part of the extractive wealth being as yet unexplored.

The Congress recognised as a pressing and urgent necessity the planting of rubber trees in Amazonas Valley, and made suggestions regarding model plantations of Hevea rubber to be made by the States, Municipalities, and Agricultural and Commercial Associations on their own account; they suggested free grants of land for this culture; reduction of export tariffs for plantation rubber; propaganda through the press, and by means of circulars, etc. demonstrating the advantages of planting and giving practical advice on the method of planting; and liberal distribution of seeds and plants of *Hevea brasiliensis*. The Congress also recommended the present owners of rubber estates to interplant and re-plant existing estradas, and to plant in open spaces, forests, or any clearing made in the forest.

The Congress advised the Governments to advertise extensively, in Europe and in the United States, the advantages of investing capital in the rubber industry of the Amazonas. Peculiar to relate, at this late hour, they advised the planting of *Hevea brasiliensis* in preference to all other varieties, owing to the backward state of knowledge relating to the cultivation of other trees. The authorities were also asked to exempt from import duties all and every modern machine intended to improve the present methods of tapping and preparation of rubber and kindred products in the Amazonas Valley. If half of these valuable suggestions are adopted the future of Brazilian supplies is definitely assured.

Sufficient has been written to prove that plantation work and protection of wild trees will go hand in hand if the Brazilian Government receive encouragement. It is now necessary to turn to the second largest source of raw rubber—the African continent—and see what steps are being taken there to maintain a supply.

African Plantations.

It becomes more evident day by day that the future of the Belgian Congo will depend on the plantations already established and to be established. It is averred that equatorial forests, in the Congo, in general are becoming more and more exhausted, which renders their progressive exploitation more difficult. The Secretary for Foreign Affairs, London, recently reported that the Belgian Government intended to plant 2,000 hectares with rubber annually.

The experimental cultivation by the Government of *Hevea brasiliensis, Funtumia elastica,* and *Manihot Glaziovii* is receiving notice, and extensive areas in addition to those already existing are to be cultivated. About 2,470 acres have been planted up with Hevea at the ten centres, and encouraging results obtained. Experiments with *Manihot Glaziovii* have been made at 20 stations, the number of trees being about 185,200, and the results being satisfactory, this species is also being taken up. The most extensive plantations are those of *Funtumia elastica,* the number of trees being 3,461,000; but it does not appear that any further development of this species is thought of. Experiments are also in progress with Castilloa, various species of Manihot and Ficus and a Euphorbia. Attention is also being given to the lianes, of which some 11,000,000 are known to exist in plantations. It is reported that at least 20,000,000 have been planted. The climatic and soil conditions within the Congo vary greatly, and some parts are more suitable for *Manihot Glaziovii* than for *Hevea brasiliensis.*

In addition to Belgian there are other interests at work in Africa—East, West, and Central—which will enable the merchants to maintain a fair supply of raw rubber in future years. Uganda, West Africa and German East Africa are already sending increased supplies from semi-cultivated trees or mature plantations of Funtumia and Manihot.

Equivalent Acreage of Wild Rubber Crop.

Granting the existence of these sources, it is now necessary to determine their value compared with regular Eastern plantations. The annual rubber-yielding capacity of tropical America can be assessed at approximately 40,000 tons; this indicates the enormous tracts of land covered by the wild Hevea trees in Brazil whence the major portion of this crop is derived, especially if Wickham's estimate (T.A., May, 1908) of 6 or 7 trees per acre is accepted. Cultivated rubber estates of any magnitude, in bearing, are almost non-existent in Brazil; the produce is collected from wild trees by labourers who either live on the spot, or periodically visit the forests as soon as the rivers have subsided. To determine the equivalent of these wild trees in terms of planted acreage is extremely difficult owing to the varying age and yielding capacity of the trees. If we assume that the wild trees yield at the rate of 4 cwt. (say, 450 lb.) per acre per annum, the annual crop of rubber from Brazil is equivalent to that obtainable from only 200,000 planted acres, assuming the crop to be pure rubber.

Calculated on the same basis, a total annual crop of 70,000 tons of rubber for America and Africa is only equivalent to the produce from 350,000 acres. It is apparent in this suggestion that I have assessed the yielding capacity of an acre of land planted with Hevea relatively high. My reason for doing this is that though my previous basis of "one ton per ten acres" has proved to approximate to the actual outturn up to the present from Ceylon, it is a yield which should be largely exceeded when well-cultivated Hevea trees attain their seventh year. In the chapter on "Yields" it will be shown that a few estates in the East possessing old Hevea trees have given crops quite equal to 4 cwt. per acre, or one ton per five acres. The above deduction will be referred to later when dealing with a comparison of future crops from various areas.

Evolution of Eastern Planted Acreages.

Having seen the gradual evolution of the Brazilian crop from 1827 to 1911 and the equivalent in planted acreage of its maximum annual outturn, we are in a position to make a more interesting comparison with the plantation industry. The differences between the histories in the two areas are marked, for in the East there is only a small crop of rubber to chronicle up to 1911, though an unparalleled development in planted acreages is recorded. At some future date about 200,000 acres in Ceylon will be rubber-producing. Malaya has about 400,000 acres that will all be in bearing. And the total world's acreage that may be depended upon to yield is 900,000 acres. From the progress thus made it is clear that the plantation industry is destined to play a leading part in the future of the world's supplies of raw rubber. Ceylon has now established a position which should enable it to produce more rubber yearly than is annually turned out from the whole of Africa ; Malaya has placed itself in the first position in the British Empire and should be able, together with other Eastern countries, to annually produce crops of rubber greater than those hitherto obtained from America and Africa combined.

Growth of Brazilian and Plantation Supplies compared.

Now let us study the figures showing what has been exported from Brazil from 1827 to 1911. It took about 80 years to raise the Brazilian output from 50 to 36,000 tons. In the first thirty years—1827 to 1857—Brazil raised its output to 1,800 tons ; the East equalled that total nearly three years ago. Brazil required over 50 years to produce an annual crop of 10,000 tons : the East turned out over that amount in 1911. But think of the handicap—Brazil started with its dense forest and old indigenous tappable trees over thousands of square miles of territory. The East commenced with a couple of thousand seeds secured by Wickham in 1876, had to rear them into seed bearers, and to wait for scientific experiments to demonstrate the value of, and public interest to be aroused in, the cultivation of Hevea. So far the crops from the East have been small, but when considered in relation to the acreages in bearing, they unmistakably show that a high average annual yield can reasonably be expected in the future. The progress of crops from the East so far—500, 1,000, 1,800, 3,800, 8,200, and 14,150 tons—for the respective years 1906, 1907, 1908, 1909, 1910, and 1911, is almost meteoric compared with the early growth of wild rubber supplies.

Malayan Exports.

The two principal sources of supply will be Malaya and Ceylon. First consider Malaya.

There is apt to be confusion if one deals with the crops of Hevea rubber from the F.M.S. instead of the whole of Malaya. For instance, the crop of rubber for F.M.S. in 1907 was given by the Director of Agriculture at 1,990,754 lb., or 893 tons; but the total crop from Malaya was (F.M.S., Straits Settlements, etc.) 2,278,870 lb., or approximately 1,036 tons.

The Director of Agriculture for the F.M.S. gives in his last report the total crops foi Malaya during the years 1906 to 1910, which were: 1906, 935,056 lb. (425 tons); 1907, 2,278,870 lb. (1,036 tons); 1908, 3,539,922 lb. (1,655 tons); 1909, 6,741,509 lb. (3,064 tons); and 1910, 14,368,863 lb. (6,531 tons).

So far as can be estimated from the official returns of exports, the output in 1911 was nearly double what it was in 1910.

The above statistics are based upon census papers filled in by estate managers. They are not the same as those given in the Annual Return of Imports and Exports for the Straits Settlements, through which all Malayan rubber at one time passed.

Distribution of Malayan Rubber.

The following table, compiled from the official return of exports, shows the destinations of the cultivated rubber exported during the years 1906-9 from Straits Settlement ports, but not Port Swettenham. It includes rubber produced not only in the peninsula, but also in the Dutch East Indies:—

	1906. cwts.	1907. cwts.	1908 cwts.	1909. cwts.
United Kingdom	6,734	14,514	26,830	3,4468
Australia	88	284	191	824
Hongkong	—	—	5	—
Ceylon	710	2,064	2,772	1,872
Austria	—	6	—	—
Belgium	532	1,168	2,492	2,001
Denmark	100	165	135	206
France	55	102	83	46
Germany	20	202	57	141
Holland	14	10	7	—
Italy	—	2	—	—
United States of America	122	37	4	201
Japan	32	104	101	443
	8,407	18,658	32,677	40,202

It will be noticed that very little rubber went direct from these ports to America during 1909. If, however, the distribution of Ceylon rubber is studied for the same year it will be seen that large quantities, considerably in excess of Malayan imports into Ceylon, were shipped to America.

Estimated Output from Malaya.

In a speech made at Kuala Lumpur, Sir John Anderson—the Governor—is reported to have stated that, "We have in the peninsula already alienated for rubber an amount of acres which runs into seven figures. A great deal of it is not yet under cultivation, although the capital necessary to bring it into cultivation is available. Actually under cultivation at present in the peninsula there are 400,000 acres under rubber, some of which is several years old and already producing large returns. Six years ago the export of rubber was five tons ; before the end of this year (1910) we shall have exported at least 6,000 tons—a considerable advance for six years, but nothing to the advance which will be shown in the next five or six years.

If you consider that there are 400,000 acres under cultivation, a great deal being three years old and much more, you may reckon an average output per acre of 400 lb. as not excessive, and we shall be turning out 160,000,000 lb., or 70,000 tons, of rubber in six years' time.''

How the planted acreage of 400,000 acres is arrived at is not stated, but the Director of Agriculture reported that in 1909 there were 292,035 acres planted in the whole of the Malay Peninsula. H. K. Rutherford (I.R.J., October 3rd, 1910) gives the following estimate of rubber from the Federated Malay States only :—

Estimated Output of Plantation Rubber from the F.M.S.

Years.	Tons.
1911	8,100
1912	12,100
1913	17,040
1914	22,670
1915	27,300
1916	35,690

The Director of Agriculture, F.M.S., Mr. Lewton-Brain, in his report for 1910, advances some estimates of future yields in Malaya. The yield for 1910 being 6,410 tons, he believed that 10,950 tons would be got in 1911, 18,750 tons in 1912, 26,550 tons in 1913, 35,640 tons in 1914, and in 1916 he estimates 65,000 tons.

Exports from Ceylon.

For some years previous to 1903, plantation rubber left Ceylon only in small quantity, but in that year the exports began really to assume definite proportions. The figures given by the Colombo Chamber of Commerce show how decided has been the increase since then. All rubber passing through the port from Malaya, etc., has been excluded :—

	Tons.		Tons.
1903	19	1908	407
1904	34	1909	666
1905	75	1910	1,472
1906	147	1911 (to Dec. 18)	2,729
1907	248		

Distribution of Ceylon Rubber.

The rubber shipped from Ceylon in 1908, 1909, and 1910, was distributed as follows :—

	1908.	1909.	1910.	1911. (9 months.)
	cwts.	cwts.	cwts.	cwts.
United Kingdom	5,001	8,193	14,037	19,465
Australia..................	349	93	52	246
Canada	—	—	67	123
Belgium	50	321	686	4,100
France	24	15	10	·1
Germany	437	190	151	234
Italy	10	10	17	32
U.S.A.	2,262	4,483	14,379	11,687
China and Japan	—	19	44	355
Miscellaneous	10	2	9	44
	8,143	13,326	29,452	36,287

The shipments from Ceylon for the first nine months of 1908, 1909, and 1910, were 4,883, 7,883, and 18,249 cwts. respectively.

Estimate of Rubber Crops from Ceylon.

A Ceylon correspondent estimates that at present there are 220,000 acres in Ceylon, from which in 1920 he predicts a yield of 20,000 tons.

In their directory, Messrs. Ferguson, of Colombo, give the following as the probable exports :—

	Acres in bearing	Possible Exports. tons.
1911	25,000	2,500
1912	40,000	3,500
1913	100,000	7,500
1914	150,000	10,000

This is less than one ton per ten acres, and should be exceeded.

The Outturn of Rubber by the Larger Companies.

The yielding capacity from good Eastern plantations will give a few surprises in years to come. How many, even among the optimists, will question the suggestion that some companies will individually produce 1,000 tons or more per annum ? Let us take a few companies, the names of which are known to most of us, and add to them the acreages planted or in course of planting this year (1911) :—

	Present planted acreage.
Malacca Rubber Plantations	15,000
Grand Central (Ceylon) Rubber Estates	12,491
Mount Austin (Johore) Rubber Estates	10,936
United Serdang (Sumatra) Rubber Plantations ..	8,285
Anglo-Java Rubber and Produce Co.	6,658
Rosehaugh Tea and Rubber Co.................	6,534
Rubber Cultuur Maatschappij "Amsterdam" ..	6,500
Bukit Sembawang Rubber Co.	6,427
Merlimau Rubber Estates	5,629
Malayalam Rubber and Produce Co.	5,524
Linggi Plantations	5,000
General Ceylon Rubber and Tea Estates........	5,000

These acreages include immature as well as mature rubber, and interplanted rubber also ; but when all the Hevea trees on each of these estates have passed their seventh year, every one of the estates, if they are efficiently handled, will eventually, at the rate of 1 ton per 5 acres, turn out its 1,000 and more tons per annum. The aggregate planted area of these twelve companies being nearly 95,000 acres, their future aggregate crops may amount to 19,000 tons and more. If we assume that 15 per cent. is the average loss on washing and drying Amazonian rubber, this is equivalent to 21,850 tons and more of rubber from that source.

Coming behind these companies, some very close to them, are others with a considerable planted área, and it will be interesting to know what crop of rubber per acre they will require to turn out to ensure a total annual crop each of 1,000 tons. One ton per five acres is equivalent to 440 pounds per acre :—

	Present planted acreage.	Amount per acre to produce 1,000 tons.
Ceylon Land and Produce Co.	4,900	449
Lanadron Rubber Estates	4,799	458
Ceylon Tea Plantations	4,561	482
Tandjong Rubber Co.	4,500	499
Anglo-Malay Rubber Co.	4,476	491
Tebrau Rubber Estates	4,384	502
London Asiatic Rubber and Produce Co.	4,371	503
Straits Rubber Co.	4,293	512
Gula Kalumpong Rubber Estates	4,272	515
Telogoredjo United Plantations	4,195	524
F.M.S. Rubber Co.	4,000	550
Sialang Rubber Estates	3,851	571
Highlands and Lowlands Para Rubber Co.	3,840	575
Jugra Land and Rubber Estates	3,781	582
Straits Settlements (Bertam) Rubber Co.	3,556	618
Lumut Rubber Estates	3,332	660
Sennah Rubber Co.	3,321	663
Java Amalgamated Rubber Estates	2,948	746

In the case of perhaps only two of these companies can it be said that their planting programme is completed, and it is a strong presumption that most, if not all, of the remainder will increase their planted areas sufficiently to be able to turn out from these areas, when mature, on the one ton per five acres basis, as much as 1,000 tons per annum. At any rate, allowing 15 per cent. as the loss on washing and drying fine hard Para, the first seven companies on this list will each be able, with their present planted acreages, to annually turn out, on the basis of 1 ton clean and dry plantation rubber per 5 acres, rubber equivalent to 1,000 tons of fine hard.

Can Plantations Treble the Amazon Crop ?

The foregoing statistics conclusively show that the future importance of plantation rubber is one which cannot be lightly put aside, if only in view of the possibility of supplanting a good portion of wild rubber by that from plantations. There can be no doubt, even at present, about the question of economy in the two classes; this is evidenced by the fact that very many of the wild-rubber areas in Africa and America are now being gradually transformed into plantations of some kind or other. The general tendency of present-day operations is to commence or extend regularly planted estates where wild-rubber forests previously existed. In view of all this planting activity, it is advisable to consider the capabilities of the areas already established in the East alone; the best comparison is furnished by a study of the present annual crop from Brazil and an estimate of produce from Hevea estates. To-day Brazil can claim rubber trees actually yielding say, 40,000 tons per annum, scattered throughout immense areas of dense forest, often in unhealthy districts; almost all the trees exist in the wild condition, very few successful plantations being yet in existence. It has already been shown that the output is only equal to 200,000 acres of mature plantations. On the other hand, there is the plantation industry with about 800,000 acres of planted trees, capable of yielding one to four cwt. per acre per annum. The possibility of securing a crop from plantations treble the amount now annually obtained from Brazil may seem optimistic, nay, even ridiculous; but it may have to be faced before 1920.

This huge plantation industry has been established in about ten years of active estate work, is controlled by European planters backed with years of tropical experience and scientific advice, and is, despite statements to the contrary, likely to undergo still further extensions in the near future. If Brazil or Africa now engage in planting operations, as the East has done, the result will be watched with natural anxiety by the planting community. It should be remembered by those contemplating such a programme, and also by planters in the East, that, whatever is planted after 1911 can only come into bearing after the produce of 800,000 acres has been placed on the market. It is, therefore, obvious that, except labour is cheaper or plants grow more rapidly and yield better in Brazil or Africa, the establishment of plantations in those parts of the world would not offer any attraction above estates already or about to be commenced in the East; it is also clear that a halt should be called in planting extensions in the latter area.

Value of Para Rubber.

Sufficient has been written to give an idea of past and future quantities of raw rubber. It will now be interesting to study the history of prices, especially that of fine hard Para and plantation rubber. The fluctuation in value of Para rubber during the last 20 years has been great. In a general way it may be stated that from 1891 there was a gradual increase in price from 2s. 7d. per lb. to 4s. 8d. per lb. in the beginning of 1900; for the following three years there was a decline until 3s. 3d. was reached. After 1902, prices rose rather sharply until what was then regarded as the phenomenal price of 5s. 8d. per lb. was recorded in 1905.

Since that year the fluctuation in value has created a record in tropical agricultural produce ; from 1905 to 1908 there was a gradual decline down to 2s. 9d., this carrying us back to the prices paid from 1891 to 1894. At about that time the plantation industry had gained a footing, and those interested in its development based their ultimate returns on an average price of 3s. 3d. per lb. for their produce when estates were in bearing. This was then quite a legitimate view to take. The following two years, however, completely changed the prospects of the whole industry. Commencing in the early part of 1908, prices began to rise, and before the end of the year, over 5s. 3d. per lb. was paid for fine hard Para. In 1909 the demand for the raw material was active from the beginning of the year and became steadily stronger until September and October, when the highest prices were reached, fine hard Para realising 9s. 2d. and smoked plantation 9s. 8½d. per lb. Nor was that all. During the rest of the year a sharp decline to about 7s. was noticed, but this proved to be only the forerunner of famine prices in the following year. The state of the raw rubber market in 1910 will be remembered for many years to come.

Phenomenal Prices during 1910.

The fluctuation in price of fine hard Para and plantation rubber during 1910 proved to be the record in the annals of the industry. Never, since the year 1827, when a total export of some 30 tons was registered, has such a variation in price been recorded as in 1910. The variation during 1910 of from 7s. 7d. in January, to 12s. 8¾d. in April of the same year for fine hard will be remembered as one of the most undesirable rises ever known. It has had disastrous results. The fluctuation is not likely to be soon forgotten. The chart of The India-Rubber Journal, showing the prices from January, 1907, to December, 1910, demonstrates the fluctuating character of our main raw product ; the irregularity in prices can undoubtedly be regarded as phenomenal. There is absolutely no relationship in maximum and minimum prices with the cropping periods. In 1907 the highest prices for fine hard were in January, and the lowest in November ; whereas in 1908 the highest prices were in November, and the lowest in February. The position was almost exactly reversed in two consecutive years. In 1909 the highest prices were in October-November, the lowest in January-February. During the year 1910 the highest was in April, and the lowest in October. The fact that the highest prices have during the years 1907-1910 been realised in the months of January, November, October-November, and April respectively, will always confuse economic prophets who claim to be gifted with the power to calculate future prices. The irregularity in the price of fine hard has been reflected in that for plantation rubber from the East. The absence of an equilibrium in price is obvious from the way in which the premium on plantation during the months of February to June was displaced by a heavy discount from June practically up to December. The variation in average price for plantation for 1910 was from 5s. 7d. to 12s. 8¾d.

High Prices and Increased Supplies.

Throughout the period under review it is to be observed that high prices had no relationship to decreased supplies; in fact, the higher prices during 1903 to 1910 are coincident with very large crops of rubber. This condition is, by some students of economics, regarded as abnormal. The following tabulation should prove instructive :—

PARA RUBBER.

Year.	Crops.	Prices per lb.
1890	15,354 tons	3/3 to 4/1
1898	21,908 ,,	3/7 to 4/5
1904	28,505 ,,	4/- to 5/5
1905	31,474 ,,	5/- to 5/8
1908	36,991 ,,	2/9 to 5/3
1909	39,112 ,,	5/0 to 9/2
1910	38,200 ,,	5/6 to 12/9
1911	37,730 ,,	3/9 to 7/1

Prices for Plantation Rubber.

The rise and fall in the price of plantation Para has generally followed the fluctuation in fine hard Para. During some years plantation rubber has obtained a high premium above the wild product, especially for forms such as block, pale crêpe, or smoked sheet, these being paid for more as novelties than as commercial quantities; at other times plantation rubber has been at a substantial discount. Probably the best way to demonstrate the relationship between the prices of the two forms of Para rubber will be to take the fluctuations throughout a typical year. If we select the year 1909, we shall find that from January to May a steady premium for plantation Para over fine hard was maintained—a difference of 2d. between the average prices being general for that period. A healthy premium was maintained until the month of August, when for some reason plantation Para sold at only 7s. 6d., while fine hard realised 8s. 3½d. Subsequently, however, plantation rubber again established itself, and towards the end of September and early October, when fine hard Para realised 9s. to 9s. 1d., plantation obtained an average price 9s. 7d. to 9s. 8d. per lb. A premium was maintained throughout the rest of the year, and in one or two instances plantation marks, well known to manufacturers, obtained a premium of 6d. per lb. over the average prices for rubber from adjacent estates in the East. Similar variability was recorded during 1910, a premium of 2d. to 4d. per lb. for plantation giving way to a discount of over 6d. per lb. compared with fine hard Para.

Effect of High Prices.

The effect of the high prices during 1909 and 1910 was to stimulate the interest of the general public in the cultivation of rubber plants. Companies have now been formed to operate throughout the tropical belt, and it is quite reasonable to expect that there will, after making allowance for a fair percentage of failures, be over 800,000 acres of plantations yielding rubber ten years hence; the amount of rubber likely to be derived therefrom has already been indicated.

The condition of Eastern estates, the yielding capacity of the acreages now planted, and the capital involved, will assuredly awaken a wider interest in this comparatively new and profitable industry. It can be taken for granted that, except something unforeseen happens, we shall have annually much more rubber from the East alone than we have in the past received from the whole of the world.

Every Eastern estate represents a centralised mass of trees from which supplies of rubber can be more rapidly and economically drawn than in any other part of the world. Every tree is under the personal supervision of trained European agriculturists, and can receive daily attention.

From these facts it will be clear that the potentialities of the Eastern industry alone are such that when the rubber is arriving in fair quantity, other rubbers of an inferior kind will feel the pinch. Para rubber is acknowledged to be superior to most other kinds. We have been assured by some of the most prominent British manufacturers that, if we can supply them with Para at 2s. 6d. per lb., they will use it in preference to most African and inferior American grades. A continuance of 2s. 6d. per lb. for fine hard Para will, to a large extent, place the world's power in Eastern plantations, for against that price but little African and American rubber can be exported under existing circumstances. At that price, and with yields only equal to those obtained up to date, planters and others engaged in plantations will secure a very handsome profit.

The capital necessary to bring present planted areas into bearing, and to execute large extensions has already been supplied; the financial position is sound, and we can now proceed to consider that side of the plantation industry.

Capital for Plantations.

At my lecture before the Society of Arts, in 1907, I was able to give some indication of the interest taken, by financial circles, in the rising plantation industry. The following is a statement of the sums then invested in notable properties:—

MARCH, 1907.

Paid-up Capital of Rubber-Planting Companies.

	£
Malaya	2,048,281
Ceylon and India	415,213
Islands in the Indo-Malayan region	651,123
America	765,000
Africa	430,000

Sterling equivalent of capital existing in rupees and other local currency in :—	
Malaya	532,748
Ceylon and India	370,566
Islands in Indo-Malayan region	28,333
Companies growing rubber in conjunction with tea, cacao, and other products	9,121,761
Grand total	£14,363,325

These figures kindly furnished in March, 1907, by Mr. Fritz Zorn, at my request, showed about five-and-a-quarter million sterling then invested in rubber alone. English capital had also been invested in the cultivation and exploitation of rubber in numerous East and West Indian islands, in tropical America and Africa, and very large sums from the Continent had then been supplied for the same purpose.

The activity during 1907 in new flotations was more pronounced in Great Britain than in any other part of the world, though a few Mexican propositions and others emanating from Dutch, French, and German sources were successfully carried through. In Central, West, and East Africa, Central and South America, and in the East and West Indies, increased activity was recorded; it was then predicted that we might during 1908 see New Guinea, New Caledonia, Samoa, Borneo, Java, and Sumatra rise to a position of importance which very few expected, though those intimately associated with some of these islands, especially the last three, stated that the conditions for rubber cultivation were better there than in many parts of Ceylon and Malaya.

The capital invested in rubber (separate and mixed) cultivation up to April, 1907, was no less than £14,363,325; I then stated that ere long that sum would be increased to £20,000,000. The following figures indicate new flotations during 1907:—

	£
Ceylon, 24 companies	1,915,830
India and Burmah, 8 companies	214,333
Malaya, 24 companies	1,449,916
Sumatra, 9 companies	1,050,739
Java, 7 companies	191,499
Africa, 10 companies	282,449
Tropical America, 15 companies	3,898,149
Miscellaneous, 3 companies	281,707
	£9,284,622

Some of these companies have not been successful, but the majority are in working order at the present time. A few syndicates are included in the above, and are responsible for much larger sums of money during 1908.

1908: £2,010,500.

During 1908 the nominal capital of companies registered in Great Britain was £2,010,500.

A number of companies were also floated semi-privately in Ceylon during that period. Some of these were the Ambanad Tea and Rubber Co. (capital R750,000), the Opata Tea and Rubber Co., etc.

Compared with the enormous activity which prevailed the previous year in the rubber company world, these figures do not seem large, but they represent, nevertheless, a considerable addition to the British investors' stake in the rubber industry. As in previous years the new enterprises were mainly British.

1909 : £12,008,000.

The high prices ruling for raw and plantation rubber stimulated activity during 1909, the total nominal capital of the companies registered in Great Britain, excluding finance companies, for that year being £12,008,000, or about six times that for 1908.

1910 : £38,941,500.

The high price of raw rubber and the wild excitement prevailing among public speculators in plantation rubber shares during 1910, resulted in the flotation of companies operating in all parts of the tropical zone. The year 1910 will stand out as the record for all time in respect of the total nominal capital of such companies registered in Great Britain; it will surprise many to learn that this amounted to no less than £38,941,500 for the year. The total for 1908 was £2,010,500 and for 1909 £13,671,000; these appear insignificant compared with the total for the year 1910. The first quarter of the year was responsible for £10,021,000, the second for £21,130,000; by that time the position became too speculative, but promoters managed to bring the total for the third quarter up to £5,120,500; this was practically the beginning of the end, the last quarter only totalling £2,670,000.

These figures will enable the reader to gain some idea of the efforts likely to be made to further plantation companies in different parts of the world. If to them is added the capital invested on the Continent of Europe and elsewhere, it will be seen that the plantation industry has sufficient financial support to enable it to achieve success.

1911 : ABOUT £6,600,000.

In 1911 many difficulties were experienced by financial and other parties consequent on the fall in price of raw rubber and the downward tendency of most plantation companies' shares. The total nominal capital up to the end of the year can be roughly assessed at about £6,600,000. During the second half of the year many debenture issues were made and others considered.

TOTAL CAPITAL : £90,000,000.

The nominal capital of the companies registered in Great Britain alone, during 1907 to 1911, therefore exceeds £90,000,000, including finance companies, a total which guarantees some measure of success. Nor is this all. Considerable capital has been subscribed in Ceylon, Malaya, Java, Sumatra, Shanghai, and on the Continent of Europe during the same period. Furthermore, large sums have been paid in subsequent to flotation, as premiums by the shareholders.

Of course the capital actually paid up is somewhat less than this, and may be estimated at about £60,000,000. Yet some addition must be made to this with respect to the debenture issues now becoming frequent.

DETAILS OF NOMINAL CAPITALISATION, 1908 TO 1911.

	1908.	1909.	1910.	1911.
	£	£	£	£
Ceylon	265,000	665,000	3,920,000	490,000
India and Burmah	85,000	938,500	970,000	450,000
Malaya	318,500	5,600,000	8,337,000	2,090,500
Sumatra	330,000	656,000	2,240,000	1,505,000
Java	170,000	595,000	5,970,000	660,000
Borneo	230,000	825,000	3,680,000	200,000
Africa	120,000	507,000	6,064,500	620,500
Tropical America	458,500	1,994,000	7,200,000	453,000
Miscellaneous Countries	33,500	227,500	460,000	150,000
	£2,010,500	£12,008,000	£38,841,500	£6,619,000

In addition to the above, it should be borne in mind that over £14,000,000 have been provided for in finance companies from 1909 to 1911 inclusive.

Having dealt with the history of rubber and past sources, it is now necessary to study the detailed history of the plantation industry in which such large sums of money have been invested.

CHAPTER II.

HISTORY OF RUBBER PLANTATIONS

We are all accustomed to give credit for plantation development to Kew and other botanic or agricultural departments. Very few people realise that, long before even vulcanization was known, Hancock and his colleagues experienced difficulties in procuring a good supply of rubber, as they were frequently using at the rate of from two or three tons weekly.

PLANTATIONS RECOMMENDED IN 1834.

This, together with the adulterated state of the raw material as it was received, led Hancock to call attention, in the "Gardener's Chronicle," to the possibility of cultivating the best kinds of rubber plants in the East and West Indies. That was in 1834. Sir William Hooker rendered him every assistance he could.

We do not know whether many have referred to this suggestion, which dated 40 years prior to the introduction of Hevea rubber into the East.

It was not, however, until *Hevea brasiliensis* was selected by Sir Joseph Hooker that any development, worthy of being recorded, took place.

COLLINS PROCURES HEVEA SEEDS IN 1873.

Six plants of *Hevea brasiliensis* were sent from Kew to Dr. King, Botanic Gardens, Calcutta, in 1873, and did not prove satisfactory. These were probably from seeds brought to Kew from the Amazon, by Collins, on June 4th, 1873. Collins afterwards became Government Economic Botanist at Singapore. He was author of apparently the first real account of the rubber industry in South America (Report on the Caoutchouc of Commerce, by James Collins, 1872). Incidentally it should be mentioned that he described and figured the herring-bone system of tapping; invented several forms of tapping knife; and suggested the use of iron vessels for collecting latex in place of calabashes or leaves plastered in with clay. The non-success of Collins' plants led to the decision of Kew to send the next Hevea plants to Ceylon instead of India.

SEEDS FROM WICKHAM IN 1876.

Wickham relates how in 1876 Sir Jos. Hooker, then director at Kew, being attracted by drawings of the leaf and seed of *Hevea brasiliensis* made by him, did not rest until he succeeded in inducing the Government of India to grant a commission for the introduction of Hevea, having interested Sir Clements Markham, at that time at the India Office, in the project. Wickham finally procured the seeds, and in 1876 Kew was compelled to turn out orchid and propagating houses to make room for them ; within a fortnight the glass houses were filled with over 7,000 young plants.

Plants from Cross in 1876.

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 1,080 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.

Introduction to Ceylon.

In 1876 nearly 2,000 seedlings of Wickham's stock were despatched to Peradeniya, Ceylon, from Kew. These were contained in Wardian cases and arrived by the ss. "Duke of Devonshire," in excellent condition.

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 about Rs. 11 for every plant delivered in Ceylon. The whole expenditure was borne by the Indian Government. Burmah, Java, Singapore, and the West Indies also received small consignments from Kew direct in 1876.

First Cuttings and Seeds in Ceylon.

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

The plants at Henaratgoda, Ceylon, 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.

Singapore.

The Botanic Gardens at Singapore received many rubber-yielding species from Ceylon and other countries. Mr. H. N. Ridley has kindly supplied me with the following information :—Twenty-two plants of *Hevea brasiliensis* were received on June 11th, 1877, from Kew, and a further consignment was despatched from Kew in the following year. In 1876, plants of *Castilloa elastica* and *Manihot Glaziovii* were received from Kew ; the former were failures, and the latter are not looked upon with favour in the Straits. In 1898, plants of *Funtumia elastica* and *Mascarenhasia elastica* were received from Kew, but they appear to grow very slowly. Plants of the vines *Landolphia Watsoniana, L. Petersiana*, and *L. Kirkii* were received in 1881 from Kew, but none have been successful as cultivated plants, though nearly all grow well. In the same year a species of Hancornia, which subsequently failed, was also received from Kew. *Ficus elastica*, at one time largely cultivated in the Straits and Federated Malay States, was received at Singapore before 1875. It is a native of Perak, and caoutchouc from wild trees of this species was obtained before 1876.

Mr. Ridley states that the Straits do not appear to have obtained seeds of *Hevea brasiliensis* from Ceylon until 1886, when they were then distributing their own seeds, and he is unable to account for the fate of the material sent from Ceylon in 1877. According to Ridley, it is clear from the records of the Botanic Gardens and Murton's reports, that the cuttings from Peradeniya were either not received or were dead on their arrival at Singapore, and in 1879 the Botanic Gardens did not possess any living cuttings or any plants except those received direct from Kew. The descendants of the healthy trees at the Singapore Botanic Gardens cover immense areas in the Colony and Federated Malay States, the islands of the Malay Archipelago, East and West Africa, Guiana and the West Indies, Mexico and Polynesia. As far as can be estimated, at least 2,500,000 seeds and plants were distributed to all parts of the Tropics from these trees up to the middle of 1909.

India.

My information regarding the introduction of rubber-producing species to India has been obtained from Mr. J. H. Burkill, Officiating Reporter on Economic Products, Indian Museum, Calcutta. For many years thousands of seeds of *Hevea brasiliensis* have been annually sent from the Henaratgoda Botanic Garden, Ceylon, to the Government of India, and in addition to these, officials and planters have frequently secured seed supplies of other species from Ceylon and the Federated Malay States.

Six plants of *Hevea brasiliensis* were first received from Kew in 1873, but these did not give favourable results ; others were received in 1876, 1877, and 1879 from Ceylon. The early results obtained in India were not encouraging, and the comparative failures then recorded had undoubtedly considerable influence among planters in South India especially. Now several localities have been proved suitable for Hevea, and regular consignments are shipped from Ceylon to Indian estates. During the last few years several estates in South India have been able to collect their own seeds. Plants of *Castilloa elastica* were received from Kew in 1881-1882, of *Manihot Glaziovii* in 1877, of *Funtumia elastica* in 1899-1904, and of *Landolphia Kirkii* in 1878-1879. All these, with the exception of *Manihot Glaziovii*, are practically valueless to planters in India as sources of rubber.

While it is true that Sumatra, Java and Borneo possess seed-bearing trees of *Hevea brasiliensis*, it cannot be said that many seeds have been distributed from these islands to other countries.

At the present time most countries are in possession of a few seed bearers, and before long will be independent of seed supplies from other areas.

Distribution of Rubber Plants from Kew.

Many trials of Brazilian species have already been made in Africa, East and West Indies, India, Malaya, Borneo, Philippines, New Guinea, Fiji, etc., and of African species in parts of America and the East and West Indies. In the distribution of rubber-yielding plants to various parts of the world the British Government have taken considerable interest.

The gradual development of the plantation rubber industry can be associated largely with the activity of the various Government Botanic Departments in different parts of the world. The Royal Gardens, Kew, naturally ranks of first importance in this respect, as a centre of distribution of species collected from all parts of the tropics. According to the Kew Bulletin (No. 3, 1907), *Hevea brasiliensis* was first sent from Kew to India in 1873; in 1876 to Burmah, Ceylon, Java, Singapore, West Indies; in 1877 to Mauritius and West Africa; and in 1878 to Fiji. Plants of *Hevea Spruceana* were first despatched to Ceylon in 1883; to India, Java, Singapore, West Africa, and West Indies in 1887; and to Fiji in 1893. *Castilloa elastica* was first sent to India in 1875; to Ceylon, Java, and West Indies in 1876; to Singapore, Mauritius, and West Africa in 1877; and to Fiji in 1882. *Manihot Glaziovii* was first sent to India, Ceylon, Singapore, and West Africa in 1877, and to Java, Fiji and the West Indies in 1878. Landolphia plants were first despatched to Ceylon and the West Indies in 1880; to Singapore and Fiji in 1881; to Mauritius in 1883; and to Java in 1888. *Funtumia elastica* was sent from Kew to India, Ceylon, Java, Singapore, and the West Indies in 1896, and a second consignment was forwarded to the same countries in 1897. That is a magnificent record, even for Kew.

Ceylon.

The distribution of Hevea seeds from Kew, Ceylon, and Singapore is an object lesson to all who regard botanic departments as being of only ornamental value. The seeds from the parent Hevea trees raised by Trimen in Ceylon and Cantley in Singapore, have been distributed throughout the world. The success which has attended the transmission of seeds has been recognised by responsible officers in all parts of the world, and remarkable to relate, thousands of *Hevea brasiliensis* seeds were sent back to Brazil, from Ceylon, for planting purposes, during 1906. The various consignments have had a varied fate, many arriving in first-class order, and others proving a miserable failure. In the latter category it is recorded that out of 300,000 seeds sent to Seychelles in 1907 and 1908, only 200 plants were raised ; the best result was out of a lot of 1,000 seeds, from Ceylon, 750 plants being raised therefrom.

Character of Parent Plants in Amazon.

Since the publication of my first edition the question of the native habitat and general character of the original parents of Eastern Hevea trees has been frequently discussed. It is well-known that most of the trees now in the East are the offspring of the seeds brought over by Wickham ; the published accounts of that explorer give all the necessary details on the interesting points in question. Wickham assures us that the seeds were selected from well-grown forest trees, which had given crops of rubber. The trees often attained a circumference of 12 feet, and rivalled all except the largest trees in the dense forest. Hevea should, therefore, be regarded as a forest cultivation. The sizes of the oldest trees in Ceylon and Singapore are certainly such as to warrant a wide distance in cultivation. It appears that all the seeds came from the same locality—from the high forest covering the great plateaux stretching back from the left bank of the Rio Tapajos, a tributary of the Amazon. These high plateaux, a few hundred feet above sea-level, are immense forest-covered plains, and occupy the spaces between the great arterial river systems of the Amazon valley. "They present a more or less steeply-escarped face abutting on to and above the marginal plains, of varying width, and are subject to inundation by the backwaters during the annual rise of the great river." So thorough is the drainage of the highlands from which the seeds were gathered that the people who penetrate into these forests for the season's working of rubber have to utilise certain water-bearing vines for their water supply, since none is obtainable by surface sinking, in spite of the heavy rainfall during most of the year.

Wickham further states that the soil in these well-drained forest tablelands is not remarkably rich, but deep and fairly uniform. It is, therefore, certain that as far as elevation, climate, and soil are concerned there are many Hevea estates in the East where conditions compare very favourably with those depicted by Wickham. It should, however, be stated that in point of distance in planting and general cultivation, planters in the East are not following the recommendations made by Wickham, who believes in adopting forestry principles in the cultivation of *Hevea brasiliensis*.

Having traced the introduction of *Hevea brasiliensis* into most tropical areas, we can now proceed to consider the evolution of plantations in each country of importance.

Labour Costs and Planted Acreages.

Before proceeding to detail the progress of planted acreages it is advisable to remark that the comparative costs of coolie labour in various parts of the East have played an important part in the progress of planted acreages. All countries in the East, except South India and Java, appear to have been largely dependent upon imported coolies for the establishment and upkeep of their estates. Ceylon secures its labour from India; Malaya from India, Java, and China; Sumatra and Borneo from Java and China. In each country the native population can also be drawn upon especially for clearing operations, notably Battaks in Sumatra, and Singhalese in Ceylon. Recently, Ferguson (Souvenir, I.R.J., 1909) pointed out that in this chief factor of labour supply Ceylon will always have great advantages. Its close proximity to the coolie districts of southern India, and the great improvement in transport which the Indo-Ceylon Railway, with steam ferry now sanctioned, will afford, must tell greatly in favour of Ceylon rubber plantations. But, in addition, it is found already, and will be increasingly seen as time runs on, that the Singhalese, in many districts, will be quite ready to take service for such simple, and to them, interesting work as is involved in the harvesting, the collection of the latex and the preparation of the same in the factory. The average daily cost of coolie labour in Ceylon compares favourably with other countries, especially Malaya, Borneo, and Sumatra.

The West Indies, tropical America and many parts of Africa include areas which, so far as soil and climate are concerned, are well suited for the growth of rubber trees; the scarcity of labour and its high cost prevent extensions being made on a large scale, and to these factors must be attributed the small acreages of cultivated rubber trees in the countries mentioned.

Even at the present time in the East the effect of increased labour costs is making itself felt; on many Malayan and Sumatra estates where coolies cost quite one shilling per day extensions cannot be undertaken as light-heartedly as in parts of Ceylon, Java, and South India, where labour is much cheaper.

Area for Rubber in Ceylon.

It appears that in a circular of the Royal Botanic Gardens, Ceylon, in 1898, the land most suitable for Hevea cultivation was described as that at about sea-level: the area of land suitable for profitable rubber cultivation, in Ceylon, being then assessed at not more than 10,000 acres. As in a further circular (1899) it was stated that "there is not very much suitable land in the colony in which this cultivation is likely to prove really successful," and this is repeated by other authorities so late as 1906 (Lectures on Indiarubber, page 154), it seems necessary to draw particular attention to the erroneous advice originally given. The area under Hevea in Ceylon is already twenty times that originally described as suitable, and a considerable portion of the plantations will, in all probability, yield fair crops of rubber.

Ceylon Acreages.

The development of rubber plantations in Ceylon has been rapid, though not quite so phenomenal as in Malaya. In 1890 Ceylon had only 300 acres under rubber; in 1900, 1,750 acres; in 1902, 4,500 acres; and in 1904, about 25,000 acres. After that year planters were attracted by the improved growth and yield in many parts of the island and the acreages showed very rapid increases, they being in 1905, 40,000 acres; 1906, 100,000 acres; 1907, 150,000 acres; 1908, 170,000 acres; 1909, 174,000 acres; and in the middle of 1910, 188,000 acres. Of the 174,000 acres under rubber in 1909, no less than 131,800 were in separate clearings, the rest being intermixed with other products. These areas have been calculated from a statement of actual acreages and numbers of trees, 150 trees being estimated to the acre and an allowance also being made for intercrops. As a matter of fact, in the middle of 1910 rubber was scattered over 238,000 acres, of which 95,500 acres were associated with tea or cacao. It is only fair to assume that Hevea will outlive the interplanted products.

It is of interest to note that the leading rubber-growing districts in Ceylon were, in 1909 and 1910, in their order according to acreage, viz.:—Kelani Valley, Kalutara, Ratnapura, Kegalla, Galle, Kurunegala, Matale East, Matale North, Matale West, Haputale, Monaragala, Madulsima, Matale South, Rakwana, Kadugannawa, Alagalla, Nilambe, Ambagamuwa, Passara, Dolosbage and Galagedara. Kelani Valley then returned 30,321 acres rubber alone, beside 22,839 tea and rubber; Kalutara, 29,902 and 12,016 respectively; Ratnapura, 12,963 and 2,352; Kegalla, 10,000 and 3,437; and Galle, 7,322 and 2,327—to name only the first five districts.

Rubber Acreages in South India and Burmah.

Though Calcutta was the first to receive plants of Hevea from Kew, in 1873, the acreage under this species in the whole of India is small when compared with Ceylon or Malaya. In a recent document regarding South India it is stated that Travancore heads the list with 18,251 acres, Malabar is credited with from 6,000 to 7,000 acres, Cochin with 3,736 acres, the Shevaroys with 1,829 acres, and Mysore with 2,000 acres; with the exception of Mysore the plants are mainly *Hevea brasiliensis*. The total acreage under rubber of all kinds in South India is approximately 42,000 acres, but this must not be regarded as the equivalent of the same acreage in other countries, owing to some estates having their Hevea trees growing at high altitudes and under unsuitable climatic and soil conditions. The United Planters' Association of Southern India estimated, in 1910, that there were 29,546 acres under rubber and that a crop of 179,400 lb. would be exported in that year.

The handbook, "Rubber in South India," distributed at the last exhibition in London, gave the acreages in Travancore and Cochin as follows:—nine years old, 200 acres; seven years, 701 acres; six years, 1,831 acres; five years, 5,259 acres; four years, 4,498 acres; three years, 4,164 acres; two years, 1,590 acres; one year old, 3,615 acres. The total was 21,988 acres.

There are, at high elevations in India, about 5,000 acres of Hevea, not including that in Coorg, Mysore and Wynaad. It is mostly planted amongst or interplanted with coffee, some of the trees being nine and ten years old. This hill rubber is at varying elevations from a little under 2,000 to 3,700 feet above sea-level, the rate of growth varying according to elevation. It may be laid down, according to Windle, that at, say, 3,500 feet above sea-level, a tree will not be of a tappable size before seven years in a dry district and a year or so less in a moist one.

In 1908 rubber in Burmah was reported to total about 4,500 acres in Mergui, Tavoy and Shweggin districts and in Rangoon (not including small holdings of Chinese and Burmans); there were also plantations in Yonngoo, Bosseim, Amherst and Bhamo.

Acreage Planted in Malaya.

Carruthers pointed out that in 1897, rubber estates only covered 350 acres in Malaya; 10 years after they had increased by 360 times. In 1902 less than 7,500 acres had been planted; five years after 17 times that amount was under rubber. Nearly all this was virgin jungle prior to its being planted with rubber, and had to be cleared before any planting operations could be begun. Nine-tenths of the whole acreage has been cleared and planted by the younger generation of planters, who deserve the greatest credit for the excellent way in which their work has been carried out.

Malaya in 1906: 99,230 Acres.

This year, in the F.M.S. alone, a total of 150,000 acres was reported as alienated for rubber cultivation. Carruthers estimated that the planted area comprised 25,000 acres under one year old; 15,000 acres, one to two years; 4,500 acres, under three years; 4,000 acres, under four years; and 8,500 acres, under five years. The total acreage in Selangor was given at 44,821 acres, Negri Sembilan at 10,600 acres, Perak 29,600 acres, and Pahang 483 acres, for the end of December, 1906, by the then Director of Agriculture. The total areas for Straits Settlements, under rubber, was given at 11,341 acres, and Johore 2,310 acres, making the total for Malaya 99,230 acres in December, 1906. These statistics do not entirely agree with those given in the Straits Settlements Blue Book; the same remark applies to the figures for the years 1907 to 1909 inclusive.

Malaya in 1907: 179,227 Acres.

It is interesting to notice at that time (1906) how close was the competition between Ceylon and Malaya to have the largest planted acreage under rubber. Carruthers' estimate of the planted acreage in the F.M.S., Johore, the Straits Settlements, and Kedah, for December, 1907, was 179,227 acres.

The rubber acreage (126,235 acres) in the F.M.S. was made up of 61,552 acres in Selangor, 46,167 acres in Perak, 17,656 acres in Negri Sembilan, and 860 acres in Pahang.

Selangor had 124 estates with 9,648,093 trees, and planted 19,135 acres during 1907; Perak had 114 estates, 6,648,957 trees, with 16,050 acres planted in 1907; Negri Sembilan had 34 estates, 3,165,388 trees, with 4,945 acres planted in 1907, and Pahang brought up the rear with 15 estates, 166,590 trees, and only 193 acres were planted in 1907.

The land alienated for rubber, declared Carruthers, was nearly four times as much as that actually growing rubber.

The rapid progress of the rubber industry in Malaya during 1907 is shown by the fact that at the end of the year 45,764 more acres of rubber land had been planted, an increase of about 46 per cent. on the total of the previous year. The number of trees in 1906 was under 13,000,000, and in 1907, 27,558,400, a large acreage being planted closer than before.

Malaya in 1908: 241,138 Acres.

Further progress was reported in planting operations throughout Malaya in 1908. It was stated that at the end of 1908 there were 37,440,020 trees as compared with 27,558,369 a year before; 60,636 acres were planted during 1908, an increase of over 33 per cent. on the previous year, giving a total of 241,138 acres of rubber on the 31st December for the whole Peninsula.

The advance in rubber planting in the Federated Malay States alone was as rapid in 1908 as in 1907; 41,813 acres were planted during the year as compared with 40,743 in 1907, an increase of 33 per cent. On the 31st December, 1908, there were 168,048 acres of rubber, containing 26,165,310 trees, in the Federated Malay States alone, as against 126,235 acres and 19,628,957 trees on the same date of the previous year. The balance of the acreage to make up the total given above was situated in the Straits Settlements.

Malaya in 1909: 292,035 Acres.

There were only 28,905 acres of Hevea planted in the F.M.S. during 1909, as compared with 41,813 planted during 1908, the decrease in rate of planting being especially noticeable in Selangor and Negri Sembilan. In the whole of the Peninsula there were 50,897 acres planted during 1909, as against 60,636 acres in 1908. In the total acreage for the F.M.S.—196,953 acres—Selangor is credited with 93,853 acres, Perak with 68,278 acres, Negri Sembilan with 31,945 acres, and Pahang with 2,877 acres.

Malaya in 1910: 400,000 Acres.

The figures for 1910 show that very rapid strides were made by planters in almost every part of Malaya. The area opened in the F.M.S. alone was 48,813 acres, against 28,905 acres in 1909. In a recent return (Straits Bulletin, February, 1911), compiled through the courtesy of land officials, an approximate acreage under rubber at the end of 1910 was given for Malacca at 55,000 acres, Province Wellesley, 22,900 acres, Singapore, 14,000 acres, and Penang, 3,000 acres, a total of nearly 100,000 acres. In the Annual Report of the Director of Agriculture, Kuala Lumpur, for 1910, the acreage of rubber is given at 362,853 for Malaya, the Straits Settlements being credited with 60,568 acres in compiling that estimate. It is clear from the above that the Straits Settlements can be assessed at nearly 100,000 acres, thus bringing the total acreage in Malaya in 1910 to approximately 400,000 acres.

Comparison for Five Years in Malaya.

It is obvious that the years 1906, 1907, 1908, 1909, and 1910, were responsible for systematic progress in rubber cultivation throughout Malaya, and as during the next two to three years heavy crops will be forthcoming from these areas, it will be of interest to give a comparative statement showing the approximate acreages of trees planted each year in the respective districts :—

Acres under Rubber in Malaya.

Year.	Federated Malay States.	Straits Settlements.	Johore.	Kelantan & Kedah.	Total.
1906	85,579	11,341	2,310	—	99,230
1907	126,235	42,866	10,126	—	179,227
1908	168,048	50,121	20,944	2,025	241,138
1909	196,953	57,587	33,344	4,151	292,035
1910	245,774	60,568	43,516	12,995	362,853

It is also of interest to note the increase in number of trees during the same period, official estimates assessing these as follows :—1906, 12,325,904 trees ; 1907, 27,258,440 trees ; 1908, 37,440,000 trees. Calculating the number of trees at the rate of 150 per acre, we should have approximately 45,000,000 and 60,000,000 in 1909 and 1910 respectively. It is now becoming quite common to thin out closely planted areas ; from this and other causes it appears reasonable to estimate a reduction to 40,000,000 trees on the total Malayan acreage for 1910.

Malaya takes Premier Position.

It will be instructive to compare the planted acreages, under Hevea, in the two leading countries—Ceylon and Malaya :—

Year.	Ceylon. (Middle of each year.) Acres.	Malay Peninsul (End of each year.) Acres.
1897	650	350
1902	4,500	7,500
1903	7,500	—
1904	25,000	—
1905	40,000	38,000 (estimated)
1906	100,000	99,230
1907	150,000	179,227
1908	170,000	241,138
1909	174,000	292,035
1910	188,000	400,000

Photos lent by W. Stewart Taylor.

HEVEA TREES AT 2,600 FEET; PASSARA, CEYLON.

Lent by India-Rubber Journal.

HEVEA TREE, FORKED, BANDAR PINANG, SUMATRA.

Lent by India-Rubber Journal

HEVEA IN PAPUA.

It will be readily understood that the statistics here given are approximate only. The figures for Ceylon can be increased by the equivalent acreage over which a large number of trees are planted, but for which no actual acreage is given. The figures given in the third column refer not to the rubber acreage in the Federated Malay States, but also to the areas planted in Malacca, Wellesley, Johore and Kelantan. When one takes into account the fact that the Ceylon statistics relate to planted acreages as at the middle of each year, it will be seen that the planted acreages at the end of each year more or less closely approximated to one another for a number of years, but later Malaya began to go ahead. A large portion of the Hevea acreage in Ceylon is associated with other products; this condition, though it may lengthen the life of the rubber trees in Ceylon, will alone account in the future for a much lower yield, per acre, per annum. It may be stated, if interplanted areas are included, that in Ceylon, in 1911, there was a little more than half the total acreage under Hevea in Malaya; this may mean that double the quantity of rubber from Ceylon may be annually expected from the latter area in future years.

Rubber in Cochin China and Annam.

The French have done their best to encourage rubber growing in these colonies by starting experimental areas, while private effort has been devoted to the planting of Hevea. The area in Cochin China, at the end of 1910, was 12,150 acres, with 1,759,700 trees. There were 886,000 trees in the nurseries, and it is anticipated that 8,265,000 trees will ultimately be planted. In Annam the cultivation is not so far advanced.

Rubber in Siam.

H.M. Consul at Senggora (Siam) stated in 1909, that the only foreign-owned rubber plantation in the Monthon of Patani was near Bangnara. It was owned by an Englishman and was started about four years ago. Reports with regard to it are favourable, and the Consul calls the attention of persons interested in rubber to the possibilities of Patani as a rubber-producing country.

Sumatra Acreages.

In 1908 it was pointed out that rubber was grown on 44 estates in Sumatra, 17 being in the Serdang and 7 in the Langkat districts. The Padang, Bedagai, Batoe Bahara, and Asahan districts were also represented.

Fourteen coffee estates of the above, on account of the lowered commercial value of that product, planted rubber; rubber and coffee in conjunction take up 19 estates; coffee-coconuts-rubber, 2 estates; tobacco-rubber, 4 estates; tapioca-rubber, 2 estates; rubber-coffee-tobacco, 1 estate; coffee-rubber-tobacco, 1 estate; coconuts-rubber, 1 estate, and groundnuts-rubber, 1 estate, make up the remainder. From enquiry made, the "Ceylon Observer" learned that the acreage under rubber cultivation on the East Coast of

Sumatra was estimated in December, 1907, at 20,800 acres. It is now 80,000 acres, of which over 70,000 acres are Hevea rubber.

English companies operating in Sumatra own approximately 50,000 acres. It is assumed that they possess about half the total acreage under Hevea rubber in that country at the present time, activity being mainly manifest in the Serdang, Langkat, and Asahan residencies. Many large estates are owned by the Dutch, but the statistics of their Hevea acreages are not available.

The most striking development in Sumatra of recent years is the acquirement of extensive areas by an American company working through subsidiaries. Some 120,000 acres have been taken over, of which 20,000 were expected to be planted before 1912.

Rubber Acreage in Java.

Hevea in Java is being mainly grown from sea-level up to 1,000 feet; there are estates up to 2,200 feet where this species is flourishing, but they are not very numerous. In many districts there is a marked dry season of many months' duration, and in others a more or less continuous and abundant rainfall. Estates I have visited had an annual rainfall of from 70 to over 200 inches; the dry period lasting three to five months in each year. The majority of the plantations are young, extensive clearings dating from 1905 and 1906.

A few estates planted in 1906 and maintained in Hevea alone will be harvesting their rubber in 1912, but others interplanted with various crops will be a little later.

Van Bennekom states that, according to official figures, it may be accepted that the following were the areas at the end of August, 1910:—

Hevea brasiliensis	about	47,500 acres
Ficus elastica	,,	31,000 ,,
Hevea, Ficus, Castilloa, Ceara ..	,,	32,000 ,,

We may safely assume that in 1910-11 there were planted:—

Hevea brasiliensis	about	45,000 acres
Ceara and other Manihots	,,	5,000 ,,

He then assumes that, at about the middle of 1911, about 160,000 acres were planted with rubber in Java.

In January, 1910, the following was the distribution of the estates, with their planted acreage, according to residencies. Bantam, 11 estates, 5,368 acres; Batavia, 13 estates, 6,490 acres; Preanger, 13 estates, 11,180 acres; Cheribon, 4 estates, 2,710 acres; Tegal, 1 estate, 175 acres; Samarang, 16 estates, 6,034 acres; Soerabaya, 3 estates, 1,211 acres; Pasoeroean, 41 estates, 20,475 acres; Besoeki, 25 estates, 15,317 acres; Banjoemas, 8 estates, 5,535 acres; Kediri, 12 estates, 5,118 acres; Soerakarta, 10 estates, 6,205 acres.

Hevea in British Borneo.

The late Mr. Cowie informed me that the total acreage under rubber at the end of 1907 was approximately 3,600 acres.

This country has made good process since then in planted acreage under Hevea. It was estimated that there were about 12,000 acres planted on the 1st January, 1911. The following particulars indicate the approximate acreages planted during and since 1906 :—

Year.	Area.
1906	1,240 acres.
1907	2,823 ,,
1908	3,380 ,,
1909	4,992 ,,
Total	12,435 acres.

A part of this acreage was planted with tobacco, but it is anticipated that such ground or land equal to the acreage under tobacco on the same estates will be planted with Hevea.

Figures are not available in the case of Dutch Borneo.

New Guinea and Queensland.

Owing to the influx of capital to this country it is possible that rubber cultivation may soon gain a sound footing in British New Guinea. Wickham has reported on the prospects of rubber planting in that area. An illustration (I.R.J., February 21st, 1910), of a young Hevea tree in Papua indicates that fair growth may be obtained on selected soils. Bloomfield is convinced that rubber planting will become a successful industry in the wet belt of Papua, and writes that Hevea plants from Ceylon seed have, in some cases, attained a height of 22ft. in 15 months from the date of planting out.

During the past few years the planting of rubber trees in German New Guinea has proceeded on a large scale. The progress of the plants has hitherto shown that the climate promises well for *Castilloa elastica*, *Ficus elastica*, and *Hevea brasiliensis*. A large number have not yet reached the age for tapping, although some tons of rubber are now being harvested.

Preuss records that the oldest plants of *Hevea brasiliensis* can now supply abundant quantities of seed.

In January, 1911, the total planted acreage in German New Guinea, was estimated by an official publication at 6,036 acres, made up as follows : Hevea, 1,144 acres ; Ficus, 4,237 acres ; Castilloa, 639 acres ; Kickxia (Funtumia), 15 acres ; Manihot, 1 acre.

Queensland is evincing activity in so far that a number of settlers are selecting land and applying for Hevea and other plants from the State nursery.

Samoan Rubber Developments.

Samoa appears to be attracting attention among several Continental firms interested in the cultivation of rubber plants. At the present time there are only two or three very large companies which are concerned exclusively with rubber cultivation, and these are yet in their infancy. There are, however, according to Preuss, several small rubber estates which have existed for a few years. The Samoan people have already secured plants of *Hevea brasiliensis*, *Castilloa elastica*, *Castilloa elastica* variety *Alba*, *Ficus elastica*, *Ficus Rigo*, *Funtumia elastica*, and *Urceola elastica*. A fair number of rubber-yielding species of repute are available for experiment and subsequent selection.

A British company, the Upolu Rubber and Cacao Company, Ltd., has already some 550 acres of Hevea rubber under cultivation, with cacao interplanted.

The Upolu Rubber Co., Ltd., amalgamated with the former owns a considerable area under Hevea.

A large area adjoining this plantation has been cleared by the Safata Samoa Gesellschaft for rubber culture ; the company is also planting rubber through its cacao.

The Berlin Caoutchouc Company is vigorously pushing on its work at Saluafata, 20 miles from Apia, having leased from the natives a tract of land measuring several thousand acres.

From 400 to 500 acres have been planted with cacao, coconuts and rubber by Messrs Gurr and Moors, the former having 350 acres under cultivation.

The planted acreage under rubber in Samoa was, in 1909, 1,507 acres ; of this, 1,418 acres were Hevea. Tapping is expected to commence on Alisa and other plantations this or next year.

Rubber in Hawaii, etc.

Rubber cultivation in Hawaii continues, according to Evans, to be vigorously pushed forward, and there are now several local companies in operation. The present area under cultivation is about 1,325 acres, the greater part of which is situated on the windward side of the island of Maui. The oldest trees are about fifteen years of age. *Hevea brasiliensis*, *Castilloa elastica*, *Manihot Glaziovii*, and *Ficus elastica* have all been given a trial. The favourite and the one most suited to local conditions is undoubtedly Maniho ; next in order of suitability comes Hevea. *Ficus elastica* is quite unsuitable, and it is improbable that Castilloa will prove of any local importance. In certain districts individual trees of Castilloa are doing well, but the general health and growth does not compare well with trees of the same age in other rubber countries.

Although climatic conditions, coupled with the high price of labour, will prevent the territory of Hawaii from ever becoming a first-class rubber-growing centre, there is evidence that in certain districts on Maui and Hawaii a limited supply of good quality rubber can be produced at a profit, providing there is no serious drop in present market prices.

Several planters in Fiji and the Solomon Islands have evinced interest in rubber cultivation, but very little progress has been so far made with plantations of *Hevea brasiliensis*.

Seychelles.

Seychelles can now boast of being able to secure supplies of Hevea seeds from its own plants, a few hundred trees having reached the seeding and tapping stage. The best trees in 1909 had a circumference of 30 inches, and were six years old. The Seychelles islands being between latitudes 4° and 5° South, are favourably situated for rubber growing. One company reported on the 30th June, 1911, that 270 acres had been planted with 52,000 Hevea trees; another expects to have over 400 acres planted by the end of this year.

Rubber Cultivation in the Philippines.

The reports by the Bureau of Forestry in Mindanao show that interest in rubber culture is increasing in that part of the archipelago. Many seeds and seedlings have been planted during the past year, especially in the district of Davao, the Island of Basilan, and along the east and west coasts of the Zamboanga peninsula. The reports show the following total number of trees growing on ten plantations at the present time :—*Hevea brasiliensis*, 9,000; *Manihot Glaziovii*, 61,000; *Castilloa elastica*, 1,000; total number, 71,000; or the equivalent of :—Hevea rubber, 47 acres; Ceara rubber, 313 acres; Castilloa rubber, 6 acres; total 366 acres.

Hevea Rubber in Africa.

Difficulties in connection with labour and transport are mainly responsible for the slow progress of rubber cultivation in Africa. Bad selection in the past appears to have been a frequent cause of failure. The soil and climate conditions over vast areas in the equatorial belt are quite favourable to the growth of *Hevea brasiliensis*. Though rubber plants of one kind or another are distributed over the southern parts of that Continent, cultivation is centred mainly on the west coast, especially Sierra Leone and the Gold Coast, in Central Africa (particularly the Congo and Uganda); and in East Africa. In the last-mentioned area but little Hevea is grown. Probably the largest number of trees of *Hevea brasiliensis* is to be found in the Congo, where the growth has often been reported to compare favourably with that in some of the poorer Eastern countries. The principal centre of distribution on the West Coast has probably been Aburi, where the Government Botanic Gardens are established—unfortunately on a site not of the best for *Hevea brasiliensis*. The demand for Hevea seed from Aburi has been great, and the majority of planters have had to procure most of their supplies direct from the East.

In German Africa the only colony where *Hevea* appears to have been cultivated is Cameroon, seeds being introduced in 1889. The 25,000 acres now existing there consist one half of Hevea and one half of Funtumia. Togo and German East Africa possess Manihot (Ceara), but in 1909 *Hevea brasiliensis* was not reported in either of these colonies. In German East Africa there are 40,000 acres of Ceara, and a small acreage under Castilloa and Funtumia.

In Angola, the principal cultivated tree is Ceara, of which there are 2,000 acres in Loanda district alone. Tapping is reported to be successful, which probably means that a fair amount of rubber is obtained. and not that the tree suffers no harm. There are also Maniçoba trees, which are being freely planted by native owners, though they are said to be delicate and short-lived. Ficus comes next in favour. Experiments with Castilloa and Funtumia are in progress on the Government's experimental farms. Experiments in growing "Bitinga" rubber have proved a failure, as the tubers grow too slowly.

Planting is being carried out upon Fernando Po, a Spanish island in the Gulf of Guinea.

The position in the Congo Free State has already been dealt with in the first chapter.

Cultivated Area under Rubber in Liberia.

Mount Barclay plantation, in Liberia, has made a promising start in the cultivation of Hevea rubber. According to the annual report of the Liberian Rubber Corporation, 1910, the estates contain the following Hevea trees :—

Number.	Age.
2,684	About 3 years and 5 months.
4,072	About 1 year and 7 months.
19,327	About $9\frac{1}{2}$ months old.
10,274	About $8\frac{1}{2}$ months.
11,623	Transplanted from Nurseries.
total 47,980	trees—about 241 acres planted.

Further land has been cleared, and is ready for planting, amounting to 400 acres, of which about 50 acres were recently planted with Hevea stumps.

Possibilities in Nigeria.

A reasonably complete census of acreages and number of plants is not available for Nigeria. There are very few large plantations, but very many small ones belonging to natives. Possibly there are more than 2,000,000 Hevea and Funtumia trees planted, mostly Funtumia. The Government has repeatedly given encouragement to the planting of rubber trees, and has distributed plants and seeds under generous terms through the Experimental Stations. In Southern Nigeria nearly every village seems to have its plantation, and of these there appear to be over 2,000, containing many lianes.

Gold Coast Colony.

For obvious reasons, it is impossible to give complete statistics for this area. Here, again, the Government is taking an active part in developing the industry, and the natives have taken freely to it, but they appear to have mostly planted Funtumia. For example, in 1909, while only 48,700 Hevea seedlings were distributed, the Funtumia seeds numbered 2,274,000. From Coomassie alone, in 1910, there were distributed 14,000 Hevea seedlings, and a considerable quantity of seeds. On the Gold Coast there are a number of larger undertakings, and in 1909 in the Central Province some twelve firms and individuals owned among them 106,820 seedlings and trees.

Cultivation in Ashanti.

The Consular report (1907) for Ashanti states that the natives were encouraged to cultivate rubber-yielding trees, no less than seven thousand and eighty two plants (*Funtumia elastica*) being distributed amongst the chiefs of the Southern Province during 1907, most of which are doing well. Twenty-three acres of *Hevea brasiliensis*, and four-and-a-half acres of Funtum rubber (*Funtumia elastica*), were planted out at distances of 15 feet by 15 feet, and 10 feet by 10 feet respectively, and are doing well. The agricultural station at Coomassie distributed some 12,500 seedlings during 1909, mainly of Hevea.

The area under *Hevea brasiliensis* at the Agricultural Station has increased to 55½ acres; and the trees, where conditions are favourable, continue, according to the report, to make rapid growth.

Central Africa.

Uganda has been taking an active interest in Hevea cultivation. Kaye reports (I.R.J., March 7th, 1910), that at Entebbe, the seat of the English Administration, the experts at the Botanic Gardens have given much attention to experimental planting. The report of the Botanical Forestry and Scientific Department, Entebbe, shows that good work is being done in distributing plants and seeds to planters and chiefs. Thus over a quarter million Hevea seeds were so distributed during the year ending March 31st, 1909, as well as some thousands of Manihot and *Funtumia elastica* seeds.

Dawe after giving an account of satisfactory results of tapping Hevea trees in Uganda (I.R.J., March 7th, 1910), states that Hevea promises to grow satisfactorily. He further reports that "at the Nsamba Mission Station, Kampala, there is a splendidly cultivated and extensive plantation of Hevea, Castilloa, and Ceara, over four years old. About 15 miles from Kampala is another thriving small plantation, Kivuvu. The soil is deep and loamy, and the Hevea trees interplanted with coffee, etc., are very strong and handsome plants."

The Mabira Forest Rubber Company have done extensive planting, and undoubtedly hold the premier position as rubber planters in Uganda. In the fertile areas of the concession and the wide open patches, thousands of *Funtumia elastica* trees have been planted, together with a few hundred acres of Hevea; the latter are reported to be growing well. At Entebbe, *Funtumia* *elastica* trees have apparently taken on a bush-like habit, but in Mabira many of the trees are growing tall and straight, as do the wild forest trees that are tappable. Dawe is quite certain that Hevea will be a success in Uganda as a rubber yielder, but he is not so sure of the cultivated *Funtumia elastica*. This opinion, coming from one who has done such excellent work on other rubber plants, will be read with surprise by many Eastern planters.

East Africa.

East Africa is not expected to show any marked advance in the cultivation of *Hevea brasiliensis*, though judging from Johnson's observations there appears to be a possibility of profitably growing this species under irrigation. A plantation is being established under such circumstances on the banks of the Buzi River, East Africa. Ceara is, however, being somewhat extensively planted in British and German East Africa.

Planting in Nyassaland.

It has been conclusively proved, says a consular report, that the Shire Highlands are not suitable for the cultivation of Hevea rubber; in fact the only locality within the Protectorate where this variety has proved successful is in the West Nyassa District, where 600 acres are doing well. The rubber of Nyassaland is Ceara, and the area under this has risen steadily to 4,500 acres. Plantation rubber is now being exported.

Mauritius.

Rubber estates have been commenced in Mauritius. Consignments of seeds from Ceylon have been secured (India-Rubber Journal, June 27th, 1910), and planted at different altitudes. These are, however, too young to furnish any useful data as to the prospects of Hevea in that is and.

Rubber in the West Indies.

Various consular reports and the accounts by Morris and Hart give interesting details of the history of rubber in the West Indian Islands. It appears that (Hart, Souvenir, Indiarubber Journal), about thirty-seven years ago there were few trees of any kind of rubber in the West Indies. The oldest specimens are probably trees of *Ficus elastica* in Jamaica. About that time Hevea and other rubbers were sent from Kew, Jamaica and Trinidad receiving about an equal share. In 1887 Hart found, in Trinidad, three trees of Hevea in the Botanic Gardens, and several scattered trees of other kinds. From 1887 onward, there was an increasing demand for plants, Castilloa in most cases being preferred, as coming earlier into bearing than Hevea and others, and little attention was paid to Hevea. "In fact, it could be hardly given away until the market prices went high, and it then became the rage, and all the plants the botanical department could supply were eagerly bought up; large numbers of seeds and plants were imported, and some good plantations have been established. Funtumia rubber was introduced, and a small plot was put out at the Experiment Station in 1898. It has grown well, and has produced tall, thriving trees. Manihot has found but few growers, and Landolphia and other climbing rubbers are not looked upon with favour. Castilloa in Trinidad stands first, but considerable plantations of Hevea and Funtumia have been made in recent years."

Trinidad will probably prove favourable for the growth of *Hevea brasiliensis.*

Rubber planting in Trinidad and Tobago is in its infancy, and owing to lack of confidence or the necessary technical knowledge in cultivation and extraction of latex, the progress had not, according to the late J. B. Carruthers, been very rapid. There are at present in Trinidad rubber trees of ages varying from one to fifteen years, but their progress in growth has been very slow, and there are no large trees anywhere. The number of trees on the two islands (1910) has been computed as follows :—Castilloa, 600,000 ; Hevea, 80,000 ; Funtumia, 25,000. Attention is now being turned more to Hevea than Castilloa.

Tempany reports that there are about 200 acres of Hevea in Dominica, and that there are prospects of a considerable extension in the near future.

Jamaica appears to be quite unsuitable for Hevea, and rubber planting has been gone in for very little.

In Hayti it has been given up.

In Grenada of recent years planting has been taken up with enthusiasm, both Hevea and Castilloa, but most of the trees growing there are less than three years old. As in other West Indian islands, the total acreage cannot be large.

Despite the favourable reports on the growth of Hevea now available from some of the islands, it should be borne in mind that labour conditions are not so favourable to the planting community as in other equally accessible areas.

British Guiana.

Hevea brasiliensis and *Sapium Jenmani* are, according to Harrison, being exploited at the Government experimental rubber stations in British Guiana. Both can be grown with great success, and a great deal of valuable information has been ascertained that will ensure more successful cultivation in the future. It was found that *Sapium Jenmani* and *Hevea brasiliensis* grew somewhat at the same rate, but with regard to girth only, *Sapium Jenmani* made more rapid progress. The latest reports of the tapping of Sapium are very discouraging, from 18 to 33 ounces, per tree, being obtained, in two years, from trees varying in girth from 30 to 92 inches. It is interesting to note that there were, in 1910, 1,700 acres under rubber cultivation in the colony as against 552 acres on the corresponding date of the previous year, over 1,000 acres being under Hevea.

The Government have recently endeavoured to attract rubber growers to British Guiana and have shown that they are prepared to lease lands for rubber cultivation on reasonable terms, providing, among other things :—(1) During the first ten years of the lease the lessee shall pay the sum of two cents a pound for all rubber, balata, or other substances of the like nature obtained by him from the land, whether from indigenous or cultivated trees. (2) The lessee shall each year plant one twenty-fifth part of the land leased with rubber trees, with an average of not less than 60 rubber trees to each acre, until he has so planted not less than ten twenty-fifth parts of the said land and shall maintain such cultivation in good order to the satisfaction of the Governor-in-Council. (3) In clearing the said land for cultivation no rubber tree or balata tree shall be destroyed without the permission in writing of the Commissioner.

Rubber in Dutch Guiana.

In Surinam the cultivation of rubber is exciting attention. There are some 165,000 Hevea trees growing, on 36 plantations, besides a large number of young plants at present in the nurseries. Some 800,000 seeds arrived from Ceylon towards the close of 1910 ; in addition there are a number of Hevea trees in the colony which are now yielding seeds. Photographs of trees have been shown me which indicated that climatic and soil conditions were favourable to the growth of *Hevea brasiliensis* in parts of Surinam. There is also the indigenous species—*Hevea guyanensis*—in the colony ; this yields less than *Hevea brasiliensis* and the produce is inferior in quality.

Central America.

It has been computed that there are 100,000 acres of plantations in Central America alone, most of which is Castilloa. Some Hevea seeds have been sent to British Honduras, but information is not yet to hand of their fate. The cultivation of Hevea has also been started in Mexico, where the growth in the nursery upon one estate has encouraged further extensions. About 75 per cent. of the first consignment of Ceylon seeds germinated. Central America was the leader in planting rubber if Brazil was not, for it was in 1867 that Don Jose Maria Chacon planted Castilloa at Soconusco in Mexico, and was followed during the next year by others in Guatemala, and later in Nicaragua and Honduras. It is now clear that Central America can never approach the Middle East as a producer of rubber.

Projected Rubber Planting in Russia.

Certain optimistic individuals in Russia are understood to have under consideration a project for planting rubber in the Black Sea provinces. We should not be surprised to learn of serious attempts being made to cultivate *Ficus elastica*, but even this species is hardly likely to compete successfully with the same plant in the Middle East. By the time the trees come into bearing we imagine the price of raw rubber will lose a good deal of its elasticity. Hevea rubber is, of course, out of the question.

The World's Planted Acreage in 1912.

It is impossible to compile an accurate statement of the acreages planted, in 1912, throughout the world, but the following may be taken to represent the approximate position.

In the Middle East Hevea may be taken as the main cultivation; elsewhere Castilloa, Ficus, Manihot, and Funtumia are planted.

Of the 240,000 acres estimated in the Dutch East Indies, etc., only 150,000 acres are *Hevea brasiliensis*.

Country.	Acres.
Malaya	420,000
Ceylon	238,000
Dutch East Indies, Borneo, and Pacific Islands	240,000
South India and Burmah	42,000
German Colonies	45,000
Mexico, Brazil, Africa, and West Indies, etc. (approximate only)	100,000
Total	1,085,000

An estimate by Van den Kerckhove gives 220,000 acres to Mexico, 80,000 to Brazil, and 100,000 to Africa. His total for the world is 1,131,000 acres.

There are already indications that *Hevea brasiliensis* will outlive many other species, and it may therefore be confidently anticipated that the countries growing this plant will ultimately predominate as rubber producers.

CHAPTER III.

BOTANICAL SOURCES OF RUBBER.

Knowing that the consumption of rubber is on a sufficiently large scale to lead to the investment of several million sterling in its exploitation, it now becomes necessary to deal briefly with the botanical sources of the raw material. The most striking feature of the industry is the almost absolute dependence in the past, and even to-day, of the manufacturers on rubber obtained from trees indigenous to certain tropical forests and their independence of the plantation product. It is necessary to point out that tropical America is the most important centre for rubber collection (about 60 to 70 per cent.), tropical Africa the next (20 to 25 per cent.), and tropical Asia the least important, since it only contributes a very small proportion (about 10 to 20 per cent.), made up of wild and plantation material. I predict, however, that in 1912 tropical Asia will become equal to tropical Africa, and will eventually overtake even tropical America. It is of interest to recapitulate that the richest wild rubber areas in tropical America (Brazil, Venezuela, Bolivia, Peru, Central America, and Mexico), and in tropical Africa (Congo Free State) are not British, though capital from this country has been recently diverted to parts of these two vast continents for the exploitation of rubber.

Natural Orders of Plants Yielding Caoutchouc.

The fact that out of a total annual rubber production of 75,000 to 90,000 tons, over 45,000 to 55,000 tons come from tropical America, and about 22,000 from tropical Africa, compels us to look to these two great continents for the majority of the caoutchouc-yielding plants, and to place the whole Asiatic or Indo-Malayan region in a minor or third position of importance. Our first duty is to see which plants provide the caoutchouc in each area, and to trace the distribution of notable species from one country to another.

The natural order which has furnished, and which still supplies the greater part of the world's rubber, is the Euphorbiaceæ ; the valuable species of Hevea, Manihot, Sapium, Micrandra and Euphorbia which it comprises are indigenous mainly to the tropical American region, but have been distributed to all parts of the tropical world. Next in importance is the Apocynaceæ, remarkable in tropical Africa for the valuable rubber species of Landolphia, Funtumia, Clitandra, Mascarenhasia, Carpodinus, &c. ; this order also comprises the genera Chonemorpha, Xylinabaria, Tabernæmontana, Melodinus, Alstonia, Hancornia, Urceola, Willughbeia, Hymenelopus, Parameria, Diplorhynchus, Forsteronia, Leuconotis, Ecdysanthera, and Micrechites known in many parts of the tropics for the quantity if not the quality of rubber they yield.

The Urticaceæ is also of importance in tropical America for its species of Castilloa, and for the genera Ficus and Artocarpus in parts of Africa and the Indo-Malayan region.

The Asclepiadaceæ, though it possesses such a large number of laticiferous species abundantly distributed, especially in tropical Africa, is remarkable for the absence of good caoutchouc-yielding plants; true, the genus Cryptostegia in Madagascar and India furnishes us with a small quantity of caoutchouc, but the other important genera, such as Calotropis, Cryptolepis, Marsdenia, and Cyanchum, have not yet been found to yield latices of high commercial value. Perhaps the most remarkable natural order in this respect is the Compositæ; though it is represented by such a large number of species and is to be observed in almost every part of the temperate and tropical world, there are hardly any species of value to the cultivator of caoutchouc plants. During the last few years, however, there is one member of this group—*Parthenium argentatum*, A. Gray—which has come to be regarded as the source of Guayule rubber (8,000 tons in 1910) in Mexico, and another—a species of Hymenoxys—as the source of Colorado rubber. The sow-thistle, *Sonchus oleraceus*, L., has also been mentioned by Jumelle as yielding caoutchouc of value.

Another natural order of note in this respect is the Lobeliaceæ, since the tropical American species of Siphocampylus, found in Colombia and Ecuador, have been said to yield caoutchouc of commercial value.

Geographical Distribution of Caoutchouc Plants.

The geographical distribution of the more important caoutchouc-yielding plants is imperfectly known, but a general idea of the plant areas where certain species thrive can be given. Rubber-producing plants occur in both hemispheres, and are confined to approximately 25 degs. or 28 degs. north and south of the Equator. In this area the three most important regions are, following the floral regions of the world as divided by Drude: (1) tropical American; (2) tropical African, including Madagascar; and (3) the Indo-Malayan region. These three regions supply nearly the whole of the rubber of commerce. In the first division Brazil is the most important indigenous area, and the West Indies the most prominent for cultivation of introduced species; in the second division the Congo State stands out prominently for indigenous and introduced species; in the last division Malaya may be taken as the centre with the Dutch East Indies and Pacific Islands to the south, and Ceylon and South India to the west.

Indigenous and Introduced Plants.

It may be said that, of the three areas enumerated, the tropical American and African are, at present, mainly concerned with the extraction of latex from, and cultivation of, plants indigenous to those areas—Hevea, Manihot, Funtumia, Landolphia, etc.—whereas the Indo-Malayan region, though it possesses a few indigenous species of value, such as *Ficus elastica*, *Cryptostegia grandiflora*, and others, is directing its attention, almost exclusively to-day, to the cultivation of species—*Hevea brasiliensis* and *Manihot Glaziovii*—introduced from the tropical American region, and to a few—notably *Funtumia elastica*—from the African zone. The tropical American region has been the home of the plants which have led to the rubber industry in Ceylon, Straits Settlements, Federated Malay States, Dutch East Indies, and Southern India, and has supplied even tropical Africa with species which rank as of first importance at the present time.

Trees, Shrubs and Climbers.

Another interesting feature of the laticiferous flora of these three vast regions is the nature of the plants predominating in each area. It may be said that the caoutchouc plants of the tropical American area are mainly of an arborescent type, *e.g.*, *Hevea brasiliensis*, *Castilloa elastica*, *Manihot Glaziovii*, and Sapium ; a few shrubby plants, such as *Parthenium argentatum*, and climbers such as *Forsteronia floribunda*, do, of course, exist there.

On the other hand, the rubber industry of the African region, especially if we include Madagascar, is principally concerned with lianes, climbers, or root rubbers,—Landolphia, Clitandra, Carpodinus, Cryptostegia, etc. ; indigenous tree forms, such as *Funtumia elastica*, *Ficus Vogelii*, *Euphorbia Tirucalli*, and introduced tree forms also abound in certain areas of Africa. In the Indo-Malayan region, on the other hand, there is a mixed indigenous flora composed of huge tree forms, such as *Ficus elastica*, Dyera species, and *Sapium insigne* ; and climbers such as Willughbeia, Cryptostegia, Urceola, Leuconotis, Parameria, etc., few of which pay to cultivate.

The introduced plants cultivated in the Indo-Malayan region are nearly all of the arborescent type, such as Hevea, Manihot, Castilloa, Sapium, Funtumia, etc., with a few lianes, the most prominent of which is Landolphia. The table given below will show the introduced and native plants now largely exploited for rubber in the three areas :—

Important Caoutchouc Plants.

(Generic Names.)

I.—Tropical America (including the West Indies) :—

Native.—Hevea, Castilloa, Manihot, Sapium, Hancornia, Micrandra, Parthenium, Hymenoxys, Brosimum, Forsteronia.

Introduced.—Funtumia, Landolphia, Castilloa, Hevea, Manihot.

II.—Tropical Africa :—

Native.—Landolphia, Funtumia, Ficus, Carpodinus, Clitandra, Cryptostegia, Euphorbia.

Introduced.—Hevea, Manihot, Castilloa, Cryptostegia, Ficus.

III.—Indo-Malay :—

Native.—Ficus, Dyera, Willughbeia, Urceola, Parameria, Cryptostegia, Chonemorpha, Ecdysanthera, Leuconotis, Rhynchodia.

Introduced.—Hevea, Manihot, Castilloa, Funtumia, Landolphia.

Rubber-Yielding Species.

Most companies engaged in rubber cultivation have selected trees for planting purposes which have become known in virtue of their caoutchouc-yielding capacities. It is as well to state that in each of the genera Hevea, Castilloa, Manihot, Ficus, etc., as in many others, there are numerous species known to yield caoutchouc, but in very variable quantities and of different qualities. Undoubtedly, in tropical America and Africa, the latices of numerous species frequently contribute to the rubber exported in a form known under only one name, and the real rubber values of many species of Hevea, Sapium, Euphorbia, Dyera, Landolphia, and Manihot, are but little known, except to the natives on the spot. This has been dealt with, in detail, in the first chapter. There are some companies operating in tropical America who find it to their interest to cultivate species of Manihot other than *M. Glaziovii*, though the latter is the species of Manihot which was first sent to the East, and which everyone has hitherto associated with Ceara rubber for many years. The results obtained with species of Manihot in Malaya are far less favourable than those reported in East Africa where the climate is much drier and hotter.

Laticiferous and Caoutchouc Plants.

It is necessary to explain that numerous plants possess latex in large quantities, but the viscous liquid is often almost useless on account of the low percentage of caoutchouc or the high percentages of albuminous, resinous, and other substances present. Everyone must have noticed the milky liquid which issues from the cut surfaces of *Sonchus arvensis* and species of Euphorbia—plants which occur abundantly in parts of Europe. In the tropics there are many trees, such as species of Carissa and Plumeria, *Euphorbia Tirucalli* and *antiquorum*; climbers or lianes, notably *Cryptostegia grandiflora*, and *Willughbeia zeylanica*, which almost squirt out large quantities of latex when cut with a knife. The same may be said of Palaquium and Bassia in Ceylon—genera from which the guttapercha of commerce is obtained, but which in the island mentioned yield latex in small quantities and of very little commercial value. Pontianak, a resinous rubber obtained from Dyera trees is, after chemical treatment, now shipped as ordinary crêpe rubber and competes favourably with plantation Para; this illustrates the possibilities with other trees now yielding inferior rubbers. The latices of importance usually possess high percentages of caoutchouc—the compound which largely determines the uses to which the dried product can be put. If one considers species of the same genus, the striking fact is revealed that the chemical composition of the latex is almost of specific importance. There are many species of Hevea, Landolphia, Ficus and Funtumia, but only certain members possess high percentages of caoutchouc and low percentages of resins and proteins.

The high percentage of rubber in the latex from *Hevea brasiliensis* and the adaptability of plants of this species have, together with other factors, led to this species being selected in most Eastern countries for cultivation. It is, therefore, necessary to deal somewhat fully with the important botanical characteristics of this particular plant.

Botanical Characters of Hevea Brasiliensis.

M. H. Jumelle (Les Plantes à Caoutchouc et à Gutta, by Henri Jumelle, Paris, 1903) devotes considerable attention to the supposed varieties of *Hevea brasiliensis*, and, like many other botanists, concludes that the differences in colour, size, and shape of the leaves described by Ule and others are not constant and may be disregarded. The leaves are trifid, long, and lanceolate, each on a long petiole.

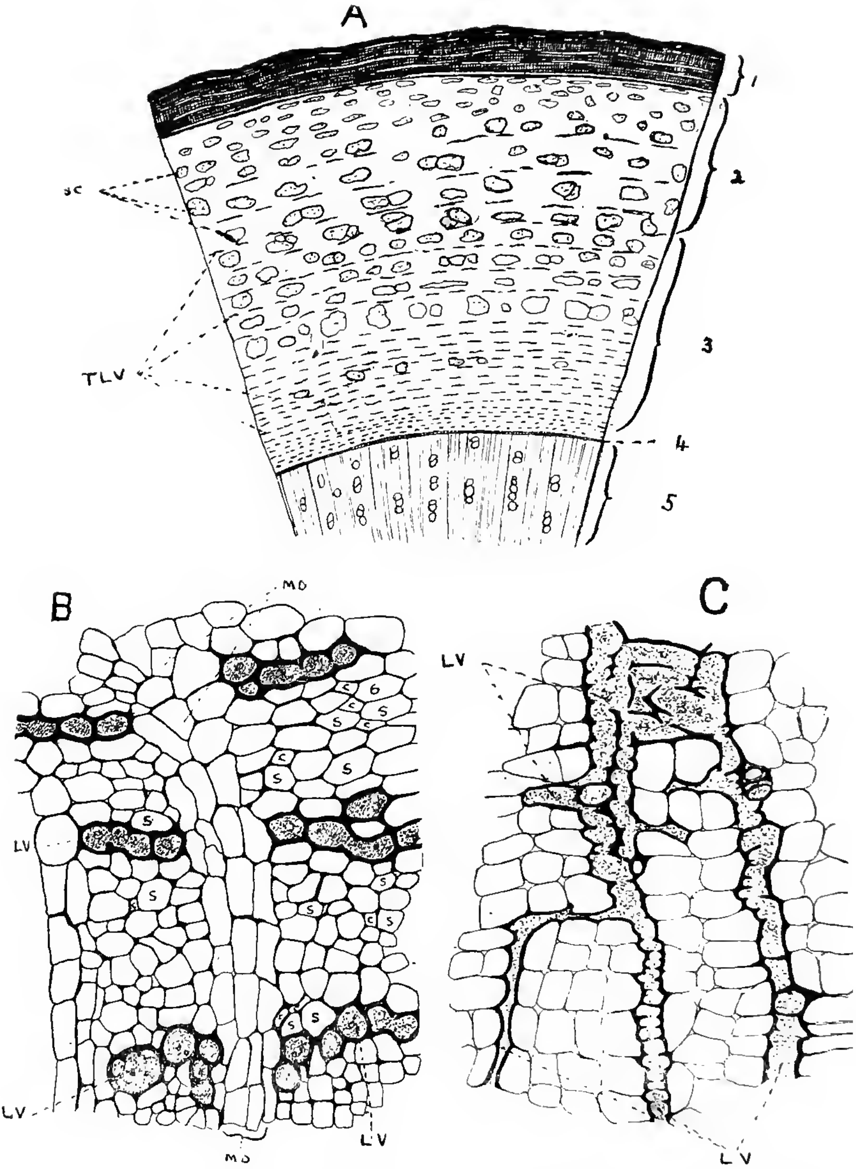
The flowers are monœcious, and are grouped, at the tips of branches, in panicles of small cymes; each inflorescence has two kinds of flowers, male and female, which permits of artificial pollination without much difficulty should plant selection be adopted in the future. The calyx is usually five-lobed; the stamens of the male flowers are united in the centre to form a column; the female flowers usually possess five staminodes, a small 3-celled ovary, and 3 sessile or short-styled stigmas; the fruit is a three-lobed capsule, in which the three oval oleaginous seeds are contained. The seeds are each about the size of a nutmeg, and shiny and speckled brown on the surface; they are often scattered a distance of 50 feet when the fruits burst with a loud report.

There are about twenty species of Hevea recognized by Müller, Hemsley, and Huber.

Botanically the genus Hevea has been divided by Huber ("Essaio d'uma Synopse das Especies do Genero Hevea sobos pontos de vista Systematico e Geographico") into two sections, each of which is subdivided into series. *Hevea brasiliensis* belongs to section Bisiphonia, Muell. Arg., and series Intermediae, and is characterised by having anthers in two complete series, inflorescence pale-yellow or white, buds of the male flowers acuminate and obsolete styles.

Photo by F. H. Macmillan.

LEAVES, FLOWERS, FRUITS, AND SEEDS OF HEVEA BRASILIENSIS.



Specially drawn by R. J. Tabor.

A. TRANSVERSE SECTION THROUGH BARK OF OLD STEM; BARK 8mm. THICK.

B. TRANSVERSE SECTION THROUGH SECONDARY PHLOEM.

C. TANGENTIAL SECTION OF INNER CORTEX.

S.C. Stone cells. T.L.V. Tangential bands of laticiferous vessels. M.D. Medullary rays. C. Companion cells. S. Sieve tubes. L.V. Laticiferous vessels.

1. Cork. 2. Cortex. 3. Phloem or inner cortex. 4. Cambium. 5. Wood.

Species of Hevea and their Distribution.

The genus Hevea furnishes the largest quantity, and perhaps the best quality, of rubber in the world ; some samples of carefully prepared Lagos lump from *Funtumia elastica* and Ceara from *Manihot Glaziovii* are said to be equal, in many respects, to the finest Para. It is represented by *Hevea brasiliensis*, Muell. Arg., and *H. similis*, Hemsl., in Brazil, Eastern Peru, and Bolivia ; by *H. spruceana*, Muell. Arg., *H. minor*, Hemsl., *H. benthamiana*, Muell. Arg., *H. rigidifolia*, Muell. Arg., and *H. discolor* in North Brazil ; by *H. pauciflora*, Muell. Arg., in North Brazil and British Guiana ; by *H. lutea*, Muell. Arg., in North Brazil and East Peru ; by *H. confusa* in British Guiana, and by *H. guyanensis*, Aub. In the basin of the Amazon and in the south of Venezuela and the Guianas, species of Hevea are abundant and scattered among other forest types ; further north they are replaced by Castilloa and Parthenium, and on the Atlantic side by Manihot and Hancornia.

Hevea brasiliensis is, in the wild state, distributed through the southern part of the Amazon basin. It occurs on the low alluvial lands of the affluents of the great river and also on the high lands. Huber states that this species is specially abundant (1) on tide-flooded islands and the mouth of the Amazon, including the lower courses of the rivers Tocantins and Xingu, (2) the middle course of the rivers Xingu and Tapajoz, (3) the Brazilian part of the basin of the river Madeira and its affluents, (4) the Acre Territory, together with the upper basin of the Rio Madeira belonging to Brazil and Bolivia, and (5) the valleys of the rivers Purus, Yuruà, Yutahy, Yavary, and the lower valley of the Ucayali. The Acre Territory is described as one of the richest rubber countries in the whole of tropical America, and the construction of the Madeira-Mamorè railway is expected to lead to a material increase in the output of rubber from that part of South America.

Commercial Value of Hevea Species.

Huber recognises, in a commercial sense, several groups of Hevea species, and has given to many species new names. He regards *Hevea brasiliensis* and *Hevea benthamiana* as the two species yielding the highest class of rubber, *H. benthamiana* being for the northern affluents of the Amazon what *H. brasiliensis* is for the main river and its southern affluents ; collectors are said to regard the former as a variety of the latter. In the second group he places *H. guyanensis*, *H. collina*, *H. nigra*, *H. cuneata*, *H. lutea* and *H. paludosa* ; these yield "borracha fraca" or weak rubber. These species do not generally grow together in the same localities, only *H. guyanensis* being found mixed with *H. brasiliensis*, and the latices are therefore not likely to become mixed with that of the premier species. In the third group *H. spruceana*, *H. discolor*, *H. similis*, and *H. viridis* are placed ; these yield only small quantities of latex which give a sticky, weak rubber.

Among the species of Hevea enumerated above there are several which yield large quantities of latex, but *Hevea brasiliensis* is probably responsible for the greater part of the Para rubber of commerce. *H. benthamiana* has been confused with *Hevea brasiliensis*, and is said to be cultivated, at the present time, in some parts of Venezuela.

H. discolor has lately received considerable attention, and though its latex is said to be used for adulterating purposes, it does not appear to possess very much caoutchouc.

The names of common grades of rubber obtained from various species of Hevea are given in the first chapter, and should be studied in connection with the above details of distribution. Steglich Von Hassel believes that in the upper Amazon there are 600 kinds (varieties ?) of caoutchouc trees.

According to Sperber (Tropenpflanzer, Feb., 1910) the following species are tapped in Peru:—*Hevea guayensis* (?), which attains a height of 15 to 20 metres, and a diameter of 60 to 80 c.m.; *H. brasiliensis*, height 18 to 20 metres, and diameter 60 to 80 c.m.; *H. audinensis* (?), height 15 to 20 metres, and diameter 70 to 80 c.m.; *H. lutea*, height 18 to 20 metres, and diameter 50 to 60 c.m.

Foliar Periodicity of Hevea Brasiliensis.

Trees of *Hevea brasiliensis* exhibit marked foliar periodicities in the East. 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 third or fourth 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 Malaya usually change their leaves from January to March; in badly-drained places the foliar change is very irregular. The tapping operations are believed, by many persons, to change to a varying degree the periodicity of leaf-fall and production.

The following observations apply to some of the oldest trees at Peradeniya and Henaratgoda:—

Number of Tree and Year.		Leaf-Fall. Commenced.	Leaf-Fall. Finished.	New Leaves Appeared.	Number of Days Trees Leafless.
I.	1901-2	.. November.	Jan. 6th.	Feb. 2nd.	26 days.
II.	1902	.. Jan. 1st.	Feb. 23rd.	Feb. 28th.	4 ,,
	1903	.. Jan. 3rd.	Feb. 26th.	March 2nd.	3 ,,
III.	1903	.. Sept. 29th.	November.	November.	—
IV.	1902	.. Jan. 4th.	Jan. 14th.	Jan. 24th.	9 days.
	1903	.. Jan. 21st.	Feb. 3rd.	Feb. 10th.	6 ,,

In its native home the tree is said to become leafless between March and July; but in parts of Peru it passes through this phase, according to Sperber (Tropenpflanzer, Feb., 1910), from July to September.

Fruit Periodicity in Singapore.

There is a considerable difference between the trees in the Singapore Botanic Gardens and the average mature trees in Ceylon. In the Straits, according to Ridley, the trees may bear fruit in any month of the year, although the period of heaviest seed crop is July-October with another heavy crop in the month of March. The following table shows the total number of seeds collected in each month for nine consecutive years in the Singapore Gardens :—

January	..	32,924	July	..	29,650
February	..	55,800	August	..	79,600
March	..	148,050	September	..	324,515
April	..	56,314	October	..	291,436
May	..	28,097	November	..	85,870
June	..	28,700	December	..	35,807

Ridley concludes (a) that while there are two seasons when flowers and fruits may occur in some years within the period of a year, there is never more than one heavy crop annually ; (b) that the autumn crop is the more uniform of the two, as the spring has only exceeded the autumn crop twice in 10 years ; and (c) that the autumn fruit periodicity represents the true normal condition of the tree.

Fruit Periodicity in Ceylon.

The fruit periodicity in Singapore agrees more or less with Ceylon, where there is a main or only fruiting period in the autumn. (The Uva province is the only district in Ceylon where there is a special spring fruit period, February-April). The best crop month in spring is March, which over a period of nine years stands third in the annual returns, and varies from nil return in 1905, and only 50 seeds in 1902, to 43,050 seeds in 1901. A similar variation may be observed in the autumn crop for August, which out of a total of 79,600 seeds for 9 completed years produced no less than 60,850 seeds during that month in 1905.

In the south of Ceylon the principal seed crop is in the autumn, collecting extending from August to November.

On the Gold Coast the fruiting season is from July to October.

In Brazil, according to Temple, the fruits begin to fall in March, and according to Witte, about December and January; the latter states that the trees sometimes blossom twice a year.

Laticiferous Systems of Plants.

All the species which yield rubber are characterised by systems of sacs, series of cells, or tubes containing latex ; these occur in nearly all parts of the plant. The commercial possibilities and the ultimate success of several species are determined by the particular type of laticiferous tissue which each contains. When one considers the great difference in the nature, mode of origin, and development of the laticifers in various plants, there is every reason for suggesting that each species should be tapped on a particular system in order to take advantage of the peculiarities of each type.

From a study of the laticiferous system of our prominent plants, I am convinced that in certain instances the old native and apparently wasteful methods adopted in the extraction of latex are probably as good as, and even better than, many which have been evolved by Europeans.

The laticiferous system in several of our important species occurs in the cortex of the stem, branches, roots, and in the leaves, flowers, and fruits. In some species, the laticifers appear to be best developed in the root and the extraction of latex is only considered in relation to that part ; in other species there appears to be a better development in the stem, and in a few others the flowers or young twigs show conspicuous developments. Generally, the laticifers and the latex appear in the embryo and remain until the death of the plant ; in some cases, however, the laticifers are not obvious except in plants of some years' growth. Sometimes they are absolutely restricted to stems and roots, the leaves and flowers never being in possession of such structures ; in a few cases they appear in the young tissues, and then gradually die and disappear.

It will perhaps be sufficient to state that there are three types of laticiferous systems the components of which are scattered freely throughout the cortex in the stem ; they may, according to their age and the condition of the plant, be partially or wholly filled with latex.

Stem Structure of Hevea Brasiliensis.

On plantations the part of the plant which is most affected is the stem, this being subject often to daily or alternate day tapping until the whole of the so-called "bark" on the lower part of the trunk has been removed. The practical man knows that he has to avoid cutting too deeply during tapping, and usually the only indication of having done this is exposure of wood. It is, therefore, advisable to give a brief description of the stem tissues excised in the principal operation on the estate.

Bark.

Commencing on the outside, we have a dark-coloured, dry bark ; this is formed by the drying-up of the outer soft cells of the living cortex in young saplings and older plants, but later on in life is largely produced by series of cells (bark-cambium) that continually divide and form bark cells on the outside and other living cells internally. The bark represents tissue which has lost all its reserve food supplies, and is always peeling off ; it can, therefore, be dispensed with as being of little importance to the planter.

Cortex.

Inside the bark there is a collection of soft living cells, which form a thick layer extending from the dry bark nearly to the wood ; this is the "cortex," and constitutes the greater part of the so-called "bark" which is cut away during tapping operations. It is this layer which contains abundance of reserve food, and which not only serves as a store-house, but as the main channel along which food, elaborated in the leaves, is conducted from above downwards. If this layer is removed entirely around the stem at one level, the cut edge on the lower part of the stem will become thin and dry ; the upper part, still in connection with the cortex and therefore the foliage above, begins to bulge out, probably because the food materials, being stopped, have accumulated there in their downward course. The wound area will always heal from above downwards—this indicates the one important function of conducting elaborated food materials in this direction executed by the cortex. This thick layer of living cells also contains the laticifers in which the latex accumulates. The latex channels are less crowded, but larger, in the outer than the inner layer of cortex. In tapping it is this thick cortex, and the thin layer of dry bark, which is removed. It is, therefore, clear that this tissue, containing food for the plant and the special structures filled with latex, is of the greatest importance, not merely now to the planter, but to the future life of the tree. It should be preserved as long as possible. Above all, the means whereby it is continuously produced should be protected.

Cambium.

This brings us to the important part known as the cambium—the layer of cells which, so long as it is not injured, produces cortical cells externally (wherein new laticifers appear and food supplies accumulate), and wood internally. This layer is not concerned with storing food ; it does not contain latex ; it does not perform any function of importance beyond that of dividing to produce cortical and wood cells on opposite sides. If, in tapping, this layer is injured, the healing and growing capacity of the tree is affected, and the production of new cortical cells, on which renewed tapping depends, is checked. It is an extremely thin layer, probably not thicker than the sharp cutting edge of the tapping knife, and is the dividing line between the cortex and wood.

Wood.

Within the cambium is the wood, detected immediately by its hard texture and lighter colour whenever the tapper has gone below the healing or cambium layer. The wood is a part of the tree which should have no claim on the planter's mind, and will therefore not be described.

Laticiferous System of Hevea Brasiliensis.

In *Hevea brasiliensis* the latex is contained in definite ducts which occur throughout the stems, roots, leaves, flowers, and fruits. The laticiferous ducts in *Hevea brasiliensis* begin as a series of cells, 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 the flow of the latex is, therefore, not as free as when the partition walls are completely broken down. The disconnected series of cells in all stages of perforation is accountable for many of the variations in yield of latex and rubber described elsewhere.

Scott, in his paper (Linn. Soc. 1885) on the occurrence of articulated laticiferous vessels in Hevea, states that the embryo of *Hevea brasiliensis* contains well-developed laticifers, which form a complex anastomosing system; numerous and extensive perforations occur in the lateral walls, though the absorption of the transverse walls may not be complete. Scott believed that the perforation of the lateral walls commenced at an earlier stage than that of the transverse walls. In many parts of his paper he points out that remnants of the transverse walls remain though large numbers of cells have undergone fusion. The same processes of perforation and disappearance of cell walls go on in the secondary cortex, and the laticiferous system is, though communicative to some degree, relatively disconnected, compared with the straight, open, non-articulated tubes in certain Castilloa and Euphorbia species.

Chimani found that in a twig of diameter 8·5 mm. ($\frac{1}{3}$in.), the latex tubes had a diameter of from $\frac{1}{1700}$ in. to $\frac{1}{1430}$ in.

How Latex Channels are Formed.

An examination under a high power of the microscope reveals how the latex tubes arise and become filled with the globules of the different substances which ultimately give the rubber of commerce, for here and there can be seen the breaking-down of the regular cells and the production of a single irregular tube by the disappearance of partition walls. This decomposition, essential for the production of the latex tubes in Hevea and Manihot rubber trees, commences in the germinating seeds and continues until death; even when the trees are to all appearances dead, they may, three years after throwing out their last leaf, still maintain the latex tubes and yield latex of fair quality. What are perfectly normal and regular cells in the bark to-day may begin to show perforations to-morrow, and within a few days or a week a system of latex tubes may arise in an area which, had it been tapped too early, would never have yielded a drop of latex. The formation of latex tubes from a series of single cells may be illustrated by knocking out the cross-walls of an ordinary bamboo: from a series of separate chambers a single tube with the remnants of the cross-walls may be obtained. It should be clearly understood that the latex tubes of Hevea trees arise by the perforation and decomposition of ordinary cells of the cortex; secondly, that the processes involved require an interval of time for their completion which the constitution of the plant determines; and lastly that in tapping operations we are dealing with a series of channels which have no very vital association with other parts of the cortex.

The formation of new laticifers cannot be pre-determined by microscopical examination of the newly-formed cortical cells, the disappearance of the transverse walls taking place irregularly in the cortex; though Ceylon criticisms suggested otherwise, the origin *de novo* in the secondary bark is accepted by microscopists. In a general way it may be stated that the longer the cortex is allowed to remain on the tree the greater the number of cell fusions effected; the greater the number of cortical cells available the larger the number of laticifers, within limits, which are likely to be formed. The laticiferous system in *Hevea brasiliensis* does not increase in size by prolongation of original sacs as in many other plants, but by the disappearance of cell walls; such a system is, despite statements implying the contrary, relatively disconnected (compared with the Castilloa or Euphorbia type), though there is, as every one knows, communication of some kind between the disintegrated cells in each area. In *Hevea brasiliensis* parts of cross walls may remain, whereas in the non-articulated types these never exist. The laticifers in Hevea rubber trees have been called "vessels," "sacs," "tubes," etc., but the name is of no great practical importance, and can only confuse the point at issue. The term "fused cells" would probably convey the most correct idea for the laticifers in *Hevea brasiliensis*, as against the word "tubes" for those in Castilloa, and the term "sacs" for those in certain guttapercha-yielding plants.

Formation of Rubber in Situ.

No one has yet determined the total quantity of rubber procurable from the whole of the bark of a Hevea rubber tree of known age or size by felling the tree and macerating the milky tissues. But it is well known that, irregularly connected though the laticifers in this species may be, the quantity of rubber procurable by tapping may greatly exceed the actual weight of bark removed even when a wasteful excision method is adopted. It is therefore obvious that the rubber must be formed in the bark in virtue of the associations of the laticifers with other parts of the plant which permit the circulation of ingredients ultimately forming part of the latex. The laticifers in the bark are usually surrounded by cells which either store food supplies or conduct the sap elaborated in the leaves from above downwards; their walls are very thin and the permeation of solutions from the surrounding cells is easily accomplished.

Whenever laticifers are cut it is obvious that they must partially drain those with which they are connected and, after closing, again become partly filled with the latex from connected laticifers. At the same time certain cortical cells, which have been cut off from the cambium in the usual manner, are gradually converted into laticifers which themselves become charged with latex. It is impossible when examining young cambium products to distinguish which cortical cells will form laticifers in the secondary cortex.

In order to determine whether caoutchouc is developed at the place where it is collected from the tree, experiments were being made (Tropical Agriculturist, September, 1907) in Ceylon: "trees are being ringed, and half-ringed, at distances of a foot, and all the milk removed, to determine whether new rubber is formed between the rings." The results of these experiments will be awaited with interest. In April, 1908, the isolated cylinders of bark possessed a fair quantity of latex.

Variability of Laticiferous System in Hevea.

Considerable variation, suggestive of internal differences, has already been recorded in the yield of latex from tapped trees in the East. Variations in the nature and yield of latex from trees at all elevations are to be expected for one simple reason: the laticiferous system, from which the latex is obtained, is not a vital part of the tree. There is, of course, a general anatomical constancy, and the majority of the trees of *Hevea brasiliensis* possess latex throughout their lives; but in some cases the trees do not yield normal latex during certain periods, though subsequently they contain this mixture in large quantities. Generally speaking, one may say that there is less constancy in parts of the plant which are not of vital importance than in those upon which the continuity of the tree's life depends; for instance, the peculiar cells which are of vital importance and conduct and store food materials from the leaves—phloem tubes and companion cells—are much more constant in the cortex of *Hevea brasiliensis* than are the non-vital latex tubes. There is no need to get alarmed at the fact that latex is occasionally almost absent or possesses a low percentage of rubber globules; it is a variation which must be expected, considering the non-vital functions of the latex and the millions of the same species already planted in the East. A complete explanation of this variability in the laticiferous part of the plant, based on anatomical or physiological grounds, has not been put forward, and in the meantime this phenomenon adds one more to the perplexing points requiring solution. We are left to explain why latex tubes occur in only a small number of plants, are never required by many species, and even when present appear to have no vital functions to perform. In some cases they remain turgid and full of latex when most other parts of the plant are dead, as in the dead stumps observed at Henaratgoda and Singapore.

Functions of the Latex.

It is well known that a system of latex tubes may or may not occur in different species of plants, and that the presence of a laticiferous system is of importance in determining the identity of species. Several natural orders, such as those which include the genera Euphorbia, Castilloa, Hevea, Funtumia, Landolphia, etc., are characterised by large numbers of plants which possess latex tubes, whereas other natural orders are not known to have any laticiferous species. It is also recognized that the number of species of plants, possessing latex tubes, is greater in the tropics than 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; in the case of *Hevea brasiliensis* many observations have been made and various theories propounded.

The latex of Hevea consists mainly of water and caoutchouc globules together with small quantities of sugars, proteins, gums, resins, mineral matter, etc. Most of the constituents cannot be regarded as forming reserve food, and even in the case of sugars and proteins 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 along 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 minor importance to the plant.

Groom (Function of Laticiferous Tubes, Annals of Botany, 1889), when dealing with this subject, pointed out that there was no reason to believe that the functions of the latex in all plants were the same, or that one function should exclude the other.

Function of Storing Water.

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 humidity of the air and the quantity of water present in the soil. The increased flow which follows rain after a drought is often very remarkable; this may, or may not, mean an increase in caoutchouc during these periods.

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.

Freeman remarked at a meeting held at the Royal College of Science, London (Indiarubber Journal, 30th December, 1907), that one view, which had a considerable amount of evidence to support it, was that the latex tissues serve as a place for storage of water to be drawn upon in periods of drought. It has been observed that trees of the Central American (*Castilloa elastica*) rubber tree growing under moist conditions develop very little latex, i.e., yield very little rubber, whilst trees growing under drier conditions yield latex more abundantly. It would be reasonable to expect, if the latex is really functional for water storage purposes, that it would be developed to the greater extent in plants living under such circumstances as necessitate their drawing on storage supplies of water during part of the year. That is to say, rubber plants growing in countries with well-marked dry seasons would have greater inducement to provide the water reserve than those growing in continuously humid districts. In the latter the trees would thrive and grow very freely, perhaps better than in the former, but they might yield less rubber because conditions are too well suited to them.

Freeman's view would appear to be contradicted by the results obtained in the wet soils of the F.M.S.

Parkin considered that the latex did not play an important part in nutrition, and inclined to the belief that the laticiferous system served as a channel for holding water in reserve to be called upon during times of drought. "Primarily," he states, "the latex may be regarded rather as a waste product, and the tubes containing it as genetically related to, and a further development of, secretory sacs. But the substitution of an extensive system of communicating tubes in place of isolated sacs apparently implies the adoption of some new function, in addition to that of removing the waste products of metabolism. A conducting function is the one which suggests itself. The tubes may form channels for the conveyance and storage of water. Laticiferous plants, at any rate the arborescent ones, are distinctly numerous in the tropics, where transpiration at times is excessive, especially during the dry season. The theory of water storage and conduction is perhaps the most plausible. The watery nature of the latex in the trunk of Hevea has been noticed to be affected by the state of the soil. When dry, the latex is thicker and flows out less readily, suggesting that the tree is drawing upon the reserve of water accumulated in the laticiferous tubes. In the alluvial regions of the Malay States the tree yields latex very abundantly. Here there is a surplus of moisture in the soil, and so the tubes are always well distended with latex. There is, in fact, no need to draw upon this reserve." The exudation and clotting of the latex prevent the many insects entering the tree, but this is not of much importance.

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 10 pounds of rubber, per tree, per year. An abundant supply of water, in well-drained land, is not harmful to young Hevea rubber trees, as is evidenced by the large yields obtained in parts of Perak and Selangor where the water-level is often only six inches below the surface and the trees have lost their tap roots.

Protective Value of Latex

Ridley doubts whether the latex of Hevea rubber trees acts as a water store or a protection against drought and points out that though many laticiferous plants thrive in desert areas, the proportion of species belonging to the wet tropical districts is relatively high. He lays emphasis on the latex as a protection against the intrusion of fungus spores and insects into wounds, and states that many of the trees of the equatorial belt are provided with either latex, resin or gum, which rapidly exudes when a wound is made.

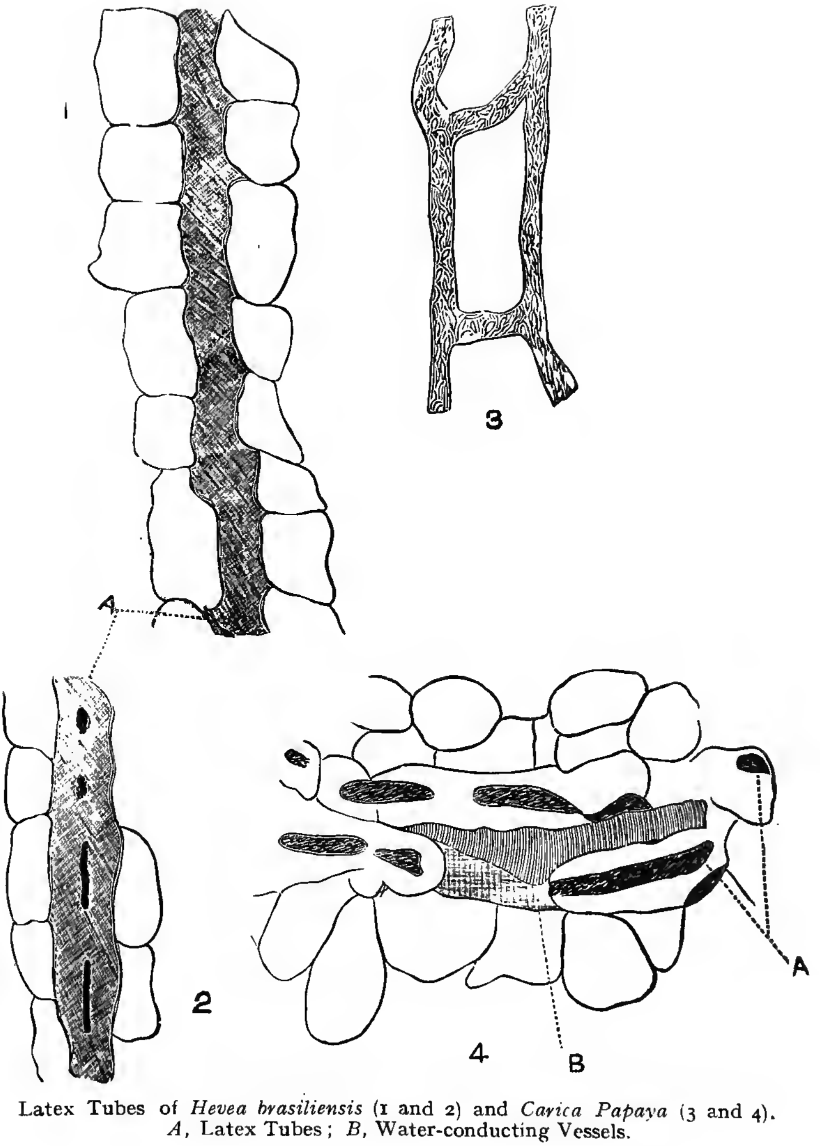
Lloyd in his paper on guayule (Lectures on Indiarubber, page 139), points out that the failure to exude upon wounding, in that plant, appears to negative the view that it serves to protect against injury.

Latex as a Reserve Food.

In the accompanying illustrations, 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 latex tubes are pitted, so that a transference of solutions may be effected from one series of cells to the other. Furthermore, the latex 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 4, 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 indiarubber. In figure 3 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 latex tubes are partially connected with conducting functions. Contact between laticifers and wood vessels is, of course, almost impossible in healthy mature bark of a tappable Hevea tree ; the close association of these elements in the embryo and seed-leaves (cotyledons) suggests a means whereby the latex in the early stages may be used as food.

But the fact that the laticiferous tubes 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 largely as water reservoirs.

Generally speaking, the latex tubes contain an emulsion of many substances, such as caoutchouc, resin, gum, sugar, proteins, alkaloids, and fats, and it is therefore very difficult to identify each component in sections under the microscope. Schulerus observed that in the embryo the latex is rich in suspended matters,



Latex Tubes of *Hevea brasiliensis* (1 and 2) and *Carica Papaya* (3 and 4).
A, Latex Tubes; *B*, Water-conducting Vessels.

and that as the plant grows the latex becomes more watery. He suggested that the emulsion of substances might be of use during the early stages. He also noticed that after germination the laticiferous system becomes prominent owing to an increase in the substances in suspension.

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 found that in some plants the starch grains disappeared from the latex 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 possible origin of caoutchouc from sugars should also be borne in mind at this juncture.

The presence of nuclei in certain laticiferous tubes, absorption in the embryonic stages, the close association of latex tubes with conducting elements in the leaf, and the occurrence of minute quantities of carbohydrates, proteins, fats, and peptonizing ferments, certainly support the idea that under certain conditions the latex contents may be useful to the plant. These substances are present in very variable proportions, and the percentage of valuable ingredients in the latex and remaining bark often diminishes as the result of tapping operations; this may be accounted for by the demand made on reserve foods in the immediate vicinity of tapping areas, these being used up in the production of new cortex to replace that excised in tapping operations. 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.

Spence believes that caoutchouc is a reserve food-stuff for the plant and bases his theory on the hydrocarbon nature of this substance and the presence of oxidising enzymes in the latex; furthermore, he found that young trees of *Ficus elastica* drew upon the latex when grown in an atmosphere and soil free from carbon dioxide. As the result of his discoveries in connection with proteins and enzymes in latices and rubber, he stated that caoutchouc is "a reserve food-stuff for the plant at certain stages of its growth, which is broken down as circumstances demand, by the enzymes associated with it in the living protoplasm, into the simple food-stuffs, the sugars, from which the caoutchouc is almost certainly formed by the plant." In support of his theory Spence refers to the entire disappearance of caoutchouc in the latex of an African plant when the rainy season commences and its reappearance at the end of the rains; his inference from this and allied phenomena is that the caoutchouc is used in the metabolic processes of the plant. Parkin states that physiologists will require much evidence before accepting such a novel theory.

Petch observes that if a fallen Hevea leaf be taken, and a thin layer of the midrib on the back of the leaf be slowly peeled off, strands of rubber appear between the midrib and the strip that is being peeled off. Rubber can also be extracted from fallen leaves with carbon bisulphide. Now, when a tree sheds its leaves, all the potash, phosphoric acid, starch, etc., in them has been absorbed. The dead leaf contains only waste products ; therefore rubber is probably a waste product.

The physiological effect of extracting large quantities of latex from trees of known age is being studied in the East, but up to the present no remarkable phenomena have been observed. Where the bark is regularly cut away it is impossible to determine the effect of removal of latex only, as the loss of living bark containing abundant supplies of reserve food is obviously a far more important factor. If incision experiments only are carried out, and all primary bark preserved, it may then be possible to determine the effect of removing the latex on the quantity of reserve foodstuffs in adjacent tissues. Even then it would be necessary to remove large quantities of latex and to make due allowance for the usual metabolic changes daily occurring in all living cells.

CHAPTER IV.

CLIMATIC CONDITIONS FOR HEVEA BRASILIENSIS.

Para (Notes on Rubber-yielding Plants, by Trimen) 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.

Ule (Review by Willis, "T.A.," March, 1905), in his book dealing with rubber in the Amazon district, points out that "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.

"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."

Rainfall in Para, Manaos and Ceara.

The following statistics are given by Leplae in his account of Hevea cultivation :—

	Para. mm	Manaos. mm.	Ceara. mm.
January	263	250	68
February	320	243	193
March	338	300	287
April	336	330	361
May	237	191	269
June	144	129	133
July	125	76	51
August	108	46	16
September	82	39	14
October	63	100	16
November	59	162	13
December	129	261	42
Total	2204 (88·2 in.)	2127 (85·0 in.)	1463 (59·5 in.)

It must be understood that Ceara is the home of the rubber of that name and is outside the Hevea areas.

Hevea Trees in Brazil.

It has been pointed out by Wickham that the true forests of the Hevea 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 forests attain a circumference of 10 to 12 feet in the bole, a considerable difference to the 6 or 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 those who intend to cultivate this tree. 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 Hevea trees can be grown. 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, Samoa, 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 Malaya, Ceylon, and India.

Climate in Ceylon.

The combination of rainfall, temperature, and elevation required for the cultivation of *Hevea brasiliensis* 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 Hevea zone on account of low temperatures or unfavourable moisture conditions. In Ceylon an elevation of 2,000 feet in the Central Province, and 3,000 feet in the Uva Province, is considered to be near the maximum and a rainfall of 70 inches near the minimum for the cultivation of this species. There are trees, planted in 1899, measuring 18 to 26 inches in girth and 22 to 33 feet in height, growing on Weweltalawa, Halgolle estate, on the borders of the Kelani Valley and Yakdessa districts, at an elevation of 3,300 feet. 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 there for many years.

The following are the meteorological details of places in particular districts in Ceylon where Hevea rubber trees are being successfully grown (Surveyor-General's Report, 1902, and by letter) :—

District.	Annual Rainfall. Inches.	Average Annual Temperature	Elevation. Feet.
Kalutara (Gikiyana-kanda)	150·74	—	200
Colombo	87·52	80·7 F.	40
Henaratgoda	106·12	—	33
Kelani	161·06	—	250
Kurunegala	84·71	—	409
Kegalla	122·33	—	729
Kandy	81·52	75·5	1,654
Badulla	75·28	73·4	2,225
Passara	88·91	—	2,800
Matale	84·38	—	1,208
Ratnapura	151·39	79·1	84
Galle	91·16	79·9	48
Ragama	100·03	79·5	—

In the Colombo, Galle, Ratnapura, Kelani, and Kalutara Districts the rains in the N.E. and S.W. monsoons are very heavy ; in the Kurunegala, Matale, Badulla, and Passara Districts they are less violent, but in all the districts mentioned above rain falls every month in the year, the monthly variation being from about five to twenty-four inches.

Climate in South India.

In some parts of India the climatic conditions are such as to allow of the cultivation of Hevea trees up to 3,500 feet above sea-level, and what appear to be satisfactory rates of growth are reported from many parts. Extensive tracts of country are being opened up, especially in the Travancore district, and good results are anticipated on account of the abundance of rich alluvial soil which is reported to exist there.

Curiously enough, we must pass around to the West Coast to find a climate at all resembling that in the rubber-growing districts of Ceylon. There is a strip of country between the hills and the coast that is suitable, though there are also some outlying parts more to the east only a little less desirable. An area of annual rainfall averaging above 75 inches lies between the coast and a line roughly parallel with it passing northwards from Quilon. It includes the extreme north-west corner of Travancore, Cochin State, Malabar, part of the Nilgiris, Coorg, a corner of Mysore, Canara, and Goa (15° N. lat.) A narrower area of annual rainfall averaging above 100 inches included in this lies between the coast and a line roughly parallel with it passing northwards from Cochin Town. It includes Cochin State, Malabar, less of the Nilgiris and of Coorg and Mysore, and Canara and Goa. But the northerly parts of these areas is marked by a very pronounced dry season, and even in Coorg the average rainfall for the whole period of four months—December to March—at the ten Meteorological Stations is only 0·949 inches, with that at the highest station only 1·69 inches. Within these areas the average number of rainy days in the year is between 100 and 125; except close to Cochin Town, where the rainfall is better distributed and the dry season less pronounced, the number being greater.

As the following table shows, the climate in Cochin district is not widely different from that in the rubber-growing parts of Ceylon :—

METEOROLOGICAL DETAILS, COCHIN.

	Average monthly temperature. °Fahr.	Average monthly rainfall. Inches.		Average monthly temperature. °Fahr.	Average monthly rainfall. Inches.
January	79·5	0·80	August	77·9	12·44
February	80·9	0·80	September	78·5	8·74
March	82·5	2·12	October	79·1	12·46
April	84·0	5·24	November	80·2	5·16
May	82·5	12·00	December	79·9	1·72
June	78·7	30·12			
July	77·3	21·71	Annual	80·1	113·31

Some Hevea rubber in coffee has done well in the Anamallai Hills at an elevation of 3,500 feet above sea-level; and the results of tapping on an estate in the Shevaroy Hills are given in one of the chapters dealing with yields. It is as well to bear in mind that the elevation up to 3,500 feet, in so far that it is related with changes of atmospheric pressure, has very little influence on the growth of the rubber; far more important are the questions of ranges of temperature and rainfall.

THE CLIMATE IN THE FEDERATED MALAY STATES.

In the Federated Malay States there is no evidence of the highest elevation at which Hevea trees will thrive, though some young trees are growing at Gunong Angsi at an elevation of 2,500 feet. According to Carruthers the growth of Hevea rubber from sea-level up to 300 feet in the Federated Malay States is better than that at other elevations.

According to the Manual of Statistics published by the Federated Malay States Government "the climate of the Federated Malay States is very uniform and can be described in general terms as hot and moist. The annual rainfall, except in places close to the mountain ranges, is about 90 inches. In towns, such as Taiping, Tapah, Selama, etc., close to high mountains, upwards of 50 per cent. more is registered, the average of ten years' records at the first-named being 164 inches. There is no well-marked dry season. Generally speaking, July is the driest month, but has seldom a less rainfall than 3½ inches. The wettest season is from October to December, and there is another wet season of slightly less degree during March and April. Rain rarely falls before 11 a.m., so that 6 hours of outdoor work can generally be depended upon all the year round.

"The average maximum temperature, occurring between noon and 3 p.m., is in the low-country just under 90°, and the average minimum occurring before sunrise is just over 70°. The general mean temperature is about 80°. There is very little change in the mean monthly temperature during the year, the average of ten years' readings in Taiping exhibiting a difference of only 3·2° between the mean temperature of May, the hottest, and of December, the coldest month of the year.

"The variation of temperature with altitude may be taken roughly as a decrease of 3° for every 1,000 feet increase of altitude."

Average Rainfall at Perak, Selangor, Seremban.

	Perak (Teluk Anson), 1894-1903.	Selangor (Kuala Lumpur), 1894-1903.	Negri-Sembilan (Seremban), 1896-1903.
January ..	10·61	6·67	5·21
February ..	7·28	6·29	6·46
March ..	8·11	9·29	8·45
April ..	8·85	10·79	10·56
May ..	7·40	9·13	7·81
June ..	5·56	5·94	5·97
July ..	4·20	4·06	4·59
August ..	5·10	6·14	5·96
September ..	6·51	8·74	5·95
October ..	13·51	13·15	9·19
November ..	12·59	11·87	10·24
December ..	13·27	9·95	7·63
Mean Total..	103·01	102·02	88·02

The above details of rainfall will be of value to all interested in the cultivation of Hevea rubber in Perak, Selangor, and Seremban.

Rainfall in Kelantan.

According to the Administration Report for 1909, the following are the rainfalls for parts of Kelantan :—

	Kota Bahru. Inches.	Kuala Lebir. Inches.	Kuala Kelantan. Inches.
1907 ..	108·37	120·54	104·40
1908 ..	109·13	95·16	106·40
1909 ..	90·09	73·09	89·56

Singapore, Penang, and Malacca.

I am indebted to the Principal Civil Medical Officer of Singapore for the following statement showing the average monthly Rainfall, Temperature, and Humidity at Singapore, Penang, and Malacca :—

	Rainfall.			Temperature.			Humidity		
	Singapore.	Penang.	Malacca.	Singapore.	Penang.	Malacca.	Singapore.	Penang.	Malacca.
	Inches.	Inches.	Inches.	°F.	°F.	°F.	%	%	%
January	13·47	4·26	4·15	78·2	80·8	79·2	81	71	94
February	7·26	2·59	5·36	78·4	80·7	79·1	78	69	92
March	5·75	4·13	2·62	79·7	81·5	79·6	77	69	93
April	10·75	6·82	6·42	80·5	81·2	79·7	80	73	93
May	4·93	9·01	6·27	81·3	80·8	79·6	78	72	94
June	6·50	8·27	6·21	81·0	80·9	79·7	79	72	94
July	6·60	9·19	6·66	80·9	80·2	79·5	78	72	94
August	8·77	13·58	9·12	80·5	79·9	77·6	78	73	94
September	4·65	14·54	8·36	80·6	79·9	79·2	78	72	92
October	5·60	15·82	12·86	80·1	79·7	79·4	79	74	94
November	8·73	10·01	10·74	79·1	80·0	79·2	81	73	94
December	6·96	5·14	5·33	78·3	79·9	79·1	80	73	92

Climate in Sumatra.

The following statistics relating to the rainfall on well-known and advanced Hevea estates in the Langkat, Serdang, and Bandar districts of Sumatra should prove of interest :—

Rainfall, 1910.

Month.	Serdang District. (Baloewa.) Inches.	Langkat District. (Glen Bervie.) Inches.	Langkat District. (Soengei Roean) Inches.	Bandar District. (Pinang.) Inches.
January	9	2½	16	5½
February	13½	9	14	11½
March	7½	8	18½	7
April	12½	9½	20	9
May	7½	15	17½	13
June	13½	2	7½	13
July	11½	6	10½	8½
August	15½	9	6	14½
September	11½	4½	14	11½
October	18¼	11	24½	21
November	9½	10½	30	4
December	16¼	10⅜	32	13
	146	97⅜	210½	128½

Java.

The climate in Java varies like that in Ceylon according to the locality; we have definite information regarding the climatic factors at Buitenzorg and East Java.

The climate at Buitenzorg differs from that at Peradeniya, Ceylon, in many ways. At Buitenzorg the rain during 1901 to 1904, inclusive, fell on an average of 263 days in each year. The humidity of the air in 1904 ranged from 75 in August to 85 in December, and the average for the years 1901 to 1904, inclusive, was 79. The average monthly temperature ranged in 1904 from 23·6 to 25·3°C. The climate in Buitenzorg is more equable than that at Peradeniya, but a definite periodicity does exist, the rainfall and humidity throughout the year approximating to those at Badulla in the Uva Province of Ceylon.

In East Java the climate is more exacting, and a comparison of the two places is given below.

I was indebted to the late Dr. Treub for the information in the following synopsis of the monthly rainfall, humidity, and temperature at Pasœrœan in East Java and Buitenzorg.

RAINFALL DURING 1904 IN JAVA.

	Buitenzorg. mm.	East Java. mm.		Buitenzorg. mm.	East Java. mm.
January ..	417	221	August ..	344	18
February..	455	192	September	388	—
March ..	169	287	October ..	799	11
April ..	204	33	November	312	24
May ..	541	155	December	498	110
June ..	389	27	Average mean, yearly 1901—1904	4,416	1,200
July ...	312	48			

The following were the monthly rainfalls, in inches, from January to December, 1910, on Soember Tengah estate, East Java :—11, 9¾, 15¼, 9¾, 7, 4¾, 5¼, 1¾, 1½, 6, 12¾, and 13, making a total of 97¾ inches for the year.

I am informed by Mr. R. C. Wright that probably the best parts of Java for rubber-growing are: a portion of Bantam ; a great part of the Preanger ; a portion of south-east Java ; and perhaps also a portion of the north side of Mid-Java. In some of these areas the temperature at about 1,000 feet altitude varies from 68°F. to 90°F ; the humidity, except in a portion of Mid-Java, is high.

CONDITIONS IN BORNEO.

The late Mr. Cowie informed me that the average yearly rainfall in British North Borneo rubber-growing districts, on the coast, is about 120 inches. In the interior, immediately behind the great central range of mountains, the average yearly rainfall is, according to Mr. Lease, Manager of the Sapong Rubber and Tobacco Company, only about 70 inches per annum.

According to the report of Mr. Berkhuysen the rainfall in the interior during 1906 was 62.34 inches. The same authority gives the average temperature at 90°F. during the day and 70°F. during the night, in his district.

On the coast the temperature averages about 85°F. during the day and about 80°F. at night.

The following are the details of the monthly rainfall from July 1910 to June 1911, on Sekong Estate:—5·52, 11·0, 12·4, 4·2, 7·6, 6·6, 11·7, 8·3, 2·11, 5·96, 5·73, and 5·75 inches, making a total of 86·87 inches.

Climate in New Guinea.

Though it is the second largest island in the world, and the rainfall and temperature are suitable in so many parts, New Guinea has as yet only a small acreage under rubber. The growth so far reported is very good. Below are given the results of observations at stations in Papua and German New Guinea :—

	Sogeri. Average Rainfall 1902-4. Inches.	Grima. Average Rainfall 1893-4. Inches.		Sogeri. Average Rainfall 1902-4. Inches.	Grima. Average Rainfall 1893-4. Inches.
January ..	9.247	14.272	August ..	3.520	5.571
February..	12.023	11.535	September	5.383	4.035
March ..	13.797	12.382	October ..	5.852	6.968
April ..	10.616	14.567	November	5.450	18.071
May ..	6.812	11.063	December	17.424	17.421
June ..	4.917	6.220			
July ..	1.332	6.988	Annual ..	92.606	128.487

Sogeri is at a height of 1,600 feet and is near to the dry-belt district around Port Moresby ; Grima is on the North Coast.

Climate in Cochin-China.

It is claimed (J. d'Agr. Trop., November, 1910,) that the dry season, from January to April, does not sensibly retard the growth of the trees. The effects of the dryness are said to be counteracted by the abundance of dews and by the physical properties of the soils, especially the red types, which always preserve a great degree of moisture at no great depth. Mathieu and Deleurance consider that this dryness lessens notably the cost of weeding, and the former claims that it is favourable to plant sanitation. One may remark that if there is any considerable force in these claims, there does not seem to be any promise of good growth of rubber trees.

Climate of the Seychelles, Fiji Islands and Philippines.

Lying at about 4°S. latitude, the Seychelles Islands possess a favourable temperature, the mean being about 83°F. The average annual rainfall at Port Victoria amounts to 101·24 inches, of which 70 per cent. falls within the period from November to March, both months inclusive. Yet this leaves more than 30 inches for the seven months remaining.

Situated further from the equator, between 16°S. latitude and 18°S. latitude, the Fiji Islands have a mean temperature only three degrees less, yet a temperature that is not so equable. The rainfall at Suva for the years 1905, 1906, 1907, and 1908 was 73·03 inches, 169·62 inches, 147·49 inches, and 104·85 inches respectively. Hurricanes sometimes occur, destroying the crops.

The Philippines also are liable to severe wind-storms. Though they stretch from 7°N. latitude to 19°N. latitude, the temperature seems everywhere to be favourable, but it is only south of the fourteenth parallel that a fairly even distribution of rainfall occurs, as in some regions of Luzon, the Eastern Viscayas, Mindanao and Jolo. The average annual rainfall at Manila is 75·491 inches.

Climate in Samoa.

The Samoan Islands possess a tropical and very equable climate. The usual range of temperature is from 68° to 88°F. According to one authority (Bulletin, Imperial Institute, London, March, 1904,) "violent winds and thunderstorms are not of frequent occurrence, but severe hurricanes sometimes sweep over the islands, though only in every seven to nine years. The dampness of the air is not so great as would be expected in tropical islands, but it is high enough to meet the requirements of all moisture-loving tropical plants. In the rainy season, which lasts from November to March, the air is usually almost saturated. The mean annual rainfall at Apia for the 13 years, 1890 to 1902, is 115 inches, and the extremes in that period are a minimum of 89 inches and a maximum of 163 inches. On the coast the rain is not well distributed in the course of the year, and there are years when periods of drought last too long and are too intense to suit the needs of the cacao plant." According to Wohltmann the climate in different parts of Samoa is very variable, the rainfall of selected places ranging from 1,600 to 3,500 mm. per year, and should therefore be as suitable for Hevea rubber trees as it undoubtedly is for cacao trees.

Upon one of the properties belonging to the Upolu Rubber and Cacao Estates, Ltd., the monthly rainfalls in 1910 were: 11·8, 16·4, 27·6, 14·3, 11·0, 5·3, 1·4, 4·0, 7·5, 14·7, 19·4, 34·6 inches, a total of 167·9 inches. Upon another property the total was 144·3 inches, apportioned as follows: 14·8, 19·2, 24·1, 12·3, 7·8, 4·5, 0·6, 3·5, 7·8, 7·0, 14·7, 28·1 inches. Such a rainfall is ample for the cultivation of Hevea.

Climate in Africa.

In West Africa are two strips of territory along and near to the coast where there is an abundant rainfall. One of these extends through Southern Nigeria and the Cameroon; the other stretches through Sierra Leone, Liberia, and the Ivory Coast. Outside these territories, as in the Congo Free State, are isolated areas that are suitable. In those parts of Sierra Leone and Liberia nearest to the coast the rainfall may be over 160 inches per annum. Further inland, and reaching from coast to coast on either side, is an area where the rainfall may be from 120 to 160 inches; and this is true also of the coast territory in Southern Nigeria and the Cameroon. Behind both these areas, and also reaching from coast to coast on either side, are areas with a rainfall between 80 and 120 inches. Between the two strips of territory lie the Gold Coast and Togoland, where the rainfall is not very liberal, though, as will be seen below, some success with Hevea is reported.

On the estate of the Liberian Rubber Corporation an annual rainfall of over 120 inches is reckoned upon.

Climate on the Gold Coast and in Nigeria.

In the Gold Coast, West Africa, the Hevea tree is, according to Johnson, being grown at an elevation of 1,500 feet above sea-level, where the average mean temperature is about 81·5°F. and the annual average rainfall only 47 inches, and there promises to do better than other rubber-producing plants, indigenous or exotic.

The following table shows the rainfall and number of days on which rain fell during 1902-1904, at Aburi, Gold Coast :—

	1902.		1903.		1904.	
	Rainfall. Inches.	No. of Wet Days. Inches.	Rainfall. Inches.	No. of Wet Days. Inches.	Rainfall. Inches.	No. of Wet Days Inches.
January ..	0·30	1	0·73	1	1·00	1
February ..	5·03	5	1·09	3	0·55	2
March ..	3·82	9	5·89	6	4·16	8
April ..	7·01	10	2·63	9	1·84	5
May ..	3·27	10	4·56	8	6·24	9
June ..	7·09	11	7·44	11	6·47	13
July ..	2·07	6	3·72	13	2·19	7
August ..	2·93	7	1·58	10	0·65	3
September ..	0·73	2	1·93	11	2·97	6
October ..	7·16	11	4·78	13	2·20	8
November ..	2·16	2	6·60	14	0·52	4
December ..	0·74	3	2·13	5	3·30	5
	42·31	77	43·08	104	32·09	71

(Annual Report for 1904 by Director, Botanic Department, Gold Coast.)

The following are the annual statistics regarding rainfall from 1905 to 1909 at Aburi :—1905, 36·87 inches ; 1906, 47·84 inches ; 1907, 50·73 inches ; 1908, 54·92 inches, and 1909, 49·23 inches. At the Tarquah Experimental Station, where Hevea trees are planted, the rainfall was as follows :—1904, 68·12 inches ; 1905, 70·66 inches ; 1906, 53·96 inches ; 1907, 74·35 inches ; 1908, 81·84 inches ; 1909, 76·04 inches. At Akim, another centre for Hevea, during the years 1908 and 1909 the rainfall was 70·8, and 80·19 inches respectively. At Coomassie, a distributing centre for seedlings and seeds, the rainfall in 1906, 1907, 1908, and 1909 was 75·33, 52·08, 61·10, and 53·47 inches respectively.

The rainfall is much more generous in parts of the Southern Province of Nigeria, where a rainfall of even 165·97 inches was recorded at one centre in 1909. In the same year at Lagos, which is nearer to the drier belt on the Gold Coast, the rainfall was 67·59 inches ; at Calabar it was 150·24 inches.

Climate in Togo and East Africa.

The adaptability of Hevea and its continued growth under widely different climatic and soil conditions is evidenced by the results obtained in many countries. Warburg states (Lectures on Indiarubber), that in the German colonies Hevea has been grown in climates characterised by definite dry seasons. Even in East Africa where there was a very dry season they had remarkable plantations of Hevea, but they were in localities which were wet, or were near a river, or had water at their side. They had Hevea in Togo, which had a long dry season, but it was only to be found in localities which had more rain generally than others. Warburg believes that it would be easy to procure Hevea seeds which could be cultivated in countries where the seasons were partly wet and partly dry, but does not give meteorological details. In support of his contention is the statement of Johnson that he has seen the foliage of Hevea trees in East and West Africa quite fresh and green when coffee, cacao, and other plants were drooping and losing their leaves on account of the drought. He further reports that in East Africa he is trying to cultivate Hevea in a very dry climate, but is relying on a system of irrigation for the necessary moisture. It is well-known that even in Ceylon Hevea trees can, without any bad effects, pass through a rainless period of a few weeks duration. It is, however, generally advisable to select districts with a rainfall, temperature, and humidity somewhat similar to those in the Amazon valley.

Speaking generally, and excepting a few well-favoured localities with sufficient rainfall, British East Africa is not suitable for Hevea.

Climate in Uganda.

Owing to the encouraging results so far obtained in Uganda it is necessary to draw attention to the climatic factors ruling there.

The average annual rainfall for nine years at Entebbe is given at 57·98 inches. It is somewhat different in other parts of the Protectorate: thus in 1909 the heaviest fall was at Mbarasa, 75·83 inches in 104 days.

The maximum temperature at Entebbe is 86.5°F., and at Jinja, 90°F.; the minimum temperature at Entebbe, 55°F., and at Jinja, 58°F.

Climate in the West Indies.

It is a most remarkable fact that the West Indian islands, many of which are well within the Hevea rubber zone, have not taken a very active interest in this cultivation. A few old trees occur on some of the islands, and seeds are being applied for only in fair quantities.

At the Botanic Gardens, Trinidad, during the years 1887 to 1899 inclusive, the average annual rainfall was 68.19 inches, which is lower than that at Peradeniya, the highest rainfall in any year being 92·49 inches and the lowest 46·76. The average mean annual relative humidity was 78·00, the highest in any year being 80·00, and the lowest 75·00. The average mean annual temperature was 78·54° F., the highest 79·4, and the lowest 77·4. The mean minimum temperature was 69·57° F.

At Springbank, St. Patrick's, Grenada, where the monthly rainfall in Grenada in 1903 most resembled that of Ceylon, it was from January to December: 6·69, 2·00, 1·32, 1·34, 5·27, 8·68, 10.13, 21.52, 11.42, 11.19, 5.02, and 11.52 inches, the total 96.10 inches. The total in 1902 was 66.10 inches. In the years 1903 and 1904 at Belvidere, St. John's, it was 168.20 inches and 151.29 inches respectively; at Dougaldston, St. John's, it was 107.12 and 102.34 inches respectively; at Dunfermline, St. Andrew's, 82.13 and 70.89 inches; at Les Avocats, St. David's, 126·19 and 100.57 inches; at Annandale, St. George's, 150.20 and 136.27 inches. These are all cacao-growing districts and, therefore, probably rubber-growing districts.

In Jamaica, the average rainfall in 1904 at 138 stations was 87.99 inches. In the North-East Division the average monthly rainfall from January to December was: 5.88, 8.45, 6.07, 4.11, 6.91, 18.27, 5.71, 7.02, 5.66, 19.38, 17.81, and 6.85 inches, the total 112.12 inches. In the North Division the average total annual rainfall was 63.72 inches, in the West Central Division 104.40 inches, and in the Southern Division, 72.35 inches.

Jamaica possesses plants of an indigenous rubber vine—*Forsteronia floribunda*, Dc., but so far does not appear to have taken an active interest in Hevea rubber cultivation, though saplings of this species are reported to be in a thriving condition.

According to W. Harris, there are many districts in Jamaica suitable for *Hevea brasiliensis*, namely:—"Portions of St. Andrew, St. Thomas-in-the-East, the lower lands in Portland, St. Mary, St. Ann, St. Catharine, Upper Clarendon, Manchester, St. Elizabeth, Trelawny, St. James, Hanover and Westmoreland." But later information is to the effect that Jamaica is quite unsuitable.

Climate in British Guiana.

Looking to the facts that Guiana is so close to the home of *Hevea brasiliensis*, and that it is the home of other Hevea species, one is not surprised to learn that its cultivation there is being anxiously considered. And yet, though the rainfall is on the average fairly well distributed throughout the year, there is some liability to years of only moderate rainfall:—

Observations made at the Botanic Gardens, Georgetown.

	Mean temperature, 1909.	Average Rainfall, 1880-1908. ins.		Mean temperature. 1909.	Average Rainfall. 1880-1908. ins.
January	78·8	8·56	August	88·1	6·03
February	78·7	6·70	September	79·8	3·06
March	79·4	7·27	October	81·0	3·09
April	80·2	7·22	November	81·6	5·57
May	80·0	11·60	December	79·4	11·84
June	79·6	11·72			
July	79·5	10·44	Annual	80.5	92.84

In the three coastal districts the average annual rainfall during the period 1899-1908, was respectively 90·94 inches, 92·73 inches, and 90·35 inches. At the inland stations in 1908 the average annual rainfall was 120·82 inches, and no station showed a lower record than 90 inches. The temperature very seldom falls below 70°F. at Georgetown. Apparently the strong winds at the coast interfere with growth.

Climate in Surinam.

The rainfall in Dutch Guiana is given as averaging 90 inches, well distributed throughout the year.

Preuss states that the climate in Surinam (Theobroma cacao, Wright) can be divided into two dry and two wet seasons, the annual rainfall averaging between 88 and 92 inches (2,200 to 2,300 min.). The first little dry season commences towards the end of February, and continues till the end of May, the great rainy season then setting in and lasting until the end of August. The great dry season follows, and drought conditions prevail until the end of November, when the second little rainy season commences and continues until the end of February.

CHAPTER V.

RATE OF GROWTH OF HEVEA BRASILIENSIS.

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 in 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.

Rate of Growth of Stem.

The growth in circumference is by no means slow; trees one year old from planting may have a circumference of three to four 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.	Girth at 3ft. Inches.	Year.	Age.	Girth at 3ft. Inches.
1878	3	14	1887	12	53½
1880	5	16	1888	13	60
1881	6	21	1889	14	69¾
1882	7	25½	1890	15	73
1883	8	30	1892	17	77
1884	9	36	1893	18	79½
1885	10	43	1905	30	109½
1886	11	49			

Peradeniya Trees Planted in 1876.

Hevea rubber trees were planted at Peradeniya in the South Garden near the river banks, 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.	Girth at 3ft. Inches.	No. of Tree.	Height. ft. in.	Girth at 3ft. Inches.
1	51 7	44	7	78 7	58
2	89 6	82	8	79 3	56
3	73 3	52	9	89 5	81
4	82 7	59	10	76 2	50
5	84 2	59	11	74 3	43
6	55 4	49			

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

Other measurements show that at Edangoda and Yattipawa, trees two years old girthed 4·96 inches, those three years, 8·75 to 9·37 inches, and the four-year-old, 12·96 inches a yard from the ground.

Rate of Growth in Other Parts of Ceylon.

The following figures show the dimensions of Hevea rubber trees, *interplanted with tea and cacao*, in Ceylon :—

CIRCUMFERENCE OF THE STEM IN INCHES, 3 FEET FROM THE BASE.

Age of Trees in years.	Kegalla.	Knuckles.	Sabara-gamuwa.	Katugas-tota.	Pera-deniya.	Nilambe.	Kalu-tara.
2	—	5	—	—	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	—

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 measured 24 to 46 feet in height and 15 to 46 inches in circumference a yard from the ground ; the following dimensions of the trees referred to will be of interest to those planters who are trying Hevea rubber at high elevations in Ceylon and elsewhere :—

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 cacao land the growth is often very slow.

Upon an estate in the Allagalla district, where the rubber has been planted in cacao on weedy land, growth has been slow. Trees 5 years old, between 12 and 20 inches girth, number 476 ; between 6 and 12 inches, 8,186 ; under 6 inches, 21,596. Four-year-old trees between 10 and 12 inches number 1,197 ; between 6 and 8 inches, 19 ; under 6 inches, 3,238. The three-year-old trees between 6 and 8 inches number 76 ; under 6 inches, 3,535.

Upon a very rocky, poor soil in the Tumpane district, supplying has been frequently done. Trees from $4\frac{1}{4}$ to $4\frac{3}{4}$ years old fall under the following measurements : 18 to 30 inches, 1,996 ; 10 to 18 inches, 18,501 ; under 10 inches, 13,062. The measurements and numbers of those from $3\frac{1}{4}$ to $3\frac{3}{4}$ years old are : 15 to 30 inches, 483 ; 10 to 15 inches, 9,699 ; under 10 inches, 19,129.

The Hewagam Rubber Co. reported, in 1910, an average increase in girth at the rate of fully four inches per annum.

The Neboda Tea Co., in their annual report for 1905, state that "the 1904 clearings range from 17 to $27\frac{1}{2}$ feet in height and from 6 to 10 inches in circumference, while last year's basket plants, put out in April-May, from August, 1904 seed, show the best growth : $8\frac{3}{4}$ to $12\frac{1}{2}$ feet in height and $3\frac{1}{4}$ to $4\frac{1}{4}$ inches in girth."

At Gangaruwa, 1,500 feet above sea-level, trees $3\frac{1}{2}$ years old averaged 10 inches at a yard from the ground. These trees, planted by me in 1905, were reported to show an average increase in girth, from December, 1908, to January, 1910, of 5·29 inches ; the minimum girth (4·94 inches) was on a plot which was interplanted with lemon grass, and the maximum (5·81 inches) on land catch-cropped with indigo.

Growth on Vogan Estate.

I have been favoured with details, by Mr. W. N. Tisdall, indicating the growth of the Hevea rubber trees on Vogan Estate, Kalutara, Ceylon. The trees were planted in July, 1904, and measured in March, 1906 (twenty months' growth), 5·88 inches average circumference at three feet from the base ; nine months after (December, 1906), the girths had increased 3·64 inches, the average then being 9·52 inches ; October 29th, 1907, the average circumference was 13·60 inches. These measurements show that twenty months after planting the trees measured 5·88 inches, and in the following $1\frac{1}{2}$ years the increase was 7·72 inches, or at the rate of 5 inches per annum.

Census of Estates.

The following examples will serve to indicate the manner in which the census of estates may be shown.

Hanipha (Ceylon) Tea and Rubber Co.

Census of Para Rubber Trees taken as on 31st December, 1909.

18 in. & over.	15 in. to 17 in.	12 in. to 14 in.	9 in. to 11in.	6 in. to 8 in.	Young Plants.	Total.
3,703	4,677	11,273	15,369	13,260	18,729	67,011

All measurements taken at 3 feet from the ground. Of this total
26,810 Trees are planted among the Tea, and
40,201 ,, ,, in separate clearings.

Pantiya Tea and Rubber Co.

Rubber Census November, 1910.

Tapping.	18 in. upwards.	15-18 in.	12-15 in.	9-12 in.	6-9 in.	Under 6 in.	Total.
23,300	1,031	7,957	15,201	18,955	19,816	68,293	154,553

Ceylon Tea Plantations Co.

Approximate Census of Rubber Trees, at December, 1910.

Girth in inches.	Over 18	15 to 18	12 to 15	9 to 12	Below 9	Totals.
In Tea	60,510	39,966	58,597	85,417	142,469	386,959
In Clearings ..	42,450	43,495	68,096	117,888	127,795	399,724
Totals ..	102,960	83,461	126,693	203,305	270,264	786,683

Ceylon (Para) Rubber Company.

The census of the trees taken towards the end of December, 1910, works out as follows :—

	18 in. and over.	15-18 in.	12-15 in.	9-12 in.	Under 9 in.	Total.
Ambadeniya	37,260	30,720	32,275	25,295	54,199	179,749
Kiribatgalla	47,356	40,175	47,876	46,224	140,269	321,900
	84,616	70,895	80,151	71,519	194,468	501,649

These figures compare with the previous year's as follows :—

18 in. and over	15-18 in.	12-15 in.	9-12 in.	Under 9 in.	Total.
13,664	29,703	65,257	96,575	275,698	480,897

Rate of Growth in India and Burmah.

Proudlock when reporting (1908) on rubber trees at Nilambur, gave the following statistics regarding trees planted in June, 1879, and measured in April, 1884 :—

Height. ft.	Girth at Base. ins.	Girth at 5ft. up. ins.
38	19	11¼
37	20	12
33½	19½	12¼
34	19½	12
34	19	9⅓

These figures are only interesting in so far as they show the proportionate development of parts of trees which had been neglected.

The growth on estates in S. India, at low elevations, is quite good. Six trees owned by the Cochin Rubber Co., planted in 1906, measured 4¾ inches, at three feet from the ground, in December, 1907, and 8½ inches in December, 1908. Kirk, of the Periyar Rubber Co. (Planters' Chronicle, June, 1910), refers to Vincent's deduction that the difference in inches between measurements made at the base and three feet from the ground gives the approximate annual increase in girth; his own trees give the difference in girth at from 4 to 8 inches, which is in general accord with his average annual increase in girth. This is certainly not characteristic of trees in Malaya; bottle-shaped trunks are often met with but generally only on poor or interplanted land.

In many parts of Southern India, Hevea rubber is being more or less successfully grown up to 3,500 feet above sea-level. Trees at an elevation of 2,500 feet have attained a height of 18 feet in three years, a circumference of 42 inches in 17 years, and nearly 60 inches in 22 years.

On the Shevaroy Hills, at an elevation of 3,400 feet, Hevea rubber trees are reported to be about 10 inches in circumference when three years old; others are reported at 3,600 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 many of these properties the rubber is used as shade for coffee, and from all accounts the latter is thriving under the shade of Hevea and Castilloa rubber.

The Hevea rubber trees in some 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 satisfactory.

The following figures showing the dimensions of nine-year-old trees in Mergui (girths being taken at 2 feet above ground), have been given by Colonel W. J. Seaton :—

No.	Height in Feet.	Girth in Inches.	No.	Height in Feet.	Girth in Inches.
1	39	29½	6	38½	27½
2	34½	37	7	36¾	31
3	40	38	8	30	18
4	43½	40½	9	31	27
5	36½	39½	10	21½	18½

Rate of Growth in Malaya.

The growth in most parts of the Straits Settlements and Federated Malay States is considered to be very encouraging and superior to that obtained in many other rubber-growing countries.

Growth in Singapore.

There are many trees in Singapore Gardens, planted 6 and 8 feet apart, over 15 years old, with girths from 50 to 70 inches and over. They are planted in isolated clumps and are not under the conditions prevailing on rubber estates.

The record tree at Singapore was, in 1908, though only 54 feet in height, no less than 120 inches in girth at a yard from the ground. It was then 30 years old, and I believe was the largest, in circumference, recorded up to that time.

The seven trees received in 1877, were first planted in the Botanic Gardens by Murton, and on the founding of the Economic Gardens in 1880 by Cantley were transferred to their present position. One tree was evidently topped at about four feet from the ground and then threw out three branches, which are now very large. It is growing in the open low swampy soil. It gave fourteen pounds of rubber on being tapped by the spiral system, and would probably have given more under any other system of tapping.

The growth in girth of this tree in the last few years has been: 1904, 109½ inches; 1905, 111¾ inches; 1906, 113¾ inches; 1908, 120 inches.

Derry recorded the girths of trees of from 3 to 18 years; the average for three years being 13 to 15 inches, and for 18 years, 100 inches.

Rate of Growth in Selangor.

The following measurements of trees in Selangor of known age and planted at definite distances apart were made by me in 1908:—

Age.	Distance apart in feet	Girths in inches, a yard from ground, of trees in one line.
8 months	24 by 12	$3\frac{1}{8}$, $2\frac{3}{4}$, $2\frac{7}{8}$, $2\frac{7}{8}$ $2\frac{5}{8}$, $2\frac{5}{8}$, $2\frac{3}{4}$, $1\frac{7}{8}$
9 ,,	24 ,, 12	$2\frac{3}{4}$, $3\frac{1}{2}$, $2\frac{5}{8}$, $2\frac{1}{8}$, $1\frac{1}{2}$, $2\frac{3}{4}$
10 ,,	—	7, 6, 7, 6, 6, 5, 7, 4, 7, 5
2 years, 8 months	—	17, 7, 11, 13, 14, 11, 13, 7, 14, 14, 17
2 ,, 9 ,	—	14, 16, 18, 10, 12, 17, 20, 12, 14, 14, 18
3 years	17 by 17	16, 19, 12, 17, 12, 14, 16, 15, 12, 9, 15
3 years	20 ,, 10	18, 14, 9, 14, 11, 15, 14, 12, 9, 11

The growth in girth during the third year on these estates was rapid; the same feature was observed on many other properties.

On another estate in the same district, on which lalang had established itself, 18 per cent. of the trees measured 20 inches, a yard from the ground, when $3\frac{2}{3}$ years old, a large number of the balance being 15 inches in girth.

Trees on an estate in Selangor grew to a height of over 30 feet and attained a girth of 19 inches in 4 years.

Growth on Jeram Estate.

On Jeram Estate, Klang, the following girths of trees of different ages taken at random have been issued:—

Age.	Girth, in inches, 3 feet from ground.
$5\frac{1}{3}$ years.	19, $26\frac{1}{4}$, $21\frac{3}{4}$, $28\frac{1}{2}$, $27\frac{7}{8}$, $20\frac{7}{8}$, $25\frac{1}{4}$, 26, 32, $24\frac{1}{2}$. $26\frac{5}{8}$, $28\frac{1}{2}$, $29\frac{1}{8}$, 17, $18\frac{1}{8}$, $25\frac{5}{8}$, $27\frac{3}{8}$, $20\frac{1}{2}$, $27\frac{3}{8}$, $20\frac{1}{2}$, $27\frac{3}{8}$, $14\frac{1}{2}$

Age.	Girth, in inches, 3 feet from ground.
5 years.	27¾, 23¼, 18½, 24⅝, 27½, 17⅝, 17⅝, 26½, 21⅛, 15⅝, 20¼, 19¾, 13, 17⅛, 16, 16¼, 26½, 13⅜, 12⅞, 14½, 15, 15, 11¾, 18⅜.
4¾ years.	22½, 21⅝, 23⅜, 24¼, 15⅞, 22⅛, 23, 20, 23, 20⅝, 28¼, 19¾, 24¼, 25.
4 years (lalang).	13⅛, 13¼, 13⅝, 15⅞, 12½, 17⅜, 18¾, 12⅞, 14½, 15¾, 15, 20½.
4 years (passion flower).	21⅝, 13⅝, 21½, 20¼, 16⅛, 23, 19¼, 12⅝, 24⅝, 17½, 19, 13⅝.

The above figures are of special interest because the trees have been grown under known conditions.

The 5⅓ year-old block was always kept clean weeded.

The 5-year-old trees were all under lalang until 18 months ago.

The 4¾-year-old trees were under passion flower for 12 months.

The first series of 4-year-old trees was under lalang up to 18 months ago; the second group was under passion flower until 18 months ago.

Growth in Perak.

In Perak are 11-year-old specimens that are 70-75 feet high, and have a mean girth of 4½ feet at 3 feet from the ground, and a 10-year-old tree that is 79 feet high and girthing 4⅓ feet.

At Kuala Kangsar an 18-year-old tree has a girth of 8½ feet at 3 feet.

Sutton stated last year at the annual meeting of the Allagar Rubber Estates, that 3½ to 4-year-old trees interplanted with coffee had a girth of 21 to 37 inches; others rising 4 years measured 22 to 30 inches; those rising 5 years girthed 23 to 33 inches; and a number rising 6 years measured 27 to 50 inches. Ten-year-old trees on the same property girthed from 55 to 63 inches, all at 3 feet from the ground.

Growth in Malacca.

There is a general impression that growth in Malacca is much slower than in other parts of Malaya, on account of poor soil or the cultivation of catch crops. It is frequently found that three or four crops of tapioca are taken by native cultivators from the same area. In one case where four crops of tapioca had been taken and the Hevea trees were 4 years old, the latter only girthed 9 to 12½ inches a yard from the ground; a range of from 5 to 7 inches and 14 to 15 inches has also been recorded for 4-year-old Hevea on land from which three crops of tapioca had been removed.

Growth in Other Parts of Malaya.

On some estates it is not uncommon to find four-year-old Hevea trees from 14 to 20 inches, and 4½-year-old specimens averaging over 20 inches a yard from the ground. On one property, catch-cropped annually with sugar canes, the 2½-year-old trees had an average of 8 to 9 inches, the largest being 14 inches in circumference.

Phenomenal growth in some parts of 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 or more inches a yard from the ground.

The 5-year-old trees upon a Province Wellesley estate have the following girth: between 15 and 18 inches, 964 trees; between 12 and 15 inches, 9,107 trees; between 10 and 12, 7,327 trees.

Killick (Financier, Sept., 1911), reported that some trees in Kelantan, $2\frac{3}{4}$-years-old, measured 15, 17, 18, $18\frac{1}{2}$ inches, even though they had been in lalang for six months. On Taku Estate he saw trees which, in his opinion, should be tappable at 3 years of age.

Growth in Java.

Detailed statistics showing the average sizes of trees of known ages in that island are not available. Many parts of Java are relatively dry, and in such the Hevea rubber plants have not developed very rapidly; in other districts, provided with an abundant rainfall, the growth is reported to be quite equal to that in most parts of Ceylon.

During the course of my recent visit to Java, I found that in a few instances the growth of Hevea was second to none. But on most of the estates I visited, the growth was not what I expected it to be from considerations of the climatic and soil conditions prevailing. The less rapid growth can, I believe, be partly explained by the intercropping, absence of drains, and prevalence of weeds, which characterise the properties I refer to. The system adopted is a very safe one, and is sometimes cheap; but it does not allow the trees to develop as rapidly as they might do in such ideal soil. When one has a soil on which coconuts can be brought to the productive stage in five years, and tea crops average 800 lb. per annum, one has some ground for expecting the Hevea trees to grow at the rate of six inches in girth per annum. I was shown some trees, reputed to be five years old, which girthed 32 inches. Such growth should be the rule, and not the exception, in Java. Trees planted at Binangoen in 1907 showed at the end of 1910 the following girths a yard from the ground:—15in. to 17in., 8,979 trees; 17in. to 19in., 3,964 trees; 19 inches and over, 1,323 trees. Three-year-old trees on this estate measured 16, $16\frac{1}{2}$, 17, and 18 inches a yard from the ground. On another estate in East Java, interplanted with robusta coffee and "Lamtoro" shade, the 3-year old Hevea trees averaged from 8 to 12 inches in girth; another field of the same age possessed trees of from 7 to 11 inches. Two-year-old Hevea on the same estate measured $5\frac{1}{2}$ to $7\frac{1}{4}$ inches in girth, a yard from the ground.

A census of $3\frac{1}{4}$ to $4\frac{1}{4}$-year-old trees on another East Java estate showed that there were 7 per cent. with a girth of between 15 and 18 inches; 13 per cent. between 10 and 12 inches; 40 per cent. between 8 and 10 inches; 31 per cent. between 6 and 8 inches; and under 6 inches there were 9 per cent. The girths of

$2\frac{1}{4}$ to $3\frac{1}{4}$-year-old trees were: between 15 and 18 inches, 3 per cent.; between 10 and 12 inches, 9·5 per cent between 8 and 10 inches, 37·5 per cent.; between 6 and 8 inches, 36 per cent.; and under 6 inches, 14 per cent.

Upon a West Java estate, trees 4 to 5 years old girthed: between 18 and 30 inches, 1,437; between 10 and 18 inches, 13,242; under 10 inches, 14,661. This was on weedy land, where supplying had been heavy.

The manager of Sampang Peundeni estate has supplied me with the measurements of trees on his estate. These show an average girth of 19·88 inches for 50 trees at 4 years; the trees were growing at an altitude of 700 feet where the annual rainfall was approximately 140 inches.

Four-year-old trees on another property, planted 14 by 14 feet, show an average circumference a yard from the ground of from 7 to 20 inches. Others planted 12 by 12 feet show an average girth of from 6 to 13 inches. Other four-year-old trees not far removed from the foregoing had a girth of from 6 to 13 inches. These were planted 20 by 20 feet apart in virgin land, and the estate had been kept clean from the commencement. On the same estate, though the trees were of the same age and planted at the same distance, but on old coffee land and only circle-weeded, the girth varied from 5 to 8 inches.

Rate of Growth in Sumatra.

Most people have the idea that phenomenally rapid growth is to be seen in Sumatra, the Hevea trees being reputed to increase in girth at the rate of six inches per year. I have certainly seen trees which have grown at that rate when planted alone and on virgin land, but most estates I visited could not generally lay claim to such rapid developments. The well-known Sumatra rubber estates have nearly all been developed out of coffee plantations, and the growth of the trees thereon is not what it might otherwise have been. Coffee bushes, especially when old, do keep back the growth of Hevea trees. The growth of the trees is most rapid when planted alone, next best when planted at the same time as the intercrop, and slowest when in old coffee or on old lalang and tobacco grounds. I should put the circumferential rate of growth in Sumatra at six, five, and four inches respectively, on lands included in the three categories enumerated above. It is very dangerous to generalise in this way, especially when the trees are scattered over the Serdang, Langkat, Bandar, and Asahan districts, but I think the above conclusion will be found to be approximately correct in most instances.

It has recently been stated by Mr. J. B. Laurent that Hevea trees in Sumatra had measured, when three years old, 16 inches; when four years old, 20 inches; and at five years, 25 inches in girth.

The slower rate of growth and smaller yield from rubber trees in Sumatra, when compared with the F.M.S., can probably be attributed to the soil conditions and to the fact that many are planted between old coffee trees. On most Sumatra—and also Java—Hevea estates the soil is volcanic and very dry, the water-level being usually many yards below the surface. The dry soil contrasts markedly with the wet soil of the F.M.S., and is the probable cause of the slower development of the trees in Sumatra, especially during the first four years. In subsequent years, when the roots reach the water-level, the growth may be very rapid.

An illustration showing a five-year-old tree on Bandar Sumatra estate with a girth of 38½ inches is given in the "India-Rubber Journal," September 6th, 1909. This, though in coffee land, is exceptional growth for Sumatra, the average being generally below this.

Different trees in the Bandar district, when six years old, measured from 22 to 38 inches a yard from the ground; a few girthed over 40 inches. Five-year-old trees measured from 14 to 28 inches; four-year-old specimens ranged from 12 to 27 inches, and three-year-old from 9 to 15 inches. A large number of these were interplanted among Liberian coffee.

On an estate in Langkat trees planted in 1906 measured in the middle of 1908, 7, 6, 6, 4, 5, 6, 6¾, and 10 inches a yard from the ground; those planted in 1905, measured at the same date, 6½, 7½, 9, 10, and 12 inches. These trees were planted among old coffee; when planted alone a much better rate of growth was recorded. On another estate in the same district where the soil was poor and the Hevea trees planted among old coffee, the four-year-old trees measured 20, 16, 17, 12, 11, 20, 17, and 23 inches; two-year-old Hevea trees girthed 7½, 6, 10, 11, and 9 inches; and 1½-year-old trees averaged 6 inches—all a yard from the ground.

On an estate in the Tamiang district two-year-old Hevea trees, planted alone, measured in one row 8, 7, 10, 9, 7, 9, 7, 8, 7, 6, 5 inches; during the growing season many two-year-old trees increased their girth at the rate of 1 to 1½ inches per month.

In the Siantar district I measured 1½-year-old trees which girthed, at a yard from the ground, 3 to 5½ inches.

Growth in British Borneo.

The measurements of 20 Hevea rubber trees on an estate belonging to the British Borneo Para Rubber Co., Ltd., have been received. Twelve 20-month-old trees show an average height of 20ft. 8in. and a girth of 8¾in., at 3ft. from the ground. Eight trees 17 months old show an average growth of 19ft. 9¼in. in height and 7⅞ in girth.

The Tenom Rubber Co., Ltd., reported in 1908 that trees only 12 months old had an average height of 10 feet. At a later period measurements were given showing an average increase in girth of 8¼ inches in two years; many trees appear to attain a girth of 17 to 20 inches in four years.

"The North Borneo Gazette" stated, in 1908, that: "One-hundred-and-fifty-five Hevea rubber trees in the Government experimental Gardens at Tenom, were planted, not before December, 1900, nor after July, 1902 (exact date is uncertain, as no records were kept). The plants have been uncared for and allowed to grow as they liked, with the result that about one quarter of them have two or three stems; this lowers considerably the average girth, as in these calculations each separate stem is regarded as a separate tree; even then we get an average girth at five to six and a half years old of 21 inches at 3 feet from the ground, and the average increase in the girth during the last 12 months (ending 31st July, 1907) is four and three-quarter inches (Singapore Botanic Garden records an average of 3½ inches)." Since this was published more reliable data have been obtained regarding the growth of Hevea rubber in various parts of Borneo. There is no longer any doubt that the climate and soil in parts of Borneo are quite as suitable as in Malaya for the cultivation of *Hevea brasiliensis.*

Growth in Papua and Queensland.

It is reported (T.A., April, 1908), that trees at four years of age in Papua are seeding. This often indicates fair growth. It is also stated that Hevea trees at Sogeri, 3½ years old, have a circumference of 18 inches a yard from the ground.

Some 10 eight-year-old trees at Kamerunga, Queensland, have girths of from 18 to 24 inches at 3 feet.

Growth in Fiji, Hawaii and Cochin-China.

In the Fiji Islands some 13-month-old plants show (Trop. Agr., Jan., 1910) irregular growth, the best being 10 feet high. The average girth at 3 feet of some 1-year-old plants was 4.0 inches; 2-year plants, 5·75 inches; 3-year plants, 9·2 inches.

Hevea is making rather slow growth in Hawaii.

In Indo-China (Trop. Agr., Jan., 1910) some trees 3 years and 10 months old were said to have a girth of 15½ inches; whether this was at the base or at 3 feet was not stated.

It is stated by Vernet (J. d'Agr. Trop., July, 1909), that the trees at Suoi-Giao are making fair growth. The mean girth of 93 eight-year-old trees at 3 feet is 25½ inches, and of 47 ten-year-old trees 32 inches. One may remark that an average annual increase of 3¼ inches is not good.

Some three-year-old trees at Ong-Yem measured from 9 to 9½ inches in girth (J. d'Agr. Trop., Nov., 1910), and the average of 400 eleven-year-old trees was at 3 feet only 37½ inches.

Rate of Growth in West Africa.

Hevea trees, planted on moist land in the Congo, were reported to be 16 feet in height in two years.

Evans, in his Annual Report for 1906, states that in the Axim and other wet districts of West Africa, *Hevea brasiliensis* should give handsome returns after a few years. Several estates in the Eastern and Western provinces are planting Hevea rubber in conjunction with other products, and the Botanic Department at Aburi, Gold Coast, supplies plants at reasonable rates. Evans also gives the following details regarding the growth of Hevea rubber trees up to December, 1908, at the Botanic Gardens, Tarkwa (average):—

Date of Planting.	Distance in feet.	Height Dec. 1905. feet	Height Dec. 1906. feet	Girth at 3 feet from ground. Dec. 1905. inches	Dec. 1906. inches	Dec. 1907. inches	Dec. 1908. inches
June, 1904	15 by 15	20	28	7	12	13	20
,, ,,	12 ,, 12	16	25	6	10	12	16
July ,,	15 ,, 15	14	24	6	10	12	18.5
,, ,,	20 ,, 20	14	25	6	11	12	19
,, ,,	30 ,, 30	12	27	4	9	10	16
,, ,,	40 ,, 40	12	27	4	9	10	16.5
,, ,,	12 ,, 12	12	26	4	9	—	—
Aug. to Sep.	12 ,, 12	12	27	4	10	—	19.29

In 1909 Tudhope reported that the trees planted in June 20th and 24th, 1904, had an average girth of 24 and 22 inches respectively.

Plants have been established in the Botanic Gardens (Annual Report, 1903), Aburi, at different dates, and most of them have made favourable growth (though planted in dry and stony ground). Some of the trees only 18 months old were 10 feet high, and had stems 3 inches in diameter; others planted 15 by 15 feet in 1900 and 1901 measured an average of 20½ inches at a yard from the ground, in 1908. The trees planted in 1901 fruited in 1907, and according to Anderson, 100 per cent. of the seeds germinated. The following table shows the growth of certain trees at different ages:—

ABURI BOTANIC GARDENS.

Age of trees in years.	Height in feet.	Girth at 3 feet in inches.
10	30.25	27
12	36	40
4	23	10
6	29	16
3	17.5	6.5
5	27	12

At Coomassie, the two-year-old Hevea plants average 16 feet in height; some are 35 feet high and 6 inches in girth at a yard from the ground.

At the present time the cultivation of Hevea rubber trees in West Africa is somewhat experimental, but it is anticipated that this phase will soon be passed. The African Plantations, Ltd., according to the report issued in March, 1907, have several thousands of young plants growing on their property at Axim. Plants which were received in June, 1906, had grown to a height of 3 to 4 feet in 8 to 9 months, and the best developed showed a height of over 6 feet 9 inches and a girth of 2½ inches. The African Rubber Co. reported, in 1909, the girths of Hevea trees of different ages growing at Axim, Gold Coast; trees 18 months old measured 4 to 4½ inches, at 36 months, 9 inches, and at 45 months, 11 to 12 inches. On the Ivory Coast, at Dabou, there were (J. d'Agr. Trop., Nov., 1909) trees planted in 1897-1898 yielding seeds and measuring in girth from 31½ to 51 inches at 16 inches from the ground.

Small plantations of this species have been made in Liberia, and there is every reason to feel satisfied at the growth already obtained. The experiments made in many parts of East and Central Africa are not so encouraging as those in West Africa, the dry climate and occasional frost preventing continuous and rapid growth in the former areas.

Growth of Hevea Trees in Uganda, Etc.

According to H.M. Commissioner's Report a Hevea rubber tree, 4½ years old, growing in that Protectorate, was 27½ feet high, with a girth of 12½ inches 4 feet from the ground. About 200 trees, 2¼ years old, grown from seed, were about 17 feet high. There has been much commercial activity in regard to this product, and ventures on a large scale were pending some time ago.

Unexpected interest is now manifested in the cultivation of *Hevea brasiliensis* in Uganda, and the following details of rates of growth given by Kaye (I.R.J., March 7th, 1910), are of importance:—

The first Hevea tree was planted in 1902, and it has made fine progress. Measured on the 31st March, 1909, it had a height of 42 ft. 4 in. and 30 in. girth. The increase during the year was 5 ft. 9¾ in. in height and 5½ in. in girth. Other trees, in the Botanic Gardens, showed an increased height of 7 ft. 4 in. in one year, and an increase of 2½ in. in girth during the same period.

Hevea trees (from Ceylon) planted December, 1903, in rich loam on clay subsoil, were measured every six months, and gave the following measurements:—

		No. of Tree.							
		1		2.		3.		4.	
When measured.		ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.
Nov. 1906.	Height ..	20	10	21	9	18	3	19	0
	Girth ..		8		6½		6½		7
Apr. 1907.	Height ..	22	8½	23	11	19	9	22	3½
	Girth ..		9¼		7½		7½		7¾
Nov. 1907.	Height ..	25	3	29	0	20	6	16	0
	Girth ..	1	0		10		11		10
Apr. 1908.	Height ..	25	4	32	10	21	5	27	8
	Girth ..		12		12		12		12
Nov. 1908.	Height ..	29	0	34	3	21	11	29	3
	Girth ..	1	2	1	2½	1	1	1	1
Apr. 1909.	Height ..	30	6	41	2	25	6	34	2
	Girth ..	1	3	1	3	1	2	1	3

Kaye further states that the growth of the Hevea trees, compared with that of other species in the same area, promises to be exceptionally good.

In Nyasaland, 266 survivors from a wardian case of Hevea seedlings, despatched from Ceylon in 1906, had a height of 5 feet in January, 1907, and 12 feet in July, 1908.

Growth in the West Indies and Surinam.

There are very few records at present available which show the average annual incremental growth in parts of Trinidad and Jamaica where this species has been planted, though the general opinion appears to be that the growth is not as favourable as in the East Indies.

In an issue of the West Indian Bulletin, Sharp states that *Hevea brasiliensis* will not yield so early or so abundantly as *Castilloa elastica* and is not so suitable as a shade tree for cacao; he further states that in dry districts, Hevea will probably thrive better than Castilloa, on account of its being a much hardier plant. These statements were intended to apply to Jamaica only; it is obvious they do not agree with the results of experience in the East Indies.

The interest in Hevea cultivation in Trinidad is more promising. At the experiment station some trees, 8½ years old, are 35 feet high and 6 to 9 inches in diameter. Hart stated (Bulletin No. 55, July, 1907) that the seeds were in great demand and that the crop on the Government trees would not meet the demand; he also informed us (Bulletin No. 54, April, 1907) that the largest tree under cultivation in Trinidad stands a short distance from the residence of the Governor, Government House. In a recent issue of the W.I. Bulletin, it is stated that on St. Clair lands, which are well-drained, but of a sandy alluvial character, Castilloa grows faster than Hevea in the first two years, but later the Hevea outgrows the Castilloa.

On the island of Grenada some three-year-old plants are 20 feet high.

Barbados, St. Lucia, Montserrat, Dominica, etc., have not yet taken up a very prominent position in the cultivation of *Hevea brasiliensis*, but whether this is due to unfavourable climatic conditions or otherwise is not clear.

Pearson records (I.R. World, Jan., 1911) that on the occasion of his visit to Surinam he saw trees at the Botanic Gardens eight years old which girthed 28 inches, others of the same age at Waterlands measured 31½ inches, while 12-year-old trees varied in girth from 35½ to 39⅓ inches.

Growth of Stem under Special Circumstances.

The foregoing statistics relate to trees which have, in the various countries, generally been grown under ordinary plantation conditions; these, though variable, have come to be regarded as normal for each country. There are, however, special circumstances under which the rate of growth of the stems is of unusual interest.

RATE OF STEM GROWTH UNDER FOREST CONDITIONS.

One of the most interesting features in the Botanic Gardens, Singapore, is the block of Hevea trees in and under forest. The Hevea rubber tree, on account of the rapidity with which the seeds lose their germinating capacity, has only a poor chance to spread in primitive forest. Long before the seed finds a bit of soil, it may have lost its germinating power through exposure to unfavourable climatic conditions. Even if it germinates, it has to compete with the roots of and shade from the surrounding plants, and finally to combat many natural forest enemies before it can top its highest neighbour. Ridley gave an account, in 1908, of the trees to which I refer. It appears that in the year 1894 some one planted rubber seedlings in a wood behind his house in the Botanic Gardens. This wood is on the slope of a hill running down to the main road and rather steep. It had been planted up by Mr. Cantley, in 1884, with *Albizzia moluccana*, *Eugenia grandis* and other trees, and had additions in the form of various trees of the character of belukar jungle. The rubber trees were quite forgotten for about ten years, and when found were crowded among other trees, but had made surprisingly rapid growth. The tallest was measured quite recently. It had grown considerably higher than the surrounding trees, and was conspicuous from afar. Its height was found to be no less than a hundred feet, while in girth at three feet from the ground it measured 72 inches. The stem was smooth and straight without a branch for a considerable height. The other two were not so tall, one having lost a portion of the top. One measured 60 inches at three feet from the ground, and the third gave a measurement of 79 inches.

On the slope the trees lessen in girth in proportion to the steepness of the hill, the slopes of which show signs of a strong rush of water during rains. The whole wood is full of seedlings from these trees, although for some years past it has been the custom for the seed collectors to gather up the fallen seeds.

The usual height given for a full-grown Hevea tree is 70 feet and the tall tree is certainly the record in height, and yet it is but fourteen years of age. The trees are grown in a thick wood of lofty trees, on a stiff and poor clay soil. They have cost nothing more than the mere putting of the seedlings into the ground, except that when they were rediscovered some trees which were pressing against them were knocked down. They are grown under absolutely natural conditions, just as one sees them in photographs of the trees of the Amazons, and they are fully twice as large as trees of the same age grown in the open, with careful and expensive felling and clearing and weeding, and are reproducing themselves naturally through the forest.

The trees have been tapped, and good returns of rubber obtained.

The following are their measurements (age 14 years) : 48 in., 38in., 28 in., 60 in., 72 in., 38 in., 41 in., 42½ in., 79 in. The three trees with the greatest girth, viz., those of 60 in., 72 in., and 79 in. circumference, grew higher up the slopes. The average annual growth in girth at three feet from the ground of these big trees in the last four years was 2·06, 2·87 and 4·06 inches. The ordinary growth in girth of big trees in general is about 2 inches a year. Younger trees seem to grow faster.

The following measurements of the trees planted in 1894 were given by Ridley (Str. Bull. July, 1908) :—

	Girth in Inches.				
Position.	1904.	1905.	1906.	1907.	1908.
Top of Hill	62⅜	68⅛	71⅜	75½	79
,, ...	60½	62⅞	65⅜	68½	72
,, ...	53¾	57⅞	58	59½	60
Slope	38½	40½	42 5/7	44 5/7	48
,, ...	33½	36⅞	41⅜	42	42½
,, ...	34¼	36½	38	40	41
,, ...	34	35	35⅝	36⅞	38
,, ...	31	32	34¾	36 5/7	38
,, ...	24	24½	26	27	28

Influence of Elevation on Rate of Growth.

The trees planted in the experimental plots on Gunong Angsi at various elevations have been measured (Rep. Dir. Agr. F.M.S., 1910) :—

Elevation in feet.	Percentage ready to tap.	Elevation in feet.	Percentage ready to tap.
300	69	1800	18
600	18	2100	0
1000	48	2400	2
1600	27		

It is remarked that although the trees at 600 feet have not done well, the results tend to show that the higher the elevation the slower the growth of the trees. The trees at an elevation of 2,400 feet look as healthy as those at 300 feet.

Influence of Age on Rate of Growth.

The fact that thirty-year-old Hevea trees have a girth of 120 inches, and are still growing, may lead some planters to imagine that the rate of growth is more or less constant throughout the life of the tree. This is far from being the case even when trees are not tapped ; when the bark is regularly excised quite a number of variations may be expected. During the first two or three years Hevea trees in the open grow mainly in length, the long spindly character of young clearings of this age being quite characteristic. Once they have attained a length of 20 to 30 feet and thrown out lateral branches the rapid increase in girth commences, and continues, generally, until the trees are 10 to 15 years old. After that time the relative growth in height and girth is largely dependent on the spacing of the trees. Ridley

(Str. Bull., July, 1910) states that the ratio of increment varies according to the age of the tree, and gives the following measurements in support thereof :—

Hevea trees.	1904.	1905.	1906.	1909.	Increment in 6 years.
5 years old.	1′ 5⅝″	1′ 9½″	2′ 1⅞″	2′ 11⅜″	1′ 5¾″
5 ,,	1′ 6⅝″	1′ 11½″	2′ 3⅞″	3′ 0¾″	1′ 6⅛″
16 ,,	3′ 9¾″	3′ 11⅝″	4′ 3″	4′ 10¾	1′ 1″
28″ ,,	9′ 1½″	9′ 3¾″	9′ 5¾″	10′ 0½″	0′ 11″

Ridley does not say whether or not these are averages. He estimates the ratio of growth, where the general conditions are fair, from 5 to 15 years at 3 to 4 inches ; from 15 to 20 years at 2 to 3 inches ; and from 20 to 30 years at 1 to 2 inches, per annum.

The normal increment of growth may be modified in any particular year through prolific seeding.

Baxendale (Jugra Estate, Annual Report, 1908) stated that there was a decided check to growth in the 6th year on fields planted 10 by 10 feet, but that where the trees were planted 15 by 15 feet this check was not evident for quite a year later.

Girth Increases Calculated, per Acre.

In the chapter on cultivation the effect of distance in planting on the rate of growth has been demonstrated. Berkhout (Tropenpflanzer, September, 1910), gives some interesting data regarding the rate of growth and its significance, per acre, on Tali Ayer estate, Province Wellesley. The following are his measurements :—

Distance.	Age.	Average Girth.	Age.	Average Girth.	Average increase in 6 months.
20′ by 20′	4½ years	20¼″	5 years	23″	2¾″
20′ by 18′	3¾ ,,	18½″	4¼ ,,	20¼″	1¾″
36 by 10′	4½ ,,	18¾″	5 ,,	20¼″	1½″
18′ by 15′	4 ,,	19½″	4½ ,,	21¼″	1¾″
18′ by 10′	4½ ,,	15¾″	5 ,,	16¾″	1″

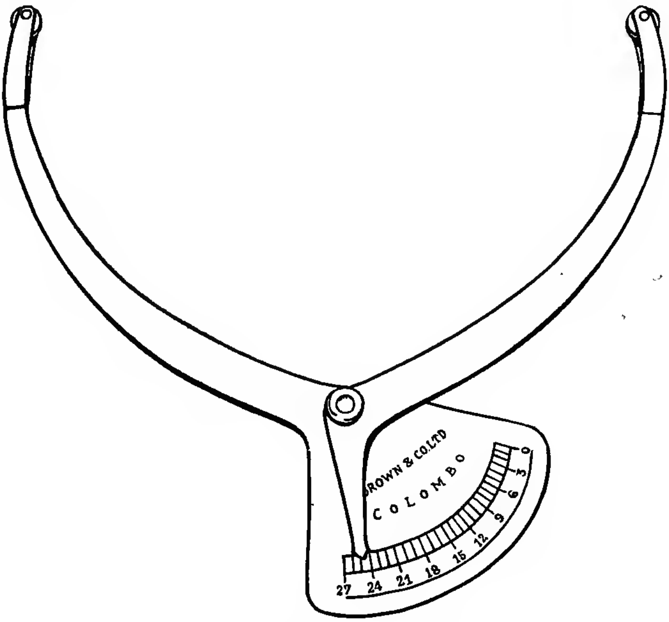
The trees planted 20 by 20 feet, 109 per acre, show a half-yearly total increase of 109 by 2¾ inches = 300 inches per acre ; those planted 18 by 10 feet, or 242 per acre, 242 by 1 inch = 242 inches per acre. The total girth per acre of the trees of any age is of course given by multiplying the number of trees per acre by the girth at that age.

Census of Trees.

It has become customary on many estates to obtain a census of the trees, especially prior to tapping, in order to determine the number of trees having a definite circumference. This information, if obtained annually, enables anyone to calculate the average rate of growth and the number of trees which can be tapped in future years.

RYAN'S CALLIPERS.

The simple appliance invented by Mr. James Ryan affords an easy way of determining the circumferences of trees. The implement consists of a pair of callipers rotating on an axis ; at one end is a pointer which moves over a graduated scale. The callipers clasp the stem and when the implement is withdrawn the circumference of the tree is indicated by the pointer on the scale.



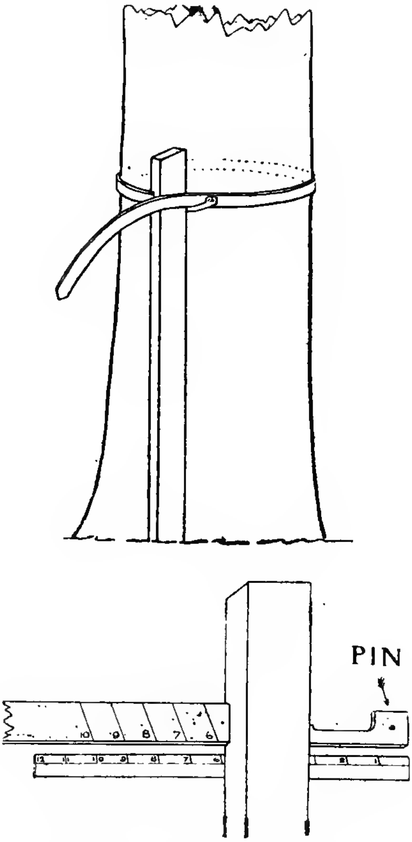
RYAN'S CALLIPERS.

This simple appliance will be very useful to planters when preparing an annual statement of the rate of growth of their young trees, or when determining the average sizes prevailing over various parts of the property.

BURGESS'S METHOD OF MEASURING GIRTH.

Mr. P. J. Burgess's device for taking measurements of rubber trees has lately been improved. It is a simple method, requiring nothing but what can be made on the estate, and enabling a coolie who cannot read or write to measure and record the girth of a thousand trees per day.

The device is made as follows : A wooden stick is taken about 3 feet 6 inches long, and at 3 feet from one end a leather strap is fastened ; this strap is about 1 to 2 inches wide, and of a length equal to the maximum growth expected to be recorded. It is fastened at right angles to the stick, and in such a way that about 6 inches of it projects on one side of the stick. This projecting portion is cut narrow so that its width is about half an inch. One surface of the strap is smooth, the other surface may be left rough, and the strap is attached with the smooth side next to the stick. Into the end of the short projecting portion a steel pin is fixed; on to the smooth surface of the strap a long strip of paper is pasted. The illustrations depict a manufactured set of sticks, etc.



BURGESS'S MEASURING DEVICE.

The stick is used as follows: The coolie places the stick upright against the tree to be recorded, with the rough side of the leather against the tree, this brings the short piece carrying the pin to the right hand of the coolie; the long strip is then wrapped round the tree trunk and brought tight across the stick above the short strip of leather. The coolie then makes a prick mark in the paper, puts a chalk mark on the tree to show that it has been measured, and passes on to the next tree.

The coolie does not personally do any reading of measures or writing at all.

At the end of the day the sticks are brought in to the superintendent, who first marks out the strip of paper, and then counts the prick marks. The paper is set out as follows: The strap is extended flat on a table, and with an inch ruler, distances in inches are set off on the lower margin of the paper, inclined lines are then ruled as shown in the illustration (this inclination is to allow for the swing of the pin on the short strip of leather when the pricking is done by the coolie). The superintendent then counts the pricks in each section, and the number gives the trees of that girth measured. If the highest accuracy be required and the thickness of the leather be allowed for, the strap may be set out by obtaining a fixed point on the paper by actual measurement of some tree with a tape and then seeing where that measurement will appear on the paper when the tree is measured by the apparatus and setting off from that. In practice, this is not necessary, but the superintendent is recommended to do it for his own satisfaction once or twice.

When the returns are counted, it will be seen that there is with all areas planted at anything like regular periods a regularity in the results, the numbers of trees increasing to a maximum about the mean girth and then decreasing.

If the coolie fancies it easier to sit down and fake his measurements by pricking at random, this is at once shown on counting, because the results are then irregular and no systematic increase and decrease is discernible. It will be noted that this method is rapid, it does not require skilled labour, it is independent of reading and writing, and it automatically sorts out the measurements into their order of girths.

There is little difficulty in the counting if the pins are kept sharp. One hundred and fifty pricks per area are easily counted, and the error owing to two pricks occurring in the same hole is less than two per cent. With care this error can be entirely avoided.

The device was invented by Mr. P. J. Burgess in 1906, and has been practically tested and used on several estates and found perfectly satisfactory.

The first set of four sticks which were used to count 174,343 trees were made on the estate out of four broom-sticks, four drawing-pins, and four bag straps.

Rate of Growth of Foliage.

Before passing to the consideration of methods of cultivation, when planting distances must be enquired into, it will be useful to learn what is known of the rates of growth of the crowns of foliage and of the root-systems.

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

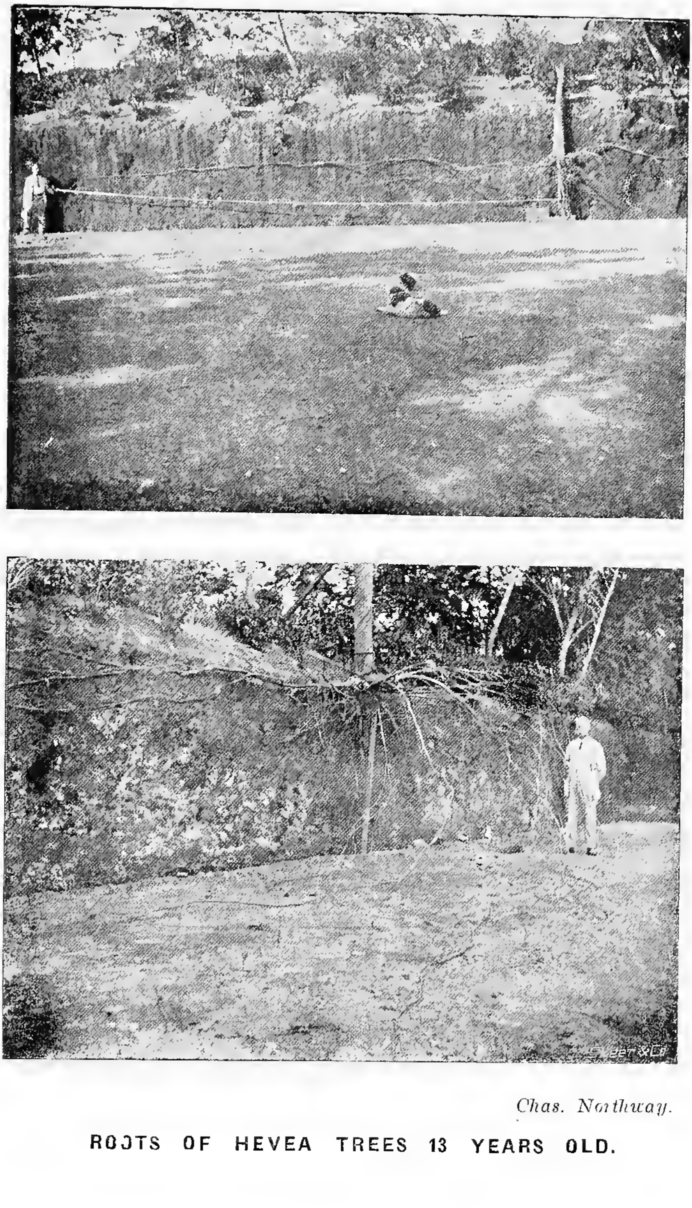
Diameter of Branches with Foliage.

Age of Trees. Years.	Matale. ft.	Baddegama. ft.	Katugastota. ft.	Nilambe. ft.	Knuckles. ft.	Peradeniya. ft.	Sabaragamuwa. ft.	Wattegama. ft.	Kalutara. ft.
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.	1,200	50	1,500	2,200	2,500	1,500	600	2,200	100
Rainfall in inches.	77	119	85	130	175	90	170	80 to 90	130

Where the trees are planted closer than 10 by 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, when thirty years old from seed, measured about 90 feet in height and 109½ inches in circumference, and there were many others of the same age which had a circumference of 8 to 9 feet and a height in proportion to the above examples. Several of the old Henaratgoda trees, owing to their being too closely planted, have only a branch spread to 15 to 20 feet in diameter.

Rate of Growth of 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 a considerable 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 very many years in conjunction with Hevea, except the latter are widely planted. The lateral roots grow at varying rates according to the conditions prevailing, but if grown alone on moderately good and flat land, an incremental minimum yearly increase in radius of about one to two feet can be allowed for ; individual roots will, of course, grow much more rapidly. In six to seven years the lateral roots (growth of which is of high importance) of plants distanced 12 by 12, in Ceylon, may be expected to form a compact mass ; planted 10 by 15 feet the



Chas. Northway.

ROOTS OF HEVEA TREES 13 YEARS OLD.

Photo by H. F. Macmillan.

TRENCH-MANURING FOR YOUNG HEVEA TREES.

larger distance will be more or less completely covered in 7 to 8 years ; in richer soils the rate of root growth is much more rapid, and a much wider distance of 20 by 20 feet or 18 by 24 feet would, in Klang, be covered in the same period of time.

The root system of young Hevea rubber plants (especially the outer zone), though superficial, is not as compact as that of an old tree. There are always a large number of lateral roots on young plants which grow much more rapidly than the rest, but the *compact* root system does not usually advance at a rate much above one to two feet, radially, each year. Individual roots have been described as growing at the rapid rate of one foot per month ; but no figures having been published, I meanwhile judge the rate of growth of the compact root system from observations made when carrying out trench-manuring experiments with young trees at Peradeniya.

These considerations of growth lead us to the subject of cultivation of *Hevea brasiliensis* in various countries, and the means adopted to maintain or increase the regular development of all parts of the tree.

CHAPTER VI.

PLANTING OPERATIONS AND METHODS OF CULTIVATION.

It has been shown that the countries possessing the largest acreages of Hevea trees are Malaya, Ceylon, Java, Sumatra, and South India. The methods adopted by planters in these areas furnish striking examples of the diversity of opinion among them and of the adaptability of the plant.

METHOD OF CULTIVATION IN MALAYA.

In Malaya Hevea is cultivated over continuous stretches of country, often as a single product. If one passes through Perak or Selangor one is impressed by the flatness of the land, relieved here and there by small hillocks or "bukits," hills of any great size being rarely met with. Hevea saplings are visible everywhere, and one estate is often only separated from another by a stretch of high lalang. From Kuala Lumpur to Klang is a typical case. Many estates are established on grass or lalang ground or on land which has grown sugar or tapioca for several years; the majority are, however, planted on land which was previously in heavy jungle. Protective forest belts of immense size are said to have been selected by Government to divide one district from another, so that in the event of some disastrous disease or pest arising it may to some extent be isolated; these may afford little comfort to those within such belts. Most estates in Malaya grow Hevea alone; a few have unwisely planted Hevea among coconuts. The principal catchcrop is tapioca, which is especially favoured by Chinese and native planters. Sugar, indigo, and bananas are also grown, the former especially in Province Wellesley. Among the characteristics of much of the land are the nearness to sea-level and the occurrence of water near the surface. There is nothing in Ceylon, Sumatra, or Java, to compare with the vast tracts of Hevea growing in the flat, wet land in parts of Province Wellesley and Selangor. The land is usually very well drained, the soil very fertile, and the trees are planted at relatively wide distances. Clean-weeding is the system generally adopted, only a few estates growing Passiflora and other weed-killers. The rate of growth of the trees during the first six years is probably quicker than in any other country.

HEVEA CULTIVATION IN CEYLON.

Compared with Malaya, Hevea is, in Ceylon, grown under a much greater variety of conditions. It is rarely grown on land with the water-level so near the surface; it is usually cultivated

Lent by India-Rubber Journal.

HEVEA AND ALBIZZIA TREES.

Lent by India-Rubber Journal.

HEVEA NURSERY.

Lent by India-Rubber Journal.

HEVEA GROWING AMONG ROCKS.

on undulating or hilly land, often abundantly provided with huge boulders. Nowhere else in the East does one meet with such large acreages of Hevea growing on rocky hillsides ; estates in the Kalutara and Kadugannawa districts furnish good examples of Hevea thriving successfully on rocky slopes. The estates are generally no higher than 1,000 feet above sea-level ; quite a number of notable properties are, however, above this elevation. Peradeniya, where some of the original trees were planted, is about 1,500 feet above sea-level, and several Hevea estates exist in the surrounding districts at even higher altitudes. The soil is generally poor, but well drained ; the water-level is usually many feet or yards below the surface. The trees are planted more closely than in Malaya, favourite distances being 15 by 15 feet or 15 by 20 feet. In many parts of the Kelani Valley and Kalutara one meets with immense stretches of country cultivated with Hevea only. The view from the summit of one of the hillocks often reveals, at the tops and beyond the hills, along valleys and small, drained swamps, the spindly stems and whorls of foliage of Hevea saplings of all sizes and ages. But this is not the only type of vegetation. Hevea is cultivated in association with tea and cacao to an extent which is not always realised. Nearly 100,000 acres of the Hevea in Ceylon are mixed with tea at low and medium elevations or with cacao at medium elevations.

Tapioca or sugar are rare ; bananas are occasionally met with on rubber estates. The relative poverty of the soil, and the interplanting on numerous estates, has resulted in a slower rate of growth than Malaya ; manuring is, however, now being carried out extensively. Clean-weeding is the one system recognised by most experienced planters. Terracing, by means of stones, is occasionally done where trees are planted on very steep hillsides ; this is more frequently seen in Java, and rarely in Malaya or Sumatra.

Hevea in South India.

In this country Hevea is grown at low, medium, and high altitudes. A large area in the hill country is intercropped with coffee, and the growth of the rubber is relatively slow. In the Travancore and Cochin districts it is mainly grown as a single permanent crop, and is there showing comparatively rapid growth. The methods of cultivation and general configuration of the estates are somewhat similar to those in Ceylon, with the exception of coffee replacing cacao and tea as the intercrop. The rate of growth at low altitudes is quite equal to that in Ceylon, and is frequently above the average for the latter place.

Method of Cultivation in Java.

On many estates Hevea has been interplanted among existing cultivations, such as cacao and coffee, or these products have been planted with or after the Hevea. Some plantations are being catch-cropped with tapioca, citronella, lemon grass or groundnuts. It is therefore obvious that Java rubber planters do not generally rely entirely on rubber, but sometimes prefer to adopt a mixed cultivation, such as is seldom seen in any other country. I like to see mixed products on the same ground for obvious reasons; but I cannot help thinking that on many estates in Java it is overdone. Where the same estate has its rubber planted through or with nutmegs, Liberian, Java and robusta coffee, Ceara, Castilloa, cacao, kapok, and other useful trees, the attention of the manager is necessarily diverted. He will not cut out his nutmegs or kapok trees while the Hevea saplings are young, and in the long run his estate consists of too many products, few of which have attained perfection; it is a natural consequence on overplanted estates.

The best estates I have seen in Java consist of Hevea alone or with a crop of either robusta coffee, cacao, or tapioca. One catch or intercrop under the rubber saplings is generally quite enough even on phenomenally rich soil. The results obtained on Kalu Minggir, Poerwodjojo, and the Java Rubber Plantations certainly justify one in advising one or other of these systems.

A feature of all Ceylon estates along hillsides, and even on flat ground, is the draining, the drains being 1 to 1½ ft. wide and deep, and running at right angles to the slope. In East Java I never saw anything approaching this, except on flat, swampy areas. The hillsides are not drained on a regular system, a few water pits being the only receptacles provided to collect the water and prevent excessive wash. The soil is so rich that a little wash may take place without seriously affecting the development of the plants; but surely it is to the interest of all to retain, by means of drains, as much soil as possible under all conditions. I commend the subject to the consideration of planters in East Java. I cannot think that Ceylon is wasting labour and money in draining; it is just as essential for rubber cultivation as for tea.

Another point which struck me somewhat forcibly after travelling through Perak was that in East Java very few sugar estates were planting Hevea among the sugar canes. A few may be doing this, but I did not see the properties.

Cultivation in Sumatra.

The cultivation of rubber plants in Sumatra is almost limited to lands near sea-level, and thereby resembles Malaya and differs from Java, Ceylon, and Southern India. The soil is very similar to that in Java, being light, fertile, and mainly of volcanic origin. I have not, in Sumatra, seen anything resembling the stiff blue clay of Malaya or the rocky slopes of Ceylon; everywhere the soil is finely divided and porous, and grows magnificent crops. The sugar of Java, and the tea and cacao of Ceylon, are replaced by extensive plantations of tobacco in Sumatra. Exactly why Java takes so ravenously to sugar and Sumatra to tobacco, though each country could probably grow both products very well indeed, is difficult to explain. The only product which is commonly grown on European plantations in Java and Sumatra, to a large extent, is coffee. In both countries the coffee estates are being rapidly interplanted with Hevea.

Hevea cultivation in Sumatra was not commenced in earnest much before 1906, and I do not think manufacturers can expect many tons of rubber from that island before 1913 or 1914. A few estates, such as those owned by the United Serdang, Langkat Sumatra, United Sumatra, Sumatra Para, and Amsterdam-Langkat Companies, possess several thousands of old or tappable trees. Most estates, however, consist of coffee interplanted with Hevea or old tobacco or lalang lands planted up with Hevea during the last two or three years. There are very few estates consisting of Hevea trees alone, and in this respect Sumatra comes into line with most other countries.

Shade in Java and Malaya.

I was much impressed with what I saw on one estate in East Java during May, 1908. In parts of East Java the dry season may extend over a period of six or seven months, and it has become a planting custom in that area to develop everything under the shade of trees—especially Dadaps. Liberian, Arabian and robusta coffee bushes, and cacao trees are all under the same shade, though in the adjacent island of Sumatra the former products are grown in the open. On the estate to which I refer the Hevea trees, now two years old, had been grown under the shade of high Dadap trees; they were spindly and backward for their age, and I consequently advised the owner to ring the shade trees to let in more light.

At the Botanic Gardens, Singapore, Mr. Ridley showed me a number of very large Hevea trees which had been developed under the shade of tall forest trees. The trees were fifteen to twenty years old and several were quite equal in size to others which had been grown in the open. The seedlings were planted among the forest trees and allowed to develop as best they could; the fact that such fine development can be obtained proves how the plant can overcome the effect of unfavourable conditions.

In Java and Sumatra the best growth of Hevea is obtained without permanent shade; the foregoing examples are, however, of interest.

In the F.M.S., according to Carruthers, the shading of rubber plants is generally of very little importance owing to the absence of severe droughts in that part of the tropics; it is only recommended in districts where "seed at stake" is the method of planting, and where dry weather may occur within ten weeks after planting.

It would be unfortunate if Hevea 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 pruned and when 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.

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

Damage by Wind.

In an article on rubber in the Journal of the Board of Agriculture, of British Guiana (October, 1910), it is stated that when trees of *Hevea brasiliensis* have been exposed to the strong winds of the coastal lands of the colony a marked dry spell of weather has resulted in a general shedding of leaves. The same effect has been noticed in other situations, and it seems fairly definitely established that exposure to wind not only retards growth, but often results in frequent change of leaf. It is anticipated that the frequent change of leaf may materially affect the quantity of latex from the trees when the tapping stage is reached.

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

Much damage is frequently done in Sumatra and Malaya by squalls, and it is customary in many districts to estimate, when planting the estates, for a certain percentage of the trees to be blown over.

In Samoa, which is liable to windstorms, Preuss suggested that the plantations be provided with windbreaks, for which he thought *Ficus elastica* suitable.

Damage is also reported from Fiji (India-Rubber Journal, February 8th, 1909), where the trade-wind continued with more than usual severity and practically defoliated Hevea trees which were then 2½ years old and had a height of 20 feet.

Forestry on Rubber Estates.

These occurrences draw attention to the lack of forestry methods on Eastern estates, though the plants cultivated are typical members of the forest group. The only general pruning of trees is that of removing branches below a certain height in order to maintain a clear tapping stem up to a minimum of ten or fifteen feet, or the removal of the terminal bud at that height in order to encourage the production of lateral branches. Once a tree has passed this stage it is generally left to take care of itself. It is advisable that all Hevea trees should be regularly inspected by competent forest officers and, if necessary, pruned in order that well-balanced specimens be ultimately obtained. This would save many losses during windy weather and would give symmetrical trees capable of yielding the maximum quantity of rubber in future years. It is never too late to commence this important work, though it is ob iously an advantage if it can be carried out from the first year onwards. At present there is only one plantation company in the East which has realised the importance of this work and has appointed an officer to deal solely with it.

Plant Selection for Hevea.

The desirability of selecting the best-yielding varieties of Hevea, or of propagating by seed or cuttings only from trees which are known to be sound and capable of yielding large crops of rubber, is recognised by scientists and planters. The records of yields are, however, so scanty and incapable of giving reliable comparative data, that the task presents more than the usual difficulties. It should, nevertheless, be possible to determine the yielding capacities of the offspring in Malaya and Ceylon and to compare these with the yields obtained from their seed parents.

The advantages of improving the yielding capacity of Hevea trees from one generation to another are apparent to all. The difficulties in the way of effecting improvement are noteworthy. In the first place, the yielding capacity cannot be determined by tapping until the trees have been tapped for several years in succession, and then an interval of perhaps ten years may be necessary before any reliable data can be obtained. Secondly, the effect of paring the bark, whereby large quantities of living tissue are annually removed, must have a deteriorating effect on the trees whence seeds or cuttings are to be derived. With other plants, notably fruit trees, one can actually improve the plant during the selecting period. Thirdly, the propagation of plants by cuttings is relatively difficult and would not be very successful if carried out by planters not provided with suitable apparatus. Selection by seed could, of course, be adopted, but this method is open to many objections, most of which can, however, be overcome if the work is done by a specialist in plant-breeding.

Habit of Trees and Yield.

Vernet (J. d'Agr. Trop.), points out that with Ceara trees there are two types ; one a tall tree with narrow crown and longer but fewer branches which is a good yielder ; the other—shorter, wider crown, with many and shorter branches, a bad yielder. Labroy, when dealing with the same species, suggests that in the nursery only plants which have attained a certain height should be selected. Johnson claims that inferior latex is yielded by trees having relatively thick bark with numerous fissures. It is possible that a further study of the habit and general vegetative character of Hevea trees of varying yielding capacity may throw light on this line of selection.

Artificial Pollination Experiments.

Parkin has made some valuable suggestions (Souvenir, I.R.J.) on this subject. After pointing out that the flowers of Hevea are unisexual and that the male part can be easily removed, he states that artificial pollination "could probably be carried out without a vast amount of trouble or difficulty. The female flowers, after the removal of the male blossoms, would have to be covered while in the bud stage to prevent natural pollination, and then be fertilised by the pollen from the selected tree when expanded and in the receptive state. The covers would have to remain on the fertilised female flowers till the capsules were ripe, in order to retain the seeds, which otherwise would be scattered by the explosive mechanism possessed by the ripe fruits. It would be advisable to put out the plants raised from these seeds in a position away from all other Heveas, so that when they flowered all danger of pollination from the outside would be removed. The yielding capacity of these trees could be tested in their fourth to sixth year and the poor ones rejected. Such a plantation in a few years' time would be capable of supplying a good strain of seed, and also afford material for further selection, and so continued improvement."

He further remarks that "If something of the kind had been begun ten years ago, when the rubber planting industry was in its infancy, we should have known ere this whether promising results were likely to be forthcoming or not.

"Perhaps in ten or twenty years' time the older estates will require to renew some of their trees. It would be a boon indeed if seed of Hevea could then be obtained guaranteed to produce trees of great vigour and yielding capacity."

Selection of Seed Parents on Estates.

Selection of the best plants during transplanting is, as explained elsewhere, easily done ; that of the original seed parents on the estate is not so simple a matter.

Seeds from trees which show irregularity in quality or quantity of latex, should perhaps not be used for planting. It is difficult to give practical advice on the subject of selecting seed parents when all the trees are healthy and artificial pollination is not resorted to. Personally, I should select my seeds from the best-developed trees on the estate—those which show the best growth of foliage and girth and a corresponding laticiferous system. It seems rather dangerous to select seeds from trees which, though showing good growth, have never been tapped ; one may be selecting seeds from trees which, had they been tapped, would have given the minimum quantity of latex, or perhaps none at all. Provided the trees have not been roughly handled in tapping operations, there is no great mistake in selecting, as seed parents, those trees which are best developed and have given fair yields of rubber. There is a theory abroad that you can induce characteristics in the vegetative parts of plants which can be fixed and transmitted, by seed, from generation to generation, in which case the selection of seeds from the best-yielding trees might ultimately give very good types of rubber rees. But the theory of transmission of vegetative characters acquired in successive generations is hotly contested by many botanists, and it has not yet been proved that it occurs with the latex tubes of *Hevea brasiliensis*.

Selection by a Chemical Method.

The excellent results obtained in Java in improving the strain of cinchona trees led Dr. Tromp de Haas to consider the possibility of effecting similar improvements in Hevea by the aid of chemical science. When cinchona plants were first introduced into Java the bark yielded 9% of quinine sulphate; to-day, through wise selection, based on chemical analysis of bark, the trees produce bark capable of yielding 17% of quinine. Can a similar result be obtained with Hevea? Planters are unable to do anything beyond determining which trees, once they have attained the tappable age, produce most rubber by tapping. If bad-yielding trees are then discovered, it is too late and practically impossible to replace them.

Dr. Tromp de Haas, referring to rubber trees, was compelled to admit "that the analytical method cannot claim great accuracy," and that analysis already made "cannot distinguish between rich and poor trees." The fact that latex is a liquid in circulation within irregular laticifers, and that it varies greatly in its distribution and contents from time to time, will always have to be faced in any analytical method of plant selection.

Selection by Propagating from Cuttings or by Marcotting.

Some difficulty appears to have been experienced in propagating from cuttings. Large numbers of plants were raised by cuttings taken from the original seedlings brought by Cross from S. America in 1876, and also from the first stock of plants received in Ceylon. In the 1906 report of the Ceylon R.B.G. it is stated that not a single plant was obtained from 3,000 cuttings. A planter in Ceylon has, however, raised several trees from cuttings.

The taking of cuttings is applicable when a tree or variety produces superior rubber or larger quantities than its fellows, or possesses other desirable characteristics. There is said to be a better chance of obtaining the coveted characters by this means than by planting seeds.

Success has been reported (T.A., November, 1907) in Java by "marcotting." This consists of selecting a promising young growth, removing a ring of bark off the stem immediately beneath a node or leaf scar, and keeping the area moist by means of a bandage of moss or similar material. When roots are produced, the shoot is severed from the parent and transplanted. It is a method which can be tried where difficulty is experienced in rooting ordinary cuttings.

We can now proceed to detail the ordinary operations on estates, commencing with nurseries, draining, holing, and weeding, etc.

Selection During Transplanting.

It is seldom that much care is bestowed on selection during planting, though this work is of vast importance, and if generally done would result in better-grown trees and more evenly-developed plantations. All plants which have twisted taproots or stems, or which have a sickly appearance, or have been attacked by diseases or pests, should be removed and destroyed. They should not be returned to the nursery with the intention of using or selling them when they have apparently recovered and attained the normal size. Those plants should be selected for planting which have shown the most rapid and even rate of growth and have been immune from attacks of fungi or insects. It is possible that the differences in rate of growth evidenced during the nursery period will be maintained when the seedlings are planted in the clearings.

Methods of Germinating and Planting.

In planting, one may use (1) seeds at stake, (2) ordinary seedlings, or stumps, and (3) nursery plants in the form of basket or bamboo seedlings.

The "seeds at stake" method, if successful, is the simplest and, in some respects, probably the best known. The seeds are placed, one to three in each refilled hole, and then covered with twigs, fern leaves, etc., to provide shade during the first few weeks. If more than one plant develops in each hole, the weaker members are removed. This system necessitates clean-weeding from the commencement, otherwise the young seedlings are soon choked. Further, the seedlings are greedily eaten by animals, and it is a common sight to see them nipped off near the base; fencing around each plant often obviates destruction by rats. If dry weather immediately follows the planting of the seeds, there may be a large percentage of deaths. The numerous difficulties associated with this method have led most planters to adopt nurseries wherein young plants can be reared until they are several months old, and can then be transplanted.

The rate of growth of plants raised from seeds at stake and nursery stumps is indicated by the following figures published in Malaya by Campbell (Annual Report, 1909):—

Seeds sown October, 1907	Planted out.	Average girth. 1908.	1909.	1910.
At Stake ..	—	$3\frac{3}{16}$in.	$6\frac{1}{8}$in.	$9\frac{3}{16}$in.
In Nursery ..	Dec., 1907	$2\frac{9}{16}$in.	$5\frac{3}{8}$in.	$9\frac{2}{7}$in.

The experiment, therefore, cannot be said to prove the superiority of either method. The point to determine is the comparative net value of clearings, planted at the same time from seeds at stake and from nursery stumps.

Nursery Beds.

If it is intended to use stumps or ordinary seedlings, it is necessary to lay out nursery beds. The site for these should be well chosen, and the soil thoroughly dug over and manured. The same site should not be used two years in succession, except it is well limed, forked, and manured. The area of the nursery beds will depend upon the acreage of land to be planted. The beds should be about four feet wide, and be separated by earth paths in order that no damage will be done to the plants during watering, weeding, and inspection. After the seeds have germinated—this generally takes place in about 10 days—they should be planted in the nursery beds at definite distances apart according to the length of time it is intended they shall remain there; a distance of 8 to 9 inches is sufficient for 9 to 12-month-old plants. If they are planted too close they grow very spindly. 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 seed. 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.

All nursery beds should be carefully shaded during the middle of the day, and be watered morning or evening in dry weather. When about to be transplanted, they should, for several days, be "hardened off" by gradual removal of shade. Transplanting should only be done during cloudy wet weather; this is, perhaps, not of much importance in Malaya, but in parts of Ceylon and East Java where dry weather is apt to set in unexpectedly it is imperative. It is not practicable to water the plantation; it is, however, easy to give the nursery a thorough watering prior to commencing transplanting.

Position of Seeds in Nursery Beds.

The seeds of *Hevea brasiliensis* are longer than they are broad, and it is usual to lay the seeds horizontally in the nursery beds. If the seeds are sown vertically with the micropyle end downwards they are usually pushed above ground when germination takes place; if they are placed with the micropyle end uppermost the seedlings are frequently twisted. It is much safer to lay the seedlings horizontally, as by this method straight taproots are usually obtained.

Nursery Stumps.

Stumps are generally used because they can be removed from the nursery when everything is ready for planting; in some countries, owing to the time of the seed crop, it is impossible to use even four to five-month-old basket plants, stumps therefore being the only possible way out of the difficulty.

The stumping of nursery plants is a very drastic operation, the foliage and green parts above ground, and also the lateral roots and part of the main or tap root, being deliberately cut away, leaving a thin rod of living material similar in general appearance to a straight walking-stick. This simple structure, the lower part of which is root, and the upper part stem, is put into a recently re-filled hole, in wet weather, and allowed to throw out roots and leaves if it can. It is a marvel that so many stumps survive and grow into such enormous, healthy trees. Most of the nursery plants are, when thus operated upon, less than twelve months old.

Transplanting.

Planting from nursery stumps is sometimes the only system possible, but were I planting my own property it is the last method I should think of adopting. I heard of an estate where several three-year-old plants were stumped and planted with such success that a visitor to the estate at a subsequent date put two years on to the age of the plantation. But whatever the appearances of such a property may be, it is as well to remember that the plants have not got either the lateral root system or main tap root which they naturally possess and require. What white ants would do with such plants may be conjectured.

It is often possible, in wet and very cloudy weather, to transplant from the nursery into the field without stumping the seedlings ; in such cases planters usually take every care not to injure the root system, this being achieved by removing the plant with as much nursery soil as possible. It would appear that in the transplanting of fruit trees in England (Report, Woburn Exp. Farm, 1908), too much care can be taken in preserving the rootlets. It is pointed out that the delicate tips of the roots are broken off, in ordinary transplanting, and cannot be reformed. The new roots develop most strongly from those parts of the old roots that are thickest, since these have more reserve food than other parts ; this reserve material accumulates at the cut end of a thick root, and generally causes many new roots to form there. Again, the closer the contact of the soil with the roots of a transplanted tree, the more readily will new roots be formed. Hence the advantage of "ramming" the soil immediately after planting. The "ramming" is likely to cause breaking of the roots, but some experiments show that this is often an advantage than otherwise, for more numerous roots develop at the place of injury. Whether this is applicable to Hevea trees is doubtful.

Basket Plants.

The use of seed-baskets is to be recommended whenever practicable, and it is a matter for regret that the success with which stumps can be used has 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. The Neboda Tea Co., Ceylon, in their annual report

A YOUNG CLEARING, SHOWING TIMBER, IN MALAYA.

A YOUNG HEVEA CLEARING IN CEYLON.

for 1905, attributed the success of clearings to the use of basket plants.

The results which have been obtained by the use of basket plants—seedlings reared in friable, loose baskets for two or four months, and planted in the field without destroying or even disturbing the foliar or root structures—are magnificent, especially when compared with those obtained from stumps. There is a minimum number of vacancies and less likelihood of encouraging white ants, borers, and fungi when basket plants or seeds at stake are used; the cuts, bruises, and dead parts on stumped seedlings are sources of danger.

The splendid growth obtained on rubber estates planted with basket plants has attracted attention even in Europe, one firm having gone to the trouble of ordering a trial consignment of empty baskets from Ceylon for use on their West African plantation. If the baskets, which are not procurable in West Africa, can be delivered at the latter place at a reasonable cost, they will be extensively used on the rubber and cacao estates now rapidly springing into being in that part of the world.

I would recommend this to some Sumatra planters who do not believe in anything except stumps, the roots of which they, for some unknown reason, cut back to about six inches. Stumping is a method only to fall back upon.

Plants in bamboo pots are sometimes used, especially for old specimens, but the method does not offer any great advantages over ordinary baskets, which readily decay when put out in the field.

Burning and Removal of Timber on Clearings.

After felling the forest and piling and burning the branches in the field, many planters commence lining and holing. A good burn means sterilisation of soil in local areas and a consequent reduction in weeding expenses; furthermore, it assists in the destruction of pests. There is, even after the best burn, a quantity of timber which hitherto has been allowed to rot *in situ* with the exception of the smaller material. Francis Pears states that "the orthodox $4 to $7 per acre for clearing after a burn-off of virgin jungle is not nearly sufficient. By spending $40 to $50, much money and worry will be saved after planting, and the odds are that much better yields will be obtained when the area comes into bearing."

Now we find that it often pays on many properties to go to a very large expense in uprooting the stumps of trees and removing partly-burnt timber. This course has resulted in a diminution of diseases and pests, especially white ants and Fomes. Estates near towns are able to dispose of the timber on new clearings without much cost, but on other estates it is necessary to hire elephants and use estate labour to clear it off the areas about to be planted. In some parts of Sumatra where the estates are low-lying and subject to floods, it is reported that considerable damage has been done by loose timber. On clearings two years old the floods have carried the loose timber through the estates, and have finally piled it against, and destroyed many of, the trees.

This method of completely clearing contrasts markedly with that recommended by Wickham, who evidently believes in only partial clearing of the forest, then planting, and cutting down the growth from time to time, allowing it to decay *in situ*. Experience in the East has convinced me that the best course is: burn all you can, and, if possible, remove the rest.

Timber on Secondary and Lalang Clearings.

Some planters believe in felling the virgin forest, burning as much as possible, and then allowing secondary growth to appear, which can be subsequently felled prior to planting. The advocates of this system state that the interval permits of some of the larger trees decaying. In my opinion it is a system liable to let in all manner of weeds and to materially increase the opening costs. Furthermore, the stumps of hard woods do not decay much under ten years. Many advocate the planting of lalang ground from which all timber and root stumps have disappeared.

The advantages and disadvantages from a plant sanitation standpoint of establishing rubber plantations on lalang are discussed elsewhere. It has been pointed out that one cannot now regard lalang as a weed against which organised effort is useless; and further there is much to be said in favour of such land for Hevea on account of the absence of tree stumps in the soil with the consequent relative immunity from root diseases and white ants.

Uprooting Tree Stumps.

The cost of uprooting tree stumps in forest clearings, apart from the difficulty of finding suitable apparatus, has long deterred planters from carrying out this most desirable work. The subject is, however, receiving attention, and success has been recorded on some estates. In some cases jacks have been used.

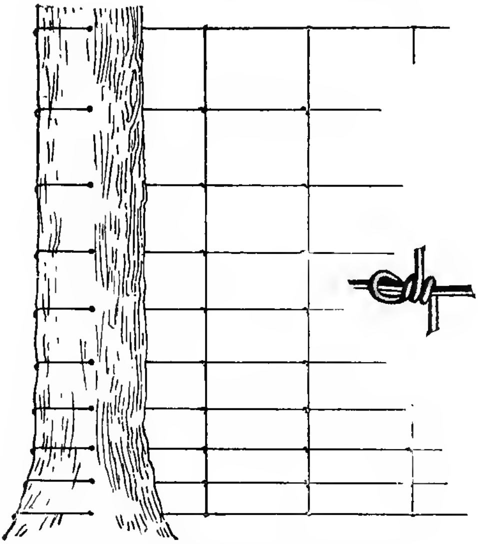
A planter in Sumatra estimates (I.R.J., Nov. 1st, 1909) that a jack worked by two Javanese is capable of grubbing from 70 to 80 roots or small stumps per day. It is capable of uprooting trees from one to two feet in diameter, and should therefore be of great service in opening up operations. When operating upon dead timber, the jack does its work with little or no aid from spade or axe. In dealing with green timber, it is often necessary to dig a little round the base of the stump and cut through some of the surface roots before applying the jack. For removing roots and sunken stones it is only necessary to dig a small hole on one side in order to allow the claw of the jack to get a hold.

In Malaya it is customary to fell the forest trees at a height of several feet above the the level of the ground, the stumps being allowed to remain, *in situ*, until they decay and fall down. This contrasts most unfavourably with the custom in Ceylon where all jungle is, in felling operations, cut as near to the ground as possible.

FENCING.

This work is necessary if the vacancies are to be kept at a minimum. Animals attack Hevea 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 newly-planted clearings are often enclosed in coarse wire netting, but where the rubber is planted in established products, such as tea, cacao, coffee, etc., it is usually sufficient to fence around each plant, either with netting or sticks. When coarse 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. When the boundaries of estates are fenced it is necessary to use from 8 to 13 strands of strong wire; the lower ones being close together, and the upper strands about one foot apart. A high strong fence is necessary to keep out animals of the porcupine, pig, and deer types.

A type of fencing which appears to be particularly strong and known as "Hercules" is now being supplied to estates.



THE "HERCULES" FENCING.

As will be seen from the above illustration this fencing, made from galvanized English spring steel wire, consists of horizontal and vertical strands at varying distances from one another. The strength of this type appears to be partly due to the fact that each wire is supported by others and knotted together in a peculiar way.

Draining.

It is erroneous to suppose that because Hevea is a forest cultivation 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. One authority with South American experience (T.A., January, 1909,) has suggested that thorough drainage as is being done in the East may lead to trouble, and believes it is better to imitate the Amazon conditions, and have low, swampy land, preferably submerged for a part of the year, and always damp enough to prevent the underground burrowing of the trees' enemies! This advice is not likely to be taken too seriously.

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 100 feet seems sufficient, whereas on steep hillsides 20 to 30 feet is not too close. They are usually about 1½ feet wide and deep, but in swampy land or in very wet districts they are not only closer together but considerably larger; on some Selangor estates they are 3 feet wide and deep.

Terracing and Silt Traps.

In some parts of Ceylon, South India and Java, where the land is very steep, terraces are dug along which the Hevea trees are planted. Malays and Chinese also terrace the hills on which nutmeg and clove trees are grown. Where the soil is very rocky and digging is impossible, stones are arranged around each tree, on the lower side, to check wash. In steep parts of East Java, where ordinary "Ceylon drainage" is rarely met with, large pits are dug at regular distances to collect the silt; on very steep estates a silt trap is recommended for each tree; this method is not applicable when the estates are rocky, but it is easily adopted with the light volcanic soils in Java and Sumatra. On some estates they are distanced about twenty apart, and are (T.A., March, 1910,) about 4 feet long, 15 inches wide, and 15 inches deep; on other properties (T.A., April, 1910,) they are 14 feet by 18 by 18 inches. The pits collect the fine soil, leaves, twigs, etc., and require to be cleared out regularly; the contents should have a high manurial value. A suggestion has been made (T.A., May, 1910,) that if Hevea grows well on flat land periodically flooded, it should thrive through the gradual percolation of water caught in these silt traps.

Holing and Filling.

The question of holing should be well considered, as the 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; if made 1½ by 2 by 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; the dribbling in of seeds in small alavangoe holes is not to be recommended. When the holes are re-filled, two or three weeks prior to planting, only the top soil and the scrapings should be used; the bottom soil from the holes should always be kept separate and discarded. It is hardly necessary to point out that the planting operations should be carried out when rain is plentiful; the plants should, if necessary, be stumped, but every care taken to avoid unnecessary destruction of sound roots. Frequently seedlings can be successfully planted without being stumped. 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. In some instances, where it has been necessary to plant in moderately dry weather, the nurseries have been flooded for two or three days prior to the plants being removed, and the results have been considered good. The holes should be re-filled with soil for a couple of weeks before planting, so that shrinkage may take place before planting is done.

Distance in Planting.

It is a principle recognized in forestry that close planting will give tall trees, and wide or open planting thick trees. One object in planting Hevea 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 18 inches or more. Such trees can be tapped. If the trees are very tall, but have a circumference of much less than 18 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, this undesirable result being the outcome of too close planting and not thinning-out or pruning the trees at the proper time. In parts of Ceylon trees have been planted 10′ by 10′, 12′ by 12′, 14′ by 14′, 15′ by 15′, and 15′ by 20′. It should be mentioned that trees in the Federated Malay States, planted 36′ by 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. A very popular distance for Hevea alone in Ceylon is 15′ by 20′, in Malaya 12′ by 24′, and 20′ by 20′; in Sumatra a distance of 20′ by 20′ is often provided.

Number of Trees per Acre.

The following table indicates from the distances of planting (square or oblong) the number of trees to the acre :—

ft.	8	10	12	13	14	15	16	17	18	20	25	30	35	40
8	680	546	453	418	388	363	340	320	302	272	217	181	155	136
10	546	435	363	335	311	290	272	256	242	217	174	145	124	108
12	453	363	302	279	259	242	226	213	201	181	145	121	103	90
13	418	335	279	257	239	223	209	197	186	167	134	111	95	83
14	388	311	259	239	222	207	194	186	172	155	124	103	88	77
15	363	290	242	223	207	193	181	170	161	145	116	96	82	72
16	340	272	226	209	194	181	170	160	151	136	108	90	77	68
17	320	256	213	197	186	170	160	151	142	128	102	85	73	64
18	302	242	201	186	172	161	151	136	134	121	96	80	69	60
20	272	217	181	167	155	145	136	128	121	108	87	72	62	54
25	217	174	145	134	124	116	108	102	96	87	69	58	49	43
30	181	145	121	111	103	96	90	85	80	72	58	48	41	36
35	155	124	103	95	88	82	77	73	69	62	49	41	35	31
40	136	108	90	83	77	72	68	64	60	54	43	36	31	27

Number of Trees per Acre at Certain Ages.

In order to allow the plants to develop freely in girth the maximum distance should be allowed, as the desired length of trunk is usually obtained even when the Hevea tree is grown in the open. From considerations of the condition of trees from 4 to 15 years old, the following table is compiled in order to show the probable number of Hevea 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

This shows the approximate number of trees to the acre at different ages without any serious 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 pruning or pollarding rather than by reducing the number of trees much below 100 per acre.

Hexagonal Planting.

The advantages of hexagonal planting have been discussed in the India-Rubber Journal, August 8th, 1910. It was there pointed out that in square planting the trees are set out in rows at right angles to one another. In hexagonal planting each tree is equidistant from six others which surround it, there being rows in three directions crossing each other at angles of 60 degs., dividing the field into a series of equilateral triangles with a tree at each angle. It is evident that a larger number of trees can be grown to the acre this way.

Various Opinions on Distances in Planting.

Cumming has expressed the opinion that distance in planting depends a great deal on the configuration of the land. Closer planting is possible on hilly land than on flat, because, he states, the light has more chance to get among trees on the slopes of hills than on level ground. He thought that, from his observations, close planting would during the first few years give more rubber than wide planting.

Gallagher (F.M.S. Bull. No. 10) estimates that on virgin jungle land from 15 to 20 per cent. of the trees originally planted will, through fungi, white ants, wind and poor trees, have been lost by the time the trees are seven years old. He recommends commencing with 120 to 140 per acre, in order that about 100 trees per acre may remain when they are seven years old. He does not point out that the percentage of vacancies is much smaller if the estate is originally widely planted.

After a visit to Eastern estates, Berkhout, late Conservator of Forests, Java, expressed his approval of close-planting, though he agreed that judicious thinning-out was necessary subsequently. It was quite a mistake, he maintained, to suppose that every acre of an estate should bear the same number of trees. He would plant 12 by 12 feet, but before the age of 20 the number of trees would have to be very largely reduced. The thinning-out ought to be done continuously and regardless of symmetry. No dead trees should be replaced except when a patch had been, for some reason, cleared.

Against the opinions of Cumming, Gallagher and Berkhout, we have that of Mr. Francis Pears to the effect that "an acre of rubber with 50 trees is likely to prove more valuable than one with 200." Wickham advises 40 trees to the acre.

Planting Distance in Ceylon.

If the estate is planted for rubber alone, all ideas of catch-crops disregarded, and a distance of 10 by 15 feet adopted in planting, the trees when six years old in Ceylon, and earlier in richer soils, will certainly have their foliar and root systems in contact. On such an estate individual trees might be stumped and tapped vigorously until they died, and thus make room for the further development of the remaining plants. It should be mentioned that there are 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 Hevea trees which, though planted the same distance and over 10 years old, did not appear to be too crowded.

Joseph Fraser (Souvenir, I.R.J.) considers that in Ceylon a distance of 20 by 10 feet is the most suitable distance for Hevea trees. Later on, if necessary, they can be thinned out to 20 by 20 feet, but he believes that with manuring on a liberal scale it is quite possible that the soil will carry 200 trees to each acre and yield large crops.

Distance in Planting and Checking of Growth.

The rate of growth is ultimately influenced by the distance the trees are apart; trees planted about ten feet apart, after attaining a girth of about twenty inches, do not subsequently increase in girth at the same rate as do those widely planted. On a Kadugannawa estate, Ceylon, where the trees are planted about ten feet apart, those trees on the boundary have continued to grow in circumference after those in the middle of the plantation have almost stopped growing; the trees on this block were, at the time these observations were made, about nine years old and had not been regularly tapped. It is, therefore, obvious that a permanent distance of ten feet apart is far too close for Hevea, though many estates have been so planted and will require systematic thinning-out later.

Many measurements have been made by Ridley and Derry which show the evils of close planting. One lot of 73 trees close-planted and another of 74 wide-planted, were measured in 1904 and again in 1905:—

	Aggregate Girths. 1904.	Aggregate Girths. 1905.	Aggregate Increase.
73 close-planted	66·86 m.	68·27 m.	1·41 m.
74 wide-planted	52·5 m.	58·56 m.	6·41 m.

For each close-planted tree the average rate of increase was $\frac{4}{5}$ inches, and for the wide-planted trees, $3\frac{1}{2}$ inches.

Ridley (Bulletin, July, 1910) also gives measurements taken at Singapore over a period of six years, which show that the average annual increase, per tree, for the widely-planted trees was $2\frac{1}{4}$ inches, against $\frac{3}{4}$ inches for closely-planted trees.

In the report of the Director of Agriculture, F.M.S., for 1910, the measurements below were given of trees in the Kuala Lumpur plantation:—

	Close Planting, 4ft. by 2ft. Average Girth at 3ft.	Open Planting, 25ft. by $12\frac{1}{2}$ft. Average Girth at 3ft.
1907	Planted	Planted
1908	$2\frac{7}{16}$in.	$3\frac{3}{16}$in.
1909	$4\frac{7}{16}$in.	$6\frac{1}{8}$in.
1910	6in.	$9\frac{3}{10}$in.

The seeds were planted at stake.

The old Henaratgoda trees, now about 22 years old and originally planted about twelve feet apart, measured, according to Willis, 30 inches in girth in 1897; but in 1907 the average girth was only about $36\frac{1}{2}$ inches; the annual increase in circumference having been much less than one inch during the last few years.

In the "Financier" of September 27th, 1907, the following measurements of trees planted at different distances were given, the details being supplied from estates in the Kelani Valley, Ceylon :—

30-Acre Clearing, Planted 1903 (10 by 10 Feet).

Tree	No.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Average.
		in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January,	1906 ..	6	$5\frac{5}{8}$	$8\frac{3}{4}$	$3\frac{1}{2}$	4	3	$4\frac{1}{8}$	$5\frac{1}{4}$	6	$6\frac{5}{8}$	5·3
January,	1907 ..	11	9	15	6	7	4	7	9	9	9	8·6
July,	1907 ..	13	$10\frac{3}{8}$	$18\frac{1}{2}$	$7\frac{3}{4}$	$8\frac{1}{2}$	$5\frac{1}{8}$	$8\frac{1}{2}$	$11\frac{1}{8}$	$10\frac{3}{8}$	$10\frac{1}{8}$	10·3

50-Acre Clearing, Planted 1904 (15 by 15 feet).

Tree	No.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Average.
		in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January,	1906 ..	$3\frac{3}{4}$	3	$3\frac{1}{2}$	3	$3\frac{5}{8}$	$2\frac{3}{8}$	$4\frac{3}{4}$	$5\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	3·5
January,	1907 ..	7	6	5	6	10	6	8	11	4	6	6·9
July,	1907 ..	$10\frac{1}{8}$	8	$7\frac{5}{8}$	$8\frac{3}{4}$	$12\frac{3}{4}$	8	$11\frac{1}{8}$	$14\frac{1}{8}$	$5\frac{1}{8}$	$9\frac{1}{8}$	9·5

These measurements appear to show that the closely-planted trees after three years have an average girth of 5·3 inches against an average girth of 6·9 inches for the same aged trees on the estate more widely planted. If these figures represent what is obtainable by a difference in age alone, they are very valuable ; a conspicuous difference in the rate of growth is not usually expected during the first four or five years.

Systems of Planting.

In the planting of Hevea there are five systems which may be mentioned :—

(*a*) Close planting—permanent ; (*b*) Close planting and thinning-out ; (*c*) Wide planting—permanent ; (*d*) Wide planting with catch and intercrops ; (*e*) Interplanting with herbaceous and arborescent plants.

What is Close Planting ?

To define close planting is a difficult matter, and though actual figures may be quoted, they are subject to modification according to the physical and chemical properties of the soil, and the nature of the climate in which it is proposed to grow the plants. The term—close planting—admittedly implies the planting of the trees at a distance which is not sufficient to allow of the full development of all parts of the plant ; the latter is determined by the natural vitality of the plants and the nature of the soil and climate. Medium distance planting in a poor cabook soil, or in a washed-out clay, above 2,500 feet in Ceylon, would be regarded as close planting in a rich alluvial soil in the low country of the same island. The trees should be planted at such a distance that they will rapidly develop and take possession of the whole of the soil ; their development is controlled by the amount of food which the soil supplies, and it is generally conceded that the better the soil, and more forcing the climate, the greater must be the distance allowed.

Disregarding the differences in quality of alluvial, cabook, swampy, forest and chena land, from sea-level up to 3,000 feet in

Ceylon, and the allowances to be made accordingly, it may be generally stated that on a soil similar to that at Peradeniya, Ceylon, a distance of ten feet apart, or less, for trees of *Hevea brasiliensis*, may be designated as close planting ; one of fifteen feet apart, as medium distance ; and one of twenty feet apart or over as wide planting. These distances are subject to modification according to local conditions, and are here given only to provide a basis for comparison ; it is obvious, for instance, that even 15 by 15 feet would be regarded as close planting in Malaya and Sumatra.

Advantages and Disadvantages of Close Planting.

The advantages of close planting are that there is a larger number of trees on a given acreage ; (2) the ground is better protected by the root and foliar systems, and consequently expenses in weeding are greatly checked, and soil loss thereby reduced ; (3) the rubber might, perhaps, be harvested cheaper ; (4) the cultivation is essentially one of rubber trees which presumably have a higher value than other trees of economic importance, and the method of cultivation over all the soil becomes the same ; (5) the inevitable proportion of poorly-developed, stunted, and damaged trees is not as serious ; (6) it is generally easier to thin out a densely planted estate than to interplant a widely planted one.

The disadvantages are ; (1) there may be considerable interference in the development of all parts of the plant and the resultant trees be dwarfed and lacking in vitality ; (2) the stems will tend to become thin, long and spindly, and the thickness of tappable cortex (bark) reduced ; (3) diseases are given a greater chance of originating and may spread more rapidly because the parts of the plant are nearer to one another or in more frequent contact.

Distance Required by Tapped Trees.

There is another point which appears to have been overlooked in connection with this subject, and that is the retardation in growth which must follow regular paring or tapping. It is no exaggeration to say that most of the old trees in Ceylon or Malaya were not systematically tapped until the last few years, and but few estates can point to acreages which have been regularly tapped, throughout successive years, from the time the old trees attained their minimum tappable size. Whenever cortical tissues are removed or mutilated, the energy of the plant is partly diverted to the production of new tissues in the affected area, for the time being the intimate connection between individual vital structures and that of the latter with cells which have less important functions is interrupted ; such changes must affect the future development of the plants, especially when of repeated occurrence from the 4th, 5th, or 6th year onwards. In the absence of any measurable effects following the tapping of trees one can only generalise and state that the sizes of trees so treated will probably be less than those of specimens which have never had their bark so excised and otherwise mutilated.

Original and Permanent Distance.

It is taken for granted that the reader is familiar with the sizes of Hevea rubber plants, from their first to their thirtieth year, in different soils and climates ; the question to discuss is whether the original should be the permanent distance. No one who has seen the uncultivated thirty-year-old trees at Henaratgoda can doubt that such specimens require, at the very least, a distance of thirty to forty feet, if they are to be allowed to continue their growth and maintain a healthy constitution ; what the required distance will be when they are 40 to 50 years old is very difficult to predict. In striking contrast to these are the thin, tall stems of two to four-year-old trees, and the poor lateral spread of the foliage when trees have just reached the tappable size. Between the first year of tapping and that represented by the old Henaratgoda trees, is a gap of nearly 25 years—probably the equivalent of a longer period when the newly-bearing trees are regularly tapped throughout successive years. I am of the opinion that it is not advantageous to plant, in a clearing, Hevea rubber trees alone at a distance which they will require when thirty years old ; we are dealing with a species which does not, like cacao and similar plants, attain the greater part of its maximum size in the first six or seven years, but with one which continues to grow, year by year, and even when thirty years old, still keeps on growing and throwing its roots into new soil. Though Hevea rubber trees continue to grow in this manner and the ultimate size attainable can only be roughly guessed at from our scanty knowledge and experience, yet we know that when their stems are only 18 inches in circumference they yield marketable rubber in very satisfactory quantities. Four to six years is a long time to wait for the first returns, and from a commercial standpoint the distance at which trees can be planted, without entailing undue interference in general development, and brought into bearing in their fourth year onwards, is one worthy of every consideration.

When the trees are widely planted they come into bearing as early as when closely planted, but there is no very great difference in the dimensions of trees planted at widely different distances, up to their fourth year ; the growth in the first four years is not as conspicuous as in later years, and even in the richest soils there is, despite ridiculous statements implying the contrary, a limit to the root and foliar development of Hevea rubber plants just as there is to other parts of plants.

Thinning-out Hevea Trees.

It is rare that a mycologist recommends close planting and thinning-out at a later date ; this, however, Gallagher does. He states that it is better to have too many than too few trees, but that thinning-out should be done in the fifth and sixth years. The roots should be completely taken out and burned along with the stem and every branch. He does not definitely state that the trees which are to be removed should be tapped to death; if this is not intended it is difficult to see the advantages, beyond removing backward trees, which such a course offers. If tapping to death is intended it should be borne in mind that it takes one to two years to kill a tree of the age mentioned, and by that time difficulties may ari e.

Carruthers (Annual Report, 1908,) stated that it would be better to pollard the trees and allow the branches to grow beneath those of the unpruned trees, than leave decaying roots of stumped trees in the soil.

Thinning-out in Klang.

The procedure adopted on some Klang estates is to select the trees which are to be removed, saw them down at a height of about eight feet, and drastically tap the remaining stumps. In one to two years the stumps will not yield paying quantities of rubber and can then be uprooted. Even under these circumstances it is surprising how the stumps develop; even though they are densely shaded on all sides by the foliage of surrounding trees several throw out branches near the top, which persist for a considerable time, and would, if permitted to do so, probably give the stumps another lease of life. Often one to two pounds of rubber are obtained within a year from the stump of a six or seven-year-old tree.

Close Planting and Available Tapping Area.

The main justification for closely planting Hevea trees is the increased tapping area which is available from the fourth year; this advantage, however, only holds good for a few years.

The object of many persons who planted this product a few years ago was to place their rubber on the market as early as possible, in order to benefit by high prices and to obtain quick returns. The results obtained by close planting can be made clear by calculating the available tapping area from the data previously given. The table given below shows the tapping area per acre possible when the plants are distanced from 10 to 20 feet apart:—

Distance of Trees in Feet.	Number of Trees to the Acre.	Available tapping Area per Acre at the End of the 4th or 5th Year in Square Inches; Base to 5 Feet.
10 by 10	435	522,000
10 by 15	290	348,000
20 by 20	109	130,800

In this table it is assumed that the effect of distance on the rate of growth is not apparent until the trees are more than 4 or 5 years old; if after that age has been reached thinning-out has not been done, the available tapping area will increase more rapidly on the widely-planted areas.

From the above table it is obvious that by planting 20 by 20 feet the available tapping area at the end of the 4th or 5th year is reduced to about one-quarter of what it would be if planted 10 by 10 feet. On an estate planted 10 by 10 about 5 per cent. of the trees could be killed out at the end of the 4th year, and a larger proportion dealt with likewise in succeeding years, until by the end of the 8th year an average of about 250 trees per acre would remain. The thinning-out of Hevea trees is, however, an unsatisfactory process, and very few estates are now being planted with this object in view. A widely-planted rubber estate with an inter-crop of cacao or coffee is apparently more valuable and less trouble-some than a closely-planted estate of rubber trees only.

The distance of 10 feet by 10 feet suggested on the above calculations is still open to the objection that the soil will, in some districts, 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 can 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 Hevea rubber plants.

The use of the Dadap or Albizzia stumps between young Hevea plants would, I believe, be accompanied by good results in very poor soils. 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.

On several estates the rubber trees have been planted 8 by 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.

I have endeavoured to give publicity to the views of leading planters on this very debatable subject. In view of my having been credited with definite opinions on this subject, I now state that for planting Hevea alone, I recommend a distance of 15 by 15 feet in poor soils and 20 by 20 feet in richer soils, thinning-out to be done later as desired. Better still, I think, is the use of intercrops through Hevea planted 30 by 15, 30 by 20, and 30 by 25 feet for Malaya, Sumatra, and Java, and 20 by 20 feet in Ceylon.

Pruning Young Trees.

It is eminently desirable to maintain a clean undivided stem for tapping; at least ten feet should be reserved at the base of the tree free from all branches. In the first few years of the plant's life, branches are frequently formed below ten feet from the base; these should be pruned back before they grow to any considerable size.

Hevea brasiliensis naturally grows to a tall slender tree, and it remains to be seen how by pruning or pollarding the young plants an increase in circumference may be obtained at the ex-pense 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 high, it would be idle to predict the possibilities with Hevea. This prevention of the unnecessary growth in height may well form the subject of many experiments. Wickham believes that the ideal tree form for Hevea is three main primary branches and to each of these three secondary branches; he recommends thumb-nail pruning as soon as saplings attain a clear stem of ten feet. Johnson advises that young trees which have been allowed to grow beyond the height at which branching is desired should be pruned back to this height.

The plants can be prevented from growing into slender woody structures by removing the terminal bud with a knife or thumb-nail, or, as is more commonly the case, by pruning the terminal young leaves and the enclosed bud. If the central bud is effectively removed, without doing considerable damage, the stem cannot grow in height except by means of lateral shoots; these will subsequently require bud-pruning once they have attained the required size. Buds which appear in undesirable places can be removed in the same manner, the ultimate result being that a tree considerably forked and supplied with abundance of foliage is obtained. The production of woody tissue in the upper part of the tree is appreciably checked, and the girth of the basal stem increases more rapidly than when the tree is allowed to grow upwards uninterrupted.

At Henaratgoda the trees which have forked at 7, 9, and 11 feet from the base show an additional increase of 30 inches in 30 years or an average of one inch, per year, throughout a long and fairly reliable period. Young trees which have been bud-pruned in the manner suggested above show an increased rate of circumferential growth; this means the attainment to a tappable size at an earlier period.

When Pruning Experiments may be Tried.

This operation is impossible or useless on old trees which have produced high woody stems. To cut off the whole of the stem and branches above fifteen feet would check the growth of the remaining stem, and such a measure is not recommended. Old trees treated in this manner produce foliage, but this mainly testifies to their hardy characteristics.

The stems of plants, when less than 20 feet in height, are more suitable for such an operation; when 12 to 15 feet high the terminal bud alone can be easily removed by thumb-nail pruning, and lateral shoots will soon appear in the axils of the leaves on the "green wood" of the stem. The object is simply to produce a forked tree, the advantages of which can be observed on any young rubber plantation. If the plants have been allowed to grow too high it is *too late* to perform the operation.

The suggestion has reference only to young clearings of Hevea rubber, but, considering how many thousands of acres are being yearly planted with this product, and the possibility of appreciably reducing the long years of waiting, it is important that it should be carefully considered and tried experimentally wherever possible.

If the young plants are made to branch too much there may be a disadvantage, as the foliage of adjacent trees may interfere. In such case, however, were it desirable, the excessive branch development could be kept down by repetitional pruning. It should be remembered that the lateral shoots, induced by pruning the terminal bud, ultimately form stout branches which tend to grow upwards and not horizontally.

Dimensions of Straight-Stemmed and Forked Trees in Ceylon.

District.	Age of Rubber Trees. Years.	Straight-stemmed. Number.	Straight-stemmed. Average Girth. Inches.	Forked Trees. Number.	Forked Trees. Average Girth. Inches.	Average Difference. Inches.
Galaha ..	7	15	21·33	7	25·14	3·81
Galaha ..	10	14	28·78	4	38·37	9·59
Kalutara ..	2	94	7·5	76	8·3	0·8
Matale ..	3	329	13·9	78	15·5	1·6
Kalutara ..	1½	14	4 to 7	32	4½ to 7½	0·4
Moneragalla ..	2¼	250	6⅞	250	8⅛	1¼
Kalutara ..	old	1	31	1	35	4
Do. ..	old	1	23½	1	29	5½
Do. ..	old	1	23	1	32	9
Henaratgoda ..	30	10	75	10	105	30

Some Experiments in Pruning.

The following is an account of one experiment carried out at Peradeniya :—Two plants of exactly the same age, grown from seeds from the same parent, were selected. In one case the plant was allowed to produce the usual long and slender stem ; the other tree had its terminal bud removed by thumb-nail pruning, and being unable to grow in height, threw out ten lateral branches. The result was the straight-stemmed tree had only one growing point at the apex of the stem, whereas the pruned one had ten, and from each of the latter were produced whorls of foliage. The plant so treated had, four months after pruning, no less than 200 fully-developed leaves, whereas that which had been allowed to grow in its own way had only about 50 leaves. The food-producing capacity of the pruned tree, as far as the foliage alone was concerned, was four times as great as that of the straight-stemmed one, and it stands to reason that the basal part of the pruned tree would probably grow at a quicker rate. The operation itself is a gentle one and does not partake of anything so drastic as the cutting away of the upper part of young or old trees. The lateral branches each produce their own whorls of foliage as though they were members of separate trees, and as they tend to grow more or less upwards may themselves require pruning at intervals of three or six months.

It is therefore possible to lead to the production of a large number of branches, and we have next to enquire how soon the effect is obvious in the girth of the stem.

The two plants referred to were over one-and-a-half year old from stumps, and the forked one showed, four months after pruning, a circumference of $4\frac{2}{3}$ inches as against 4 inches for the straight-stemmed tree; this means an increase of over half-an-inch within six months of the pruning operation.

Growth of Forked Trees on Estates.

The young trees on various estates in Ceylon and the old trees at Henaratgoda indicate that an average increase of about one inch per year may be obtained by making them fork at the proper height.

If an average increase of one inch per year can be obtained, it means that a year is gained in the first four or five years and a minimum tapping size of 20 inches may be reached in the fourth year.

An interesting series of figures obtained in the Kandy District showed that trees of the same age, which had branched at a point 12 to 14 feet above ground, had an average circumference of 19 inches, and those which had branched at 5 and 8 feet from the ground had an average of 26 inches.

In the Kalutara District trees of the same age, but divided at the base into two, three, and four stems respectively, measured, in stem circumferences per tree, 14·4, 18·1, and 22 inches respectively. In all parts of the island the increased circumference due to forking of the trees can be seen, and the fact has even been noted in the annual report of a prominent company largely interested in rubber.

The Neboda Tea Co. of Ceylon, Ltd., in their annual report for 1905, state that the two tallest trees show the smallest girth, and the shortest and well-branched trees the best.

Tudhope (Annual Report, Aburi, 1909,) states that the Hevea trees, especially those which have branched low, are making rapid growth. Proudlock, in his report on rubber trees at Nilambur, 1908, after giving girth measurements, points out that 13 out of the 37 trees measured have forked stems, and that the "tappable girth" is greater than in trees unforked. He shows that the average girths at 4 feet of the two or three forks together is greater than the average girths of the unforked.

Some Opinions on Pruning.

Since I suggested, some five or six years ago, that experiments should be tried in thumb-nail pruning, the subject has received attention. My critics, however, are in the main not planters; some—Wickham, Johnson, and Proudlock—favour the system, but many others do not. Experiments made under my direction on estates in Malaya and Sumatra have demonstrated that in windy places or on light friable soil the system is not to be advocated; on the other hand, districts not frequented by strong winds and having stiff clayey soils appear to give more favourable results. The most important objection arises when either too many lateral branches are allowed to develop at the same level and thus make the tree "top heavy," or when two opposite branches only are allowed to grow, the juncture serving as a receptacle for water; in the latter case decay sometimes sets in and the tree splits down the middle. I still think that where climatic and soil conditions are favourable the experiment may prove useful providing the lateral branches are allowed to develop in positions consistent with the symmetry of the tree. It is, however, a matter which should be left to the direction of those on the estate.

Towgood (T.A., March, 1908,) states that in thumb-nail pruning the place of the main stem is taken not by true branches but by suckers, very liable to split off, and the tapping height is fixed for all time. He suggests that the leaves of the saplings be removed leaving only the stalks, in the axil of which new branches will arise if the operation is performed before the terminal shoot has made its appearance.

Ryckman (Jour. d'Agric. Trop. Jan., 1909,) suggests that in ordinary thumb-nail pruning the equilibrium between the root system and foliage may be disturbed, and that the liability to disease is increased; while admitting the latter, it is difficult to see the force of the former objection.

Bailey (Singapore Free Press, April 10th, 1908,) was against the system, as he believed it to be unnatural and accompanied by numerous disadvantages.

Weeding.

The question of suppressing weeds on rubber estates affords ample opportunity for new suggestions and criticisms of systems now in vogue.

The only real item of expense on a large rubber estate, newly planted with rubber alone, is that of weeding. Annual reports to hand give some information of the cost of weeding on well-known properties. Some balance-sheets show that weeding has cost one-third or more of the total cost (including clearing jungle, planting, and managerial salaries), of a block of land recently opened. Another list shows that to weed a plot of 100 acres to the end of the 5th year cost £550; while other properties are known which have cost £10 per acre in one year alone for weeding. Instances could be quoted where the costs of weeding are much higher, especially when lalang has appeared. On the other hand, if an estate is kept clean from the beginning, weeding should not cost more than 75 cents. (rupee) per acre, per month; even this can be reduced in later years.

Every planter knows that the work of weeding is one of the most important and frequently difficult tasks when dealing with newly-planted rubber estates. If any part of the property begins to show a green cover, trouble will assuredly face the planter when dealing with his weeding contractors. This is especially so in Ceylon, where almost without exception European planters and visiting agents are wedded to the system of clean-weeding estates, whether they be of rubber, tea, or cacao. To keep the estate free from weeds is the test as to the fitness of a planter to keep his post in Ceylon.

Planters, even in Ceylon, are conv nced that it is impossible to exaggerate the soil loss that must take place when young clearings are, year by year, exposed to tropical heat and rain, and scraped by weeding contractors. Nobody seems to entirely like or approve of the system. The proprietor knows t is costly, the planter regards it as his most troublesome task, and all who have studied the pros and cons pronounce it as injurious to the soil. Why, then, is the system continued ? The answer to this question is that it is the only system whereby labour can be retained, costs kept near the minimum, and the Hevea trees made to show the most rapid growth.

Alternative Schemes in Cultivation.

Many systems have been tried by planters in Ceylon, Malaya, Java, Sumatra, and Borneo ; schemes have been evolved one after the other by the writer and others ; money has been spent and experiments have been carried out for several years in succession ; and after all the same questions crop up among the planters. Most planters know, on an estate with rubber trees only, often from bitter experience, that there is very little to choose between clean-weeding and no weeding ; to attempt to weed only three feet around each rubber tree is a dangerous and generally impracticable system. To allow any and all weeds to develop will retard the growth of the rubber plants. If there are any planters who do not believe this, let them try their hand and make careful measurements of the trees on plots cultivated on these systems.

The only practical way out of the difficulty seems to be to interplant the rubber properties with additional crops which will not rapidly run to seed and in turn become dangerous weeds, or which will, in course of time, give some return as a catch crop before the rubber is ready for tapping. To interplant the rubber saplings with Dadap or Albizzia trees, which grow rapidly and will stand frequent lopping, is one good system, but, nevertheless, quite impossible in some countries. To interplant with cacao, coffee, tea, tapioca, tobacco, etc., is even better, providing the required space is allowed around each rubber tree. Many planters have tried tobacco and coffee in Sumatra, tea in Ceylon, South India, and Java, tapicoa, indigo, coffee, and sugar in Malaya, and cacao in Ceylon, West Indies, Samoa, and Java, in conjunction with Hevea, and though each country frequently claims to be satisfied with the results there does not appear to be much change of system in each of the areas enumerated, except that Malaya appears to be gradually abandoning all catch-crops.

SYSTEM IN CLEAN-WEEDING.

Clean-weeding in the tropics, though appalling in its effects on the soil and costly to the enthusiasts accustomed only to agriculture in temperate zones, seems, nevertheless, to be the most desirable system from the commercial point of view. Once an estate is perfectly clean it should be maintained in that condition for all time; this can be accomplished at far less cost, and the minimum of dissatisfaction to the labour force, than any system of partial weeding at irregular, opportune intervals. After having had a fairly extensive experience with the various systems in India, Ceylon, Borneo, Java, Sumatra, and Malaya, I have come to the conclusion that any system other than systematic clean-weeding is only advisable on very steep ground, or when an estate is taken over in a bad, weedy condition; these circumstances warrant, and sometimes necessitate, a departure from the system of clean-weeding, at least for some little time.

Clean-weeding should be done in a thorough and systematic manner. The area weeded should be divided into blocks, I., II., III., IV., &c., and each block gone back upon and again clean-weeded once every 21 working days before the area of clean-weeding is further extended. In this way the whole area should be gradually overtaken without any portion being allowed to fall behind.

Believers in this system usually instruct their managers that planting extensions must not be undertaken until the areas already planted are being regularly weeded every 21 working days or once every month.

Joseph Fraser, after a long residence in the East, states (Souvenir, India-Rubber Journal): "Many estates in Ceylon and Malaya have been kept perfectly clean from the first, for small cost, with the best results. In other cases where weeds have over-run the state, and especially where illuk (lalang) has been allowed to grow, the results have been absolutely disastrous, and the cost of bringing the estate into bearing has been enormously increased. The Passion flower plant and various other palliatives have been recommended, and have no doubt done good in certain cases, but *there is only one right and economical method which is to eradicate all weeds before they seed.*"

Francis Pears believes that grass should be avoided like poison. As for sowing Crotalaria broadcast on a new clearing with just sufficient timber heaped and burned for planting, it is only inviting disaster.

CICELY ESTATE AND WEEDING.

It is only fair to state that some managers have been able to secure excellent results without attempting even regular weeding of the estate. At the annual meeting of the Cicely Rubber Co. in 1911, Dr. S. Rideal drew attention to the yield from the trees, 10 to 12 years old, that had never been clean weeded. When the trees were taken over in 1905 clean-weeding was not thought of, and the opinion of those who saw the estate at that time was that it was very much neglected. The undergrowth was kept down from time to time by scything and cattle had eaten it down too. The trees on this part of the estate, nevertheless, gave 8lb. of rubber each during the year under review, a crop quite as good as that from estates maintained in a clean condition at all times. The directors have only recently decided to clean the area; subsequent yields will be watched with unusual interest. Opponents of weedy estates may think that the excellent yield was in spite of the weeds, and that a much larger crop would have been obtained from similar aged trees on estates clean weeded from the beginning.

Cultivation of Weed Killers.

The cultivation of plants to cover and kill ordinary weeds is quite distinct from that of growing leguminous plants to turn into the soil as green manure, though the objects of both methods are often attained by growing the same plant.

Crotalaria, Desmodium, Trifolium, Cassia, Vigna, Tephrosia, Mimosa, Soya bean, have, among the leguminous tribe, been largely grown as weed killers in Ceylon and Malaya; their slow rate of growth, the protection they give to porcupines and rats, the poor cover they give to weeds and the necessity to annually sow seeds, have brought them into disfavour; much better results have been obtained with Kratok—a species of Phaseolus—on estates in East Java. The wild passion flower (*Passiflora fœtida*) has been extensively used as a weed killer in the Federated Malay States; it certainly keeps the weeds—even lalang—in check. It grows very rapidly, and appears to keep back the growth not only of the weeds, but also the rubber trees; when uprooted weeds begin to grow quickly and should be systematically attended to from the moment the Passiflora is removed.

The Madu Vine along with the Pupala shrub (T. A. March, 1909) has been recommended by a planter as superior to Passiflora for suppressing lalang. *Mikania scandens*, a plant in Ceylon, was recommended (Circular R.B.G., 1909,) for suppressing weeds; the cultivation of this plant as a weed killer is purely experimental. Very few weed killers are systematically grown in Ceylon, Malaya, or Sumatra, except the land is, in addition to being weedy, very steep; the use of these plants under the latter circumstances is more justifiable.

Experiments with weed killers were carried out by the Agricultural Department, Kuala Lumpur. According to Campbell and Spring (Annual Report, 1909 and 1910,) four one-acre plots of Hevea were experimented with at Batu Tiga and the following results obtained:—

	Average Girth. 1908. in.	1909. in.	1910 in.
Planted with Mimosa, and not weeded after it was established	5·19	6·08	13·20
Clean weeded	6·75	11·15	14·00
Weeded three feet around each plant	4·56	5·43	7·01
Not weeded	5·19	7·08	10·37

The Mimosa plot was much interfered with by lalang. The "not weeded" plot was helped by the fact that one end was damp and somewhat shaded.

Campbell, after growing many weed killers, concluded that: (1) As a substitute for weeding on old land they are a failure. Lalang and other weeds generally infest the land. (2) As an aid to weeding they tend to greatly reduce its cost. (3) They tend to retard the growth of the trees planted among them. This has been noticed even with nitrogen-producing plants like Mimosa and Crotalaria. The question whether the reduced cost of weeding compensates for the delay of, say, one year in five in reaching the tapping period is, Campbell admits, an open one.

LALANG.

On neglected estates the tall, narrow leaves of that much-feared weed—lalang—soon make their appearance. Tobacco lands in Sumatra, after being cropped, are allowed to develop in lalang and secondary growth. The same happens with the sugar lands in Java and tapioca estates in Perak. Whether the frequent sight of lalang has dulled my sense of fear I know not, but I certainly must admit that I no longer look upon it as the terrible weed against which organised effort is of no avail. I have seen thousands of acres of Hevea developed on old lalang grounds and now thriving exceedingly well. As already pointed out, many planters are to-day selecting such land for rubber on account of the absence of tree stumps in the soil and the relative immunity from the root fungus and white ants which such a condition gives. There is usually nothing wrong with the soil except that a crop of tobacco, tapioca or sugar may have been taken from it in past years.

On flat land I have seen an American steam plough used to turn the soil over and bury the lalang. This seemed to me to be the wrong thing to do, but as the lalang was kept in check at a cost of two guilders (3s. 4d.) per bouw (1¾ acres) per month during the first year, and at a nominal cost subsequently, I could not seriously complain. On other estates the land is kept free from weeds along the lines of the rubber trees to a width of six feet, and the lalang between the rows smothered with kratok, or the wild passion flower. If the estate has ultimately to be clean weeded and is completely under lalang, it will cost at least, even by the most economical method, two guilders per month per acre for the first year, 1½ guilders monthly for the second year, and one guilder for the third and fourth years. Compare that cost with the combined cost of felling, clearing, burning, and weeding on an ordinary estate developed from forest. Lalang does not come out as badly as the average rubber investor imagines; on many estates, however, £6 per acre have been spent per annum in eradicating lalang.

I do not for a moment wish it to be thought that I *like* lalang. I wish it were not in existence, and strongly advise that every effort be made to prevent it from getting a hold on any planted estate. But from what I have seen accomplished in Java, Sumatra, and Perak, on lands originally possessing only lalang, I no longer regard it as a weed beyond the control of the planter.

Lalang Destruction by Spraying.

One firm, interested in the production of destructive chemicals, submit that the only effective method of ridding land of weeds, especially lalang grass, is to attack the roots with a solution of arsenite of soda. Where the roots are not more than a foot below the surface, and the soil is fairly loose, the solution will find its way to the roots if the ground is well and carefully sprayed. If the grasses and weeds have been cut down and removed, and the surface so cleared that there will be no waste of solution upon the rubbish lying about, a good dressing at the rate of 25 gallons to 70 or 80 square yards (that is, 80 by 1) will be sufficient to kill the roots without taking them up; the time chosen for application is when the ground is moist with dew. The ground should be well sprayed once, and then again before it has time to dry, one dressing following the other whilst the ground is wet. If the roots are more than a foot down it may be necessary to fork them up or to loosen the ground so that the solution can easily penetrate to them. It is stated that to destroy young lalang by forking costs at least about $60 per acre, whereas the cost of arsenite of soda of sufficient strength to accomplish this more effectually upon an acre of ground would only cost about $13 (1 dollar = 2s. 4d.) c.i.f. Port Swettenham, Singapore or Penang. Campbell (Annual Report, 1908) used a 1-10th% solution and sprayed the lalang ten times. The time occupied in spraying the solution over an acre would take three men, with a fairly good distributing apparatus, from three to four hours. There may be cases where, from the nature of the ground, or the fact that the lalang is so deeply rooted, that it has to be dug up and the roots taken away and destroyed; but even in such cases many broken pieces of root are bound to be scattered over the surface. These will grow again if not destroyed. One spraying would be sufficient to destroy these pieces of broken roots, thereby using just half the quantity of solution.

Ants or any other vermin feeding on vegetable matter in the soil would also be destroyed. Merryweather's have made a special feature of their apparatus for use in spraying weeds over large acreages; pumps and lengths of tubing being varied according to the area under experiment. The same apparatus, and often the same chemical, can be used for weeds and diseases common to Hevea.

This method of destroying lalang has, under the direction of the Agricultural Department in Malaya, been tried, and appears to have given encouraging results. Experiments were also made in Borneo and elsewhere, but the conclusion finally arrived at seems to be that the sooner it is uprooted, by forking, the better.

Even when dealt with in this manner coolies have to repeatedly go over the ground to collect broken fragments of roots lying on the surface. The expense of ordinary changkoling is high, especially when the roots are two feet below the surface ; many estates have spent from £6 to £8 per acre in removing lalang, and even then have not got the areas under control.

Changkoling Advocated.

Mr. Alma Baker, in the India-Rubber Journal, September 5th, 1910, strongly advocated changkoling everything once every three months from the time of planting. "This system has," Mr. Baker states, "the following advantages :—

"1. It prevents all surface wash from the beginning.

"2. It enables the land to retain more moisture.

"3. The land does not only retain all the plant food it originally had, but has in addition the humus derived from the vegetable matter turned in four times a year, Also, the turning up of the under soil renders readily available, through exposure to the atmosphere, a portion of the otherwise unavailable salts.

"4. It forces the tree, by cutting the small surface laterals, to root firmer and lower, and to take its nourishment from cooler, damper, and richer soil.

"5. It greatly helps in the eradication of Fomes and white ants, as it clears the land of all small pieces of timber, at the same time opening up the soil for the air and sunlight to penetrate."

Baker feels certain "that this system of cultivation will give a larger percentage of tappable trees at a given age than any other. Trees growing in land thus treated must have a more vigorous, healthy and longer life than trees grown in clean weeded, undulating soils denuded year after year of all surface soil and humus. The cost of changkoling four times a year is not more than ordinary clean weeding. The one thing that must be absolutely certain in this class of cultivation is your labour supply. This must be sufficient to come back on the area changkoled once every three months for certain."

Approximate cost of changkoling in average land—not big lalang: a fairly low average for this work per man is 2½ acres per month of 25 days' work; 100 coolies with an outturn of 80 per cent. (very low), constantly at work, will changkol 200 acres per month, i.e., 600 acres per three months."

Mr. Baker does not say whether the repeated destruction of roots encourages white ants and Fomes at a later date ; once Hevea trees have attained the age of three or four years it is not usually deemed advisable to more than lightly scratch the soil even when manurial operations are being carried out.

Disc Harrows and Cultivators.

The disc harrow has recently been tried in Java and Ceylon ; it can be used when the soil is comparatively dry. According to Lock (T.A , Feb., 1910), it disturbs the soil to a depth of 2 or 3 inches, and can finish 3 or 4 acres a day; each crop of weeds is said to be destroyed as fast as it appears. These harrows are also being used extensively in Province Wellesley, if not also elsewhere in Malaya. For similar purposes cultivators, say, 9-tine, are employed, and probably are more suitable for certain classes of soil.

Once a lalang area has been changkoled or ploughed a number of times, both disc harrows and cultivators may be successfully used to keep down the weeds.

Root Pruning.

The effect of changkoling on the roots would be still more marked if systematic root pruning were adopted, as suggested by Mathieu. He states (page 126) that :—

"When the roots have reached the limit of their feeding ground they cease to spread. They then coil up and form tangled masses through every inch of the ground till, space lacking, they cease to throw out new feeders." . . . . At that time he has found that a partial and light cutting of the roots, at the extremity of their feeding ground, renews them to a wonderful extent. The opening of the ground causes moisture to penetrate deeper; and the roots strike downwards into new layers of soil. Thousands of new rootlets are formed. He has tried this with coffee, and only suggests it for Hevea. To carry it out make a trench one foot deep between the row of trees and 10 feet distant from the trunks, merely turning the sod up to the sides; then two parallel trenches one foot on either side of the first, but only 4 inches deep so as not to injure the main roots.

It is needless to add that this is only a matter for experiment; it should certainly not be adopted until the effect has been accurately demonstrated on isolated trees.

CHAPTER VII.

CULTIVATION OF CATCH AND INTERCROPS.

There is a large number of planting and scientific authorities who believe in adopting a mixed cultivation, whenever possible, because by so doing they imitate nature closely. It is apparent that different plants may help each other, and also that they may feed on different layers of soil or draw to some extent upon different soil constituents in different degrees. The necessity of strictly imitating nature in cultivation is not obvious to the writer. On the contrary, we ought, with all the knowledge and skill at our command, to considerably improve on the results obtained from plants growing in the wild state. There is far more discord prevailing in jungle or forest areas than one is at first inclined to admit, and it is easily possible, under cultivation, to eliminate many factors which ordinarily impede the development of a particular plant. Further, one can go so far as to state that if one had not in the past resorted to most unnatural methods in cultivation, many products would to-day hardly be known. Take, for instance, the tea bush. The plant which supplies us with tea leaves grows to a large bush or medium-sized tree in its native habitat. Even on estates it develops, if not interfered with, into a tree of sufficient height and general size to offer substantial shade to cacao plants. But on tea estates this vigorous plant is cut down to, say, two feet, nearly every year at low altitudes. Three months later the bare woody branches throw out leaf-buds. The coolies pluck the leaves and continue this stripping every ten days until near the time for pruning. The regular plucking of leaves, pruning back of the bush every year or so, forking the soil often to a depth of nine inches and thereby destroying enormous numbers of roots, tramping daily over the hard sun-baked soil whence the tea plants derive their food supplies—these methods are no imitation of nature's conditions. Yet it is upon some of these factors that the success of tea under cultivation depends. I draw atention to this point because one so often hears opinions being expressed to the effect that *Hevea brasiliensis* in the East will not continue to thrive owing to its being taken away from its native habitat and to its being grown under conditions so unlike those prevailing in the jungle whence the parents were derived.

There are products which, unlike tea, must to some extent have conditions under cultivation similar to those prevailing in the forest. Cacao, for instance, during its early life, at least, must have shade. Castilloa rubber trees, which grow under the shade of higher trees in the undisturbed forest, are also said to grow better, during early life, with a little shade under cultivation. The adaptability of some tropical plants is sometimes very limited, whilst in other species it is the reverse. Each tropical plant should be studied from the individual point of view. *Hevea brasiliensis* is, fortunately, a species which compares very favourably with even tea and coffee in point of adaptability. It grows at sea-level to over 3,000 feet altitude, in swamps, dry plains, and rocky hillsides, and in districts having dissimilar climates. This adaptability enables us to use Hevea, under cultivation, in a variety of ways: (*a*) as a single product, (*b*) in association with more or less permanent intercrops of tea, cacao and coffee, or (*c*) with catch-crops of cotton, tobacco, chillies, etc.

Advantages and Disadvantages of Subsidiary Crops.

The main advantages claimed for inter and catch-crops under Hevea are briefly: loss by soil wash is checked; the soil conditions may be improved; plant pests are sometimes reduced; revenue is obtained before the Hevea can be tapped; and the intercrop may prove useful when rubber no longer shows an unusual margin of profit.

The main disadvantages are: the manager's attention and the labour force are diverted from the principal cultivation—rubber; the soil may become exhausted; the intercrop often retards the growth of the Hevea, and has often to be neglected when Hevea is in bearing; the intercrop has usually a short life, and the total revenue therefrom is often less than the total expenditure thereon. All the foregoing advantages and disadvantages must be admitted. At the same time it must be acknowledged that mixed products usually have a longer life, and many of the disadvantages of intercroping can be overcome by adopting a definite system of distance in planting.

Intercrops and Diseases.

There is also another point which is now being appreciated by planters who have lost a large number of Hevea trees on forest clearings through Fomes and white ants; viz., the reduction of losses through disease on lalang and old coffee clearings compared w th those on land previously in heavy jungle.

The dangers attending new clearings of Hevea trees on land rich in roots, timber and excess of organic matter, can perhaps be mitigated by the adoption of a system which appears to have gained favour especially among planting circles in the Dutch East Indies. On some estates it is now the custom to plant the intercrop of coffee two or three years before the Hevea trees, the interval of time being sufficiently long to ensure decomposition of many of the roots. The atmospheric agencies and the growing crop of coffee soon lead to a reduction of organic matter in the soil, thereby affecting the food supply of fungi like *Fomes semitostus*. The disadvantage—deferred planting of rubber—is obvious, but the scheme strikes me as one which, in future, when

Photo by F. J. Holloway.

HEVEA AND CACAO, KEPITIGALLE, CEYLON.

Photo by Ivor Etherington.

HEVEA AND TEA, BOTH IN BEARING. NIKAKOTUA ESTATE, CEYLON.

crops in addition to rubber have to be kept in view, may receive more support than it has done during recent years. Any plant which temporarily cultivated will act as a "trap crop" and lessen the liability to disease of the main crop should receive consideration. Some plants—notably certain green manures—used as weed killers may assist in the spread of certain diseases common to them and Hevea trees; but this does not appear to be the case with many quick-growing "catch-trap" crops at our command.

It must not be surmised that Hevea plantations established on such areas are immune from Fomes or equally dangerous diseases or pests. Even soft woods like kapok (Eriodendron) and *Albizzia moluccana* will require from three to six years to decay, whilst the stumps of hard timber such as Jak (Artocarpus), Marabau, Eugenia, and in fact most of the trees on old jungle land, will remain for ten to twenty years or longer. A large number of the smaller trees can, of course, be uprooted.

Financial Considerations.

The main reason why I am inclined to urge the interplanting of more or less permanent products is that I believe that long before 1920 we shall, in rubber plantation companies, be far more dependent on intercrops for our revenue than we are to-day. This view was not always logical; it has, however, been made so by the events of the last few years. We now know that there are about 400,000 acres in Malaya and 500,000 acres in Ceylon, Java, Sumatra, South India and Borneo—all planted with rubber trees. Throughout the tropical belt, and even in Brazil and Africa, plantation work is being encouraged. Within seven years it is quite possible that the plantation crop of rubber will be treble the amount we have been in the habit of receiving yearly from Brazil. This means that plantation rubber may, possibly only for a limited period, be sold at or below cost of production. It will take several years for the trade of Europe and America to accustom itself to consuming the new crops of plantation rubber, and it is only reasonable to anticipate that the history of cultivated rubber will be somewhat similar to that of other vegetable products in the tropics. It is because I believe this so thoroughly that I recommend the cultivation of intercrops in association with Hevea; it is a measure of protection. The cultivation of other crops under rubber, to last more or less permanently, is possible by adopting a wide system of planting, say 30 by 25 feet in the rich soils of Sumatra, Java and Malaya, or 30 feet by 20 feet in Ceylon and South India. This distance will give a long life for the intercrops of tea, cacao and coffee, which are the principal permanent crops recommended for this purpose. It should also be remembered that one cannot abandon tapping operations, temporarily, on Hevea trees without almost entirely destroying the labour organization on the estate, should it ever be necessary to do this when prices for raw rubber are below cost. Where the estate is interplanted, however, there would be ample work for a good part of the labour force with the intercrops.

Intercrops in Ceylon and South India.

There are about 230,000 acres over which Hevea trees are planted in Ceylon; about 130,000 acres are Hevea alone, the rest—about 100,000 acres—being through cacao and tea and various minor products. Tea is met with as an intercrop in Ceylon at all altitudes between sea-level and 3,000 feet; the greater part of the acreage associated with Hevea, however, is below 1,500 feet. In many cases—and this applies in the main to cacao as well—the Hevea trees have been planted out last of all, the result being a very slow rate of growth and a large number of vacancies, the latter especially on cacao estates. Where the Hevea has been planted at or about the same time as the tea or cacao, the rubber trees grow more rapidly. The areas composed of cacao with Hevea in Ceylon are mainly on estates between 750 and 1,800 feet above sea-level, the Matale and Kandy districts being well represented in this respect. The distance adopted in Ceylon is not one which can be recommended for richer soils, and even in that island much of the tea will have to be abandoned at an early date where the Hevea is planted closer than 20 by 15 feet. The cacao plantations will last considerably longer, owing to the advantages accruing to the cacao bushes when grown under the shade of forest trees. In the low-country districts of Ceylon, citronella, sugar, tapioca, and other minor products are often grown as catch-crops, but these do not cover very large acreages.

Intercrops on rubber estates in South India are met with mainly at high altitudes. Cacao is not grown as an intercrop. Tea and coffee—Arabian and Liberian—are the principal intercrops in South India.

Intercrops in Malaya.

Intercrops are not cultivated very largely in Malaya; in fact, they find least favour in that area. Only about 6 per cent. of Hevea is interplanted in the F.M.S., and 16 per cent. in the Straits Settlements. Coffee as an intercrop is gradually disappearing on account of the rapid growth of the Hevea trees; this can also be said of other intercrops, particularly in the F.M.S. The following statistics (Report of the Director of Agriculture, F.M.S., 1910), show the interplanted acreages throughout the Peninsula :—

	Federated Malay States.	Straits Settlements.	Johore.	Kelantan and Kedah.	Total.
Rubber alone	231,797	50,928	38,222	12,011	332,958
Rubber and coffee	5,236	—	—	—	5,236
Rubber and coconuts	4,106	1,000	2	350	5,458
Rubber and sugar	820	676	—	—	1,496
Rubber with other crops	3,815	7,964	5,292	634	17,705
Totals	245,774	60,568	43,516	12,995	362,853

Lent by India-Rubber Journal.

HEVEA AND SUGAR, PRYE ESTATE, MALAYA.

Lent by India-Rubber Journal.

HEVEA AND COFFEE, UGANDA.

Lent by India-Rubber Journal.

HEVEA AND COCA, UGANDA.

Lent by India-Rubber Journal

HEVEA AND COFFEE, NSAMBA MISSION, UGANDA.

Intercrops in Sumatra.

Permanent intercrops are not numerous in Sumatra. Tea is not cultivated in that island, neither is cacao to any extent. I believe that the former is now being tried, and the latter is practically limited to about 30,000 trees under Hevea on Tamiang estate. The principal intercrop is coffee, Liberian being the most popular variety. The only shade given to the coffee is that of the Hevea tree, and this may, to some extent, account for the comparative failure of robusta coffee in that island. The principal catch-crop in Sumatra is tobacco; this could be used much more than at present if a wide distance was permitted for the Hevea trees. The tobacco is ruined by the drip from the trees if the two products are too near each other.

Intercrops in Java.

It is in the island of Java that one meets with mixed cultivation on a large scale. There it is not uncommon to find on the same estate, in addition to Hevea, coffee (Arabian, Liberian, and robusta) cacao, coca, pepper, and indigo, as intercrops, and also trees of cinchona, nutmeg, kapok (Eriodendron), Ceara, Castilloa and Ficus rubber. Mixed cultivation has undoubtedly been carried on to a ridiculous extent on many estates, the soil being frequently crowded with thousands of trees per acre of all descriptions and ages. On the better estates it is customary to grow only one or, at the most, two intercrops under the Hevea, coffee and cacao being the favoured products for this purpose. Citronella, sugar, indigo, indian corn, beans, and tapioca are also grown on several estates as catch-crops.

Effect of Rubber on other Cultivations.

On many estates the effect of rubber cultivation on the intercrops is already apparent, especially where the Hevea is closely planted. Sooner or later the Hevea trees alone must be in possession of the land. As in the low-country tea lands of Ceylon and the sugar estates of Perak, the closely-planted Hevea trees with increased age demand more soil, and prevent the intercrops from receiving the light they require. In Sumatra and Java the old coffee estates interplanted with rubber will soon be transformed into purely Hevea propositions, and unless new lands are planted, much of the machinery used in the preparation of coffee will be useless. In Sumatran districts like Serdang and Langkat the change will be great, owing to the very large acreage now under Liberian coffee. In five years time the appearance of these two residencies will be considerably changed, and for the first time a forest cultivation will reign. This can, in future, be avoided by adopting a wider distance in planting the Hevea trees.

Distances when Intercrops Grown.

It is not only necessary to adopt a wide distance when permanent intercrops are grown, but it is also advisable to have a differential arrangement of, say, 30 by 15, 20 by 10, or 30 by 25 feet, instead of an equal distance of 20 by 20, or 15 by 15 feet, etc. This is necessary in some cases where, as with sugar and indigo, the intercrop requires much light. The wide space in which the crop is planted should run east and west, and thus get the maximum amount of light from the time of the sun's rising to that of its setting. Furthermore, an unequal distance permits of the short distance line being kept free from intercrops in order that tapping operations can be supervised as easily and almost as effectively as when only Hevea is grown. The planting of the intercrop should always commence some distance from, but be parallel to, the lines in which Hevea is widely planted. By this arrangement one always has a clear space, free from all crops, along the short distance lines, and a distinct gap along the wide distance lines; both useful in supervision later on.

The annual leaf-fall should be taken into consideration if the Hevea 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.

Catch-Crops.

If 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 to two feet should be allowed each year for the growth of the roots of the rubber trees and catch-crops should not be planted within the rubber root area.

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

As most plants used as catch-crops are very exhausting, it is not deemed advisable to take more than three crops off the ground when each crop occupies the land for the greater part of a year; in some instances, only one crop should be taken.

Lemon Grass and Citronella.

Lemon grass gives a return six months after planting, and may be expected to yield about 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 2d. to 8d. per ounce, and is obtained by steaming the freshly-cut grass. A distilling apparatus is required, and can be kept in constant use by the grass from 300 acres. The fresh lemon grass contains 0·65 per cent. of potash, 0·09 per cent. of phosphoric acid, and 0·12 per cent. 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.

Citronella can be cultivated and distilled in exactly the same manner as lemon grass, and may be expected to yield about 50 to 60 lb. of oil per acre per year. The pure oil is valued at from 1s. 4d. to 1s. 10d. per lb. in Europe and America. Citronella is cultivated on rubber estates in Ceylon and Java ; also in parts of Malaya.

Gambier.

The leaves and twigs of this shrub (*Uncaria gambier*) yield an extract used by tanners and dyers and in medicine. The shrub grows to a height of 8 to 10 feet. Protection of the nursery against heavy rains is necessary, as the seeds are very minute. Statements regarding the length of time they retain their vitality vary, the range usually being from two days to two months. Seedlings are transplanted when 6 to 8 inches high in holes 7 feet apart, with the tip of the seedling showing just above the level of the ground ; in later stages it is said to be an advantage to heap the soil around the base of the stem. The seedling must be protected from sun and rain at first by a canopy of branches. It may be possible to crop twelve months after planting, and again at eighteen months. After two years three or four crops a year may be taken. It must be understood that these statements regarding times of cropping are only approximate. Cropping goes on throughout the whole year over the estate. When the branches are from 20 to 25 inches long, they are pruned at about 2 inches above their bases. Shears leave a cleaner and less harmful wound than the knife. The prunings are passed through a chaff-cutter and are then boiled for 5 to 6 hours. The extract is concentrated to a thick, nearly solid syrup by further heating. After cooling, the mass is cut into cakes, which are dried by artificial heat or naturally. Upon a Sumatran estate an elaborate installation of machinery, including a vacuum chamber, has been fitted up for preparation of the gambier ; as the installation is to be extended, the crop must be remunerative.

Ipecacuanha.

The annulated root of *Psychotria ipecacuanha*, a small, shrubby plant, comes into the market in worm-like masses 6 inches long. This medicinal plant is a native of South America, growing in moist, shady places in forests. It cannot endure the hot sun, and suffers much in dry weather ; on the other hand, heavy rainstorms are fatal, and good drainage is necessary. It has been grown with some success on some estates in Malaya. It can be readily grown from cuttings, and even so small a portion of the root as $\frac{1}{16}$ in. in length may develop into a fresh plant. The root is prepared for the market by drying ; this should always be done quickly. Planting is in rows four inches apart, with two or three inches between the plants. Cuttings are not so satisfactory for propagation as portions of the roots.

Groundnuts.

Groundnuts 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—groundnut cake—containing 7½ per cent. 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 per cent. of nitrogen, and when mixed with lime, form a good plant food for the young rubber trees. 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. In the Philippines they are planted between the rubber as soon as the trees have commenced growing. They are harvested in three months, the crops being from 7 to 9 piculs per acre (T.A., Nov., 1910). Experiments are now being carried out by the Director of Agriculture, Malaya, with this plant as a catch-crop.

Cassava or Tapioca.

There are several famous Hevea rubber plantations in Malaya 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 6 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. On one estate in Malaya cassava or tapioca is largely cultivated, and on one field, from which very good crops of this product have been taken, the six-year-old Hevea rubber trees have an average circumference of 20·21 inches, the largest measuring 33 inches and the smallest 13 inches in girth at a yard from the ground.

Gallagher believes (Str. Bull., Feb., 1909), that if carefully handled and planted among Hevea distanced 30 by 15 or 25 by 15 feet, it does not do much harm. He saw a plot of 5-year-old trees which had not cost the owner 1 cent for upkeep, and were quite equal to other Hevea trees at that age ; Chinese had planted the crop, manured the land, which was previously in lalang, and left it clean.

In parts of Malacca the cuttings are planted 5 by 2½ feet apart (3,000 per acre), among Hevea distanced 20 by 17½ feet (125 per acre).

Cassava thrives best in good soils, and can, according to Lewis (Manioc, by J. P. Lewis, Government Agent, Northern Province, Ceylon), be grown in districts in Ceylon with only 14 inches of rainfall per year or in districts with over 100 inches per year. The plant is propagated from the stem, which is cut into pieces about twelve inches in length, each being planted in a mamoty hole at distances of 3 to 8 feet. The yield in Ceylon is said to be from 8 to 10 tons of tubers per acre, or from 40 to 80 lb. per plant. The cuttings should be planted in wet weather ; once established, they continue to grow even during periods of severe drought.

The exhaustion following the cultivation of cassava can be partly overcome by the application of manure. The growing crops would for the first three years protect the soil and thus mitigate the loss which invariably accompanies the exposure of the surface to sun and rain. The tillage of the land necessary in the cultivation of cassava is a material benefit to the soil.

On several estates, owing to the cassava having been planted too near the rubber saplings, a considerable amount of harm has been done. The growth of the rubber trees should not, however, be very seriously interfered with if proper distances are adopted. Some object to the inter-cultivation of this plant because it is the same natural order—Euphorbiaceæ—as *Hevea brasiliensis*.

Cotton.

The Hevea districts in Ceylon usually have a rainfall far in excess of that required for cotton, but in other countries where rain falls only during certain months and where sufficient dry weather can be relied upon, the prospects for cotton as a catch-crop in rubber are somewhat favourable. Rain is required during the first two or three months after planting, and irrigation may or may not be required subsequently. The ground should be lined in rows five feet apart and the seeds sown at distances of 18 to 20 inches apart in the rows, 6 lb. of seed usually being sufficient for one acre. Selection of seed is necessary to prevent deterioration from year to year. Plants sown in September-October may flower in January, and the first crop may be picked about six weeks after flowering. According to Mee and Willis, about 80,000 bolls give 100 lb. of lint and 200 lb. of seed.

Hevea rubber and cotton has been tried experimentally in the dry Northern Provinces of Ceylon. The land at the Experiment Station in that part of the island is relatively flat and can be irrigated. In one experiment Mr. Mee planted the rubber trees 20 feet apart with irrigation channels running midway between the trees, so that each Hevea rubber tree had an irrigation channel running down 10 feet on either side of it. The cotton was planted 5 feet apart between the rows of rubber, and in the first year there might be three, in the second year two, and in the third year one, row of cotton between adjacent lines of rubber trees. On an experimental plot planted on this system, the Hevea rubber trees planted in October, 1904, and at intervals up till April, 1905, showed in September, 1906, a height of 8 to 15 feet and a girth of from 3 to 6 inches ; the growth is very satisfactory for a dry, irrigated district.

Manila Hemp, Sanseveiria, Etc.

Manila is grown on several East Java rubber estates. It is a very exhausting crop, the whole of the foliage being removed from the soil by every harvest. Within 18 months the plants (*Musa textilis*) are sufficiently large to afford good shade to the ground. The profits from this source are not known to the writer.

Sanseveiria, or bow-string hemp, is sometimes grown. It develops very slowly, and is not likely to prove very remunerative.

Maize or Indian Corn.

Two or more crops per annum can be obtained from this product under very young rubber. I have seen it growing as a catch-crop in Java; but like most other plants of this group, it appeared to exhaust the soil. The seeds are planted in rows 3 feet apart. They are positioned in the lines 2 or 3 feet apart. The yield in East Africa is, according to Johnson, 4 to 10 bags (each of 203 lb.), per acre.

Chillies.

These are not cultivated extensively as a catch-crop by Europeans in Ceylon, though the successful results obtained in India and the West Indies appear to warrant full consideration. The plant is propagated from seed, the latter being put in well-prepared nurseries. The seedlings are transplanted when 2 or 3 inches high, in rows 3 feet apart and 1½ to 2 feet apart in the rows. In Ceylon the planting generally begins in April, and picking commences in June, and continues for five or six months. According to Drieberg, a chillie plant, with proper attention, lives for a year. The produce per plant varies from 10 to 20 fruits and upwards per picking, and two or more pickings can be got. He further states that in Colombo the ordinary market price of fresh chillies may be put down at 12 cents per 100 and dry imported ones 15 cents per pound of about 750 chillies. The chillies require to be thoroughly dried or cured before being despatched to the market. A crop of 1,500 lb. per acre is considered satisfactory.

Pineapples.

These are occasionally grown as a catch-crop under Hevea. If the rubber trees are distanced 30 by 15 feet and pineapples are not planted closer to any rubber tree than 4 feet, they might be used to advantage on rich soils. The foliage can always be returned to the soil to reduce the exhaustion consequent on the cultivation of this crop. The plants flower in 15 to 18 months, thus ensuring a crop in the second year. After the fourth year cultivation is not advisable. The following estimate (Strs. Bull., Sept., 1910), has been given for an estate near Singapore:—

Receipts, per Acre.

Year.	Pines.	Price and Receipts.
Second year	2,000	At 2 cents., $40
Third year	3,000	Ditto $60
Fourth year	2,000	At 1½ cents., $30

Tobacco.

Tobacco as a catch-crop under rubber has not been largely cultivated either in Ceylon or Malaya, mainly owing to the atmosphere being too moist. It is largely grown under rubber in Sumatra and on a few estates in Java and Borneo. The time taken from transplanting to harvesting varies from about 70 to 100 days; and dry weather is necessary towards the beginning of harvesting time. It may yet be possible to cultivate either the "wrapping," "binding," or "filling" types of leaves during certain seasons in parts of Ceylon.

The cultivation of tobacco requires very careful selection of soil, varieties and climate, and frequently one finds that it is only possible to grow one variety in a particular area. The methods of cultivation depend upon the variety being grown, but in nearly all cases the plants are first reared in a nursery and are subsequently transplanted. The seedlings are planted out, in moist weather, when about five to seven weeks old, and are distanced according to requirements, those for Sumatra wrappers usually being close together. When the plants are 1 to 1½ feet high the basal leaves are removed and the earth heaped up around the plants. At a later stage the flower buds are pinched off, and all suckers are removed as soon as they appear. The leaves are ready for harvesting when the plant acquires a yellowish colour. Sometimes the whole plant is cut, but in Sumatra the leaves on each plant are plucked separately when ripe. The leaves are then carefully sorted, cured, tied in bundles and packed. In some countries this cultivation is very profitable, but requires very careful supervision at all stages and a large working capital.

Sugar.

This is planted for three or more years in succession under Hevea rubber. The latter is planted 30 by 15 feet and the sugar planted in rows six feet apart. There is one estate in Perak with 2,000 acres of sugar under Hevea, the total expenditure on the estate having been more than covered by the revenue from sugar. From 7 to 11 tons of cane per acre per annum may be expected as a catch-crop, and 12 to 18 tons if canes are grown alone on virgin land; from 25 to 30 piculs of sugar per acre per annum may be expected as a catch-crop under Hevea in Perak.

Bananas.

These are grown as shade for rubber plants in some parts of the tropics. Thousands of acres are cultivated in the West Indies. In Malaya, Java, and Ceylon, they seem to give satisfactory yields on light soil.. They assist materially in keeping weeds down. They have been reputed to pay £3 per acre per annum on estates near towns in Malay. They are propagated from suckers, and if grown alone are planted in rows 14 by 14 and 18 by 12 feet apart. If the foliage is not returned to the soil, the crop is very exhausting.

Indigo.

Turner states (Souvenir, I.R.J.) that indigo, though looked upon as exhausting, has allowed probably the best growth of rubber of any catch-crop we have tried. This may be due to its being a leguminous plant, and even with a heavy crop of stems taken from it at least twice a year, it still appears to add to the growth of the rubber, which is better than if grown on clean land with no catch-crop.

Cultivation of Intercrops.

The successful and continued cultivation of intercrops with Hevea mainly depends on the distance the plants are from one another. The rapidly-growing surface roots of rubber trees will utimately take possession of the soil, and the intercrops of tea, cacao, or coffee cannot be expected to thrive unless the rubber trees are widely planted.

Tea as an Intercrop.

If a distance of 20 by 30 feet or 15 by 30 feet is allowed for the Hevea, and the tea is planted three to four feet apart at the same time as the rubber trees, the intercrop of tea ought to last many years, especially if the narrow interspace is free from tea plants. Low-country tea in Ceylon, Java, and India, must have shade, and there are many reasons why the shade trees should be of *Hevea brasiliensis* instead of Albizzia, Erythrina, or Grevillea. Tea planted under such conditions should yield a small crop towards the end of the second year, and give a crop of 350 to 400 lb. made tea per acre per annum for about ten years. After that time the Hevea trees could, if circumstances warranted it, be pruned back in order to give the tea a longer life.

I have seen several examples of 14-year-old tea interplanted with 6-year-old Hevea trees in Ceylon, the latter 15 by 10 feet apart ; the tea presented a very weak, spindly appearance, and could not be profitably plucked. The cultivation of tea under closely-planted rubber is more or less of a catch-crop, but several estates are known where the rubber is widely planted amongst tea, and both are bearing and doing well. The two products are very frequently grown together in Ceylon—especially in the low-country and in parts of Matale, Kegalla and the Uva Province up to 2,600 feet, and in South India up to 3,500 feet.

Camphor and Coca.

The desirability of growing camphor as an intercrop has often been discussed, but so far very few rubber planters in the East have given the subject much attention. The plants can be planted out on lines very similar to those adopted with coffee. A crop of pruned leaves and twigs cannot be expected before two years at least, and a distillation plant of a simple type is required.

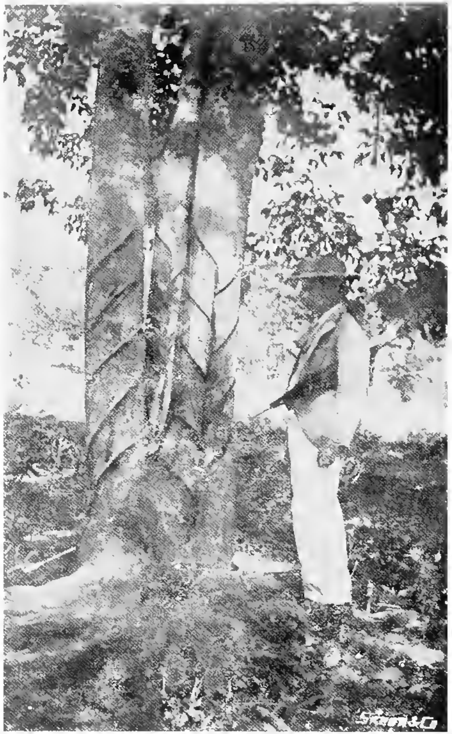


Photo lent by A. O. Deritt.

FALLEN TREE. DIVIDED TREE.

THE HARDY CHARACTERISTICS OF HEVEA BRASILIENSIS.

RUBBER AND CACAO.

Lent by India-Rubber Journal.

The cultivation of Coca (*Erythroxylon Coca*) especially the *novo-branatense* variety, which is suited to a hot, moist climate, has been suggested. It is a native of Peru, and is cultivated for its leaves, which yield cocaine.

Cacao as an Intercrop.

Cacao planted in the middle of the lines under rubber will last for several years. The roots of these plants do not as closely ramify in the soil as those of the crowded tea plants, though they will ultimately have to face the struggle for existence with the roots of Hevea rubber, and will probably be choked out. Cacao may be planted 10 to 20 feet apart, and the amount of soil on good cacao estates which is free from roots is often very large, and permits of the growth of other trees on the same acreage. Cacao under rubber will last much longer than tea, and the protection by the Hevea rubber trees against excessive exposure is no doubt greatly in favour of the two products being grown together. In the Matale, Dumbara, Kurunegala, Polgahawela, and Kandy districts of Ceylon, cacao and Hevea rubber as a mixed cultivation is extending. Good results have been obtained on Kepitigalla, Dangan, Wariapolla and many other estates in Matale and on numerous private and public properties in the above-mentioned districts. The planting of both products on the same soil is done in such a way as to allow free root areas for both species during the first five years, many planting the cacao and rubber both twenty feet apart, so that there will be approximately 100 rubber and 100 cacao trees per acre. Though the rubber ultimately becomes the stronger component, it is surprising how long both products can be successfully grown together. A yield of one to two cwt. of dry cured cacao per acre can be expected annually as an intercrop in Ceylon; more in Samoa and parts of Java. In the cultivation of cacao under Hevea rubber it is essential that both products be planted at the same time, as the rubber tree is about as strong as the coconut palm in its root system and quickly takes possession of the soil. I am aware that there are diseases common to Hevea and cacao, and that some authorities recommend the cutting out of cacao interplanted with Hevea. This would be of very little use, seeing that cacao estates may exist in the same district; while I imagine there would be considerable difficulty in compelling cacao planters to fell their trees because Hevea plantations were liable to infection therefrom; or *vice versa*. The best advice is to control the diseases on both plants, and maintain each in good condition.

Coffee as an Intercrop.

In Java, Sumatra, and at high elevations in South India, coffee is often grown between Hevea rubber trees. In most instances the rubber trees have been interplanted among existing coffee bushes. This is especially so with Arabian and Liberian coffee varieties. When Hevea rubber and coffee trees are planted at the same time, or the former a few months in advance of the latter, the length of life of the coffee bushes is mainly dependent on the distance at which they and the Hevea trees are planted. With Hevea planted 20 by 20 feet, two rows of coffee may be planted six feet apart in the middle of the rows, the distance from the rubber plants being seven feet on each side. But, even when planted at such distances, the rubber soon shades the coffee, and the latter cannot be expected to yield much produce after the fifth or sixth year from planting. The very small crops obtainable from Arabian and Liberian varieties under such a system offers no encouragement, and these varieties are now rarely planted as an intercrop. On most rubber estates interplanted with coffee the object is to retain the coffee until such time as the tapping and cultivation of the rubber trees demands the whole of the manager's attention and the entire cooly force. Consequently, it has come to be regarded on some estates more as a catch-crop than a permanent intercrop. The variety most suitable for this purpose appears to be robusta coffee, since it begins to yield at the end of its second year, and is expected to yield large crops before the sixth year. Robusta coffee, planted alone in a clearing, may in its third or fourth year give from 10 to 20 cwt. per acre. Among rubber it yields less per acre per annum for obvious reasons. Furthermore, robusta coffee requires shade from the commencement, and in Java, even though planted among rubber, has to be shaded by means of other plants, "Lamtoro" being generally selected for this purpose. The relative absence of shade in Sumatra may account for the comparative failure of this variety up to the present. Where it is deemed advisable to make coffee a more or less permanent intercrop, I would suggest a distance of 30 by 25 feet for the Hevea, the coffee not to be planted in the line of the narrow space, but as four rows, six feet apart, in the 30-foot space. This would leave a clear space of at least six feet from every Hevea tree, and a slightly greater distance if the lines of coffee commence in a row parallel to, but $3\frac{1}{2}$ feet from, the 30-foot lines. Already on certain estates in Java the robusta coffee bushes, though only 3 years old have grown at an astonishing rate and have had an adverse effect on the Hevea trees planted 20 by 20 feet.

CHAPTER VIII.

SOILS AND MANURING.

During the first few years of active Hevea planting in the East planters were in the habit of selecting, whenever possible, the banks of rivers or areas liable to inundation for the cultivation of their rubber trees. This was due to erroneous advice originally obtained from Brazil and circulated among planters and others.

Consul Churchill stated in 1897, in his report dealing with the trade of Para, that the rubber trees (Hevea) thrive best on islands and low ground near to rivers where the banks are periodically flooded. He went so far as to report that ground above water at all times or that had no drainage was not so suitable to the tree.

Where Hevea Thrives on the Amazon.

This information was widely read, and government departments tendered advice accordingly. Time and experience have shown how erroneous the view was that plantations should be along river banks, and not on ground above water at all times. Wickham, to whom the plantation industry owes so much, repeatedly pointed out the mistake made by planters who were acting upon advice based on Churchill's report. He states that the true forests of Hevea trees lie back on the highlands, where they often attain a circumference of ten to twelve feet, and an immense height. He believes that the trees seen by travellers on the "wet marginal river-lands are never well-grown trees." They are the offspring of seed brought down from the inner lands during the rainy season. The soil of the true Hevea forests is described by him as not being remarkable for its fertility, but for depth and uniformity; it is generally "a stiff soil, overlying marl formation."

Pearson (India Rubber World, August, 1910) states that at Manaos, on an estate which he visited, trees planted on land well above the usual water-level, but subject to inundations, apparently suffered no harm. Further up the slope, above the high-water mark, were trees equally large and healthy.

He was informed by the acting director of the Para agricultural experiment station that the railway from Para affords access to a tract of well-drained and healthful territory, immune from the caprices of annual floods. This area is part of the great forest system of the lower Amazon, and is a typical rain forest. The large size of the Hevea tree testifies to its adaptability and ability to compete with its neighbours. There are large, strong, and productive trees planted in Para along a railway; yet here the soil is poor, the trees are crowded, and have been neglected.

Ule (Notizblatt Königl. Bot. Garten, Berlin, Bd. III. and IV., 1901-4) found *Hevea brasiliensis* growing on the flooded areas up to the edge, but beyond were trees giving good and rich latex, though he could not definitely class them as the same species.

Witt (Lectures, Rubber Exhibition, 1908) asserted that in the state of Amazonas *Hevea brasiliensis* is to be found only on the lower part of the rivers in those regions subject to periodical inundations. Yet higher up country, on the Purus, Jurua, etc., in regions where there are no inundations, but only very heavy rains, a first-class, though not so good a rubber, is collected. On the islands, where the rubber forests are daily more or less submerged by the tides, *Hevea brasiliensis* lives on very low ground.

A United States Consul at Para, Mr. Kerbey (Special Consular Reports, vol. VI., 1892) believed that on the river Purus, where the flood-plains were covered with water from one to three or four months in the year, the trees yielded latex in abundance, while thriving trees of the same sort not reached by the floods did not pay for the trouble of tapping them. Yet on the lower Amazon, not only the trees on the tide-flats and flood-plains yielded latex in paying quantities, but also those on the high land, because the abundant rains of six months or more in the year supplied abundance of water to the soil.

Mathews ("Up the Amazon and Madeira Rivers," 1879) claims that, on the Madeira river, trees on lands that are inundated only at times yield better than those on very low or on elevated ground.

Another observer (T.A., August, 1910), hailing from Bolivia, remarks that the best-yielding Hevea trees grow on steep slopes, often between broken rocks; yet in this case one would like to be assured as to the species.

Wickham's Views Challenged.

Nevertheless, statements to the effect that *Hevea brasiliensis* grows only or yields best in regularly-flooded areas are numerous, and making an allowance for negative evidence, the information to hand comes from such authoritative sources that one is not surprised to find that the earliest planters followed the advice then tendered. One of the strongest cases is that made by De Kalb (India-Rubber Journal, July, 1894) who, challenging the assertion of Wickham noted above, pointed out that both Von Martius and Popping spent many years in a study of the flora of the Amazon, in the course of which they penetrated both high and low country, and their verdict was that *Hevea brasiliensis* occurred only in low, alluvial situations. He mentioned also that Bates, who spent seven years in scientific research in the basin of the Amazon, was most positive to the same effect. De Kalb noted that every tributary of the Amazon has been ascended by explorers, and in accounts of the high country—except where there are local basins subject to inundation—there is no mention of *Hevea brasiliensis*. His belief was that Wickham was mistaken in his identification of the species, the suggestion being that it may have been *Hevea lutea*. Surely Bates's statements do not justify De Kalb's making such an unqualified use of them. What Bates said was that the tree grows only on the low lands in the Amazon region, and that when he was in Brazil, now about 60 years ago, the rubber was then collected chiefly in the islands, and in the swampy parts of the mainland. Some of these islands, of which he had direct knowledge, were submerged in the rainy season. Bates did not intend to make a general statement covering the whole of the Hevea areas.

Origin of Erroneous Views.

There is no doubt, to my mind, that the advice regarding the desirability of cultivating Hevea on the banks of rivers can be traced to the custom of native collectors to tap those areas nearest the rivers. The seringueros have to wait till the rivers fall before commencing operations, and it is natural that the areas nearest the means of transport should be first dealt with. In course of time they must necessarily go further inland, when the marginal trees have been impoverished or destroyed, and competition becomes keener.

Hevea not Constructed for Swamps.

There are no features, anatomical or physiological, in any part of *Hevea brasiliensis* which even suggest that this species is especially suitable for wet land. The leaves, branches, and roots are not in any way xerophytic, but conform to the types commonly met with among deciduous tropical trees. Had this species been specially suitable or adapted for growing in wet lands, there would have been anatomical characteristics discernible without the use of a microscope. The fact that all such features are absent makes it difficult to understand why botanists of repute should have recommended the plant as one specially suitable for wet soils or river banks. It has, nevertheless, proved itself capable of adaptation to a remarkable extent.

Good Growth in Poor Soils.

It has been conclusively shown that Hevea trees can be grown in soils relatively poor in physical and chemical properties, and the following analyses of soils in different parts of Ceylon (Circular, R.B.G., Peradeniya, Vol. III., 1905) will demonstrate the composition of those which have given good results with Hevea :—

	Peradeniya Soils.	Udagama Swamps.	Henaratgoda. 1 Soil under Old Rubber.	Henaratgoda. 2 Soil from Pasture Land.
Mechanical Composition :—	%	%	%	%
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 :—				
Moisture	4·000	5·600	1·200	1·600
Humus and 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	4·960	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

Hevea Rubber Soils in Ceylon.

The extension of Hevea rubber cultivation in various parts of Ceylon is, in a general way, an indication of the suitability of the soil and climate for this product ; it is therefore of importance to dwell upon the soil characteristics in some of the more promising districts, though these points should be considered in conjunction with the climatic factors for the same areas.

The soils in which rubber is cultivated in Ceylon are relatively poor from a chemical standpoint. The organic matter and combined water vary from about 2 to 20 per cent., the potash from 0·03 to 0·04 per cent., phosphoric acid from 0·01 to 0·1 per cent., and the nitrogen from 0·1 to 0·5 per cent. But it has been proved beyond doubt that the physical and climatic characteristics often outweigh any advantages of richness in chemical properties.

The large tracts of land in the up-country districts which are richest from a chemical standpoint cannot be included in the Hevea zone of the island on account of unfavourable climatic conditions.

The following notes and analyses of Ceylon soils are largely taken from a circular (R.B.G., Circular No. 6, 1905), dealing with this subject.

Cabooky Soils, Ceylon.

"*Cabook.*—The cabook soils are met with as local areas in many districts. They are usually inferior from a chemical and physical standpoint, though in many cases the growth of the rubber trees appears to be satisfactory. Such soils usually show a small percentage of organic matter, potash, phosphoric acid, and lime. One analysis shows only 8 per cent. of organic matter and combined water, 0·085 per cent. of potash, 0·010 per cent. of phosphoric acid, 0·060 per cent. of lime, and 0·128 per cent. of nitrogen."

Alluvial Soils, Ceylon.

"In physical properties these soils are usually good, and the amount of sediment periodically deposited during floods adds considerably to the chemical richness of the soil. They are largely composed of the lighter materials carried down in suspension by moving water. The particles are very fine, most of them passing a 60 mesh. This matter is arrested and precipitated all along the bank of the river during flood time. During heavy floods very large quantities of matter are often deposited along the banks, but they are often of a coarser nature due to the higher speed. The particles which go to make up an alluvial soil may have been brought from considerable distances; they constitute the fine parts of soils liable to wash within the drainage area of the river."

One analysis shows about 11 per cent. of organic matter and combined water, 0·130 per cent. of lime, 0·162 per cent. of potash, 0·076 per cent. of phosphoric acid, and 0·230 per cent. of nitrogen. The soils are usually good, and we know that Hevea grows exceedingly well in such soils, and has continued to thrive therein for over twenty years in the Peradeniya District.

Swampy Soils, Ceylon, and Drainage.

The cultivation of rubber in such areas has, during the last year or so, shown a considerable increase. Providing the draining and liming of the soils are efficiently carried out, there seems no reason why continued satisfactory growth should not be obtained on such land. The drainage should be very thorough, so as to allow of a good percolation of air and water through the otherwise sour soils. In some cases each rubber tree should have a separate drainage system, the drains being two or more feet wide and 3 to 4 feet deep, the material from them being heaped up near the rubber tree. In other cases each line of rubber trees may be separately drained. When the drains are sufficiently large and the soil from them is heaped around the rubber, a dry soil is ultimately obtained in areas which have hitherto been too swampy for any cultivation except paddy."

One analysis of a swampy soil shows it to contain 20·4 per cent. of organic matter and combined water, 0·05 per cent. of lime, 0·061 per cent. of potash, 0·064 per cent. of phosphoric acid, and 0·448 per cent. of nitrogen. Such an analysis indicates a chemical richness in organic matter and nitrogen which rarely obtains in low-country districts, and strongly reminds one of the soils at high elevations in Ceylon. It is to be regretted that the area of such rich land in the low-country is small, and the above analysis is certainly encouraging to planters who have such swampy soils capable of being effectively drained and made sweet by the application of lime or by burning.

Treatment of Swampy Soils.

In the Straits Settlements and Federated Malay States and in parts of Ceylon drained swamps have been proved to grow Hevea rubber. In the former place large sums of money have been spent in providing good canals for the free circulation of water through rubber estates near the coast.

"Swampy soils are usually in a very fine state of division, a condition which may prevent the soil being aerated, and to some extent may hinder the free oxidation of the humus. Owing to the extremely fine state of division the soil can retain large quantities of water, due to the particles being in such close contact with one another that they form a very large number of capillary tubes which become full of water. Again, such a soil may suffer during periods of drought, as it is difficult to get the air out of the capillaries. A water-logged soil is usually cold and therefore generally unsuitable for cultivation, unless it can be modified both physically and chemically. One of the chief aims in reclaiming such land is to have the soil well drained, in order that the superfluous water may be carried off and the air drawn through the soil.

"Burning has been tried on peaty soils at high elevations, and the results are satisfactory. Paring the surface and collecting into heaps and then burning has also proved successful. The heat should not be allowed to become too great, and should just be sufficient to char the vegetable organic matter ; the heaps should then be distributed over the surface. There is a loss of nitrogen and organic matter, but the physical condition of the soil is improved, and the potash salts are converted into carbonates which are useful for the neutralization of the free acids present. After burning, the potash, &c., is in a much more available condition.

"Opening up of swampy soil by the addition of sand or gravel has been tried, but this is expensive. Liming is very beneficial for such soils, as it not only opens them up but also neutralizes the free acids present, and thus gives a freer action to nitrifying organisms. The addition of lime frees the potash from the double salts by double decomposition, and makes the mineral plant-food generally more available. Swampy soils are usually deficient in mineral plant-food, and should have occasional dressings of potash and phosphatic manures, basic slag and sulphate of potash or kainit being considered suitable."

Johnson recommends for drained swamps or land previously water-logged, that slaked lime at the rate of 2,000 lb. per acre be applied.

Hevea Rubber Soils in various Ceylon Districts.

In order to give some idea of the composition of the soils of typical rubber districts in Ceylon, it is necessary to draw inferences from many analyses. The districts known as Kelani, Kalutara, Kegalla, Matale, Peradeniya, Kurunegala, Ratnapura and Passara are of considerable importance, and the information given in the circular previously referred to is here quoted.

Kelani Valley District.

According to Messrs. Ferguson's "Ceylon Handbook and Directory," there were about 32,507 acres planted in rubber alone in August, 1910, in addition to nearly 25,000 acres interplanted with tea, etc. The abundant rainfall and high temperature, together with the moderately good soils in the Kelani district, seem very suitable for Hevea.

"*Mechanical characters.*—The mechanical composition of the soil is moderately good ; generally 14 to 35 per cent. passes through a 90 mesh, 20 to 40 per cent. through a 60 mesh, and 3 to 8 per cent. through a 30 mesh ; sand and small stones constitute 30 to 60 per cent. on an average. The plants are mainly dependent upon the finely-divided soil particles for their food supplies, and therefore the amount which passes through the 90 mesh is of the greatest importance. Some soils which are very finely divided are not so well suited for cultivation as coarser types, the latter frequently allowing of a quicker and more complete circulation of air and water in the soil. The retentive power of moisture of the soils depends upon the physical properties and the amount of organic matter present. This variation for the Kelani soils is from 2 to 6 per cent. : *i.e.*, every 100 lb. of air-dried or sun-dried soil can retain from 2 to 6 lb. of water."

Chemical properties.—The percentage of chemical ingredients is, relatively speaking, rather low when compared with soils at higher elevations. In some cases the percentages of organic matter and nitrogen are satisfactory. The organic matter varies from 8 to 13 per cent. ; the nitrogen from 0·05 to 0·2 per cent. ; the lime from 0·05 to 0·15 per cent. ; the magnesia from 0·05 to 0·35 per cent. ; potash from 0·05 to 0·2 per cent. ; and the phosphoric acid from traces to 0·07 per cent. In some cases the high percentages of organic matter and potash are exceptional, and do not represent the general characters in the Kelani District. The figures here quoted indicate the general variation in the proportions of the ingredients which may be expected in the district ; they do not represent the maximum and minimum compositions."

Kegalla District.

The Kegalla district might also be considered in connection with the Kelani, as the soil and climate appear equally suitable for Hevea rubber. According to the Ceylon Handbook there were in August, 1910, 15,500 acres of rubber, either alone or interplanted. Good growth has been obtained in clearings only 10 and 18 months old on the Mabopitiya, Dickellia, Waharaka, Parambe and other estates in this district, and the tapping of trees from 12 years upwards on Yataderiya and Undugoda estates has been accompanied by profitable yields. On many of the estates in the Kegalla district, Hevea rubber is interplanted among tea.

Kalutara and Galle Districts.

During the year 1910 the acreage under Hevea rubber in the Kalutara district was largely increased. The Ceylon Handbook showed in August, 1910, 33,447 acres in rubber alone, 11,606 acres in rubber planted through tea, and 50 acres in coconuts. During and since 1906 a considerable acreage of new land has been planted, but it is not thought that very much more tea will be planted up with rubber.

South of Kalutara, in the Galle District, soils of similar character are met with and swamps frequently occur. In August, 1910, no less than 8,037 acres were then in Hevea rubber alone, and 2,370 acres interplanted with tea.

Mechanical Composition.—"The soil analyses show a slightly coarser texture than those examined from the Kelani Valley; usually from 11 to 28 per cent. passes through the 90 mesh, 16 to 40 per cent. through the 60 mesh, 4 to 10 per cent. through the 30 mesh, and sand and small stones form from 30 to 70 per cent. of the soil. The retentive power of moisture is very similar to the Kelani, varying from 2 to 6 per cent."

Chemical Composition.—"The organic matter shows a variation similar to that in the Kelani Valley soils; the general range is from 7 to 15 per cent., and the same can be said about the nitrogen, which varies from 0·1 to 0·15 per cent. This is of course excluding swampy areas, which we have seen to be very rich in organic matter and nitrogen, and alluvial soil such as that quoted below. The potash varies from 0·04 to 0·2 per cent. and usually shows a relation to the amount of magnesia, both being derived from the decomposition of double silicates. The phosphoric acid varies from a trace to 0·06 per cent., and this low percentage is common in most Ceylon soils. The lime varies from 0·03 to 0·15 per cent. and the magnesia from 0·04 to 0·2 per cent.

Another district in which there has been extensive planting in rubber is the Galle district. Here in August, 1910, there were 8,037 acres in rubber alone and 2,370 acres with tea. The soils of this district were not included in the above survey.

Matale District.

In the Matale district there were in August, 1910, some 9,753 acres of cacao interplanted with rubber, 4,589 acres interplanted with tea, and 15,326 acres in rubber alone.

It is well known that the Matale district contains some very old Hevea trees that are now being tapped, and that large areas have been planted in association with cacao and tea as well as a single product. Trees at an elevation of 2,300 feet are being tapped in that district.

"The soils characterising the Matale district are somewhat similar to those near Peradeniya."

Mechanical Composition.—"The soils from the Matale district are on an average in a better state of division than those in the districts previously dealt with, usually from 15 to 30 per cent. passing through a 90 mesh, 14 to 25 per cent. through a 60 mesh, and 3 to 7 through a 30 mesh. Sand and small stones may form from 40 to 60 per cent. of the soil. The retentive power for moisture of air-dried soil does not show a very great variation, and is from 3 to 6 per cent."

Chemical Composition.—"The organic matter usually varies from 8 to 14 per cent. and the nitrogen from 0·1 to 0·2 per cent.; the lime from 0·08 to 0·2 per cent.; the magnesia from 0·05 to 0·25 per cent.; the potash from 0·03 to 0·25 per cent., and the phosphoric acid from 0·01 to 0·1 per cent."

In the Pussellawa district the soil and climate appear to resemble those in sections of the Peradeniya and Matale districts, and although part of the district is considered to be too high for Hevea rubber, there were in August, 1910, about 2,700 acres of this product planted alone or with tea.

Ratnapura and Ambagamuwa.

The Ratnapura district, differing so widely from the foregoing in having such a heavy rainfall and being one already extensively cultivated in rubber, is here synoptically dealt with. The acreage in August, 1910, in rubber alone was 14,036 acres, with tea 3,557 acres.

Regarding the mechanical composition, "out of about a dozen soils 17 to 20 per cent. of the soil passes a 90 mesh, 16 to 25 per cent. a 60 mesh, and 4 to 5 per cent. a 30 mesh, and sand and small stones account for from 50 to 60 per cent. The retentive power for moisture varies from 3 to 5. The chemical composition shows from 10 to 12 per cent. of organic matter, 0·1 to 0·2 per cent. of nitrogen, 0·06 to 0·2 per cent. of lime, 0·07 to 0·15 per cent. of magnesia, 0·04 to 0·1 of potash, and from 0·03 to 0·8 per cent. of phosphoric acid." Hevea rubber has been extensively planted in this and the surrounding districts.

In the Upper Ambagamuwa district, where the rainfall is very heavy, Hevea rubber trees are being tapped and planting operations continued, though the elevation in such a wet district is thought by many to be near the maximum. About 3,000 acres were planted by August, 1910, and some of the plants now show satisfactory growth.

Kurunegala District.

The rainfall of 75 to 100 inches is evidently suitable, and a general glance at the average composition of the soils would not be out of place here. The soils vary greatly, as can be seen from the following figures :—

Mechanical Composition.

	Per cent.
Fine soil passing 90 mesh	17 to 35
Fine soil passing 60 mesh	20 to 35
Medium soil passing 30 mesh	5 to 9

Chemical Composition.

	Per cent.
Coarse sand and small stones	20 to 60
Moisture	3 to 7
Humus and combined water	4 to 8
Lime	0·1 to 0·35
Magnesia	0·1 to 0·45
Potash	0·08 to 0·18
Phosphoric acid	0·02 to 0·04
Nitrogen	0·08 to 0·11

In August, 1910, there were over 8,700 acres of rubber alone and with intercrops planted in this district.

Passara District.

In the Passara district there were in August, 1910, some 9,200 acres of rubber alone and interplanted. The results from the older trees being tapped at all elevations up to nearly 3,000 feet are satisfactory. In the Uva Province the climatic conditions are said to be such as to allow of the cultivation of Hevea rubber up to an elevation of 2,900.

"Very few soils have been analysed from the Province of Uva, but from those obtained from Passara the following information has been compiled. Usually from 17 to 30 per cent. passes the 90 mesh, 20 to 30 per cent. the 60 mesh, 7 to 8 per cent. the 30 mesh, and sand and small stones form from 40 to 43 per cent. The retentive power for moisture is about 2½. The chemical analyses show the presence of from 7 to 11 per cent. of organic matter, 0·1 to 0·15 per cent. of nitrogen, 0·06 to 0·1 per cent. of lime, 0·07 to 0·13 per cent. of magnesia, 0·05 to 0·08 per cent. of potash, and from 0·03 to 0·04 per cent. of phosphoric acid."

Soils in South India.

There are extensive areas of alluvial soil, lying within regions of abundant rainfall, stretched along the West Coast through Cochin, Malabar, etc., which are quite suitable for Hevea. Windle considers that Cochin is an ideal land for Hevea. The soil is a deep, well-drained loam, and the country flat or gently undulating. Elsewhere, in possible rubber-growing districts, ferruginous soils of various characters are met with ; even laterite occurs in some areas. The analyses below are each the average of a number of samples, all of coffee soils in various parts of South India ;—

	Coorg. (By Massey) %	Yarcand, Shevaroy Hills. (By Leather.) %	Munjerabad, Mysore. (By Voelcker) Laterite. %
Moisture	6·334	?	?
Humus and combined water	4·201	12·87	11·36
Oxides of iron	4·186	10·10	9·63
Alumina	6·158	18·64	15·24
Lime	0·920	00·36	00·28
Magnesia	0·279	00·53	00·30
Potash	0·655	00·20	00·15
Soda	0·355	00·05	00·11
Phosphoric acid . ..	0·622	00·12	00·13
Sulphuric acid	0·178	00·01	00·03
Chlorine	0·056	?	00·003
Silica and insoluble matter	70·419	56·78	61·37
Nitrogen	0·792	00·123	00·157

Hevea Soils in the Federated Malay States.

I was indebted to the late J. B. Carruthers for much information regarding the land and soil in various parts of the Federated Malay States. The rocks from which most of the non-alluvial soils are formed are limestones, sandstones, laterites, and granites, the disintegration products of red laterite being considered good. The low-lying land at the foot of the mountain range is composed of a deep alluvial deposit ; the subsoil in such areas is said to be far below the water-level, and for purposes of cultivation may therefore be neglected. The majority of the alluvial land planted in Hevea rubber is, if anything, too well supplied with water, the latter being within 3 to 4 feet from the surface all the year round. The water-level all over the plains on the west of the mountain range is, according to Carruthers, very near the surface—often as near as 16 to 18 inches.

On the estates I visited in the Klang district, the soil was composed of a rich clayey loam with plenty of humus in the first twelve inches, and a stiffer bluish clay below. It is often so soft that one can push a walking stick out of sight with a little exertion. There is hardly a stone to be seen on many estates, and the land is mainly flat. The water-level on many estates was observed to be from one to two feet below the surface. It is the custom to drain the land prior to felling, in order that the soil may have a chance to dry and sink before planting operations are commenced.

Bamber states that some samples of Malay soils pass almost entirely through a sieve of 8,100 meshes to the inch. The organic matter frequently exceeds 30 per cent., and the nitrogen is sometimes as high as 0·9 per cent. These high percentages are not, however, obtainable over all estates in the Federated Malay States. Many of the Ceylon soils are quite as good as, and occasionally superior from a chemical standpoint to, those in the Federated Malay States, but in only a few low-country soils in Ceylon does the organic matter reach 20 per cent. In relation to Ceylon soils the mineral contents of the Federated Malay States soils are very often inferior, the chief deficiency being potash rather than phosphoric acid.

In many parts of the Malay Peninsula, usually near tidal rivers, a peat formation occurs. It is composed of dead timber, roots, and decayed leaves, sometimes to a depth of twenty feet, clay, stones, etc., being absent. The water of these "soils" contains an excess of humic acid. The deaths or vacancies are very large, often nearly 100 per cent. One or two well-known plantations have been tried on such land and so far have been failures.

Selangor Soils.

As so many notable Hevea plantations have been established in Selangor the following analyses, by R. J. Eaton, are here given :—

	No. 1.	No. 2.
Loss of moisture at 100° C. ..	6·490	11·260
Humus and combined water ..	5·290	6·430
Oxide of iron	4·900	1·400
Alumina	5·790	6·658
Manganese	0·050	0·065
Lime	0·065	0·065
Magnesia	0·130	0·115
Soda	0·160	0·160
Potash	0·106	0·106
Phosphoric acid	0·108	0·112
Sulphuric acid	0·026	0·004
Insoluble sand and silicates ..	76·885	73·625

Typical Soils of Malay States.

Bamber, in a report published by the late J. B. Carruthers, stated that "the soils of Malaya may be roughly divided into two distinct kinds:

"(a) The flat alluvial clays or muds on the banks of rivers and near the sea coast.

"(b) The undulating low soils a few miles inland, where they vary from free sandy loams to heavy clays.

"The alluvial clays or muds are in an exceedingly fine state of division, about 96 per cent. passing through a mesh of 8,100 per square inch, and the balance through a mesh of 3,600 per square inch. Although having the appearance of fine clays there is very little alumina present, the bulk of the soil being composed of very finely-divided sand and insoluble silicates. When wet they are compact and greasy, but on drying they break up into comparatively free loams, through which roots can permeate freely, so that, unless liable to flooding with salt water, they are all well suited for the growth of Hevea, coconuts, and Liberian coffee. The amount of organic matter in these soils varies considerably—from 8 to 35 per cent., or even more if the surface layer is at all peaty. They are generally very rich in nitrogen, containing from 0·4 to 0·9 per cent. on the air-dried soil; a soil with 0·2 per cent. being considered rich in other countries.

"With regard to the mineral matter, which forms the ash of the plants, they are not so rich, although the exceedingly fine state of division of the soils renders a high proportion less necessary. They are more or less deficient in lime, which accounts for the markedly acid character of the soils when first opened; the acidity is neutralized to some extent by ash from the burnt forest, but it also gradually diminishes as the drainage water is removed to a lower level and the soil becomes aerated. Magnesia is present in ample quantity in most cases. Potash, one of the chief mineral constituents required for plant growth, is frequently deficient, though a few of the river deposits are rich in this constituent, and the subsoil is usually richer than the surface soil especially if of a clayey nature. The proportion of phosphoric acid is also variable, ranging from 0·012 to 0·13, the average being about 0·076 per cent. on the air-dried soil. All this class of soil requires very efficient drainage as it has often been more or less under water for years, so that air has been excluded, resulting in a rather high proportion of the lower oxide of iron, which in excess is poisonous to many cultivated plants. The vigorous growth of rubber on this class of soil after drainage is unequalled elsewhere during the first years of growth.

"They are richer in nitrogen than the proportion of organic matter would indicate, but are usually a little deficient in total potash and to some extent in phosphoric acid.

"Their free character and suitability for root growth makes the proportion of the set constituents ample for present requirements, and it is evident from the growth of Hevea on these soils that there is no deficiency in any respect."

The following analyses (Bamber) show the composition of alluvial and sandy loams in Malay:—

Chemical and Physical Analyses of Federated Malay States Soils.

	Alluvial Clays.			Sandy Loams.		
Mechanical Composition:—						
	%	%	%	%	%	%
Fine soil passing 90 mesh ..	96·00	95·50	68·00	30·00	36·00	26·00
Fine soil passing 60 mesh ..	4·00	4·50	32·00	34·00	38·00	30·00
Medium soil passing 30 mesh ..	—	—	—	26·00	8·00	22·00
Coarse sand and small stones ..	—	—	—	10·00	18·00	22·00
	100·00	100·00	100·00	100·00	100·00	100·00

	Alluvial Clays.			Sandy Loams.		
Chemical Composition :—						
Moisture ..	6·920	5·560	5·000	1·400	4·000	2·200
Humus and combined water ..	24·080	16·640	8·000	3·000	9·600	5·600
Oxide of iron and manganese ..	1·120	1·200	3·000	0·300	8·240	0·700
Oxide of alumina ..	2·971	3·019	2·520	1·165	4·183	2·516
Lime ..	0·284	0·200	0·160	0·140	0·160	0·160
Magnesia ..	0·252	0·381	0·230	0·130	0·100	0·130
Potash ..	0·131	0·169	0·014	0·014	0·053	0·030
Phosphoric acid ..	0·025	0·012	0·076	0·051	0·064	0·064
Sand and silicates ..	64·200	72·800	81·000	93·800	73·600	88·600
Chlorine ..	0·017	0·019	—	—	—	—
	100·000	100·000	100·000	100·000	100·000	100·000
Containing nitrogen	0·667	0·425	0·403	0·492	0·386	0·403
Equal to ammonia	0·810	0·516	0·489	0·598	0·469	0·489
Lower oxide of iron	Much	Fair	Good	Good	Good	Good
Acidity ..	—	—	Marked	Marked	Marked	Marked

Soils in Java.

The fertile soil of Java is well known. Its richness is due mainly to its volcanic origin. The ranges of volcanic hills are very conspicuous in the Kederi and Pasoeroean residencies, where notable Hevea estates now exist. Some of the old volcanoes are rugged and steep, whilst others have a gentle slope many miles in length. They form the interesting feature of the country in most of the districts. There are several well-known companies that have their estates along the sides of volcanic mountains. The crops are good, and dividends high. In contrast with these, in situation, are the estates in the Langen district, where rubber is planted on land as flat as a billiard table. Most of the rubber estates are planted on gently undulating or flat land. The water-level is usually many yards below the surface, in this respect differing from Malaya. I have seen only two estates which for their steep slopes approach much of the rubber land in Ceylon. The Java rubber estates I have seen are notable for the absence of stony, rocky slopes, such as one meets with in Ceylon, and for the comparative scarcity of swamps so abundant in Malay.

The soil is, almost without exception, of first-class quality. It usually consists of a dark-red finely-divided loam, sometimes light and sandy, at other times a trifle clayey. It is a volcanic soil on which luxuriant vegetation has been grown for many years. Physically it is often perfect, and chemically nearly so.

Analyses are given below of soils in rubber-growing districts in East and West Java. The first three, by Szymanki and Scholiren, are each the average of five samples from the same area. The fourth, by Kramer, is the average of three soils of slightly different characters. All are clay soils.

	Padhipaten (Cheribon) %	Kemantren (Pekalongan) %	Kalibagor (Banjoemas) %	Pasoeroean %	Poppoh (Soerabaya) %
Humus & combined water	7·342	8·300	9·760	?	8·90
Lime ..	0·608	0·854	0·664	1·22	4·00
Magnesia ..	0·073	0·067	0·059	0·22	1·32
Potash ..	0·058	0·048	0·069	0·13	0·07
Phosphoric acid ..	0·037	0·086	0·050	0·05	0·03
Nitrogen ..	0·050	0·059	0·133	0·08	?

Soils in Sumatra.

The soils are somewhat similar to those in Java, being light, fertile, and mainly of volcanic origin. Busse (Tropenpflanzer, Feb., 1906), remarks that in Sumatra rubber is cultivated upon alluvial loams of a sandy nature as well as upon volcanic soils, which are very sandy, reddish-yellow loams. The growth is good on the higher volcanic soils owing to the absence of ground-water and to the greater rainfall. In the case of the alluvial soils growth is healthy at first, but is less rapid later, unless deep drains are cut. The following analyses, by Schidrowitz, of a soil in the Siantar district (Eastern Sumatra Rubber Company), on which secondary and primary forest were flourishing, will give some idea of the richness in certain constituents, and of the good mechanical condition of the soil in this area. The poverty of one soil in phosphoric acid and of both in lime will be noted.

Mechanical Analyses.

	I.	II.
Passing 90″ mesh	5·7	4·1
,, 60″ ,, ...	5·7	4·3
,, 30″ ,, ...	26·5	30·1
Coarse sand and gravel	62·1	61·5

Chemical Analyses.

	I.	II.
Moisture	25·03	17·01
Humus and combined water ..	5·12	4·55
Iron	Much	Much
Carbonates	Nil	Nil
Lime	Trace	Trace
Potash	0·260	0·210
Phosphoric acid	0·072	0·007
Nitrogen	0·270	0·340
Nitrogen equal to ammonia ..	0·330	0·410
Citric soluble potash	0·016	0·014
Citric soluble phosphoric acid ..	0·010	0·003
Acidity	Faint	Faint

To these may be added the averages of certain analyses, made by Hissink (Journ. Landw., 1905) of dark, humus-rich tobacco soils from Deli :—

	Padang Boelan. %	Soengei Mentjerim. %	C—— %	Namoe Oekoer. %
Lime	0·09	0·35	0·36	0·42
Potash	0·05	0·10	0·05	0·11
Phosphoric acid ..	0·52	0·53	0·40	0·43
Nitrogen	0·63	0·49	0·51	0·84

Soils in British New Guinea.

It is reported by Guthrie and Symmonds (Agric. Gazette, New South Wales, April, 1908), who examined twelve typical soils, that, speaking generally, they were rich, fertile soils of a loamy nature, friable and fairly easy to work. The capacity for retaining water was high in all cases, and the humus content was satisfactory. Of the following soils, the two first were from the East Coast, the area in which rain is most abundant ; the third was from the hills above Port Moresby, and in a district where there are coffee plantations.

	Buna Bay. Grey loamy sand. %	Milne Bay. Dark brown sandy loams. %	Sogeri. Brown loam. %
Mechanical Composition.			
Stones	—	1·54	4·54
Gravel	—	3·14	1·14
Coarse sand	—	3·87	1·06
Sand	82·70	68·50	41·40
Fine sand	2·34	3·20	3·80
Silt	1·70	2·20	2·22
Fine silt	1·70	1·60	6·04
Clay	10·46	13·40	29·37
Chemical Composition.			
Moisture	1·10	2·55	10·43
Humus & combined water	5·02	5·90	13·67
Soluble in hot hydrochloric acid (Sp. gr. 1·1) :—			
Lime	0·722	1·593	0·048
Potash	0·069	0·252	0·023
Phosphoric acid ..	0·205	0·999	0·231
Nitrogen	0·126	0·182	0·182
Reaction	Neutral	Faintly acid	Very strongly acid.

Soils in Hawaii.

In view of the experiments being made to cultivate Hevea in this part of the world, the following analyses (Thompson, Hawaiian Agr. Exp. Str., 1908), may be of interest :—

	Brown loam %	Dark red loam %	Dark brown loam %
Moisture	14·141	3·763	7·536
Humus and combined water	—	15·864	13·660
Nitrogen	0·505	0·295	0·226
Phosphoric acid	0·185	0·127	0·127
Potash	0·178	0·547	0·148
Lime	0·590	0·940	1·720
Magnesia	1·622	0·450	1·564
Manganese oxide	0·115	0·400	0·130
Acidity	acid	neutral	?

Soils in the West Indies and South America.

According to Hart, the following are types of good cacao soils as determined in the Government Laboratory, British Guiana ; they should be well suited for Hevea rubber :—

	Demerara.	Grenada.	Trinidad.	Surinam.
Humus and combined water ..	9·031	10·442	3·768	15·452
Phosphoric anhydride	0·087	0·184	0·084	0·139
Sulphuric anhydride	0·018	traces	traces	0·047
Chlorine	traces	nil	nil	traces
Iron peroxide	4·783	9·485	3·910	5·952
Alumina	9·217	10·024	2·038	16·076
Manganese oxide	0·347	0·313	0·127	nil
Calcium oxide	0·596	2·379	0·356	0·495
Calcium carbonate	0·032	0·026	nil	nil
Magnesium oxide	0·404	3·367	0·495	1·071
Potassium oxide..	0·291	0·343	0·118	0·072
Sodium oxide	0·208	0·574	0·278	0·258
Insoluble silica and silicates ..	74·986	62·863	88·826	59·438
	100·000	100·000	100·000	100·000
Containing nitrogen	0·262	0·271	0·100	0·306
Water retained by air-dried soil	6·5	12·4	1·8	11·00

In Jamaica, Hevea has been reported a failure on account of the absence of a stiff, clay soil. But Ridley (Str. Bull., Feb., 1910), points out that Hevea grows on rocky laterite hills as well, if not better, than on stiff clay soils.

Soils in British Guiana.

In British Guiana, *Hevea brasiliensis* does not appear to have grown very satisfactorily in the heavy clay lands at the Botanic Gardens. It is reported to be growing well on the clayey loams at Onderneeming, and also on the pegassy-clay lands at the Issorora Station, but not so rapidly on the lateritic hill-slopes. Several young plants on clay soils at Christianburg are promising, although older trees have not grown very satisfactorily.

Manuring to Increase 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. These areas contain, besides the latex 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 time required in the development of the narrow band of cortical tissues containing the laticifers.

The latex tubes form part of the cortical tissues, and an increased leaf activity appreciably affects the elements in this region. The more abundant the foliage, the more rapidly will the food material be built up and the more vigorous will the cambium become. From these and other considerations it may be concluded that if manuring is carried out, so 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. The main object in manuring Hevea trees 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, stages involved in the formation of the latex tubes of *Hevea brasiliensis*.

Experiments on Manihot in Hawaii.

In the Hawaiian Islands, at Keanae, experiments were carried out (Hawaiian Agric. Exper. Station, Bull. 19, 1910), by Wilcox, to determine the effect upon the yield of manuring with nitrate of soda, but upon Ceara trees. They were divided into three groups of three trees each. The group receiving one half pound per tree gave 2·3 ozs. of dry rubber ; that receiving one-quarter pound per tree gave 1·3 ozs. ; that receiving none gave 1·2 ozs. The effect of the manure was manifested in 48 hours, the weather being rainy during the experiment. In another experiment, at Tantalus, the yield of rubber was doubled by the application of one half-pound per tree. A further test was made on trees at the station. One group of five trees gave 0·9 ozs. in the three days before the nitrate was applied, and 1·3 ozs. in the three days following. Another group of five trees in the same times gave 0·9 ozs. before and 1·2 ozs. after. These results may indicate the possible effect of manuring on the latex of *Hevea brasiliensis*.

The analyses of various parts of *Hevea brasiliensis* given elsewhere should be carefully considered when mixtures of artificial manures for rubber are being compounded.

Forest Vegetation and Soil Improvements.

It must be remembered that Hevea 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 that the climatic conditions are favourable. In fact, the outstanding feature of *Hevea brasiliensis* is that it can grow on soils and in climates which exhibit great variability. 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 Hevea 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 maintained under pasture ; the lime and magnesia have decreased under the old rubber, while the phosphoric acid is the same under both conditions.

Food in Hevea Leaves.

The manurial value of the leaves from Hevea rubber trees cannot be doubted when it is remembered that the material, dried at 100°C., contains 1·72 per cent. of potash, 3·44 per cent. of nitrogen, 0·6 per cent. of phosphoric acid, and 0·51 per cent. 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 Hevea rubber plant will indicate, in a general way, the ingredients required. Potash and nitrogen are very abundant in the fresh and fallen leaves and lime is abundant in the woody structures. Lan (*Notes sur l'Hevea brasiliensis*, 1911), showed that yellow leaves when about to fall from the tree possessed, when freshly gathered, 0·49 per cent. of nitrogen or 1·14 per cent. in the material dried at 100°C. The fresh yellow leaves also contain 0·12 per cent. of phosphoric acid, and 0·20 per cent. of potash.

Application of Readily Soluble Manures.

The method to be adopted in manuring this plant 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 soil areas not possessing rootlets, the greater part will probably be carried away during the first few rainy days. After the manures have been applied, the land should be forked to a depth of four to six inches, but care should be taken not to destroy many of the rootlets. Decaying rootlets may encourage ants and fungi. The young rootlets which absorb the manure are not near the stem of the tree, but usually some distance from it ; hence the necessity to scatter the manure some distance from the trunk. Cowie recommends (I.R.J., April, 1909) that artificial manures be sprinkled round the tree at a distance of from 1 to $1\frac{1}{2}$ feet from the stem for each year of the plant's growth and then very lightly forked into the soil. In order to prevent the manure from being washed away by the rain, however, a shallow trench may be cut round the tree, the manure forked therein and the surface soil then replaced.

Application of Bulky Manures.

Where cattle manure, green manure, leaf-mould, or bulky artificial manures are 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 Hevea rubber tree grow at a fairly rapid rate in good free soil, and can be easily observed. The manure should be applied at a distance just within reach of the last-formed rootlets. Around each newly-planted tree a shallow trench can 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 can 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 might be approximately 2 feet or more for two-year-old trees, 3 feet or more for three-year-old trees, an allowance of about one to two feet per year being made in each subsequent year until the trees are 6 to 8 years old, when the lateral roots will almost certainly have met. 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 or left undisturbed.

Manuring Young Plants.

A convenient time for manuring young plants is when planting out has been completed, for the young plants are helped at a crucial period, and further, the manure is brought within the immediate reach of the rootlets. In Cochin China, on a poor, sandy soil, seven ounces of ground-nut oilcake has been put into each hole when planting. It is not, however, usual to go to considerable expense in manuring young plants, though this work might conceivably be sometimes carried on with advantage.

Artificial and Green Manures.

The use of both kinds of manures, on the same area, is often advisable. It is sometimes an advantage to broadcast readily soluble manures over land on which a young crop of herbaceous green manures is coming up; this leads to more rapid growth, and consequently a better cover and more effective check to the growth of weeds. When the green crop is applied to the land the rubber trees would benefit from the original application of soluble manures. In other instances large quantities of concentrated artificial manures are applied, in addition to lime and basic slag, when the green crop is forked in the land or buried in trenches. A mixture composed of 34 parts of potassium chloride, 44 of precipitated superphosphate, and 22 of finely-divided bonemeal has been so used.

Results of Manuring Experiments.

As previously pointed out (I.R.J., July 29th, 1907), I have been placed in possession of the results of several manurial experiments, in which (a) green manure and lime, (b) cattle manure and lime, (c) cattle manure, lime, and artificial manures, and (d) artificial manures only, have been used on Eastern rubber estates. The results clearly show that manuring may bring the trees to a tappable size six to twelve months before the usual time, a point which must appeal to all interested in developmental companies. The requisite quantities of the various essential ingredients vary with the age of the trees and climatic and soil conditions, and only a continuation of the experiments on a large scale can give us accurate information on this point. It appears to have been proved, however, that potash and nitrogen produce the most immediate effect, and will both be required. Nitrogen, if applied in excess or in very soluble forms, appears to be followed by a conspicuous development of foliage not always desirable, and some care must be exercised in fixing the quantity and nature of artificial nitrogenous manures. Potash, as might have been anticipated from a consideration of analyses of parts of the plant, is needed in large quantities, and its application has so far been attended with profitable results.

Manurial Experiments in Sumatra.

There are few records of actual increase in girth consequent on the application of artificial manures, though no one doubts that better growth is obtained by their use, especially on poor soil. Cowie (I.R.J., April, 1909), reports the following experiment at Deli-Moeda, East Coast of Sumatra. Commencing in October, 1906, at which time the trees (Hevea) were two years ten months old, three plots of land were taken and differently treated from a manurial point of view. At the end of two years the circumferences of the trees on the different plots were measured, at one yard above the ground, and the average for each plot was calculated. The results are shown as follows :—

	I. No Manure.	II. Completely Manured.	III. Manured without Potash.
Manuring per tree.	—	2 lb. Pea-nut Cake Meal. 12 oz. Double Superphosphate. 8 oz. Muriate of Potash.	2 lb. Pea-nut Cake Meal. 12 oz. Double Superphosphate.
Average girth.	9 inches.	14 inches.	12 inches.

From the results of these and other experiments, it is clear that potash may be made to play a very important part in the manuring of rubber. While this ingredient may be applied fairly abundantly with advantage, nitrogen must be used with a little more caution, in order to prevent a too luxuriant growth of foliage. Phosphoric acid is also, of course, indispensable, and although it may not benefit the wood to the same extent as potash, it serves like it to counteract the excessive stimulating effect of nitrogen on the development of the foliage.

Leplae states (T.A., May, 1910), that on an island in the Rio Archipelago, off Sumatra, applications of nitrogenous manures on clay soils were doing good for trees in their second year. And as much as ½ lb. of guano was applied, per tree, on some young Hevea plantations.

Manurial Experiments in Ceylon.

Experiments with artificial and green manures have been made at Peradeniya on the trees planted by me in 1905, which show the effect of these manures, and also, incidentally, of catch-crops.

Plot.	Manure or Crop.	Average girth in inches. Dec. 1908.	Oct. 1909.	Increase in inches.
78	Soluble manure	10·27	14·46	4·18
79	Crotalaria striata	9·96	13·76	3·80
80	Lemon grass	7·97	11·11	3·15
81	Indigofera	9·27	13·38	4·12
82	Blank (control)	9·58	13·28	3·70

Another experiment, carried out by Mr. Eckert, Vincit, Ruawella, shows the evil effect of an ill-balanced manure. A mixture of castor and rape-cake, crushed fish, blood and bone meal, and muriate of potash, containing 15 per cent. of potash, 4·5 per cent. of phosphoric acid, and 4·5 per cent. of nitrogen, gave a healthy tree. But a mixture of the same substances containing 5 per cent. of potash, 4·9 per cent. of phosphoric acid, and 5·7 per cent. of nitrogen—one with excess of nitrogen compared with potash—gave a weak-wooded tree with heavy foliage crown, so that the stem was easily bent over and even broken.

Manurial Experiments in Malaya.

The following experiments are recorded (Str. Bull., Aug., 1910) on Umbei Rubber Estate, Malacca :—

Manure applied.	Number of trees.	Average girth in inches. March 19th, 1910.	June 19th, 1910.	Average increase in inches.
Bone meal	60	6·34″	7·20″	0·95″
Fish manure	60	6·25″	7·30″	1·05″
No manure (control)	59	5·72″	6·70″	0·98″

Half-a-pound of manure was applied to each tree, and it is quite probable that the whole effect was not registered in the three months' interval shown in the above statistics.

Ridley (Straits Bulletin, October, 1904), treated each of five rows of nursery plants differently. The rows received respectively burnt earth and leaves, burnt earth and leaves with cow-dung, cow-dung, poudrette and lime. Manuring with cow-dung gave the best results, and burnt earth came next. Lime seemed absolutely injurious. Ridley points out that cow-dung is too expensive to use on a large scale, but he suggests its use in the nurseries.

Mathieu (Trop. Agric., Sept., 1910) performed some manuring experiments on an estate in Singapore with two-year-old plants. The records published so far deal with a period of only four months, and though the experiments are not conclusive, they undoubtedly prove that a greatly accelerated growth is obtained by giving each tree of that age two pounds of a mixture of which the composition is roughly given as follows: sulphate of ammonia and superphosphate, 55 lb., muriate of potash and bonemeal, 25 lb.

Manurial Experiments with Hevea in Hawaii.

To test the effects of different fertilisers on Hevea in soil of the experimental station type—of which an analysis is not given—Miss Thompson (Annual Report, Hawaiian Agric. Exper. Station, 1908) used the paraffined wire-basket method. Seeds were planted in wire-baskets filled with soils containing various manure mixtures. The whole was sealed with a film of paraffin wax, except for an aperture allowing the plants to grow out and allowing the soil to be watered, the latter being done daily with a known quantity of water. The table below shows the average weight of the plants after they had been allowed to grow a little, and it also shows the average transpiration of water, which might conceivably be a measure of the activity of the plant.

	Amount applied, calculated per acre. lb.	Average Transpiration. grams.	Average weight of Plant. grams.
Check (unmanured)	—	10·95	3·14
Superphosphate	200	11·56	3·42
Sulphate of potash	200	11·42	3·55
Nitrate of soda	200	16·58	3·90
Lime	2,240	13·05	3·22
Manure (dry)	11,200	15·50	3·56
Superphosphate and sulphate of potash	200 each	17·16	3·83
Superphosphate and nitrate of soda ..	200 each	10·50	3·40
Nitrate of soda and sulphate of potash	200 each	13·20	3·29
Superphosphate, lime, nitrate of soda, and sulphate of potash (lime, 2,000lb.)	200 each	7·06	2·45
Superphosphate, nitrate of soda, and sulphate of potash	220 each	12·35	3·18

The following are Miss Thompson's comments: with dry manure, sodium nitrate, or lime alone, the transpiration increased materially; superphosphate or sulphate of potash gave a slight increase; superphosphate with sulphate of potash gave a large increase; but superphosphate in the other combinations either decreased the transpiration or gave but little increase.

Sodium nitrate used alone is a good fertiliser for rubber trees, while superphosphate has some deleterious effect.

It is very difficult to form any conclusions from the above regarding the comparative value of the manures employed in these experiments.

Constituents in Woody Stems, Twigs, and Leaves.

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 (Circular R.B.G., No. 6):—

Analyses of Parts of Hevea Tree dried at 100° C.

	Fresh Leaves. %	Decayed Fallen Leaves. %	Fallen Stalks. %	Wood. %	Twigs. %
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	0·66	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 constituents of common artificial manures obtainable from local merchants, and the compositions here quoted are those guaranteed by various firms in Colombo :—

Manure.	Potash. %	Phosphoric Acid. %	Nitrogen. %
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
Kainit	13 to 15	—	—

Manure Mixtures.

The following mixtures have been recommended :—

Mixture I.

This is suitable for land rich in nitrogen and where there is a good leaf growth.

	Potash. %	Phosphoric acid. %	Nitrogen. %
28 per cent. muriate of potash	14	—	—
25 per cent. superphosphate	—	4·50	—
20 per cent. bonemeal	—	5·60	0·2
17 per cent. oilcake	—	—	1·3
10 per cent. sulphate of ammonia	—	—	1·6
100 per cent. contains	14	10·1	3·1

400 to 800 lb. per acre to be applied.

MIXTURE II.

This is recommended for land which is in a poor condition with regard to its nitrogen content.

	Potash. %	Phosphoric Acid. %	Nitrogen. %
20 per cent. muriate of potash ..	10	—	—
30 per cent. superphosphate ..	—	5·4	—
10 per cent. bonemeal	—	2·8	0·1
24 per cent. sulphate of ammonia ..	—	—	4·9
16 per cent. oilcake	—	—	1·0
100 per cent. contains	10	8·2	6·0

400 to 700 lb. per acre to be applied.

The mixture below has, according to Johnson, been found to yield good results, and may be modified to suit particular requirements: basic slag, 1,500 lbs.; nitrate of soda, 250 lbs.; sulphate of potash, 250 lbs. This should be applied at the rate of about 300 lbs. per acre, and ploughed or harrowed in.

TURNING WEEDS INTO THE SOIL.

When estates are planted with rubber alone one must either elect to allow the clean-weeded soil to be exposed to the sun and rain and to be thereby impoverished, or decide to protect it by a green crop and increase the organic matter and mineral constituents for the future benefit of the growing rubber.

In many countries, especially Java and certain West Indian islands, weeds are frequently allowed to grow, and are periodically cutlassed and applied as a mulch on the surface or turned into the soil. If we could select our own weeds, or feel fairly certain that lalang or its equivalent would not gain a footing, we might be excused for allowing other weeds to grow. Even then it must be admitted that the growth of the Hevea trees is likely to be retarded. It is difficult to explain the very slow rate of growth of Hevea trees on weedy land except by assuming that the growing crop of weeds takes up plant food which might otherwise have been absorbed by the Hevea rootlets, and checks the circulation of air, water, and plant food in all directions through the soil.

GREEN MANURING FOR HEVEA TREES.

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 green manures can 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.

Disadvantages of Green Manures.

Though no one can doubt the benefits accruing, to the soil, from the use of green manures, there are many disadvantages which cannot be lost sight of. Firstly, they may lead, if grown on the land where they are used, to serious disorganization of the weeding labour force and lalang may establish itself; secondly, they may harbour pigs, rats, porcupines, and may lead to the spread of pests through the plantation, and increase the risk of fire; lastly, their regular cultivation may be very expensive and still retard the growth of the Hevea trees. No one can deny that many estates have been almost ruined by allowing weeds to get out of hand, and the system should not be considered if the estate is already clean-weeded. It is wiser to maintain a clean-weeded estate in that condition, and buy green and artificial manures on the market for application to the soil. On weedy or steep estates, or on properties that cannot be kept clean, the subject is, nevertheless, of some importance.

Herbaceous Plants.

Herbaceous plants can be best grown from the first to the fourth year on account of the abundance of light they are able to obtain and the relative freedom of the soil particles from the roots of other plants. The plants which can be used are *Crotalaria striata*, *C. laburnifolia*, *C. incana*, *Cajanus indicus*, *Mimosa pudica*, *Desmodium trifolium*, *Tephrosia purpurea*, 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. Indigo appears to be favoured in many parts of Java and Malaya. 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; they 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 its composition in several species:—

Name of Plant.	Weight of Organic Matter per Acre.	Time between Sowing and Uprooting.
Crotalaria striata	20,244 lb.	Ten months
Vigna	12,092 ,,	Four months
Pondicherry groundnut	4,692 ,,	Five months

Composition of Various Green Plants, in the Fresh State.

Name of Plant.	Nitrogen. %	Potash. %	Phosphoric Acid. %	Lime. %
Crotalaria striata	0·7 to 1·0	0·47	0·154	0·210
Vigna	0·6	0·738	0·177	0·727
Pondicherry groundnut	0·914	0·493	0·155	0·242

It is interesting to work out what is the equivalent of 15,000 lb. of green manure of *Crotalaria striata* from a purely *theoretical* standpoint. According to the above analyses it is approximately equal to a manure of the following composition :—

	lb.
Castor cake	500
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, or forked in as previously explained. During its decomposition it leads to the liberation of 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 in connection with other products. The green manure seeds should be sown a reasonable distance from the Hevea trees in order to permit of ordinary daily inspection. On steep land they should be sown at right angles to the slope to check soil wash as much as possible.

Tree Forms.

The cultivation of trees for green manure is only possible on young rubber estates ; their adoption does not endanger the weeding work on the estate as in the case of herbaceous types—generally their growth renders the weeding problem less difficult on account of the shade given by the foliage.

The best tree-forms to use for green manure are Dadaps (Erythrina sp.) 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 ; they should be 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 by 8 feet apart in July, 1904.

		lb.
November,	1904	791
December	,,	967½
March	1905	1,935
April	,	1,444¼
May		2,255
June	,	2,240
July		2,180
August	,,	3,058
September	,	1,569¾
November	,	2,104¼
December	,,	1,653½
	Total	20,198¼

These experiments show that Dadap cuttings may produce over 18,000 lb. of fresh green leaves within one year from planting, and the leaves may be hand-pruned nearly every month in the year. The fresh leaves contain 0·3 to 0·8 per cent. of nitrogen, 0·148 per cent. of potash, 0·08 per cent. of phosphoric acid and 0·197 per cent. of lime.

Albizzia.

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 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 up to January 1906, 3,246 lb. of green material and woody twigs, so that if planted as close as the Dadaps (8 by 4) they should yield about 13,000 lb. per acre per year. On some rubber estates the young Albizzia plants have been so pruned as to be easily overtopped by two-year-old rubber trees, the branches and foliage of the Albizzia trees covering the greater part of the soil. The fresh leaves contain 0.395 per cent. of nitrogen, 0.406 per cent. of potash, 0.178 per cent. of phosphoric acid, and 0.441 per cent. of lime.

If it is found necessary to plant belts of trees enclosing various sections of a rubber estate for the purpose of checking the spread of disease, the possibility of using mixed lines of Dadap and Albizzia trees should be worth considering; the former can be easily pruned and made to produce a close, low-lying, bushy fence, and the latter allowed to grow and form a belt of foliage and branches above the tops of the Dadap plants.

Green Manuring in Malaya.

Ridley maintains that in the Straits and F.M.S. manuring the trees by the trenching system or the interplanting of Hevea trees with Dadaps is not to be recommended as it involves an interference or destruction of the roots and cutting out of the trees at a later date. He is of the opinion that green manuring in the Straits and F.M.S. should be done only with herbaceous plants, and these should be merely cut and thrown on the ground and not dug in. In Malaya very little green manuring is done. In Java, where the soil is equally rich, the system is frequently tried with varying degrees of success.

A number of experiments have been made in the F.M.S. A planter states (Str. Bull., April, 1909), that the following is the cost of cultivating *Tephrosia purpurea*, and he compares it with clean-weeding, as follows :—

Clean-weeding, for 5 years, per acre . .			$100·00
Tephrosia.			
1st year—	$		
Establishing	4·00		
Keeping drains clear	1·00		
Rent (!)	1·00		
Cutting down twice	2·00		
Various	1·00		
Superintendence	1·00		
	——	$10·00	
2nd to 5th years—			
As above (less cost of establishing)	24.00		
	——	$24·00	
		———	34·00

In the above it is assumed that the crop is more or less self-seeding; to rely upon the plant doing this effectively would be risky. No mention is made of the cost of weeding before and after each green manure crop; information on this point is essential before one can recommend this cultivation.

Campbell (Report, 1908), after conducting numerous experiments has arrived at the following conclusions :—

Crotalaria.—The best method of planting is as follows :—

(1) For hill lands, or any ground with hard surface : holes cut one changkol deep, about 15 inches apart, and dibble the seeds in.

(2) For ordinary slightly undulating land : dibble seeds in.

(3) On land with loose surface : sow seeds broadcast (2 lb. per acre) and rake in.

(4) On wet, low-lying land : sow seeds broadcast (2 lb. per acre).

Mimosa pudica.—This has been grown over six acres in Batu Tiga, where it has made a dense cover and keeps in check all weeds except lalang. Where lalang was already present, the ground was dug up and the roots picked before the plants were put in. The lalang in some cases grew rapidly, and threatened to kill the mimosa. In some places, where there was no lalang before planting, none has come up.

Three plots with mimosa, 10 months old, were cut down to 6 inches and the cuttings weighed ; the average weight of mulching material worked out at 2,950 lb. per acre.

Passiflora foetida.—This grows rapidly on low-lying moist land, but the growth is slow on hard ground, especially in districts subject to occasional drought.

Recent Experiments in Ceylon on Soil Wash.

The loss of soil on land clean-weeded is known to be great and to vary when covered by various green manures. Experiments were commenced in Ceylon in March, 1909 (T.A., Sept., 1910), to determine the loss of surface soil by wash on average sloping land. The soil wash, in tons per acre, from March, 1909, to March, 1910, on the various plots, was as follows :—

Clean-weeded	115	tons.
Dadaps	106	,,
Deep-forked land	79	,,
Albizzia	67	,,
Ipomea	45	,,
Crotalaria, across slope	43½	,,
Crotalaria and Indigofera in rows 1 foot apart up slope	26¾	,,
Crotalaria, across slope 1 foot apart	26½	,,
Desmodium	12½	,,

The rainfall during the period of the experiments was 59·03 inches.

It is generally acknowledged that the soil-wash under arborescent (Dadaps, Albizzia), shade is greater than that under herbaceous types (Crotalaria, Ipomea). The foregoing results may be materially altered as the experiment proceeds, but the loss on land deeply-forked is, meanwhile, of more than passing interest to planters whose estates are steep.

CHAPTER IX.

TAPPING OPERATIONS AND IMPLEMENTS.

The question of tapping Hevea rubber trees is one which deserves special consideration and is not outweighed in importance by even the methods of planting or by the processes of curing the raw rubber. 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.

In the case of *Hevea brasiliensis* we are concerned with the laticiferous tubes in the outer part of the stems—the secondary cortex—when the trees are ready for tapping. The thickness of this tissue may vary from $\frac{1}{8}$ to about $\frac{1}{2}$ 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 $\frac{3}{8}$ inch (9·5 mm.), though trees at Singapore, only 11 years old, possess bark of this thickness. The outer part to a depth of $\frac{1}{8}$ inch (3 mm.) does not contain many tubes charged with latex, but the inner part has a large number, and from the inner $\frac{1}{16}$ to $\frac{3}{32}$ inch the latex mainly flows. The latex tubes in the outer part dry up and are regularly shed with the outer bark tissues.

When the primary cortex has been removed new tissue is produced, mainly 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, that in many instances the parts of the laticiferous system are not extensive, and in tapping operations only a fraction of the whole of the latex-containing tubes may be drawn upon.

Recent experiments have shown how improvement can be made on the old method of tapping every alternate year and obtaining 1½ lb. of rubber per tree, per year, from eleven-year-old trees. The yield obtained in parts of the East shows that by somewhat drastic methods it is possible to procure 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. With all due respect to many inventors who have placed their knives before the public, it may be stated that the faultless or ideal paring implement has not yet been produced, though there seems every likelihood that it will soon be on the market. There are still several implements sold and used which should be classed as dangerous.

In faulty tapping severe wounds may be inflicted, and several years after the injury is made, the parts above it may be found to be very hard and to give very little latex. In one particular case the outward appearance was not striking in any way, and only the poor yield of latex led to an inquiry which revealed the extent of the permanent injury that had been done. In all cases where the wood has been damaged, 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 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 incapable of being 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 for many years practically an impossibility.

The tapping of irregular surfaces requires special consideration; but it may be stated that in no case should the woody protuberances be excised; the incisions should, if possible, be made above or below all woody warts, and the latter allowed to work themselves out in their own way and time. In such cases the zig-zag method of tapping can often be adopted with advantage.

Bad Tapping on Old Trees.

The Director of Agriculture, Malaya, stated in his report for 1910 that "the results of bad tapping will be noticeable in about four years' time when the irregularly renewed surface comes to be tapped again; the tapping will then be very difficult to carry out and still more difficult to carry out without again increasing the damage. Some of the oldest trees in various places in the Federated Malay States are an object lesson in what may be accomplished by bad tapping; little blame can be attached to the original workers, who had to learn by experience how to tap and how not to; but estates with trees now being tapped for the first time should profit by others' experiences, as upon the quality of the present tapping a good deal of their future prosperity will depend. I strongly recommend that all wounds to the wood in tapping be immediately painted with cold coal-tar. This draws attention to bad tapping and saves attack by wound-fungi and borers."

Knives Made on the Estate.

That a scientific implement for tapping rubber trees is not required is evident from a study of results obtained in Malay by knives of the simplest construction. In one case (I.R.J., August 26th, 1911) it was reported that the manager of the Anglo-Java Rubber Estates, Ltd., had been able to make his own tapping knives on the estate at a cost of 6 cents each ; these implements, it was claimed, were, though of the simplest description, capable of excising bark shavings from $\frac{1}{30}$th to $\frac{1}{25}$th of an inch in thickness.

Requisites of a Good Tapping Knife.

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

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.

In the official report of the judges at the Ceylon Rubber Exhibition, 1906, the following points were considered in connection with the tapping knives exhibited :—

1. *Thinness of paring.*—Under this head the judges decided that the uniformity of the section ; adjustability ; cleanness of cut or absence of drag ; and efficiency of the guard or control of the section were points of practical importance.

2. *Convenience and facility in operation.*—In this group the points considered related to the muscular effort required ; visibility of cut during tapping operations ; capability of cutting in all directions ; suitability for unskilled labour ; absence of clogging ; and prevention or impossibility of incorrect use by cooly.

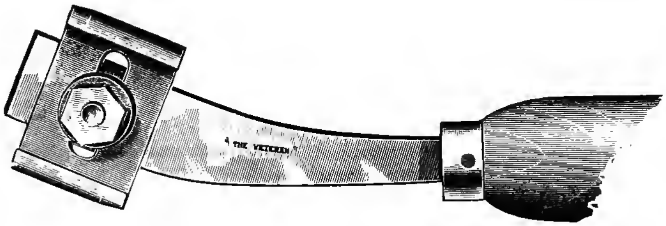
3. *Simplicity and durability* :—These items necessitated a study of the price ; length of life ; retention of sharpness ; facility for sharpening ; and lack of complication in relation to each knife.

The primary considerations are as follows :—

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 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 the latex tubes, and left an uneven surface along which watery latex could not readily 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. It is generally an advantage if the cutting parts can be adjusted with ease and replaced without great expense, but, more often than not, tools which are adjustable are very dangerous in the hands of coolies. The damage done by many adjustable knives has led to the demand for non-adjustable tools which are, as far as possible, fool-proof.

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 from right to left from above downwards. This is a necessary qualification in all tapping methods except the



YATES'S "PULL AND PUSH" KNIFE.

right-hand half-herring-bone and spiral systems. It is also advisable that knives should be constructed so as to permit of paring being done by "pushing" from below upwards or "pulling" from above downwards. Such knives are described as "pull and push" implements.

A fourth point, which has obviously received attention in many knives recently put on the market, is that the instrument used for re-opening 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 capable of demolishing twelve inches of bark in three months, and others which will not use up the same quantity of tissue in two or three years. The very narrow cutting margins of several knives are specially devised for paring away very thin shavings of the bark. The thickness of the parings varies from 1-10th to 1-30th of an inch, 20 to 25 parings per inch being considered a fair average.

The introduction of pricking instruments for cutting the laticiferous tubes in the wound area, though duplicating the tools, may be 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.

Paring and Pricking.

The amount of cortical or bark tissue removed by one paring operation is sometimes surprisingly large. The average cooly will excise the lower surface until a large number of white globules of latex have appeared, when by the use of other implements the latex tubes might have been tapped without excising any cortical cells at all. It has been asserted that since the most careful method may only allow one to tap the whole of the surface from the base up to six feet in three to four years, the care advocated is not necessary when large acreages have to be tapped. But the necessity for tapping every tree on a large plantation is no excuse for excising the cortical tissues in a wasteful manner. The best results will accompany those methods involving the removal of the minimum amount of cortical substance during tapping operations.

It has been urged that even if one removes large quantities of tissue when tapping, the rubber can still be extracted from the material thus removed. This is correct, especially when large quantities of bark are cut away, but the greater part of the rubber can, by proper tapping, be removed without such great waste of tissues.

Furthermore, it should be distinctly borne in mind that the removal of the cortical cells means the destruction of living tissues wherein the latex tubes arise. The actual quantity of rubber in the cortex at any particular time is very small compared with that which can be obtained by pricking the latex tubes, allowing them to become refilled, and encouraging their development. The use of pricking implements must, however, depend on the ultimate effect which their adoption has on the renewed cortex; this will be discussed fully in a later chapter.

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; this implement has not, however, been adopted in the middle East, owing to the damage inflicted by its use.

At the present time the East is taking a very active interest in inventing and improving tapping knives for use in obtaining latex from Hevea rubber trees, and the following accounts of some well-known implements 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 3-16th 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 $1\frac{1}{2}$ in.

The Farrier's Knife.

This knife is one of the simplest on the market at the present time. It consists of a long piece of metal turned on itself at the end to form a cutting curve. It is largely used on some estates in Malaya and gives satisfactory results when the coolies have had fair experience. There is hardly any limit to the damage which can be done by such a knife, but to those planters who crave for simplicity and a tool which cannot be adjusted at will by the coolies, this form should appeal. A double-edged farrier's knife is also being used.

Founded upon the farrier's knife are the Jebong, Johore, and other kinds.

Gouges.

The gouge is largely used in Malay and has found favour on account of its simplicity. It is, like the farrier's knife, capable of inflicting dangerous wounds, but it is little less than marvellous to see how skilfully it can be manipulated by properly-trained coolies. Bark shavings having a thickness of from 1-25th to 1-20th of an inch can easily be obtained by the use of the gouge in Malaya, where patent adjustable tapping knives have been almost entirely abandoned. Some gouges are straight and others bent ; the latter are often preferred except for very old, rough bark. Some have the edge receding or hollowed towards the handle ; others have the edge projecting and forming a rounded point. The gouge varies in width, standard sizes being $\frac{1}{4}$, $\frac{9}{32}$, $\frac{5}{16}$, and $\frac{3}{8}$ of an inch ; the $\frac{5}{16}$ inch tool appears to be extensively used in parts of Malaya. The Director of Agriculture, F.M.S., recently stated that "In spite of numerous new inventions, the favourite instruments are still the simpler tools, the gouge (straight or bent) and the farrier's knife or jebong. Which of these is best depends really on which the tapping cooly is used to. Where there is sufficient European supervision and a stable labour force, the tapping in Malaya is usually excellently done, with consequent good renewal of the bark. Where one or other of these conditions does not obtain, it is common to see wounds right down to the wood."

Surgical Scrapers.

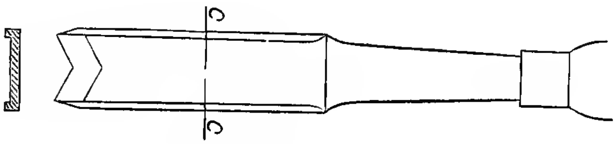
With the idea of re-opening the wound area without cutting away a large quantity of tissue, several surgical scrapers and planes have been brought forward, but in every case have proved unsatisfactory. They tend to clog the freshly-opened latex tubes.

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.

This knife is a chisel with the end in the shape of a short, sharp, bevelled V, and a cutting groove along the sides. The knife



GOLLEDGE'S 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.

Holloway's Knives.

The Holloway tapping tool is an improved V 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.

Holloway invented another knife essentially provided with a two-flanged and a basal cutting surface. The blade is made of metal and is curved like a hook at the top; the cutting area is provided with a flange at either side at right angles to the base, and all parts can be easily sharpened. The basal cutting surface or either of the angles can be used in making the original incision, and the two angles may be used for paring either from right to left or left to right. The parts are changeable and all operations can be done with one implement.

Mackenzie's Knife.

This consists of a tempered steel head of box section having cutting edges on three sides. The cutting surfaces are in one piece and movable. By an ingenious screw arrangement the depth of the cutting edges can be adjusted according to requirements by two side guards. The knife can be used for tapping from left to right or right to left. When the incision is so broad that the guard on the upper side of the knife does not rest against the bark on the top side of the cut, the upper guard can be lowered so as to come in contact with the excised area, along which it rubs during paring operations.

Collet's Knife.

This 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. The blade of the knife is like a sharp curved gouge, and has on it a brass support, which is set at an angle with the blade and—before cutting—is adjusted at a definite 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, that 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 "Para" tapping knife is designed for making the first cuts 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 re-opening the original incision in such a manner as to renew the flow of latex with the minimum loss of bark 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.

Cater-Schofield Knife.

A novelty in the matter of the grip afforded is provided in the above-named knife (I.R.J., November 28th, 1910). The grip is shaped like that of a flat-iron and is placed immediately over the blade. That this gives a better control of the action—compared with the tools where the blade is guided from a point six or eight inches distant from the centre of effort, as is the case with the ordinary handle—appears to be manifest, though I have not had an opportunity of testing whether this is so in actual practice.

The blades provided are interchangeable, easily fixed and removed, and cheap to renew. They may be had separately or in the form of combined reversible incising and paring blades.

In use the combined blade is inserted through the central aperture in the platform of the tool, and is adjusted to the required depth and angle. The angle of the incising blade is "started" in a small hole made by the pricker, and the complement is then drawn firmly round by the operation. The result is a clean-cut groove or channel, the floor of which is horizontal, and prevents the latex from overflowing. For paring it is, of course, only necessary to reverse the knife, the V-shaped edge being thus replaced by a straight-edged "parer."

Rollers are provided on which the tool runs smoothly over the bark. The distance between the rollers and blade being permanent, the cut is of uniform depth. Having once set the blade—depths from $\frac{1}{64}$ to $\frac{5}{8}$ of an inch are allowed for—the intended depth will not be deviated from.

The knife is adapted to all the well-known systems of tapping.

V Implement for Tapping Rubber Trees.

The Eastern Produce and Estates Company are responsible for a knife at one time 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 trees. 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 clearing the old cuts of scrap rubber. It is occasionally used on estates for piercing the stem or newly-formed cortical tissue to see if the latex is abundant. 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. This knife was one of the first to be placed on the market, and a detailed account of it is given in the India-Rubber Journal of February, 1904.

Bowman and Northway's Knives.

These knives were continually used by me in the experiments at Peradeniya and Henaratgoda, and in response to suggestions the originals were slightly modified in order to be of use in any of the numerous systems of tapping, and to still further economize in the removal of the cortical tissues. These knives appear to have been superseded, to some extent, by others, but they are of historic as well as practical interest, as in my opinion they have been the basis of many recent inventions. 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 pricking the latex tubes in the area of the wound response without removal of any cortical tissue.

Knife No. 1 is provided with a two-edged guide, which, on pressing against the bark, cuts the tissue 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. As soon as the proper depth is reached, the bark is of a white colour and becomes 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 latex-bearing tissues below the bark and next to the cambium are 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 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. Several of the No. 2 knives are provided only with one angular cutting surface. By this means only a very thin layer of cortical or 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 bark is 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 in use 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. The basal cutting surface of this knife has now been made much narrower, the change effecting a greater economy as less material is likely to be removed during each operation.

No. 3 consists of a spur-like arrangement, provided with a number of sharp cutting teeth. It is used to cut the latex tubes near the cambium or to tap the latex vessels which have become unduly distended with latex. The latest patterns are provided with one or two pieces of metal, the solid margins of which prevent the teeth from penetrating too deeply; these can be changed in order to allow the teeth to penetrate the cortex to the necessary depth—a wise provision when tapping trees of widely different ages. It can be used alternately with No. 2 knife, though in the Peradeniya experiments the spur knife was used at least twice as often as knife No. 2. It was by the use of these knives that a 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. Despite the reputed bad effects of pricking it is only fair to point out that by means of such an implement the excised area in three months' work, tapping twice per week, was less than one inch.

A New Bowman-Northway Knife.

Another knife has been more recently invented by Messrs. Bowman and Northway, and has been fully described and illustrated in the "India-Rubber Journal" of January 13th, 1908. The cutting part is shaped like the letter T. The cross part of the cutter has its extreme points turned up at an angle and sharpened at both ends. Guide pins are provided to regulate the depth of the cut and the thickness of the shaving, and also to sustain the tool with the blade at a correct angle. The implement can be used either on the right or left hand and will cut either backwards or forwards.

Dixon's Knife.

This consists of a grooved open knife blade, capable of being 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, removing scrap rubber from the cuts, making holes for attaching tins, &c. It can be used for making the original groove or for paring the lower surfaces in any direction, the excision being made by drawing the knife towards the operator. In a later pattern the cutting blade is provided with sharp margins, two blades, detachable and adjustable, to be used according to particular requirements.

Macadam's Comb Pricker.

Another type of pricking instrument has been introduced by Mr. Macadam, of Culloden estate, Kalutara. This is worthy of a detailed description, as it is constructed on a sound principle and is different from any other pricking instrument known. In order to distinguish it from others I propose to name it a "Comb" pricker. It consists essentially of a flat steel blade or comb provided with a dozen sharp teeth on one side ; the teeth are 5 mm. wide and 9 mm. long and the blade is 11½ cm. in length, so that a tapping line one foot in length (30½ cm.) could be pricked in three operations. The blade slides along two side grooves and is provided with two projecting pieces of metal for handling during adjustment. The blade can be pushed outwards or drawn inwards, thus allowing only a definite length of each tooth for the pricking operation. The ease with which the length of all the teeth can be adjusted is a great advantage, as a cooly going from tree to tree can, though he only possesses one piece of metal, accurately change the length of the teeth according to the thickness of the bark on the trees being tapped.

A further advantage in the "Comb" pricker is that the latex tubes are incised by merely pressing the line of teeth against the cortex. Dragging of the bark cells is therefore almost impossible. In other prickers the tapper naturally draws or pushes the instrument in a particular direction, and the unavoidable dragging may result in a clogging of individual latex tubes. The teeth of the "Comb" are very easily sharpened, and the simple and effective apparatus is mounted on an arched handle whereby a good grip is obtainable and the required pressure conveniently applied during tapping operations.

The Macadam-Miller Paring Knife.

This paring knife consists of two detachable paring surfaces connected by a screw roller. The cutting parts are on opposite sides and may be moved outwards or inwards by turning the screw, and can therefore be adjusted according to the depth of the bark to be excised. The essential parts are lodged in a substantial steel head firmly attached below to a wooden handle.

The knife is constructed so that the operator may cut from right to left or left to right, from above downwards or below upwards. The essential parts are rather difficult to get at and may prove troublesome to a cooly who is not accustomed to adjusting the paring edges.

Miller's Knife.

This knife was, at the Ceylon Rubber Exhibition of 1906, classed as equal with the Bowman-Northway knives. It is very simple, and consists of a rectangular or box-shaped piece of metal, open at both ends, and provided with four cutting edges. It can be used for excising bark from right to left, left to right, below upwards, and above downwards. The base of the cutting surface is drawn out at both ends to form a fixed, sloping guard which prevents the operator from cutting too deep. It is simple, non-adjustable, and capable of paring only the thinnest strips of bark.

Sculfer's Knife.

A cheap and durable knife has been brought out by Mr. H. G. Sculfer. The knife is fitted with a guide which allows only a small paring to be taken off at each cut, also stopping any danger of cutting the cambium. It will cut either right or left, pulling or pushing; it is easily sharpened and there is no possibility of the knife choking.

"Barrydo" Tapping Knife.

The "Barrydo" knife comprises a blade provided with four cutting edges; this can be changed rapidly and the remaining sharp edges employed in whatever direction the operator is paring. The knife cuts right and left, pull or push, without any adjustment being necessary. It has been recommended by many Ceylon planters and has been used on several Malayan estates.

Pask-Holloway Knife.

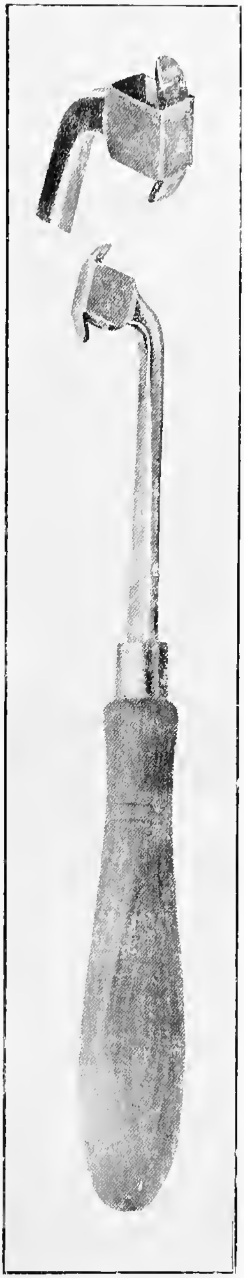
In this knife the rectangular-shaped piece of metal at the end of the blade is almost blocked so that only very narrow cutting edges remain for excising the bark. The cutting section of the metal is to some extent adjustable, and is attached to the block by means of a bolt, and can therefore be removed and easily replaced. It is a strongly-made knife and can be used both for the initial and subsequent cuts. The double cutting edge enables right and left-hand cutting to be done, and the paring can be changed from medium to narrow.

The "Secure" Knife.

This knife will cut in either direction, pulling or pushing, and can be adjusted according to the thickness of the bark to be tapped. The blade is joined to a circular disc by means of a bolt, and is fitted so as to rotate in a slide to any angle required. The

SCULFER'S KNIFE.

BOWMAN AND NORTHWAY.



MILLER'S KNIFE.

DIXON'S KNIFE.

TISDALL'S KNIFE.

circular base and disc are toothed and lock securely in any position. The pin has a square shoulder to prevent turning, and the shank is rivetted in the handle.

VAN DEN KERCKHOVE'S KNIFE.

This knife consists of a steel spike, with handle. At the end of the spike, which is slightly curved, is a plate with a screw and three movable blades with oblique edges. These blades can be regulated according to the thickness of the bark to be cut; the blades can be used combined or singly, according to requirements.

NORZAGARAY'S KNIFE.

At the end of this tool is a dome, below which is a pair of knives formed so as to cut two slots, preferably inclined one towards the other at their lower ends, so making a groove. The knives are attached to a spindle passing through the centre of the dome. This spindle is threaded and can be lowered or raised to alter the depth of cuts. The knives can be raised out of the bark by means of a lever operated from the handle. They are driven into the bark by striking with a mallet the end of the spindle where it projects above the dome. In a simpler form of the instrument, the knives are attached to the cylindrical end of the tool and through this end passes a screw with a foot-plate at the base for adjusting the depth of the cut. This, though, is very complicated.

WALKER'S COMBINATION KNIFE.

An ingenious knife, brought forward by Mr. H. E. Walker, is provided with paring section and rotatory pricker. The claims of the inventor are as follows: (1) the combination of shaving blade and pricking spur allows the operator to use either (a) blade and spur in the same operation, or (b) blade or spur separately without removing any part; (2) by pressing the guard against the trunk it acts as a guide and causes the spur to prick the latex channels in the innermost layer of the cortex, but prevents the teeth from going too deep; (3) the spur may be easily adjusted by means of the slot in which it is fixed and may be made to penetrate to varying depths, or be withdrawn from use, without removal of any part of the instrument; (4) the form of the spur is such that during use it will prick only the bark on which it is used; (5) the guards are made at such an angle with the blade that the excised plane will always, when properly used, be inclined towards the tree and thus prevent overflowing; (6) the knife can be used for right or left-hand tapping without any adjusting.

THE "SCORPION" PARING KNIFE.

This knife, more generally known as Cameron Brothers' "Scorpion" Paring Knife, is claimed to be one which will enable a skilled tapping cooly to pare 300 lineal feet in one hour, on trees 25 feet apart carrying 2 feet of tapping line each. The cutting parts have been designed to allow the operator to pare thick bark shavings 1-18th of an inch in thickness.

Tisdall's Knife.

This knife, which received commendation at the Ceylon Rubber Exhibition, consists of a long piece of metal curved at the end to form a cutting blade, and with a revolving disc attachment which can be adjusted to regulate the depth of cut.

Srinivasagam's Knife.

This knife is designed to make the original incisions, to pare off thin shavings, to channel the side of the tapping cut, and to clean the trees or remove dead bark. The boat-shaped front prevents the cooly from cutting too deep, the clip protector guards the cutting edge, and the openings at the sides allow the bark shavings to escape.

The Huber Tapping Knife.

This knife has been designed by Dr. Huber, of Para, and stands alone in the nature of the grip provided. In general appearance the tool resembles a tin-opener. Behind the nose is an adjustable, chisel-like blade projecting backwards. In use, the nose rests on the surface of the tree, serving to give steadiness, and at the other end of the handle is a small wheel for the same purpose.

The "Burgess" Tapping Knife.

The knife is ten inches long, it is made in one piece, and there is nothing to adjust. The blade of the knife is made of a small flat sheet of tool steel bent into gutter or "pot-hook" shape,

THE "BURGESS" TAPPING KNIFE.

resembling the curved blade of a farrier's knife. This is joined to a metal shaft, which is carried in a wooden handle. The shaft has double curves, which are specially designed for preventing damage to the tree and waste of bark in tapping.

In use the knife is held with the shaft and broader flat side of the blade applied to the surface of the tree, and the shoulder of the bend of the shaft resting on the groove or ledge in the bark of the tree made by previous tapping. The cut is made by the cooly pulling the knife towards himself.

The knife is said to be equally suitable for making first cuts on a tree and for deepening previous cuts. It is then held at right angles to its usual position, so that the broad flat side of the blade is at right angles or inclined to the surface of the tree. Owing to the curvature of the trunk of the tree the shoulder on the shaft which normally limits the thickness of the paring is then ineffective, and the desired depth of the first cut can be rapidly and easily obtained.

It will be noted that the pulling force exerted by the cooly is practically in direct line with the resistance at the cutting edge, and there is therefore no tendency for the knife to slip or rotate in the hand, and there is no wrist fatigue in using it.

The curve of the blade is designed to leave a clean grooved channel for the flow of the latex, and there is no tendency for the latex to overflow the groove and run to waste down the tree trunk.

The knife is sharpened from the inside of the bend of the blade. This is easily done by using the thin rounded edges of wedge-shaped stones which are sent out with the knives. The advantages claimed by the inventor may be thus briefly summarised: it is simple, safe, economical of bark, no other tool is wanted, it is easy to learn, easy to use, easy to sharpen, it cuts a grooved channel, and is cheap.

Wynn-Timmins Knife.

This is a knife which can be adjusted. A regular and uniform depth of cut may be obtained by locking the knife in a certain position, while at the same time it can be regulated to give a greater or smaller cut as desired, and when regulated is firmly fastened in place. The body of the tool is provided with the usual slot or recessed portion for the reception of the knife, which is engaged by a screw pin (I.R.J., May 13th, 1911). When the knife has been adjusted, by unscrewing the pin or key, a spring forces the catch into engagement with the particular notch in the knife and thus locks the latter. The pin or key can then be withdrawn from the tool body, whereupon the knife is locked until the pin or key is again applied.

The "Reafer" Tapping Knife.

This is a non-adjustable knife similar, in some respects, to others already on the market. It consists entirely of steel, the head being provided with four cutting edges for paring in both directions by pushing or pulling. It is one of those knives which cannot get choked by bark shavings. It is simple, and is made without any removable screws, bolts or nuts, and is said to be capable of excising parings from 1-25th to 1-20th of an inch in thickness. Compared with many other knives, it is cheap and durable.

CHAPTER X.

HOW TO TAP.

Principles to be Followed in 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 later by a process of perforation and decomposition of the cells. 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 again be tapped to the same advantage.

Fitting (p. 41, Eng. trans.) thinks that the above statement is not complete, and suggests that the following addition, at least in the case of young trees, should have been made: "And the best method of tapping is, furthermore, one that checks the transport of organic material in the bark towards the base of the tree for the minimum length of time, with the minimum degree of intensity, which most confines this interruption to a local area, and which consequently does not in course of time damage the tree or injuriously affect the renewal of bark or latex." I cannot refrain from stating that my original "maxim" covers many of the points in Fitting's addition, and the latter might have been framed in more comprehensive terms.

At Henaratgoda and on estates many examples of the effect of injuring the cambium may be seen at the present time, though the damage may have been done many years ago. The surface of a badly-tapped tree does not become even and smooth for many years, and tapping on the best system on such trees is difficult and often impossible.

Methods of Collectors in America.

The felling of wild trees and the ringing of the bark and cortex in order to collect the milk are now only practised by native collectors upon Castilloa. The latex is generally collected from Hevea trees while they are still standing. An upward incision is made in the bark by means of a small axe, and a cup then placed beneath each cut.

Tapping Methods in Africa.

Funtumia and Ficus trees, and also lianes, are, in Africa, usually tapped by collectors in a rudimentary manner, long

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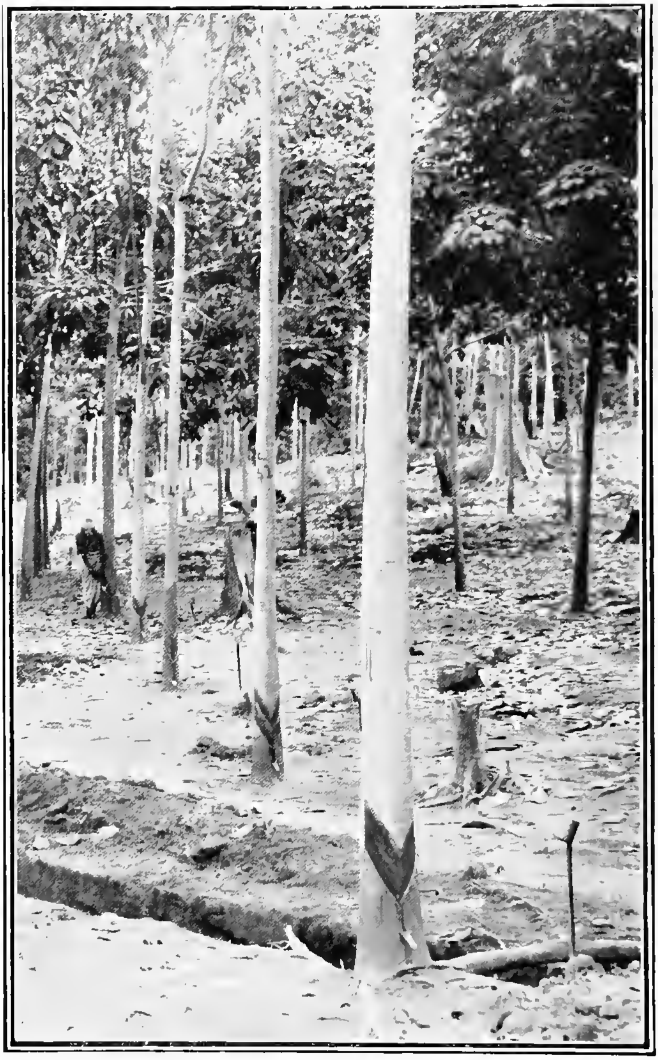
A NEW PRICKING METHOD OF TAPPING.



Lent by India-Rubber Journal.

BASAL TAPPING IN MALAYA.

incisions being the general rule. There are few Hevea trees in bearing, but where these exist, as in Uganda, the Gold Coast, and Nigeria, the herring-bone system is being generally adopted.

Estate Methods of Tapping.

At the present time the various methods of tapping Hevea trees may be roughly described as: (a) single oblique cuts; (b) basal V or Y; (c) multiple V incisions; (d) single cuts with a vertical channel joining them (when the cuts are on only one side of the vertical channel, the system is termed the half-herring-bone, and when on both sides the full herring-bone system); (e) full and half-spiral curves. There are various modifications, but they are not of sufficient importance to warrant a detailed 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 regarded as extravagant by some observers. Parkin proved that simple incisions made in an oblique direction gave about double the yield of latex as either the vertical or horizontal, the latter two showing very little difference in yield of rubber. Lecomte has pointed out that vertical incisions lay open very few latex tubes, and must in some degree have the effect of relieving the tension; one may therefore expect a poorer flow of latex from such incisions.

Each oblique cut may be from one to six or more inches in length, according to the size of the tree, but a distance of nearly one foot apart should be allowed. They slope at from 35° to 45° towards the vertical. The oblique incision is practically the basis of most other methods now in use, and is spoken of as the half-spiral system when the incisions are of considerable length, and as the herring-bone when connected by vertical channels. The distinction between the half-spiral and the half-herring-bone systems is that separate cups must be fixed to each cut in the former, and the cuts are also longer, while in the latter the cuts are joined by a vertical channel and only one cup is required at the base.

Basal V or Y.

The V incision is nothing more or less than a 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 the greatest advantages of this system.

The Y is merely a V with a conducting channel.

The system of tapping by means of a basal V or Y is generally limited to the first tapping period of a tree. The base of the tree trunk is somewhat bottle-shaped and possesses bark of considerable thickness compared with that three to five feet from the base. Comparatively large yields have been obtained from four-year-old Hevea trees in Malaya by these methods. Subsequently, as the tree increases in girth, tapping lines are added and the system of half-herring-bone tapping instituted.

Recent investigations suggest that the basal V may not be as beneficial as two basal single oblique cuts on opposite sides of the tree. Until this point has been definitely proved it may be wiser to adopt the latter system, as it would allow the cooly to tap areas separated from each other with the maximum amount of bark, and only one side need be tapped on separate occasions. The basal system of tapping is generally believed to give a better yield of rubber per area of bark excised and a reduced quantity of scrap than certain other systems ; but if it is carried out on young trees, and in any way affects the growth of the plants at that age, I advise planters to abandon it.

It has been suggested that the reason why the quantity of latex obtainable is not double that from a single oblique cut is because the cuts 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.

Multiple V Incisions.

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. There is, however, a great variation in the size of the cuts, the smallest incisions measuring about one inch in length.

It cannot be doubted that in a system 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, though most of the implements previously described may be tried in these systems.

Limitations of the V System.

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 latex after two months' tapping becomes very poor. This method obviously cannot be carried out for the same length of time as the half or full-spiral curves, because the oblique cuts sooner or later interfere with one another and draw on the same limited area. Four trees, tapped similarly by the use of a paring knife and the spur, gave 10 lb. 14¾ oz. of dry rubber from the 29th June to the 6th September, 1905.

Some experts in Java believe that a very high yield of rubber per unit of bark excised is obtained by the V method.

In some countries the exudations from trees are obtained by making incisions in the form of inverted V's, but such a method has no great advantage in connection with the tapping of Hevea rubber trees. Srinivasagam (Ceylon Observer, Sept. 22nd, 1910), claims that this system is being vindicated by recent workers.

Yield from V Tapping in Ceylon.

The following are the details of the trees at Peradeniya, which were tapped on the V system. The letter P indicates the days on which the pricker was used.

It will be noticed that the quantity of latex obtained by the use of Bowman and Northway's pricker 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 pricker.

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 long enough interval of time is allowed to elapse. The large yield resulting from the use of the pricker was followed by a poor flow after paring.

Four Peradeniya Trees—29 Years Old : Yield of Rubber from V Cuts.

Date.	Weight. lb.	Weight. oz.		Date.	Weight. lb.	Weight. oz.
29-6-05		4		Brought forward	6	15
1-7-05		3¾		31-7-05		7⅞
5-7-05		11⅞		2-8-05		7
7-7-05		10¼		3-8-05		5⅝
10-7-05		14		4-8-05		3½
12-7-05		12½		5-8-05		3¼
14-7-05		6¼		7-8-05		4⅞
17-7-05		9⅞		9-8-05		2⅞
19-7-05		8⅛		10-8-05		1 9/8
21-7-05		9¼		11-8-05		1 6/8
24-7-05		7⅛		12-8-05		1 6/8
26-7-05		7	P	15-8-05		3
28-7-05		7		17-8-05		1⅜
Carried forward	6	15		Carried forward	9	11⅝

	Weight. lb.	oz.		Weight. lb.	oz.
Brought forward ..	9	11¾	Brought forward ..	10	11½
P 18–8–05		1⅝	P 2–9–05		1¼
19–8–05		2⅛	4–9–05		0⅜
P 21–8–05		2⅛	P 5–9–05		1⅛
22–8–05		0⅝	6–9–05		0⅞
P 23–8–05		1⅝	P 7–9–05		1⅛
24–8–05		0¼	8–9–05		0⅜
P 25–8–05		1⅜	P 9–9–05		1⅛
26–8–05		1⅜	11–9–05		0½
P 28–8–05		1	P 12–9–05		1
29–8–05		0¼	P 13–9–05		0¾
P 30–8–05 .. .		1⅜	15–9–05		0⅜
P 31–8–05		1	P 18–9–05		1⅜
1–9–05		0½			
Carried forward	10	11½		11	5¾

At the end of the tapping operations the lines of adjacent V's were beginning to interfere with one another, and the trees were therefore rested. The average yield in the first five weeks was two pounds of rubber per tree, but subsequently the yield fell off considerably.

Vernet's Results.

Vernet (Bull. Econ. de l'Indochine, No. 44) gives an account of experiments in V tapping. From 100 open V's, by re-opening both edges, 1,153 cc. of latex were obtained ; by re-opening the lower edge a yield of 872 cc. of latex was secured. It might appear that had the lower edge been opened twice, a yield of 1744 cc. (872 by 2) would have been obtained, thus showing a better result from the lower edge.

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 vertical channel may vary from 1 to 6 feet in length, and is usually sufficiently wide to conduct the latex from a dozen oblique cuts. The cup 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 methods, this system is in use on most estates in Ceylon, and has been adopted with success by planters and officials in the Malay Peninsula, India, and Africa. It appears to receive more favour than any other system of tapping known at the present time.

After the original oblique incisions have been made, they are re-opened 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.

When the herring-bone system is used, there is no necessity to fix spouts at the base of each incision, as the latex flows down the vertical channel in the bark. Experiments have been made with conducting channels composed of clay, the inner ridge being left open at the base of the incision and the outer one continuous from top to bottom in the half-herring-bone system, and both ridges open at the base of the incisions when the full herring-bone system is adopted. Such a channel is easily made, it lasts for quite a long time, and in so far that it does away with the vertical cut in the bark is to be recommended experimentally.

According to Fraser (T.A., July, 1910), the full herring-bone system, three months on one side and three months on the other, is considered wasteful in Malaya, as every change means three cuts wasted before a normal flow begins.

Zig-Zag Tapping.

The zig-zag system of tapping consists of a series of irregularly arranged oblique cuts of varying length, joined together by sloping conducting channels, and so arranged that the latex is collected at the base of the lowest incision in the series. 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.

Northway and Bowman's Spiral Curves.

Another method which, on account of the good yields obtained, attracted considerable attention 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 of 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 12 to 18 inches of girth at the top of the tapping area. In this method of tapping a series of special knives was used; these ensured the minimum waste of tissue when re-opening the lower side of the wound. As this system gave an average of 2 lb. per tree for each month's tapping at Peradeniya, and was continued in some districts until a total of 16 lb. per tree was obtained in twelve months, it was viewed favourably for a time.

When Spiral Tapping can be used.

It cannot be doubted that the full-spiral system is drastic, and though excellent yields were once obtained by its adoption, it has been realized that cortical stripping should not be effected too rapidly even on old trees. It is a good system to adopt when it is intended to kill out intermediate trees on estates which are too densely planted, and can in such instances be carried out on young trees. The results obtained by this system on 10-to-30-year old trees at Henaratgoda and Peradeniya appeared at one time to justify its adoption on old Hevea trees, providing the operation was carried out carefully and slowly. The bark on the old trees at the places mentioned was removed at the rate of only *one inch* in *three months.*

Despite the numerous advantages of this system of tapping there are so many disadvantages, especially if it is practised on young trees, that it has fallen into disuse except for trees which have to be killed and ultimately uprooted.

Yields from Spiral Tapping in Ceylon.

Four trees, 29 years old, were tapped 65 times, and yielded a total crop of 27 lb. 3 oz.

The results which have been obtained from the full-spiral system at Peradeniya are not as satisfactory as those at Henaratgoda, and are only briefly indicated here. At Peradeniya four trees, then nearly 30 years old, were tapped from June, 1905, to February, 1906, at irregular intervals. About three-quarters of the bark tissues were removed from the base to a height of five to six feet by alternately pricking and paring the lower surface. Altogether each tree was tapped on 150 occasions during the time specified, and the yield obtained was approximately $6\frac{3}{4}$ lb. of dry rubber per tree.

At Henaratgoda 25 trees, from 15 to 20 years old, were tapped approximately twice per week from September 26th, 1905, to February, 1906. The pricker was used alternately with the paring knife, and in an interval of $4\frac{1}{2}$ months the width of bark tissues removed along each line was only $1\frac{1}{2}$ to 2 inches. The results show that by tapping on 37 occasions a total of $50\frac{7}{8}$ lb. of dry rubber was obtained.

The following shows some of the yields obtained by tapping on the full-spiral system at Henaratgoda. Each tree was tapped from the base to a height of 5 or 6 feet during a period of about $4\frac{1}{2}$ months :—

Number of times tapped.	Number of Trees.	Yield of Rubber. lb.
37	25	$50\frac{7}{8}$
112	5	$30\frac{11}{16}$
56	5	$26\frac{1}{16}$
18	5	$8\frac{9}{16}$
100	5	$27\frac{13}{16}$

According to Joseph Fraser (T.A., July, 1910) in Malaya the full and half-spiral and also the full herring-bone systems are being abandoned in favour of the half-herring-bone system.

New Tapping Systems in Ceylon.

It is not long since a system of pricking the trees, and washing the latex down previously cleaned stems by means of water ejected from syringes, was favourably reported on by officials and planters in Ceylon. The system was not made public, but

Photo by D. L. Gunawardane.

HALF-SPIRAL TAPPING.

Photo by D. L. Gunawardane

FULL SPIRAL TAPPING OF RENEWED BARK.

was specially recommended for young trees, and was said to be remarkable for the economy of bark effected by its adoption. This system will be criticised later in the present chapter.

A Vertical System for Young Trees.

Another system was advertised at the recent Rubber Exhibition in London (I.R.J., July 1st, 1911). A tree, originally planted by me at Gangaruwa, was shown. It was $4\frac{1}{2}$ years old, and was tapped 70 days, the yield being 1 lb. 3 oz. An acre of similar trees was tapped, and an average yield of 1 lb. 3 oz. per tree obtained.

In this new system of tapping the minimum amount of cortex is removed. Commencing at a height of 6 ft., two channels are cut right to the ground. A tapping-knife having four or five blades, each about an inch apart, is placed vertically on the trees and hit with a small hammer. The latex flows down the channels and is collected at the bottom. The next day other channels are made an inch to the right on both sides, and so on until they have gone completely round the tree. The system could be described as tapping on alternate days by incision, and only vertically. The object of tapping vertically is not to interfere with the circulation of the sap. At the end of the 70 days the trees which have been experimented upon showed no sign of injury, according to the inventor. It was claimed that a cooly could tap one hundred trees per day by this system. The system must, however, be regarded only as experimental.

Comparisons of Yields by Different Systems of Tapping.

The objects of my experiments at Henaratgoda were numerous. One of them was concerned with the yield of dry rubber obtainable by different systems of tapping, and is of particular interest to those persons having rubber trees in bearing. A plantation of 75 rubber trees, 15 to 20 years old, was selected for the experiments, and 25 trees in each of three groups were marked out and tapped on the (*a*) full-spiral, (*b*) half-spiral, and (*c*) the full herring-bone systems. Tapping was commenced on the 26th September, 1905, and continued until the 13th of February, 1906, the latter being the period when most of the trees were undergoing their change of leaf.

It was impossible to obtain exact equality in all the physical conditions, and it is beyond the power of any one to calculate the individual potentialities of the selected trees; nevertheless, the following details will serve to indicate the results which may be obtained from such trees under conditions similar to those prevailing at the time of the experiments.

	Full Spiral.	Half-Spiral.	Full herring-bone.
Area excised, in square inches	$12{,}414\frac{3}{4}$	$5{,}003\frac{1}{4}$	$7{,}348\frac{1}{4}$
Number of times tapped	37	41	39
Yield of dry rubber, in lb.	$50\frac{7}{8}$	$35\frac{1}{8}$	$47\frac{5}{16}$
Yield of dry rubber per 5,000 square inches, in lb.	20·49	34·47	32·55
Yield of dry rubber per 40 tappings from 25 trees, in lb.	55·0	34·20	48·52

Spiral and Herring-Bone Tapping Compared.

It is probably unwise to draw final conclusions from the above experiments, as the period occupied by the whole of the work was only about five months and the trees were 15 to 20 years old at the time of the experiment. But care was exercised to equalize, as far as possible, the physical conditions in the three sections and to avoid erroneous deductions being made. A synoptical statement of the significance of the above table is here given.

In the first case it is obvious that the full-spiral system necessitates the stripping of the cortex or bark at the quickest rate, and the half-spiral at the minimum rate.

The largest yield per group of 25 trees was obtained from the full-spiral system, the next best from the full herring-bone, and the poorest yield from the half-spiral system of tapping. This is only what may be expected when one realizes that the bark removed in the full–spiral, full herring-bone, and half-spiral systems was in the ratio of 12 : 7 : 5, respectively. It seems reasonable to conclude that since the above results show that the maximum quantity of rubber per tree has been obtained from the full-spiral system, such a system might be recommended where it is expedient that the rubber should be placed on the market as quickly as possible irrespective of the effect on the trees. By adopting this system the maximum quantity of bark is removed in a given time, and it is, therefore, the best one to follow in thinning-out estates which are too closely planted. It is extremely doubtful whether this system should be adopted on trees intended to permanently occupy the land ; the effect on the trees is bad.

On the other hand, it appears that the maximum quantity of rubber for equal areas of bark has been obtained from the half-spiral system, and, therefore, that this system is not only the least harmful, but is the most economical, and is one which, on a permanent estate, will give the best yield from the available tapping area.

It should, however, be pointed out that in these experiments the different systems have been followed in such a manner that the paring operations have only removed from 1½ to 2¼ inches of cortex along each incision in five months. The tapping lines were originally 12 inches apart, so that the whole of the area prepared for tapping will only be worked through once in about two to three years.

Half-Herring-Bone and Basal Y Systems Compared.

Upon the Sapong estate, British North Borneo, some observations have been made upon the merits of these two systems. The trees were tapped for twelve months, and were 5 to 6½ years old. It was determined that there is practically no difference in yield per tree by either method of tapping, but the "half-herring-bone" system required the excision of 189 square inches of cortex for each pound of dry rubber obtained, whereas the "Y" system only required the excision of 147 square inches to obtain the same amount.

Half-Herring-Bone and V Systems in Java.

The Buitenzorg experiments indicated in 1908 the highest yield of rubber per unit of bark excised from the half-herring-bone system as against the full herring-bone and spiral systems. Dr. Tromp de Haas appeared inclined to think that the short V cut would be still better. It certainly would give a higher yield per square metre of bark than any other system, because there is so little bark cut away. I cannot, however, regard the V method as being systematic. The lines of adjacent V's draw on the same area after a very short time. They prevent regular paring from above downwards throughout the length of the trunk; and the apex of each V is apt to turn up in dry weather. I should not be surprised to see some planters giving the system another trial. Such a development would be a very natural reaction after the drastic methods adopted on some estates.

Estate Considerations in Tapping.

Having briefly described the various systems of tapping in the Middle-East and the results obtained, it is now necessary to consider other points which require attention, no matter what system of tapping is adopted. Incision and pricking as against paring, the distance between tapping lines, thickness of bark shavings, cooly tapping tasks, and the systems of tapping according to girth and bark-renewal, are all of paramount importance to estate managers.

Excision versus Incision in Brazil.

From observations made in the Amazonas, Norzagaray (Lectures on Indiarubber, page 155) contends that incision is to be recommended for the following reasons: (1) the same incision produces always the same quantity and quality of latex, irrespective of direction of cut or its position in sunlight or shade; (2) the quantity of latex obtained increases up to a certain extent in proportion to the number of previous incisions; (3) 300 incisions of only one inch in length yield from 5 to 12 lb. of dry rubber per tree during, approximately, 150 days in the year. His objections to the paring or excision method are: (1) the unnatural process of removing the living bark impairs the nutritive functions of the tree, exposing it to the injurious effects of atmospheric influences and to the attacks of certain insects; (2) the excision of the living bark introduces a considerable quantity of chemical and mechanical impurities; (3) an appreciable percentage of scrap rubber is produced; (4) not one of the many present-day inventions completely meets the requirements of this system, and professional skill or the discovery of a special implement is necessary. He also points out that though the collector in the Amazon is hampered in his work by natural obstacles, he uses the incision system only, by which he makes about 300 incisions on each tree every year. Yet he admits that the system adopted by native collectors ultimately destroys the trees, a large quantity of sap is liberated which mixes with the latex, and there is considerable loss of latex. The rough method of incision as practised in Brazil has, in a measure, been tried on a Ceylon plantation, and from the disastrous results obtained no one could ever recommend its adoption by planters.

The faults of the system, can, however, be partly eliminated by careful incision without damaging the cambium.

Wickham still adheres to the principle of clean sharp incision instead of the paring method adopted in the East. He contends that the published estate returns do not show an appreciable increase in yield over that obtained by making clean incisions which entail the minimum strain on the trees. This appears to be rather a bold statement to make.

It is now generally admitted that while there is every reason why the bark should be preserved for as long as possible, the incision method adopted by native collectors in Brazil is accompanied by so many serious disadvantages, arising mainly from wounding of the cambium, as to render its adoption on Eastern estates undesirable.

Pricking and Paring Methods.

Incision by native collectors leads us to the consideration of incision by pricking implements. It is obvious that in the various systems it is possible to use either paring or pricking knives alone or these instruments alternately. A recent system of pricking only, invented by a Ceylon planter, and reported favourably upon by Willis (T.A., Feb., 1909), Fraser, and Clements, was said to be simple and less costly than the usual paring methods, and to give quicker and possibly increased returns. It was condemned (T.A., June 1909), because it tapped the whole circumference of the tree at one time and appeared likely to induce undesirable growths. The incisions were said to close up prematurely, the latex then flowing between the cambium and bark and there forming pads. On the other hand, some authorities claim that much of the damage was due to bad work on the part of the tappers, and that the system in its original or improved state was worthy of a longer and more scientific test.

Pricking is now rarely adopted on Hevea trees, except alternately with paring. Even the latter system is being discarded, mainly on account of the very thin bark shavings which are now cut by ordinary paring knives and also for other reasons. The effects of pricking will be dealt with in a later chapter.

General Principles in Systems of Tapping.

It is now necessary to detail a few of the important principles underlying tapping operations, such as direction of cuts, distance of tapping lines, thickness of bark shavings, tapping tasks, etc. I cannot do better than preface these with four axioms laid down by Francis Pears, of Lanadron (Souvenir, India-Rubber Journal):—

(1) That touching wood is a sign of bad tapping, yet the reverse is not necessarily a sign of good tapping.

(2) That it is not advisable to let latex come in contact with anything but glazed surfaces, such as glass, enamelled ware, or glazed pottery.

(3) That in tapping it is most important to have organization and a system whereby there are fewest loop-holes for coolies to do what they should not.

(4) That a good average tapper is capable of cutting 1,200 feet of bark as a daily task.

Direction of Cuts.

Most up-to-date tapping knives allow the tapper to cut right to left and left to right. This is essential where the full herring-bone system is in vogue, and is, according to some observers, desirable on account of the yield obtainable by tapping with the cuts in a certain direction. It is stated (T.A., Aug., 1910) that in 25 stems examined, the fibres sloped slightly up to the right in 18, in the other 7 they were practically vertical. It was, therefore, argued that a cut sloping down to the right would cut more latex tubes than one sloping to the left.

A series of experiments was made (T.A., Oct. and Dec., 1910), on trees at Peradeniya, some being tapped with the cuts sloping from right to left and others from left to right, both on the half-spiral system. After computation to equalise the numbers of trees and of tappings, the comparative yields may be given as follows :—

Right to left	14,904 grammes of dry rubber.
Left to right	12,774 ,, ,,

Any advantage in girth lay with the trees cut from left to right.

The presumption is that cuts sloping from right to left yield better than those sloping left to right. The difference is so small, and the period of the experiments so short, that any deductions therefrom are, in my opinion, extremely dangerous. There is every probability of parts of even the same tree showing considerable variation, and experiments should be made on a very large number of trees for a long period of time before advice is given.

Upper and Lower Sides of Cuts.

It is customary in paring to excise the bark only on the lower surface. Some authorities have suggested that the upper surface as well as the lower should be re-opened. This is dangerous, especially if bad tapping is frequently done, as much of the healing which normally takes place from above downwards (as well as from within outwards) is prevented. Dr. Tromp de Haas tapped four trees at Tjikeumeu, and obtained the following yields :—

	Incised on lower edge only.	Incised on both edges.
(1)	380 grammes	552 grammes
(2)	180 ,,	370 ,,
(3)	237 ,,	403 ,,
(4)	221 ,,	300 ,,
	1,018 ,,	1,625 ,,

A higher yield is naturally to be expected by tapping two surfaces instead of one, but to be justifiable the yield must be maintained for a long period and be in proportion to the quantity of bark excised. In the above experiments the yield from the double incision was far less than double that from the single incision. Another series of experiments gave per square metre of tapped area: incision on lower edge only, 390 grs.; on both edges, 414 grs., thus proving the advisability of tapping the lower edge only.

With some bearing upon this point is an experiment made by Vernet (Journ. d'Agric. Tropicale, Jan. 1910), who ringed a tree, and with circular cuts tapped the upper and lower sides of the ring. In 17 days 77 c.cm. of latex were got from the upper and 156 c.cm. from the lower edges. Two factors were suggested by Vernet. First, there is a difference in tension of the tissues, because the lower part is in communication with the water-absorbing roots, while the upper part is in communication with the water-losing leaves. Second, the flow from the upper part stops sooner owing to greater readiness on the part of the rubber to coagulate, a fact proven by another experiment of his own.

Supervision of Tapping.

Much of the success or failure in tapping can be attributed to the care with which the tapping lines are laid out. It is necessary to have all tapping lines parallel and at definite distances in order to check subsequent work. On most estates separate batches of coolies are reserved for laying out tapping lines and making the first cuts. When the latter work is being executed the cooly should make two or three clean strokes rather than rub the tapping knife over the newly-made cut.

When tapping has been commenced, Murdoch advises (I.R.J., June 13th, 1910) keeping a daily return of yields and dividing the force into groups, a separate record for each being kept. A group showing a sudden rise or fall can at once be visited.. He would not recommend more than 6,000 trees in a section, each group of coolies being controlled by a good cooly or sub-kangani. He claims that it is impossible for the European staff to watch all the labour. Parkinson reported that on his estate they worked by fields of 20 acres or more.

Parallel and Irregular Paring.

It is a very common sight on some estates to see the bark between the original parallel tapping lines of varying width after tapping has been going on for several months. This is due to the tendency of the cooly to cut away at every tapping operation more bark near the end of the tapping line where it meets the vertical conducting channel than in the upper part. Towards the end of the tapping period, strips of bark are left which are not continuous with the vertical conducting channel. Very often this bark cannot be tapped, and is allowed to peel away. This represents so much bark, and therefore rubber, lost to the planter, and though every care is taken to prevent this on well-managed estates, it is frequently observed on some properties.

Number of Trees Tapped per Cooly.

The number of trees tapped per cooly per day varies enormously and is particularly small in fields tapped for the first time or when the trees are very large. Furthermore, the number and length of tapping lines per tree, and the bad or good condition of renewed bark, greatly affect the number of trees which can be tapped, per cooly, in an ordinary day. In some accounts the tapping task includes not only making the cuts but fixing collecting cups and collecting scrap from the tapped trees each day. The maximum number of cuts made per cooly per day is reported as 1,600; there, however, the coolies did not collect the scrap. On Malayan estates from 800 to 1,500 cuts per day, or 250 to 310 trees per day, seems to cover most tasks.

Parkinson states (I.R.J., June 13th, 1910) that the task must vary with the age of the tree. He gave an average of 150 trees with 8 cuts each, making a total of 1,200 cuts, the cooly collecting the latex and bark, washing the cups, and carrying the latex to the coagulating sheds. With older trees he gave an average of 120 trees with 8 cuts each. The "scrapping" was done by women and children. When doing 150 trees the cooly did 75 in the morning, stopped collecting the latex, then another 75, finishing at from 2 to 2.30 p.m.

Number of Tapping Cuts per Inch.

The number of cuts per inch is often an index of the amount of supervision given to the tapping coolies. The larger the number of cuts per inch, the less detrimental will be the effect of tapping on the tree, and the larger the yield of rubber per unit of excised bark, presuming, of course, that the parings are always sufficiently thick to permit of an issue of latex. The various tapping knives now on the market vie with one another in their ability, when skilfully used, of cutting away bark of the minimum thickness. The actual thickness of the bark on young and old trees, and its texture, is said to determine to some extent the minimum thickness of each paring.

Malcolm Cumming states that, in tapping ten-year-old trees for the first time, only 10 to 12 cuts per inch can be made. Parkinson affirms that it is not possible to get so many cuts on renewed bark as on trees newly tapped. It is said, nevertheless, by Gallagher, that more cuts to the inch can be made on the soft bark of young trees than on the hard bark of older trees tapped for the first time.

The thickness of the parings varies by about 100 per cent., the minimum being 1-30th of an inch, and the maximum about 1-16th of an inch; the former is reported in the F.M.S. and the latter in Ceylon. Experience has shown that a better yield is obtained with 20 cuts than with 15 to the inch. Anything less than 20 cuts to the inch denotes, according to Gallagher, faulty management; 23 is considered as average, and 25 and over as very good. This does not include the first incision, the width of which varies according to the knife and the amount of skill used.

Distance between Tapping Lines.

Where tapping is done on the four-year-system on four sides of the tree, it is often convenient to have the tapping lines twelve inches apart in order that, at the rate of one inch per month, each section can be made to last one year. If each side is tapped on alternate days throughout the whole year, and the average thickness of bark excised at each tapping is about 1-15th of an inch, the system is almost ideal. In parts of Malaya, however, the strip of bark removed in each operation is usually much thinner than 1-15th of an inch, varying generally from 1-20th to 1-30th of an inch. Furthermore, during certain months work cannot proceed regularly, on account of holidays, bad weather, etc.; this affects the average total width of bark excised each month. It is therefore necessary for each planter to adopt a distance between tapping lines according to the general system upon which he is working the estate. If he is tapping one quarter-section only for each of four years on alternate days, working 25 days in the month, and his bark shavings are 1-15th of an inch thick, the tapping lines should be 10 inches apart to last one year. If the thickness of the bark removed is 1-20th or 1-30th of an inch, the distance should be about 7½ or 5 inches apart respectively, a spacing which is obviously too close. If daily tapping is adopted, then the distance should be doubled. It is generally better to make the tapping lines too far apart than too close together.

If the system adopted is the two opposite quarters to last two years, and the opposite sides are tapped on alternate days (each tree being tapped each day, but on opposite sides), then the distances of the tapping lines should, if the shavings are 1-15th, 1-20th, or 1-25th of an inch in thickness, be 20, 15, and 12 inches apart respectively. It is therefore seen that, allowing: (1) for only an average of 25 working days per month, (2) bark shavings 1-25th of an inch thick, and (3) alternate day tapping, using two opposite quarters to last two years, the original distance of 12 inches between tapping lines suggested by me still stands good. The distance must, of course, be increased if the working days per month or the thickness of the bark daily excised are increased beyond those specified. If the number of tapping days for the planned period is divided by the thickness of the bark shavings, the quotient is the distance to be allowed between the tapping lines. The following table will perhaps prove useful to planters planning out their tapping operations:—

Average thickness in inches of bark shavings.	Distance between tapping lines For Daily Tapping to last. 1 Year. ins.	2 Years. ins.	For Tapping on alternate days. 1 Year. ins.	2 Years. ins.
24 Working Days each Month.				
$\frac{1}{10}$	$28\frac{4}{5}$	$57\frac{3}{5}$	$14\frac{2}{5}$	$28\frac{4}{5}$
$\frac{1}{15}$	$19\frac{1}{5}$	$38\frac{2}{5}$	$9\frac{3}{5}$	$19\frac{1}{5}$
$\frac{1}{20}$	$14\frac{2}{5}$	$28\frac{4}{5}$	$7\frac{1}{5}$	$14\frac{2}{5}$
$\frac{1}{25}$	$11\frac{13}{25}$	$23\frac{1}{25}$	$5\frac{19}{25}$	$11\frac{13}{25}$
$\frac{1}{30}$	$9\frac{3}{5}$	$19\frac{1}{5}$	$4\frac{4}{5}$	$9\frac{3}{5}$
25 Working Days each Month.				
$\frac{1}{10}$	30	60	15	30
$\frac{1}{15}$	20	40	10	20
$\frac{1}{20}$	15	30	$7\frac{1}{2}$	15
$\frac{1}{25}$	12	24	6	12
$\frac{1}{30}$	10	20	5	10
26 Working Days each Month.				
$\frac{1}{10}$	$31\frac{1}{5}$	$62\frac{2}{5}$	$15\frac{3}{5}$	$31\frac{1}{5}$
$\frac{1}{15}$	$20\frac{4}{5}$	$41\frac{3}{5}$	$10\frac{2}{5}$	$20\frac{4}{5}$
$\frac{1}{20}$	$15\frac{3}{5}$	$31\frac{1}{5}$	$7\frac{4}{5}$	$15\frac{3}{5}$
$\frac{1}{25}$	$12\frac{12}{25}$	$24\frac{24}{25}$	$6\frac{6}{25}$	$12\frac{12}{25}$
$\frac{1}{30}$	$10\frac{2}{5}$	$20\frac{4}{5}$	$5\frac{1}{5}$	$10\frac{2}{5}$
27 Working Days each Month.				
$\frac{1}{10}$	$32\frac{2}{5}$	$64\frac{4}{5}$	$16\frac{1}{5}$	$32\frac{2}{5}$
$\frac{1}{15}$	$21\frac{3}{5}$	$43\frac{1}{5}$	$10\frac{4}{5}$	$21\frac{3}{5}$
$\frac{1}{20}$	$16\frac{1}{5}$	$32\frac{2}{5}$	$8\frac{1}{10}$	$16\frac{1}{5}$
$\frac{1}{25}$	$12\frac{24}{25}$	$25\frac{23}{25}$	$6\frac{12}{25}$	$12\frac{24}{25}$
$\frac{1}{30}$	$10\frac{4}{5}$	$21\frac{3}{5}$	$5\frac{2}{5}$	$10\frac{4}{5}$
28 Working Days each Month.				
$\frac{1}{10}$	$33\frac{3}{5}$	$67\frac{1}{5}$	$16\frac{4}{5}$	$33\frac{3}{5}$
$\frac{1}{15}$	$22\frac{2}{5}$	$44\frac{4}{5}$	$11\frac{1}{5}$	$22\frac{2}{5}$
$\frac{1}{20}$	$16\frac{4}{5}$	$33\frac{3}{5}$	$8\frac{2}{5}$	$16\frac{4}{5}$
$\frac{1}{25}$	$13\frac{11}{25}$	$26\frac{22}{25}$	$6\frac{18}{25}$	$13\frac{11}{25}$
$\frac{1}{30}$	$11\frac{1}{5}$	$22\frac{2}{5}$	$5\frac{3}{5}$	$11\frac{1}{5}$
29 Working Days each Month.				
$\frac{1}{10}$	$34\frac{4}{5}$	$69\frac{3}{5}$	$17\frac{2}{5}$	$34\frac{4}{5}$
$\frac{1}{15}$	$23\frac{1}{5}$	$46\frac{2}{5}$	$11\frac{3}{5}$	$23\frac{1}{5}$
$\frac{1}{20}$	$17\frac{2}{5}$	$34\frac{4}{5}$	$8\frac{7}{10}$	$17\frac{2}{5}$
$\frac{1}{25}$	$13\frac{23}{25}$	$27\frac{21}{25}$	$6\frac{24}{25}$	$13\frac{23}{25}$
$\frac{1}{30}$	$11\frac{3}{5}$	$23\frac{1}{5}$	$5\frac{4}{5}$	$11\frac{3}{5}$
30 Working Days each Month.				
$\frac{1}{10}$	36	72	18	36
$\frac{1}{15}$	24	48	12	24
$\frac{1}{20}$	18	36	9	18
$\frac{1}{25}$	$14\frac{2}{5}$	$28\frac{4}{5}$	$7\frac{1}{5}$	$14\frac{2}{5}$
$\frac{1}{30}$	12	24	6	12

Tapping Systems and Other Considerations.

A visit to the East will convince everyone that there is great diversity of opinion and methods among planters of repute. This applies not only to methods of planting, but to systems of tapping, kinds of tapping knives used, and curing apparatus. The following summary of the methods on three estates in Ceylon will serve to illustrate this point :—

	Estate Cu.	Estate Gk.	Estate De.
Tapping system ..	Half-herring-bone.	Full herring-bone	Spiral.
Knives used ..	Miller's.	Michie-Golledge.	Bowman & Northway.
Curing systems ..	Vacuum driers.	Chambers maintained at 85° F.	Tea-withering shed.
Form of rubber ..	Crêpe.	Worms.	Sheet.

It is obvious from the above that the systems adopted on these three estates are as different as they can possibly be. Nevertheless, at most exhibitions the produce from all of these estates is generally well thought of.

A still more striking example is furnished by Bryce, of Tebrau Estate, Johore (Souvenir, India-Rubber Journal) who brings forward the arguments of two managers of two of the largest rubber-producing estates in Malaya.

For convenience Bryce refers to them as A and B.

A's argument is as follows :—

"The present price of rubber is approximately 5s. 6d. per lb., and there is no reason to think that the price of rubber will ever be much higher than this. The area now being tapped on the estates in his charge is only a fraction of the total planted area. His object, therefore, is to get as much rubber as possible from these trees without unduly injuring them. Later on it is possible that he may have to give them a year's rest to allow time for bark renewal, but by then he will have a very much larger area in bearing. It is true that his cost of production is higher than B's cost of production, but that is because his method of tapping is necessarily more laborious, and the extra amount of latex obtained is not in proportion to the amount of extra work involved, yet at the existing price of rubber his profit is much greater than B's profit, since he is getting double the amount of latex per tree. Furthermore, owing to large dividends, his company's shares are at a high premium, which enables them to issue new shares at about this premium, and purchase other estates partly in bearing at a very low cost to original shareholders."

Now follows B's argument.

"His object is to get the cost of production as low as possible, and to tap lightly to ensure always having sufficient bark area. He has chosen, therefore, the simplest and lightest method of tapping, which enables his coolies to tap the maximum number of trees (800 per coolie per day) and which necessitates cutting the minimum amount of bark. The tapping is all done on contract, and the tappers divided into three classes according to their skill, with heavy fines for too deep cutting.

"Furthermore, his tappers are not, as on most estates, allowed to place the cups and collect the latex, but are confined to tapping only, since, as he rightly states, tappers are skilled labour, and collecting the latex can be done by women and children at a much cheaper rate.

"In this way he has reduced the cost of production to a very low figure, and is sure of having sufficient bark area to continue tapping indefinitely."

The above examples show how, from financial and other considerations, the views of planters may be influenced. In this volume the views I express on tapping are mainly based on the principle that the best methods of tapping are those that are sound from a hygienic point of view. The future health and yielding-capacity of the trees are regarded as the most desirable features to strive for, rather than large and quick returns and diseased or weak trees.

General Estate Systems of Tapping.

Whatever system of tapping is adopted, I think it is essential that the same areas should be regularly tapped, and not one side or part of it allowed to rest for one or more months and then be re-tapped. Where tapping every alternate day is carried out the cooly removes a very thin piece of bark, and gets a reasonable flow of latex. If tapping is commenced on a given area after one, two or more months' rest, the first few tappings give very little latex, a quantity of bark and also valuable labour being thereby wasted. Of course, where the tree, through some cause or other, does not yield latex in proper quantity or of the required quality, a rest must be given. Such a procedure is, fortunately, not often necessary.

Three-Year System.

The main factor underlying modern tapping operations is the interval of time allowed for secondary bark to mature before being re-tapped. In some countries three years are allowed, but in most a four-year interval is regarded as much safer. When the three-year system is adopted, the tree is marked out into thirds, and one part is tapped each year. This is a system which has been approved by some directors and planters in Malaya. Adherents to this system generally believe in tapping every day, and in having the tapping lines nine inches apart, trees 16 inches in girth having two, trees 18 inches having four, and trees 20 inches as many as six cuts on each tapping area. Many prefer this system because the tapping lines on young trees can then be made longer than in the quarter-section system. It appears to be gaining favour among Ceylon planters.

Four-Year System.

In May, 1908, my system of tapping was drawn up for, and adopted by, a large estate in Province Wellesley :—

1. The tapping lines should be about 12 inches apart, and sloping at an angle of approximately 45 degrees.
2. The half-herring-bone system, or, in the case of smaller trees, basal Y or V to be adopted.
3. Tapping to be done on each side every alternate day (each tree being, therefore, tapped daily).

4. The renewed bark to be four years old before being tapped.

(A) Trees 15 to 18 inches girth.

Tap the basal foot only on half the tree. This should be done only where the trees have a vigorous appearance, and are ove three years old.

(B) Trees 18 to 20 inches girth.

Divide the tappable section into north, south, east, and west. Tap to a height of 3 feet on the half-herring-bone system on two opposite quarter-sections, these two quarter-sections to last two years.

(C) Trees 20 to 24 inches girth.

Tap up to only 4 feet in the same manner as B.

When the trees are above 24 inches, the tapping area should be raised to 5 feet, the same system, i.e., four quarter-sections, being adopted. The girths referred to above are those at a yard from the ground. As each tree increases in girth and passes from one class to the other, additional tapping lines are added. On some estates where the tapping lines are 18 inches apart, and the trees are tapped daily, trees with a girth of 15 inches may have one cut, and 18-inch trees two cuts.

This system, if properly carried out, will not unduly tax the trees. It will give a gradual increase in yield from the beginning, and will permit of an interval of at least four years for the renewed bark to mature.

This quarter-section system has since been adopted by some planters in Selangor, and on estates with which I have some connection in Sumatra, Borneo and Java, and has been approved by independent experts in Malaya.

Fitting, at a later date, advised that the tapping system to be recommended was the division of the bark into four quarter-sections, on the half-herring-bone system, each to be tapped for one year, the whole of the bark to last four years. He states that Ridley confirms the adoption of the system.

Several planters have objected to this system because they consider that four years is too long a period to allow for renewed bark to form and mature. My own view is, that if any change in the bark–renewal period is made it should be to lengthen the time, rather than to shorten it, for each cycle of renewed bark. It is surely a great enough strain on the trees to renew the bark four times in the first twenty years,

Gallagher favours the quarter-section system of tapping (half-herring bone), as he believes bark renewal and flow of latex will be better from this than from any other system in vogue. He prefers tapping one quarter for one year only, instead of two opposite quarters for two years. The following is the system he outlined from the beginning of tapping :—On young trees, measuring 18 to 20 inches at a yard from the ground, put on a basal V 18 inches high, and tap every day. This will last one year. The second year, put a similar V on the other side. The third year begin the one-quarter-in-one-year system on either of the first two quarters tapped, and put on cuts as high as the girth allows, taking the opposite quarter the fourth year. His reasons for departing from the one-quarter-in-one-year system for the young trees are: (1) In trees 5 to 6 years old which have had only one cut upon them the renewed bark in two years is thick enough to be tapped; (2) the cuts are short, and the distance which building material must move transversely is not so great as in later years; (3) the cut on one quarter is too short, and the bark is too thin higher up.

Northway and Bowman's System of Marking the Trees.

The system consists first in marking out the grooves at the correct distance and angle at which 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 2 ft. 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 2 ft. long and at intervals of one foot, starting one foot from the base of the tree, up to a height of 5 ft., 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, and at the same time avoiding 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 would be needed. A tree 36″ in circumference would require 2 vertical channels on opposite sides of it, 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.

Holloway's System of Marking.

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.

The Collecting of Latex.

Having indicated the general principles concerning tapping implements and operations, it now remains for us to consider the more special contrivances and methods adopted in the process of collecting latex.

A Protector.

Mr. A. H. Bury, Ceylon, has devised an apparatus to protect the collecting cups from rain and mechanical impurities during tapping operations. "The protector is to consist of a zinc collar round the trunk of a rubber tree, sloping slightly downwards at an angle approaching 45 degrees. The protector will have a centre edging of felt, fitting on the tree so as to catch any moisture running down it and allow it to drain off the roof over the latex cup. It will also fasten with a stud fastening, in the same way as an ordinary collar, only there will be several holes on the one end of the collar that fastens over the other, so as to allow of the same sized collar being attached at various times to trees of different girth." This does not appear to have been adopted by many planters.

Centralizing the Latex from many Trees.

On all estates each tree is separately visited for the collection of the latex, an arrangement which requires a very large labour force when large acreages are in bearing. Where the trees are regularly planted and the slope of the ground is favourable, it has been suggested that an arrangement for collecting the latex from all or a large number of the trees should be adopted.

A method has been brought forward having for its object the collecting of the latex from an indefinite number of incisions in one or more trees and conveying it to a common centre. Its complete success depends upon keeping the latex in a liquid condition for a period of time varying according to the distance over which the latex has to be transmitted. The method, though ingenious, is not considered practical.

Drip-tins: their Construction and Action.

It is well known to most planters who are tapping Hevea rubber trees that the latex as it issues from a newly-made incision may vary much in consistency, sometimes being very watery and flowing freely, at other times being too thick to trickle along the lines prepared for it. In high tapping the latex may have to traverse a distance of over twenty feet along the stem before it reaches the receptacle at the base, and in many instances never succeeds in being collected except as scrap rubber. Furthermore, the latex during periods of drought does not run so freely as when the moisture conditions are more favourable.

In all such instances the latex tends to coagulate on the tree and is subsequently collected as scrap. An attempt has been made to overcome this difficulty by the use of a receptacle called the drip-tin. This consists of a tin vessel made to hold a known quantity of water or water containing ammonia or formalin. It has a concave surface to fit the convex outline of the tree and is fixed to the bark by means of pins. At the base it is drawn out to a fine point, which, when the drip-tin is adjusted, is in contact with the tapping area on the stem. The point is provided with an ingenious screw arrangement by means of which the drop of liquid allowed to issue can be regulated according to requirements. The apparatus is placed at the top of each incision, and as soon as the tree has been tapped the drip is allowed to commence. By these means the latex is to a great extent prevented from drying up on the stem and is carried rapidly towards the base ; the latex tubes, not being blocked by the coagulated substances, continue to give forth latex for a long period. It is claimed that this invention will greatly reduce the amount of scrap, and that the laticiferous tubes are more nearly emptied by its adoption.

The above refers to the more complex type of drip-tin, but several others designed on an improved and simpler plan and more suitable for coolies have already been made in Ceylon. They are useful but are not largely adopted in the East.

Collecting Cups and Spouts.

In all methods it is necessary to fix the tins or spouts on the trees and therefore to have some sharp point to press against the bark for fixing. In most systems now in vogue a spout, preferably of aluminium, is fixed at the base of each line and the tins are placed on the ground immediately under the spout ; this arrangement is found to be economical.

The advance made recently in cups for collecting latex on rubber plantations is of more than usual interest. Four or five years ago it was the custom to use, on many Eastern plantations, coconut shells in preference to the leaves or bamboo cups employed in Brazil and Africa. The shells were popular on account of their cheapness and cleanliness, and were replaceable at a very small cost. Tin, aluminium, and subsequently galvanized iron and enamelled cups were also largely used, but it was soon found that these corroded, and were apt to discolour the latex or scrap rubber in the cups. The place of these has been taken by glass, earthenware, and Chinese paper cups, the latter being preferred on account of their not being so easily broken and their comparative cheapness.

Number of Collecting Cups Required.

Having run through a good variety of utensils and selected what appear to be reliable forms of collecting cups, the planters are now engaged in evolving a scheme whereby theft can be reduced to the minimum, and cleanliness maintained. The systems adopted on two Malayan estates may be compared. In both cases only one cup per tree is used; in one case the cup when empty is turned mouth downwards, and placed on the top of a stick some two or three feet from each tree, and projecting about one yard above the ground; in the other case each empty, clean cup is lodged on some projection from the tree above the height of the tapping area. In each case the manager can see all the cups, and can thus detect loss by theft or otherwise. Furthermore, the cups, being upside down, are clean when the tapper commences his morning round, instead of being partially filled with dirt from the splashing of rain on the ground, fall of leaves, etc. As the same tree is not tapped morning and evening of the same day, one cup per tree should suffice under this system. We cannot see the reason for some planters insisting on two collecting cups for each tree tapped on alternate days.

Glass and Earthenware Cups.

The importance of cleanliness in all departments of estate work has been so well recognised that even enamelled collecting cups and coagulating dishes are being superseded by others made of glass. Collecting cups to-day are of a varied character. The majority of estates still use tin or iron cups and will probably continue doing so until the utensils have been worn out; others use coconut shells on account of their cheapness, and one or two have adopted enamelled cups. Undoubtedly the last mentioned is the best of the three, but I believe they will be replaced, in very many instances, by glass or earthenware receptacles.

In tapping operations there is always a certain amount of sap emitted from the cortical cells; this contains various acids which become mixed with the latex from the laticiferous channels. The acids act upon the tin or iron cups and invariably lead to considerable discolouration in the latex; subsequently the rubber is often stained to such an extent as to lower its value. When glass cups are used, no such chemical reaction can take place, and a pure clean rubber should result from their use.

Another point of importance is the ease with which the glass cups can be cleaned. After each day's work the collectors have to pick out all scrap or coagulated rubber in the cups; often this necessitates some amount of scraping which, with receptacles other than those made of glass, results in exposure of surfaces readily marked by acids. It is obvious that glass stands first in this respect. The more easily the collecting cups can be cleaned, the less likelihood there is of the rubber being stained or turning tacky. Most planters now recognise that in the handling of latex one has to be as careful as in a dairy, so susceptible are its contents to decomposition. Cleanliness is of the utmost importance, and the use of glass cups will materially assist planters anxious to turn out even-coloured rubber.

One firm has devoted considerable time and attention to the manufacture of glass collecting cups and has put on the market some new shapes and sizes, not only for collecting the latex at the base of the tree, but also for use higher up the trunks of the trees. Some of these cups (registered designs) are made with rims and holes suitable for hanging purposes. They are being made in the ordinary clear white glass and also in light and dark green and amber colours, and may be had in any special pattern, as required. Another important point is that the glass cups can be supplied with the name of the estate marked on them, so that they are easily recognised.

A new design of glass collecting cup has been made in the half-lemon shape, and is equally suitable for fixing to the tree or for embedding in the ground at the foot of the tree. It is moulded with two rims at the top, between which a string or wire can be passed round the cup and the tree, so that it can be securely attached to the latter. The side nearest to the tree is concave and fits closely to the bark of any-sized tree, permitting all the latex to run into the cup and not trickle down between the bark and the cup, as is the case with circular cups. These cups do not require any hole upon which to hang them. This obviates the damage to the bark of the tree, as no nail is necessary. The shape of the bottom of the cup is also a considerable improvement, as it combines the advantages of the two different cups which are often used, one for above and another for the base of the tree. The cups are strongly made in clear white, amber, or green colours, and are shaped so as to pack easily one within the other.

CHAPTER XI.

WHERE TO TAP.

It is well known that in *Hevea brasiliensis* 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 these 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 tissues and foliage is never abundant and is said to clot in little lumps where it exudes. The rubber from these structures is adhesive and has less elasticity and strength than that 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, scaffolding, and the use of ladders and walking stilts for tapping higher parts and thick branches have been attended with good results in some cases. 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 from 20 to over 30 lb. of rubber per tree have been obtained from the lower part of the stem alone within twelve months makes it very doubtful whether tapping of less accessible parts will come into general force except where the lower part has been severely mutilated during tapping. The strain on the plant to heal the wound area from six feet downwards is quite as much as it need stand. Furthermore, it must be remembered that the maximum quantity of latex and rubber may be obtained not so much by tapping virgin areas as by taking advantage of the wound response.

Areas Tapped on Estates.

On most estates in the East tapping is done only from the base up to six feet. On a few first-class estates, where the bark in this area has been badly tapped, the affected trees have been worked at from six to ten feet above the base until the lower areas healed. Trees three to four years old are tapped from the base up to two feet, five-year-old up to three feet, six-year-old up to four or six feet. On only one or two estates have trees under three years of age yielded, when tapped towards the base, paying quantities of rubber. The low percentage of trees having a girth of 18 inches

—below 30%—on three to four-year-old clearings, prevents most planters from economically carrying out regular tapping operations at that age.

BASAL TAPPING OF YOUNG TREES.

Tapping the base of young trees has been extensively done on some Malayan and Ceylon estates, with what results to the tree only the future can tell. It has been contended that planters will not allow any latex to escape if it is at all possible to collect it at a profit. Certainly the tapping of the basal part of trees which are admittedly too thin to tap at the usual height lends colour to this declaration. I do not think that any efforts will be spared to secure the maximum quantity of rubber from trees at all stages of their growth. I am more afraid that damage may be done to the young trees by thus taking advantage of a difference in thickness of the bark at different sections. Most managers have profited by experience already gained in the tapping of very young plants, and are now inclined to let the trees have the very best chance to develop into the strongest types so that a regular output of rubber can be reasonably anticipated during the years to come. There are no data available which would lead one to believe that the latex at the base of a four-year-old tree would vanish if not immediately collected. The latex, if left alone for another year, would probably increase in quality and quantity.

The following experiments (L'Hevea Asiatique, M. Collet), indicate that the lower part up to 60 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, per given area, is to be obtained from the base up to a height of about five feet. Other experiments have proved that the yield from the base to three feet is considerably more than that from three to six feet. According to Tromp de Haas, the trees in Java give the largest yield in their lower parts, and tapping up to a height of 1·5 metres (5 feet) gives the best results.

EXPERIMENTS IN CEYLON.

Experiments carried out in Ceylon strongly support the same conclusion, and the following are typical examples of the results obtained by Parkin :—

	Number of Incisions.		Area tapped.		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	..	30·0
	14	..	At 48 inches from base	..	14·0
	14	..	At 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 Malaya 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.

16 *High Tappings give* $3\frac{1}{5}$ *lb. Rubber.*

It is of considerable interest to note that though the rubber-yielding capacity of the cortex of the stem generally decreases from below upwards, the yield of rubber obtainable from the higher parts of single trees, similar to those at Henaratgoda, is sometimes surprisingly large. The following results show that as much as $3\frac{1}{5}$ lb. of rubber were obtained from *one* tree in 16 tapping operations at 10 to 20 feet.

Where tapped.	Number of times tapped.	Yield of Rubber per tree.
6 to 16 feet	16	2 lb. $5\frac{1}{16}$ oz.
10 to 20 feet	16	3 lb. 3 oz.
20 to 30 feet	16	2 lb. 6 oz.
Base to 30 feet	23	4 lb. 6 oz.
Base to 50 feet	8	1 lb. 10 oz.

Experiments at Singapore.

Ridley (Straits Bulletin, July, 1910) considers that tapping should be done from the base to a height of five feet. The richest latex is got from the part nearest to the base, and the amount of latex per incision is greater at that level. From the upper branches the weight of rubber obtained is much smaller, while in young trees the flow soon ceases. In recommending basal incisions for young trees, he further points out that there is quick renewal at the base and less distortion of the bark.

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 Haas in Java, by Arden in Malaya, as well as by native collectors in the Amazon valley. One critical observer (T.A., August, 1910) seems to doubt this, but does not give original results to support his view. It is on account of this that the idea of increasing the lower tapping area, by pruning the young plants and retaining a few of the basal shoots to grow into leaders in after years, has been recommended, for

Photo by Ivor Etherington.

TAPPING A 30-YEAR-OLD HEVEA IN CEYLON.

Photo by H. F. Macmillan.

TAPPING FROM BASE TO 50 FEET. TAPPING FROM 6 TO 16 FEET.

instead of one stem there would be two or three available for tapping. If only one stem is retained, it will show a large increase in circumference.

Yielding Capacity at Different Heights.

The yielding capacity of *Hevea brasiliensis* is influenced by its constitution and environmental conditions, and it may, at first, seem impossible to arrive at any reliable conclusions as to the rubber capacity per unit of cortical tissue. Dr. Tromp de Haas has determined the rubber-yielding value, under known conditions, per square metre of cortex for certain Hevea trees in Java. A large number of results will be required before anything definite can be asserted, and the following figures should be useful for comparison with those of other observers. The experiments were carried out at Henaratgoda between September 26th, 1905, and February 13th, 1906, on trees 15 to 20 years old. The original groove, about one-quarter of an inch wide, was made without obtaining rubber in quantity ; in subsequent operations the bark was removed by paring only when the yield of latex obtained by pricking the tubes was considered too small. The rubber was therefore obtained more by incising rather than excising the latex tubes.

Tapping Section.	Area excised in square inches.	Yield of Rubber. lb.	Yield of Rubber in ounces, per square foot of cortex removed.
Base to 5 and 6 ft.	7,348¼	47 5/16	14·8
6 to 16 feet	796½	4⅝	13·37
10 to 20 feet	1,472½	6 11/16	10·26
20 to 30 feet	1,424¾	4 11/16	7·58
Base to 30 feet	1,666	4⅜	6·05
Base to 50 feet	2,726	3¼	2·74

These experiments lead one to suggest that the first six feet of bark produce larger proportions of rubber, per unit of excised bark, than any other, and that there is a general decrease in the rubber-yielding capacity of the bark the higher one goes up the stem. In the above results one can discern a fairly regular agreement. Other results over larger surfaces agree, more or less, with the above, except that the average yield of rubber per square foot is sometimes higher from the stem between 6 to 16 feet than that here given.

The trees, on account of their age, had moderately thick bark, and the average yields per square foot are higher than those obtainable from younger trees. It is important to note that an average yield of over 13 ounces of rubber may be obtained per square foot of excised cortical tissue from the base up to 5 or 6 feet and from 6 to 16 feet from the base. In a fairly general way it may be stated that an increase in circumference of five inches gives an increase in the basal tapping area of 360 square inches.

High Tapping Results in Malay.

On the property of Highlands and Lowlands, 717 trees, probably about 10 years old, were tapped six feet above the former tapping, and yielded 1,160 lb. of rubber. The rubber was collected by 720 coolies, thus giving a return of 1·6 lb. per cooly during the three months—the period of the tapping referred to.

Results of Experiments Regarding Quality.

The following experimental tappings by Burgess (Straits Bulletin, May, 1904), indicate the quality of the rubber from different parts of the plants :—

Position of the Cut.	Nature of Cut.	Crude Rubber in Latex. %	Resin in the Crude Rubber. %
1. A large root exposed by removal of some soil.	Simple three-inch cut.	43·8	2·27
2. The main trunk 1-2 feet above the ground.	Herring-bone.	44·4	2·12
3. The trunk after forking 20 feet above ground.	Herring-bone.	39·8	1·88

"It will be noted that the latex from the higher portions of the trunk is, in the above experiments, poorer in rubber than the latex from lower down—at the same time the proportional amount of resin in the latex appears to decrease."

Burgess's results, so far as they apply to the resin content, do not agree with those obtained by Weber in the case of Castilloa rubber. The latter found that the percentage of resin increases as one passes to younger parts of the same tree. The percentages of resin were : trunk, 2·61 ; largest branches, 3·77 ; medium branches, 4·88 ; young branches, 5·86.

The latex obtained from areas twenty feet from the base, in Hevea, is often very sticky and may not yield good rubber, but this is by no means always the case. On some estates in the Ambalangoda, Kalutara, and Matale districts of Ceylon the old rubber trees are said to give latex of good quality from six feet upwards.

It has been previously pointed out that the cortex of the seedlings of *Hevea brasiliensis* and the cotyledons of the seed itself possess a large number of laticiferous channels, but the latex obtainable therefrom is usually very sticky and the dried product of low commercial value. Rubber prepared from two-year-old trees of *Hevea brasiliensis* is sticky and easily snaps when lightly stretched ; that from four-year-old trees or from stems which have a circumference of about twenty inches, though it does not possess the properties which manufacturers most desire, realizes a price which is, to the producers, satisfactory.

Tacky Rubber from First Tappings.

When a tree is tapped for the first time, though it may be 4 or 29 years old, the rubber obtained from the latex is apt to turn soft, sticky, or tacky, on keeping. This is, in all probability, primarily due to the large percentage of sap contents which exude from a proportionately large surface of fresh cortical cells. In subsequent tapping operations fewer cortical cells are excised and excess of sap constituents has had every chance to escape. Sap contents are usually rich in soluble food materials, notably sugar and mineral matter.

Occurrence of Non-coagulable Latex.

Ordinary tappings of medium-sized and old Hevea trees usually give good rubber when the tapping operations are carried out on the basal part (base to 5 or 6 feet); it is curious, however, to note that when the higher parts of even the oldest trees in the East are tapped the latex obtained often appears to be changed in constitution. The latex from high parts of very old trees is often very watery, and possesses a low percentage of caoutchouc; on treatment with the requisite quantity of acetic acid coagulation does not take place; even when allowed to stand for several days a curdled liquid only is obtained, the particles of which are not elastic and do not adhere to one another. The following results were obtained in Ceylon:—

Height of tapping area.	Number of times tapped.	Number of times when latex not coagulable.	Per cent. of tappings giving non-coagulable latex.
Base to 5 or 6 feet	1,165	9	0·77
„ 6 to 16 „	95	1	1·05
„ 10 to 20 „	94	1	1·06
„ 20 to 30 „	94	2	2·12
„ 30 feet	171	24	14·03
„ 50 „	84	5	5·95

The number of times when non-coagulable latex has been obtained from various sections of the stem of 29-year-old trees is given in the table; in considering them one should remember that the circumference of the stems at the highest points tapped was not less than 30 inches. It will be obvious that this phenomenon was most frequently observable in connection with the latex secured when tapping from the base to a height of 30 and 50 feet.

CHAPTER XII.

WHEN TO TAP.

In entering upon this subject, it must be borne in mind that there are three main points at issue. First, there is the question of the age and size of a tree when tapping operations may be commenced, and the frequency with which these operations may be repeated with an increase in age and girth. Second, the seasons in the various countries must be considered; for while most parts of Malaya have no marked seasons and tapping can be continued throughout the year, this is by no means the case in parts of India, Ceylon, and Java. Third, the interval between successive tapping operations must be determined in conjunction with many factors involving considerations of rate of growth, composition of latex, distance between tapping lines, and thickness of bark parings.

Importance of Age and Size.

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 than the wild ones in their native habitat, or that the collectors are less eager to commence tapping operations in the Amazon district than in the Middle-East.

Cross stated that in Parà 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 in the East such dimensions may be attained in four to six years.

Trimen, in 1884, believed that the trees in Ceylon should be ten years old before commencing tapping operations. Recent advances have shown, however, that five-year-old trees in that island can be economically tapped, especially if they have been grown in virgin forest clearings.

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. As a matter of fact, basal tapping is usually commenced when the trees have a girth of from 15 to 18 inches, and several tapping lines are worked on trees of the girth mentioned by Johnson.

RUBBER FROM YOUNG TREES.

If one studies the many analyses of Castilloa rubber quoted by Weber and the publications of the West Indian Botanic and Agricultural Departments, one cannot help being struck with the fact that the quality of the rubber from Castilloa trees depends, in almost every case, on the age of the trees. In some cases the rubber from old trees is shown to contain 82·6 per cent. of caoutchouc and 7·4 per cent of resin. The rubber from two-year-old Castilloa trees has been shown to contain 42·33 per cent. of resin as against 7·21 per cent. for eight-year-old trees. Decrease in resin content with increase in age is also characteristic of rubber from Ficus 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 per cent., the large branches 3·77 per cent., and the main trunk only 2·61 per cent. of resinous substances. If the rubber contains a very high percentage of resin, it is usually considered inferior, and is in some cases almost useless. Increase in age is certainly to be associated with an improvement in the physical properties and quality of the rubber, whether one considers plantations of different ages or parts of the same tree.

COMPOSITION OF HEVEA RUBBER FROM TREES OF DIFFERENT AGES.

	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 ,,
Proteins	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 ,,
Proteins	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%

YOUNG RUBBER FROM CEYLON.

The above analyses show (Bamber) the composition of Ceylon-grown Hevea 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 ordinary use.

Samples of plantation rubber from four-year-old trees were many years ago deprecated 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, while the value put upon them was only equal to that for "Congo ball or a similar quality of African."

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 Hevea in the East.

Young Rubber from Malaya.

Clayton Beadle and Stevens (I.R.J., Jan. 28th, 1911), state that "determinations carried out on trees about four years of age, and just brought into tapping, yielded in one series of experiments 22 to 25 per cent. and in another 27 to 33 per cent. of dry rubber in the latex. The trees were tapped every day and on different systems, but not heavily. The results are the average figures over periods of some months. The figures, taken in conjunction with others, where the trees were older, but tapped under similar conditions, show that the latex from very young trees is poorer in caoutchouc than that from older trees."

Their analyses of latex from four and ten-year-old trees were as follows:—

	Trees four years old. %	Trees ten years old. %
Water	70·00	60·00
Acetone extract (resin)	1·22	1·65
Protein	1·47	2·03
Ash	0·24	0·70
Caoutchouc (by difference)	27·07	35·62

These latices were also dried and examined:—

	Dried Latex from trees four years old. %	Dried Latex from trees ten years old. %
Acetone extract (resin)	4·06	4·13
Protein	4·90	5·08
Ash	0·80	1·75
Caoutchouc (by difference)	90·24	89·04

It was reported by Mr. E. B. Davis, director of the General Rubber Company, New York, to Mr. Maude of the Cicely estate, after a series of tests upon rubber from 4½, 5, 9, 10, 17, and 27-year-old trees, that the rubber from young trees is not materially different from that of older trees.

One manufacturer is reported (I.R.W., December, 1905) as saying that the rubber does not attain its full strength unt l the tree is at least 8 or 9 years old, and material from younger trees "has not the strength of hard-cure Madeira fine Para, and is uneven in strength." This inferiority is not seriously reflected in the prices paid for the produce. It is also asserted that there is no difference noticeable in the rubber from 8-year-old trees from different plantations, and that it is not safe to use it for the finest work, such as thread and the best bladders.

Stanley Arden has shown that in parts of Malaya the rubber from trees 3½ to 4 years old is decidedly inferior. His results have been quoted in the section dealing with yields in Malaya, 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 obtained only when the trees were about or over seven years old. He calculated that by the time the trees in Malaya are six years old, 75 per cent. should give an average yield of 12 ounces.

Recent events have nevertheless shown that the rubber from four-year-old Hevea trees in Malaya, if properly prepared, commands a very satisfactory price. Furthermore, a yield of one pound of dry rubber, per tree, has been obtained from a large number of trees in Selangor and elsewhere, before they attained their fifth year.

Age and Size Considered.

With regard to experience in Ceylon it should be pointed out that under favourable circumstances the Hevea 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 Hevea 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 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 Hevea rubber tree in Ceylon is such that a circumference of 18 inches cannot be attained much before the fourth, fifth, or sixth year, it is obvious that, under ordinary methods of cultivation, all ideas of extracting rubber from trees under these ages should not be encouraged.

Parkin suggests (Science Progress, April, 1910) that the inferiority of rubber from young stems and shoots may be associated with the fact that the latex is contained chiefly in tubes formed in primary growth. The latex, in young trees, will mingle with that from tubes formed during secondary growth.

Minimum Size for Tapping.

If the tree has a circumference of much less than 20 inches, systematic tapping cannot be recommended, because the available tapping area is so small; nevertheless, on several estates the trees having a circumference of only 15 to 18 inches are tapped. The production of new tissue is a strain on the young plant, and the thin bark tissues are quickly cut away long before the desired quantity of rubber has been obtained.

If the circumference is 20 inches a yard from the ground, and the tree is four years old, it can be tapped. I have seen good rubber from such trees. A tree 24 inches in circumference should not have more than five tapping lines. It could be tapped on the herring-bone system on one or both sides of the tree.

On one estate in Ceylon 41 trees of considerable height, but having a circumference of from 18 to 25 inches a yard from the ground gave with very light tapping during March and April 19½ lb. of dry rubber.

From the foregoing remarks it is clear that the questions of available tapping area and size cannot be neglected; they are as important as the ages of the trees. A minimum circumference of from 15 to 18 inches a yard from the ground, and a minimum age of 3 to 5 years can be accepted for most rubber properties, the better developed trees being tapped first.

It is generally conceded that the minimum girth at which tapping may commence in Malaya is 15 to 18 inches a yard from the ground, this being attained when the trees are about 3½ to 4 years old on good estates. In Ceylon, especially where the Hevea trees have been planted among old tea, or at high elevations in South India, East Java, and Ceylon, the trees may sometimes not attain this size until they are quite six or even seven years old. Tapping at the base under these circumstances is sometimes done when the trees are 15 and 16 inches girth a yard from the ground.

Minimum Percentage of Trees for Tapping.

While the minimum girth for the commencement of tapping operations in Malaya is agreed upon, there is still to be considered the important question of the percentage of trees on the estate which have attained the required circumference. Tapping cannot be economically carried out with only 30 per cent. of the trees of the tappable size. At a recent planters' conference in Malaya, Baxendale stated that if 65 per cent. of the trees had a girth of 18 inches tapping could be commenced. Duncan, while expressing his unwillingness to tap young trees, would not mind tapping trees with a minimum girth of 16 inches if 80 per cent. of the trees were of that size.

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 pruning the trees at a certain stage the plant may be made to increase in girth at the expense of the longitudinal growth; a very striking illustration of this is to be seen in the first clump of old Hevea rubber trees in the Henaratgoda Garden, Ceylon. The dimensions of forked and straight-stemmed trees on various estates in Ceylon have been previously given.

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 girths at 3 feet of some of the low-branched and straight-stemmed trees :—

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.
in.	in.	in.	in.
61, 65, 83, 85, 76	109	104	109

In all instances those trees which have forked near the ground have a much larger basal circumference. 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 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. Experiments have been made with young trees in their first and second years, and in each case the increased rate of circumference has been obtained in trees within the second year. In dealing with young plants it is an easy matter to nip off the terminal bud of the main stem, when the desired height has been obtained; this is usually followed by the development of lateral shoots, the growth of which should be encouraged according to circumstances. An increase in the number of lateral shoots means an ultimate increase in the foliage, and it is on this point that the success of the work depends. The pruning should be carried out in such a manner that the resultant plant has an increased quantity of foliage, whereby a larger food supply can be built up for the benefit of all parts of the tree. If the work is done in such a manner as to deprive the plant of its leaves for a long period of time, the growth of the stem will be temporarily checked, and the immediate increased rate of growth of the stem tissues cannot be expected.

The Best Season to Tap.

The trees of *Hevea brasiliensis* exhibit a definite foliar, flower and fruit periodicity; and though they will stand tapping throughout the year, it is questionable whether periodicity in tapping should not be done in association with that of the plant. The trees should be tapped at a time when the bark is most quickly renewed, in order that cortical tissues may be formed wherein new laticifers can be produced. The periodicity of the trees varies according to climatic and other factors, and the period including the fall of leaf, the leafless phase, and that of foliar renewal appears to be the most critical one. In most parts of the Straits Settlements, according to Ridley, from December to March is probably the resting or relatively inactive period, and the bark renewal during these months cannot take place as rapidly as during the rest o the year. One observer records that experiments on 17-year-old trees in Krian indicated a decrease in yield during the leafless period, and also during the fruiting period. On a large estate every planter is aware of the fact that it is impossible to entirely suspend tapping operations during any month of the year, but the above consideration should, whenever practicable, be allowed for. The periodicity in estate crops noticeable in March, 1911, was due to the effect of drought, and Malcolm Cumming stated that he would in future be prepared to advise that tapping be stopped during the dry period of foliar renewal.

Witt points out that in the Amazonas careful proprietors often suspend tapping during the fruiting period—August to September. The same principle appears to have actuated many planters who believe in stopping tapping when the trees are leafless, a period of some two or three weeks each year. The experiments which have been continuously carried on for some 18 months on 17-year-old trees at Krian show, according to Carruthers, a slight decrease of yield during the leafless period. The notion is also prevalent that tapping should be discontinued during the fruit-bearing period. The figures obtained at Krian show a decrease during the time the trees were in fruit, but not a decrease sufficient to seriously increase the cost of tapping.

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 Ridley's experiments at the Botanic Gardens, Singapore.

Tapping during Leaf-Change.

Ridley (Straits Bull., May, 1903), remarks: "Mr. Larkin, whose estate at Castlewood I have visited, told me that during the late dry month of March all his trees in one part of the estate shed their leaves simultaneously, and remained bare for a time. He continued to tap during this period and found no diminution in the amount of latex produced."

If yield is in relation to turgidity it should be largest when the trees are leafless, as they cannot then lose much water by transpiration; 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 they were 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 other rubber trees contains the highest percentage of caoutchouc during the dry season. The possession of abundance of latex during the dry season may lend support to the theory that it functions as a water-store during drought.

Tapping During Leaf-Change and Drought.

In many parts of the tropics, however, the leafless period occurs when rhe dryness and temperature of the air are at the maximum, and the collecting of latex would, during such a time, be limited to the very early part of the day and 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 effects the flow of latex, but though, under such conditions, the quantity is reduced, the quality is usually improved. The latex dries rapidly on the tree in hot, dry weather ; this can, however, be overcome by the use of ammonia, formalin, &c., placed in the drip-tins at the top of each incision.

Effect of Humidity on Yield.

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.

Dr. Haas, as a result of his experiments in Java, concludes that if the humidity of the soil is great, and if the rains are equally distributed, the difference in yield during the year is not great, and he further states that though the best times for tapping, in Java, are at the beginning and the end of the wet season, in wet years it does not matter when the trees are tapped.

Seasonal Tapping and Rainfall in Malaya.

At a conference of Malayan planters Baxendale stated that an average of nine pounds, per acre, per month, during the first three months' tapping of four old trees was the lowest yield he had experienced. While it may be asserted that a large and well-distributed rainfall is essential, the benefit is not always immediately apparent. He found the yield per cooly in the wettest month in one year considerably below the average. When the trees became very wet, the latex washed over the cuts and spread itself in such a fine layer down the bark, that it was most difficult to collect, even as scrap. This has not, however, any adverse effect on the yield. For two years his highest yields, not only by the cooly, but also by the acre, were in February and March, when wintering of the trees was general. Parkinson and Carey stated that they obtained their best yields in wet weather.

Experiments at Singapore.

In this connection some useful information was published by Messrs. H. N. Ridley and R. Derry (Straits Bull., Dec., 1904). These authorities state that the results show that there is much difference in the amount of rubber obtained from the same quantity of latex at different times of the year, at different times of the day (i.e., at morning and evening tappings), and from the same group of trees when they have had a sufficient interval of rest and when they have not. This is explained by stating that "although in over-tapping latex is renewed in the bark quickly, caoutchouc takes much longer to produce, though it does not seem in the worst cases ever to be entirely absent from the latex. Thus in a trial of the spiral method of tapping on the largest tree in the Botanical Garden they obtained from the first period of tapping 531 fluid oz. of latex giving 9 lb. of rubber, and from the second period of tapping, one month afterwards, 433 oz. of latex, giving only 4 lb. 15 oz. of rubber, the ratios of caoutchouc to latex comparing as $3\frac{11}{16}$ fluid ounces to one ounce dry rubber, as against $5\frac{7}{16}$ fluid oz. to the same amount of rubber. It is therefore of the greatest importance to the cultivator to avoid tapping at the wrong season when he is very liable to interfere with the special physiological processes in the trees then performing their functions. The bark of the tree does not recover as well from wounds during the resting period between December and March, nor does it appear that the return of caoutchouc is as good. Rapid and good renewal of the bark is very necessary, not only to protect the wound from injurious attacks of fungi, but also to increase the production of caoutchouc. Too frequent or prolonged tapping is not only injurious, but produces a latex inferior in quality.

Seasonal Results at Henaratgoda.

Regarding this question the results given below may be of value. The trees marked "H" were first tapped when the leaf-fall commenced, and the operations were continued through the period of leaf-fall and renewal. The trees marked "I" were tapped from the first of October right through the rainy and dry seasons; on a few days tapping was not carried out owing to inclement weather.

	Number of Times tapped.	Yield of Dry Rubber per 5 trees. lb.	oz.
Trees tapped every day from October 1, 1905 (I)	157 ..	38	$12\frac{5}{8}$
Trees tapped every day: first tapped on February 1, 1906 (H) ..	68 ..	13	$14\frac{5}{8}$

The tapping operations (I) were continued at Henaratgoda right through the dry months of January to April; towards the end of the latter month the flow of latex was not copious, and in some cases the coagulation, instead of being complete in 24 hours, required a period of nearly two days. The trees had been regularly tapped from September, 1905, to April, 1906, during which period they shed all their leaves and produced new foliage and also flowers.

On estates possessing rubber only it is difficult to see how the labour can be employed if tapping is suspended during the leafless stage or the dry months, and the point to determine is the maximum frequency that the trees can be tapped with the minimum damage to the tree during these months.

Further Seasonal Results at Henaratgoda.

The tapping experiments conducted at Henaratgoda from June, 1908, to February, 1911, by Bamber and Lock (Circular R.B.G., No. 18, Vol. V.), led them to, among others, the following conclusions :—

"There is a slight but definite seasonal variation in yield, which rises to a maximum about December, and falls to a minimum about May.

"Although climatic conditions have an undoubted effect upon yield, there is no close relation to be traced between rainfall and yield for particular months."

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 tapping may be continued up to 8 or 10 a.m., and re-commenced at 3 to 4 p.m. Wickham states that Hevea bleeds most freely at or before sunrise. All-night tapping is of course only possible when the artificial lighting of estates is more perfect than at present. The best times for tapping in Malaya are given by some planters at from 6.30 to 9.30 a.m. ; and by others at 5 to 10 a.m.

In the early and late 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 (Ann. Rep. Bot. Garden), 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.

Ridley also states (Ann. Rep. Bot. Gardens, for 1904) that the most favourable times for tapping are morning and evening. From the same number of trees which produced a total amount of 578 lb., the morning trees realized 314 lb., while the evening trees gave only 263 lb., showing a difference in favour of the morning tapping of 51 lb. Ridley and Derry concluded that evening tappings to be successful should be deferred to as late an hour as possible.

Later experiments at Singapore (Straits Bulletin, July, 1910) show a slightly higher balance than this in favour of morning tapping One lot of trees gave 110 lb. 15¼ oz. of dry rubber in the mornings and 90 lb. 2½ oz. in the evenings. Another gave 109 lb. 10½ oz. in the mornings and 85 lb. 14 oz. in the evenings.

Vernet (Jour. d'Agric. Tropicale, April, 1910) tapped three trees at Suoi Gaio, South Annam, and got the markedly different yields of 296 c.c. of latex in the mornings and 91 c.c. in the evenings. He asserts that constant great humidity reduces the difference.

On the Mergui Rubber Plantation, South India, tapping by the V method, it was found that morning tapping gave much better results than evening tapping. The figures for the whole season show the average quantity of latex per incision, each 6 inches in length, obtained in the morning to be 3·54 c.c. compared with 1·89 c.c. in the evening. Tapping in the rains was found to give almost double the amount of latex per incision, namely, 6·62 c.c., but the yield of dry rubber per 1,000 c.c. of latex was much less, being 12·8 oz. as compared with 16·4 oz. from morning tapping and 15·1 oz. from evening tapping before the rains. The best season for tapping was found to be from October to February.

Compass Tapping.

Several experiments have been carried out with the object of proving which is the best part of the tree to tap during morning and evening. It would appear that the tapping areas of the trees can be conveniently divided into four parts: one side to face north, the next south, and the other two east and west respectively. Each side can be tapped on a definite system, say once per day, twice per week, and so on. When the east side has to be tapped it is best to perform the operation in the afternoon or evening, and to tap the west side during the early part of the day; such a method, applicable to the east and west sides of the tree, prevents direct exposure of the tapping area to the sun's rays during working operations, and allows the flow of latex to continue for a slightly longer period of time.

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 in many cases have never been tapped before. Nevertheless, it is of interest to learn that in those districts Hevea is often tapped for 180 days each year without apparently doing very serious damage to the trees.

In Ceylon tapping every day throughout alternate months, or every day when moisture is abundant, or on alternate days throughout the year, has given good yields. Available returns show that alternate-day tapping is almost the rule on Ceylon estates.

Experiments in Ceylon on Frequency.

The following results of experiments at Henaratgoda are of value, as they show what yields have been obtained by tapping trees of similar age at varying intervals. The tapping operations were commenced in September, 1905, and ended in February, 1906, the full-spiral system being adopted in all cases quoted below, from the base to a height of five to six feet.

These results suggest that the average amount of rubber obtainable per tapping operation is likely to increase when an interval of one or more days is allowed between successive operations. They also indicate that the average yield, per tapping, is better when the trees are tapped every alternate day than when tapped once per day or once per week. At Singapore the yields obtained by tapping every day were better than those secured by tapping every alternate day. From a practical standpoint, however, the total quantity of rubber obtainable when the trees are judiciously tapped at regular intervals is of more importance than the deductions just made; the latter must not be construed as contradicting the accepted theory of wound response discussed elsewhere.

Frequency of Tapping.	Number of Times tapped.	Number of Trees.	Yield of Dry Rubber per five trees.		Yield of Rubber per tapping, per five trees.
			lb.	oz.	oz.
Every day	168	5	42	7⅛	4·0
Every alternate day	83	5	49	7⅞	9·5
Twice per week ..	57	25	14	0	4·0
Once per week ..	28	5	12	9⅛	7·7
Once per month ..	7	5	0	15⅝	2·1

The following table shows the results obtained in Ceylon by tapping trees at different periods during eleven months:—

Frequency of tapping.	Number of times tapped.	Number of trees.	Yield of dry rubber per tree.	
			lb.	oz.
Every day	270	5	11	0
Every alternate day ..	136	5	12	8
Twice per week ..	91	25	2	8
Once per week	44	5	3	13
Once per month ..	11	5	0	10

Alternate and Daily Tapping in Malaya.

Tapping every alternate day or every day appear to be the two frequencies adopted in Malaya. Some records show a better yield from tapping every alternate day, others show very little difference over a period of many months. Campbell (Malay Mail, May 3rd, 1910) stated that as a result of numerous experiments he had found that over a period of six months tapping on alternate days gave the best results in the first three months, but during the second three months tapping every day gave the bigger yield. An independent authority, after carrying out a lengthy research in Malay, states that in his opinion the alternate day system is better for a variety of reasons.

Frequency Experiments at Buitenzorg.

Haas, in his account of the experiments in Java (I.R.J., July 8th, 1911), stated that experiments were conducted on trees planted in 1904-5, and all the trees tapped had a minimum circumference of 18 in., 3 ft. above the soil. The results were based on one square metre of tapping surface, and showed that the largest quantity of rubber was collected from those trees which were tapped every day. He thought, however, the experiment should be conducted over a longer time before any decisive result could be obtained.

Tapping Frequency and Composition of Latex.

Clayton Beadle and Stevens (I.R.J., January 28th, 1911), have determined the composition of latex got by tapping trees of a known age every alternate day. They state that "the percentage of total solids and caoutchouc depends on the manner and frequency of tapping. For trees of an average age of seven or eight years, lightly tapped every other day, the total dry solids were found to be about 40 per cent. The specific gravity varied from 0·980 to 0·972. In another series of experiments where the same trees were more heavily tapped, the total dry solids were approximately 30 per cent. The total solids in the latex, other than caoutchouc, amount to about 2½ per cent. on the latex, so that by subtracting 2·5 from the figure for total dry solids, we obtain the approximate figure for caoutchouc. Of the samples examined, the highest figure for caoutchouc was 43 per cent., and the lowest 18·5 per cent."

Wound Response.

It has been stated that native collectors of Hevea rubber do not attempt to gather 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. It is certainly not advisable to make the first incision so deep that a good flow of latex is obtained at once; only small quantities of latex should be expected from the original incisions. The first cuts can be deepened as necessity determines in subsequent tapping operations. The flow to the injured part increases gradually, and may reach the maximum after three to fourteen tappings, after which it declines if the wound area is continuously tapped. The first reliable results were obtained in Ceylon, and as the "wound response" is now recognized as one of the most important principles in determining the frequency of tapping, the following digest of Parkin's results is given :—

Number of Tappings.	Number of Incisions.	Date of Tapping.	Yield of Latex in c.c.
1st tapping	40	March 25	61·0
2nd ,,	40	,, 30	105·5
3rd ,,	40	April 6	220·0
4th ,,	40	,, 12	208·5
5th ,,	40	,, 15	255·5
6th ,,	40	,, 20	290·0
7th ,,	40	,, 25	276·0
8th ,,	40	May 1	253·0
9th ,,	40	,, 6	264·5
10th ,,	40	,, 13	275·0
11th ,,	40	,, 20	255·0
12th ,,	40	,, 26	262·0
13th ,,	40	June 1	328·0
14th ,,	40	,, 6	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. Recent experiments in Ceylon do not show the same large increase as that originally obtained by Parkin. The wound response is not evident twelve hours after tapping, but within twenty-four to forty-eight hours it is decidedly obvious. In these results it will be observed that the quantities of rubber in the increased yields of latex are not given. This point has been cleared up in some recent Ceylon experiments.

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 was 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, to some extent, for the variation in yields from the same area. The tubes require a certain time to complete their formation, and for this reason 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 Singapore.

Ridley (Straits Bulletin, July, 1910) states that the increase in latex begins between the fifth and tenth tappings, and is accompanied by a fall in the percentage of rubber in the latex, though this is more than made up by the increase in quantity of the latex. He notes that in the case of some trees tapped daily and on alternate days at different periods, the increase in the latex began in both series of tappings after the sixth tapping, and yet this was after six days in one and twelve in the other. The increase in latex is usually exhibited in the second and subsequent periods of tappings after fewer tappings than in the first period. Ridley noted a change in the colour of the latex from yellow to white;

this is, according to him, comparable with the alteration in colour at seasons of heavy rainfall, due to excessive water in the latex.

Wound Response in Java and Trinidad.

In Java, Haas has proved that wound response occurs in the Hevea trees in that island. He also points out that an increase in the number of incisions increases the yield of rubber, but not in the same proportion, and states that an increase of 25 grammes of rubber per square metre of tapped surface is only obtained after more than doubling the number of incisions.

Hart (W.I. Bull., 1907), observed that a second and even third flow could be obtained from the same cuts if the rubber were allowed to dry for some hours in the cut and were then removed. That this should be held as wound response is a matter of doubt.

Explanation of Wound Response.

A satisfactory explanation of the phenomenon of wound response has not yet been propounded. It is commonly assumed that the increased flow of latex is due to the lowering of pressure in the area excised and to the consequent rush of water and other liquids in the direction of least pressure. On arrival at the excised area, the water and latex contents find that the laticifers opened the previous day have been closed by coagulated substances and, consequently, they accumulate in this area until the second incision is made. It has been suggested, but on what anatomical evidence it is not clear, that during the development of wound response the cut ends of the laticifers become swollen and assume a trumpet-like form. This is a point which can easily be settled by examination under the microscope. Parkin does not believe the increased flow to be due to the formation of new laticifers, and suggests that it may be caused by latex from adjoining areas flowing into and refilling the drained tubes.

Wound Response in 24 Hours.

Arden concluded from the following experiments that the length of time which should elapse before re-opening incisions need only be 24 hours, and that tapping every alternate day instead of daily was not always advisable. The following were his results :—

60 incisions	made on six consecutive days gave	$99\frac{1}{2}$	oz. wet rubber.
60 ,,	at intervals of two days ,,	111	,, ,,
60 ,,	,, ,, ,, one week ,,	$104\frac{3}{4}$	,, ,,

In the Peradeniya experiments, where the spiral system has been used, it has been noticed that the renewed cortical tissue becomes more or less convex in outline. 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 and Northway's pricking instrument gave abundant flows of latex.

Recent Ceylon Experiments.

A recent Peradeniya Circular, by Bamber and Lock, is of interest. The writers state that the experiments were designed with a view to ascertaining what differences, if any, exist in the quantity, composition, and properties of rubber latex drawn from the trees by tappings carried out at different intervals of time. They were made upon trees upwards of twenty years old at Henaratgoda. Seventy trees were chosen, in seven rows, such that the total circumference of the ten trees in each row was as nearly as possible the same. The plan of the experiment was to tap the trees of the first row every day, of the second every second day, and so on up to the seventh, which was tapped every seventh day.

In giving conclusions they emphasise the fact that the experiments were carried out upon trees which had not previously been tapped with any regularity, and which were beginning to show obvious signs of the ill effects of close planting. The principal conclusions are as follows :—

"Taking the first 40 tappings of each series, there is no sensible difference in yield which can be ascribed to the length of the interval between successive tappings. The yield from trees tapped daily and from trees tapped weekly is practically identical for the same number of tappings, both in the gross and in proportion to the area of bark tapped.

"During the first few tappings the rate of fall in the percentage of rubber contained in the latex is more or less inversely proportionate to the length of the interval between successive tappings, the fall being more rapid as the tappings succeed each other at shorter intervals. Sooner or later a nearly constant percentage composition of the latex is arrived at. This final percentage is lower in the case of trees tapped at short intervals than in the case of trees tapped at longer intervals.

"As might be expected from the less concentrated condition of the latex, the proportion of scrap rubber obtained is lower in the case of more frequent tappings.

"Mature trees tapped daily for eighteen months continue to afford a profitable yield of rubber. After yielding over 7 pounds of rubber per tree in this period, the average yield at the 440th tapping was at the rate of 4 pounds of dry rubber per tree annually. The general appearance of the trees at this time was quite healthy, and they showed no signs of having suffered from the severe tapping which they had undergone.

"It is apparent, therefore, that frequent tappings are to be recommended from a practical point of view so far as more yield is concerned, but the removal of bark is, of course, proportionately more rapid. On the quarter-system of tapping this is of less importance, and it still remains to be determined whether it would not pay better to tap daily during certain months and rest the trees, or only tap at two or more days' interval during the months when flow is less.''

In a later circular (Vol. V., No. 18), computations are given of the average annual crop, per acre, and the rate of the exhaustion of the original bark for the different rates of tapping :—

Frequency (days)	I.	II.	III.	IV.	V.	VI.	VII.
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Per acre	885	566	480	381	364	315	257
Bark exhausted in (years) ..	2¼	4	6	7	8	9	10

Resting Periods During Tapping.

Apart from the rest sometimes given during periods of leaf-shedding and fruiting, the question of refraining from tapping during certain months in the year has been considered. Such a system will, perhaps, be necessary in the event of labour being inadequate to tap each tree every alternate day. In parts of Bolivia the trees are tapped during a period of two years, and are then rested for a similar period. Other rubber trees are tapped for six years at a time and then left untouched for a like term.

In the report of the Director of Agriculture for Malay, 1908, reference is made to this point. On some estates, after a period of some weeks or months of tapping, 'a period of about equal length is allowed to elapse without tapping. On others, and the majority of places, tapping is continued without cessation, in some cases trees having without any reduction of yield been tapped for 3½ to 4 years every other day without cessation.

Carefully kept data on some Malayan estates show that after a period of some three months alternate days' tapping, the amount of latex per tree decreases to an amount which is of less value than the cost of tapping, but after a rest of two months the trees again on the fourth or fifth tapping yield the maximum, which, after some forty tappings, begin to rapidly decrease. The reverse of these observations is to be found on other estates where accurate figures of yields show that after continuous tapping for some two or three years, the amount obtained varies only slightly, never steadily decreasing. The variation is caused by climatic conditions, short periods of little or no rainfall reducing the yield, and periods of excessive rainfall producing somewhat the same results.

It is easy for the planters to determine when the yield of latex of rubber is showing a serious decline, and to modify accordingly the tapping system.

Fitting (page 47, English trans.) believes in resting periods, and suggests that it would be advantageous to tap for two or three months, then rest for one or two months, and subsequently re-commence tapping. He further recommends that when the first tapping period is over, the trees should be rested for five to six months. He does not, however, indicate the difficulty of organising the labour force to carry out work on these lines, neither does he prove the necessity for such long intervals.

Tapping Frequency and Bark Renewal in Malay.

It is obvious that the interval of time to be allowed before renewed bark is tapped will largely depend upon the depth to which the bark has been previously cut and also upon the rate of growth of the trees. Gallagher advocates a four-year-interval if the trees are planted closer than 24 by 24 feet; at this or a wider distance he suggests three years. Parkinson is reported to have declared that he considered two years as ample for bark renewal after the first tapping and three years thereafter. It is quite clear that most of the authorities quoted have been influenced, in advocating short periods for bark renewal, by the rapidity with which bark has been formed after the first or second cortical stripping. They do not appear to have considered that renewed bark cannot always be tapped as economically as the original, neither have they appreciated the fact that in the first few years the tree usually grows at its maximum rate on plantations. In future years, when trees are older and bark renewal is slower, the bad effect of rapid cortical stripping will assuredly be manifest.

Rate of Bark Renewal in Ceylon.

The rate at which the bark of tapped trees is renewed varies considerably. Generally the renewed bark forms at the most rapid rate on trees grown alone and at a wide distance from each other. It renews very slowly on closely-planted trees, and on those which have been planted in poor soil or where associated with intercrops. The bark does not renew quickly when the root growth of the trees is checked by the roots of other plants, and some surprising results may yet be recorded from estates with crowded mixed products.

On young trees the renewed bark is often bulging and convex in outline, and within a few months may attain the same thickness as the primary untapped bark. On older trees which have been deeply pared, a longer interval is required for the renewed bark to grow to the same thickness as the untapped areas. Thickness of renewed bark is, however, not the only criterion of maturity; often the cells in renewed bark are equal only in size, and not in contents, to those of the primary bark.

Measurements made in April, 1908, showed that on Gikiyanakanda estate, the renewed bark, on a nine-year-old tree grown on poor soil, was when three years old, $\frac{4}{16}$ to $\frac{5}{16}$ of an inch in thickness.

The following measurements were also made on an estate in the South of Ceylon, in April, 1908:—

	Age of renewed bark.	Thickness of renewed bark.	Height from ground of point of measurement.
Second renewed bark.. ..	2 months	$\frac{3}{8}$ inch	Base
Second renewed bark.. ..	15 ,,	$\frac{4}{8}$,,	$5\frac{1}{2}$ feet
First renewed bark	36 ,,	$\frac{5}{8}$,,	5 feet

These measurements were made on a tree, 14 years old, with a girth of 71 inches a yard from the ground. The remnants of primary bark above the tapping area had an average thickness of about $\frac{5}{8}''$, so that the renewed bark three years old appeared to be equal to the original. The tree has given 15 lb. of rubber in 4 years.

Another tree $4\frac{1}{2}$ years old, had its renewed bark $\frac{3}{16}''$ in thickness though only two months old ; this was nearly equal to the thickness of the primary bark above the tapping area.

The old Henaratgoda trees, measuring 68, 56, 29, and 18 inches a yard from the ground, had renewed bark about two years old measuring $\frac{5}{8}$, $\frac{4}{8}$, $\frac{3}{8}$, and $\frac{2}{8}$, of an inch respectively, in thickness.

The bark renews fairly rapidly on the majority of the trees, but the latex takes longer to mature.

When to Tap Renewed Bark.

There have been several attempts to reduce the interval between removing one bark and tapping its successor, which, in 1908, I suggested should be a minimum of three to four years. Carruthers, who was perhaps under the misapprehension that my deductions were based on Ceylon only, argued thus : "The time of four years has been arbitrarily fixed, and tapping schemes are arranged in relation to that period. That four years, three years, or two years are necessary for the formation of bark suitable for tapping cannot yet be definitely stated, but it is highly probable from isolated cases where such experiments have been made that four years is unnecessarily long. Experimental work and observations on tapping and yield of rubber made in Ceylon are unfortunately of little value for Malaya. The climate of Ceylon rubber districts, with its periods of dry weather, is not comparable with the condition in Malaya, where rubber trees are in active growth of root, leaf and other tissues practically every day of the year, and where, even when they are leafless, the growth of trees is not entirely stopped." While I admit that growth is slower in Ceylon and other countries where the soil is inferior, and the rubber trees are planted among other trees and shrubs, this only shows the necessity, to my mind, for a still longer interval to be allowed before renewed bark is tapped. It is better to remove too little than too much bark, especially in view of the fact that, with a few exceptions, only two—or at the most three—generations of bark viz., primary, secondary and tertiary—have so far been dealt with on Eastern estates. I am not at all sanguine that Hevea trees, even in Malaya, are going to present a healthy spectacle ten years hence if cortical stripping is permitted once every four years. It cannot be too strongly impressed on all planters and proprietors that the repeated removal of the bark always injures or weakens the tree, that few tropical trees have survived such treatment, and that the growing layer (cambium) is invariably damaged, sooner or later, Only on one occasion (T.A., June, 1909) have I noticed a futile attempt to persuade planters that it may not be necessary to preserve bark.

CHAPTER XIII.

HOW NOTABLE ESTATES ARE BEING TAPPED.

Having described how, where and when Hevea trees are tapped in various parts of the tropics, it will now be of interest to give some idea of the practices adopted on well-known estates in the East.

Early in 1911 I submitted blank forms to managers of rubber estates in the middle East, in which were set out certain questions relating to tapping methods and tapping knives. It has been impossible to use all the results obtained, but sufficient has been compiled to indicate the beliefs of planters in the various countries.

HOW MALAYAN ESTATES ARE BEING TAPPED.

The following table will serve to show tapping practices on some of the oldest, as well as on the youngest, estates in Malaya :—

	System of Tapping. Trees 3-5 years.	System of Tapping. Older Trees.	Distance between opening cuts Inches.	Frequency of Tapping.	Number of Cuts to Inch. Including Opening Cut.	Number of Cuts to Inch. Ordinary Paring.	Tapping knife Preferred.
Batu Caves	Basal Y	Full H.B.	12 lasts $1\frac{1}{3}$ years	Alternate	15	15-18	Double edged farrier's knife
Glenshiel ..	Basal V & half spiral	—	17	Daily		20-30	Farrier's knife
Seafield ..	Full H.B.	Full H.B,	12	Alternate	15-18	$15\frac{1}{4}$-$18\frac{1}{4}$	$\frac{5}{16}$"wry-necked gouge.
Bukit Rajah	—	Half H.B.	12-18	Alternate	—	—	—
Chersonese	Basal Y	Half H.B.	12-15	Daily	16-22		Single and double jebong
Jeram ..	Halt H.B. opp. quarters	—	18	Alternate	15	20-25	$\frac{1}{4}$"bent gouge.
Labu ..	1-2 single cuts opp. quarters	Half H.B., 2-3 cuts	18	Alternate	20-25	25	Farrier's knif
Banteng ..	1 or 2 V's	Multiple V's	15	Alternate	12	20	Jebong.
Sungei Krian	Basal Y	Half H.B.	15	Daily	35	42	Pull & push.
Bujang ..	Basal V	—	—	Daily	15	17	Double jebong or straight gouge.
Batak Rabit	Basal Y	—	—	Daily	20-22	26-28	Jebong.
Rubana ..	Basal Y	—	—	Daily	26	30	Farrier's knife

	System of Tapping. Trees 3-5 years.	System of Tapping. Older Trees.	Distance between opening cuts. Inches.	Frequency of Tapping.	Number of Cuts to Inch. Including Opening Cut.	Number of Cuts to Inch. Ordinary Paring.	Tapping knife Preferred.
Nova Scotia Estate ..	Basal Y	Basal Y	12	Daily	16-21	20-25	Jebong.
Gedong Estate ..	Basal Y & then half H.B., 2 cuts, opp. qrs.	—	15-18	Daily	20-30		Pull & push.
Bagan Serai	Do.	—	15-18	Daily	20-30		Pull & push.
Batu Tiga	Half H.B. opp. qrs. 3 cuts.	Half H.B. opp. qrs.	15, in young 18	Alternate	20 at most		Jebong.
Klabang ..	Single lines on quarters	Half H.B.	16	Daily	21	23	Jebong.
Bradwall ..	Single lines, half H.B. on quarters	—	12 for 10 months' tapping	Daily	25	26	Farrier and Pull & push.
Klanang ..	Basal Y, or full H.B. with 2 or 3 cuts	Half H.B.	Y and H.B., 18; ½ H.B., 12	Alternate	12-16	20-25	Estate-made knife like Farrier's.
Sungei Bahru ..	Half spiral & basal V.	Half H.B.	12	Daily	15	20-30	Gouge.
Sempah ..	Basal V	Half H.B.	15	Daily	18-24	20-30	Jebong
Pendamaran Estate ..	—	Double or treble V. over half tree	18	Alternate	26-30	30-34	Bent gouge.
Bukit Lintang ..	Basal V	Half H.B.	V's., 16, ½ H.B. 12	Daily	—	—	Gouge.
Batu Unjor Estate ..	Half spiral	Half H.B. opp. qrs., & high & low V's opp. sides	Half spiral 14, ½ H.B. 18	Young trees & half H.B. alternate, V's daily & alternate	Young, 25-30 old 18-25	Young, 28-33 old 21-28	Straight or bent gouge.
H. & L. Estate ..	Full H.B., half, H.B. opp. qrs., and half-spiral		Young 14, old, 18	Alternate	Young, 30, old 18-20	Young 35-40, old 20-25	Bent gouge.

(H.B. signifies herring-bone. H. & L. Signifies Highlands and Lowlands.)

Basal and Half-Herring-Bone Systems.

It will be observed that, for young trees 3 to 5 years old, the basal Y is the most popular system in vogue, though several estates prefer single tapping lines on opposite sides of the tree. The system most popular for older trees is the half-herring-bone. A few estates adopt the full herring-bone system, but none have advised the full-spiral system.

Distance Between Tapping Lines: 12 to 18 inches.

The distance between tapping lines depends upon the thickness of the bark shavings and the time interval allowed before tapping renewed bark. The estates mentioned appear to have a range of from 12 to 18 inches between parallel tapping lines. On the same estate, it will be observed, there is sometimes variation on this point.

Frequency of Tapping.

As might be anticipated from official results already published, and the rapid growth in most parts of Malaya, many managers prefer daily tapping. There are, however, quite a number who adopt alternate-day tapping, and in this category will be noticed some prominent companies already renowned for their careful management.

Number of Cuts per Inch.

The advance made in tapping operations is obvious from the figures given in this column. If we exclude the original incision, which must of necessity be somewhat wasteful, we find that the thickness of the bark shavings varies from 1-40th to 1-15th of an inch. In old-established companies, where tapping has been going on for a few years, the range is from 1-30th to 1-20th of an inch. This means that with daily tapping every inch of bark will last from twenty to thirty days, and double those periods when alternate-day tapping is adopted. This is a very satisfactory result.

Favourite Tapping Knives in Malaya.

It is remarkable that such fine bark parings can be recorded for a country which has never taken kindly to the numerous scientific tapping knives evolved mainly by Ceylon planters. The gouge, bent or straight; the Jebong, single or double; and the farrier's knife, appear to be the principal kinds used by managers in Malaya.

How Ceylon Estates are Being Tapped.

A comparison of the systems of tapping in Ceylon with those in Malaya will be almost as instructive as that of yields in both areas :—

Estate.	System of Tapping.		Distance between Tapping Lines.	Frequency of Tapping.	Number of Cuts per Inch.		Tapping Knife Preferred.
	Trees 3-5 Years.	Older Trees.			Including Opening Cut.	Ordinary Paring.	
Grand Central ..	Single lines	Fittings' system	15	Alternate	20	25	Ordinary gouge.

ESTATE.	System of Tapping. Trees 3-5 Years.	System of Tapping. Older Trees.	Distance between Tapping Lines.	Frequency of Tapping.	Number of Cuts per Inch. Including Opening Cut.	Number of Cuts per Inch. Ordinary Paring.	Tapping Knife Preferred.
Dimbula Valley ..	Inverted V and half-spiral	Half-spiral	15	Alternate	15		Sculfer.
Rayigam ..	Half H.B. on one-third sections		18	Alternate 1st six months. Daily at height of flow.	Average about 20		Barrydo, with Northway's improved for 1st cuts.
Narthupana Estate ..	Half-spiral		18	Alternate	18-20	20-25	Ordinary gouge or Michie-Golledge chisel.
Geragama Estate ..	Single lines on thirds	Full H.B.	15	Every 3rd day	12-14	16-18	Barrydo.
Pelmadulla Estate ..	Half-spiral	—	18	Alternate	18	22	Sculfer.
Lochnagar ..	Basal Y	Half H.B.	18	Alternate	Works out at 7		Barrydo.
Anonymous	2 cuts, spiral on thirds	3 cuts, spiral, on thirds	12 & 15	Alternate	16-22		Sculfer.
Penrith Estate ..	—	3 cuts, half-spiral	—	—	20	25	Barrydo.
Mahawale ..	2-3 cuts, single lines on thirds	Half-spiral	12	Alternate	12 ins. of bark lasts 12-14 months		Barrydo.
Matale Estate ..	—	Half H.B.	12	Alternate	23¾	30⅓	Barrydo or Sculfer
Old Haloya Estate ..	Basal Y	Full H.B.	18	Daily	18	16-17	Barrydo
Beddewelle Estate ..	—	Half H.B.	12	Alternate	16	15	Barrydo.
Suduganga Estate ..	—	Half H.B. & half-spiral	Young 18, old 15	Alternate	9-10	12-14	Barrydo or Sculfer.
Mudamana Estate ..	Single lines	Half H.B.	12	Alternate			
Ingoya Estate ..	1 cut, straight	Do.	15-18	Varies throughout year			
Mariawatte Estate ..	—	Do.	12	Alternate			

ESTATE.	System of Tapping. Trees 3-5 Years.	System of Tapping. Older Trees.	Distance between Tapping Lines.	Frequency of Tapping.	Number of Cuts per Inch. Including Opening Cut.	Number of Cuts per Inch. Ordinary Paring.	Tapping Knife Preferred.
Atgalle Estate ..	2 single lines, qrs.	Half H.B.	18	Alternate			
Dunedin Estate ..	Single lines	—	18	Alternate, daily in last 5 months			
Humbuswalana Estate ..	Single lines	—	18	Alternate			
Dewalakande Estate ..	—	½ H.B. on thirds	12	Alternate, proposed to tap daily in Nov. and Dec.			
Houpe Estate ..	—	—	12	Alternate			
Alluta ..	Basal Y	Half H.B. opp. quarters	12	Alternate	15	20	Barrydo.
Lavant ..	Basal V	Half-spiral, 3-5 cuts.	18	Alternate	20	25	Sculler.
Debatgama Estate ..	Quarter spiral						
Maousava Estate ..	Do.						
Muwankande Estate ..	½-spiral (small trees)	¼-spiral (large trees)					

Basal V and Other Systems Adopted.

Young trees in Ceylon have not, age for age, the same girth as those in Malaya, and even when old, the rate of growth of trees in Ceylon is comparatively slow. These factors must be borne in mind when the systems of tapping are being considered. In Ceylon the basal V or single lines running around half the base of the tree (half-spiral) appear to be favoured for young trees. For old trees the half and full herring-bone systems either on ⅓ or on opposite quarters of the tree are adopted. It would appear that the trees are not sufficiently large to permit of quarter-section tapping until they are considerably older than similar girthed trees in Malaya. The distance between the tapping lines varies from 12 to 18 inches, and in this respect there is similarity to the method adopted in Malaya.

Frequency of Tapping.

Whereas in Malaya the daily system appeared to be favoured by many managers, in Ceylon there is remarkable unanimity in the preference given to tapping every alternate day. This may perhaps be correlated with the rate of growth of the trees in Ceylon and a longer interval being necessary for the accumulation and concentration of latex and caoutchouc in tapped areas.

Number of Cuts per Inch.

The thickness of bark shavings does not, in Ceylon, come up to the standard in Malaya. An average thickness of 1-25th to 1-20th of an inch is evidently considered exceptionally good. This only proves that there is still much improvement possible. Perhaps the lower yields from tapped trees are capable of being associated with the thicker bark parings.

Complex Tapping Knives Favoured in Ceylon.

The ingenuity displayed by Ceylon planters is reflected in the selection of tapping knives made by the various companies mentioned. The "Barrydo" and "Sculfer" knives appear to be in great demand, and it is natural that these should have followed the "Bowman and Northway" knives. All of these knives were always noted for the economy in bark effected by their use, a point of considerable importance where rate of growth and thinness of primary bark have to be seriously dealt with. There is apparently no desire, even in Ceylon, to adopt knives which are adjustable by the cooly while working in the field.

Tapping Methods in Sumatra, Java, Borneo, South India, and Samoa.

Though the countries here considered are numerous, there is a similarity in methods which is striking.

	System of Tapping. Trees 3 to 5 Years.	Older Trees.	Distance between tapping lines	Frequency of tapping.	Number of Cuts per Inch. Including opening Cut.	Ordinary Paring.	Tapping Knife Preferred.
			SUMATRA.				
Serdang Central ..	Basal Y	Half H.B. opp. quarters	12	Alternate	20-22		Burgess knife.
Soengei Gerpa ..	Basal Y	Full H.B.	12	Daily	25	22	Bent gouge.
Bandar Sumatra	Basal Y	Half H.B.	12	Alternate	23	26	Burgess knife.
Bangoen Poerba ..	Half H.B. on half of tree 2-5 cuts.	Same, 4-5 cuts.	10	Alternate	20-25	25-30	Sculfer and Jebong.
Anglo-Sumatra ..	—	Full H.B.	14	Alternate	20-22	20-22	Straight and bent gouge.

	System of Tapping. Trees 3 to 5 Years.	Older Trees.	Distance between tapping lines.	Frequency of tapping.	Number of Cuts per Inch Including opening Cut.	Ordinary Paring.	Tapping Knife Preferred.
Sungei Roean ..	Basal Y, on 15″ girth	Half H.B. on larger trees	12	Daily	20	25	Jebong
Blankahan	Basal Y	Half H.B.	15	Alternate	24	26	Jebong.
			JAVA.				
Bantardawa	Basal Y	Half H.B. on opp. quarters	18	Alternate	12	18	Burgess.
			BORNEO.				
Sekong ..	Single lines	Half H.B.	12	Alternate	22	26	Farrier's knife.
			SOUTH INDIA				
Poonmudi	Fitting's system	—	12	Alternate	—	—	—
Vanguard Group ..	Basal Y	Half H.B. opp. quarters	12	Alternate	22	24	Barrydo.
Glenburn Group ..	Do.	Do.	12	Do.		11-16	Do.
Hawthorne Group ..	—	Do.	12	Do.	20-23	22-25	Farrier.
			SAMOA.				
Upolu ..	Basal Y	Multiple V's	12	Alternate	26	28	Rengam.

In these countries it will be noted that in systems of tapping the basal Y or V are adopted on young trees, and the half or full herring-bone systems on older trees. The quarter-section system, as in Malaya, also appears to be favoured.

The distance between the tapping lines is generally 12 inches, and alternate day tapping is usually adopted. The thickness of the bark parings being from 1-30th to 1-22nd of an inch, is creditable when one remembers that tapping has not been carried on for many years in these countries.

There is a greater variety of opinion as to the best tapping knife, though there is an obvious tendency to use only those knives which are simple in construction and are non-adjustable.

CHAPTER XIV.

EFFECTS OF TAPPING.

It is common knowledge that many excessive yields have been obtained by completely excising the whole of the bark from the base up to a height of 6 or 15 feet, and it is natural that some questions should be put forward as to the effect of such treatment on the plants.

At the outset it must be recognized that the great function of the cortical or bark tissues is to conduct the elaborated food materials produced in the leaves, *from above downwards*, to various sections of the growing plant, and also to store up, in certain of its cells, a quantity of food as reserve material. As a storehouse and conducting-channel the bark or cortex is of vital importance to the plant, and if it is removed too quickly the life of the tree may be endangered. The internal wood, though of great importance to the plant in conducting, *from below upwards*, the water and mineral food absorbed by the roots, is less vital than the cortex, and the internal portion may, to a certain extent, be dispensed with without very seriously injuring the tree. The cortical tissues are dependent for their renewal on the activity of the cambium—a delicate tissue separating the inner cortex from the wood—and in the natural course of events they gradually dry up near to the surface and peel off in the form of dead bark. The inner cortex, originally containing the latex tubes, is therefore ultimately cast off as dead bark, so that it may be said that cortical stripping, in tapping operations, is one way of expediting the removal of the bark tissues and may be effected without seriously disturbing the execution of the normal functions of the plants.

Effect of Repetitional Bark Stripping.

It must be obvious to every one that the stripping of the bark, as executed in tapping, is an unnatural process and not exactly comparable with the same phenomenon in nature. It differs from the natural process in so far that the cortical cells are excised while they are in a living condition, and are entirely removed at a time when they contain reserve food intended for the use of the plant. It also differs from the natural process in so far that the average operator exposes the inner, more delicate, and vital tissues of the cortex and cambium to atmospheric influences. Such treatment does affect the vigour of the trees, and if carried out too frequently may hasten the death of the plants. The complete stripping of the bark, *every year*, is most dangerous. The writer has seen many trees which are not thriving under such treatment; it can only be recommended in cases where thinning-out of the trees is desired. On many estates where the parallel spiral tapping lines are originally distanced twelve inches apart, the bark is excised at the rate of one inch per month, which means complete stripping in a year; on other properties an inch is made to last from two to four months.

Effect of Tapping on Plant Reserves.

In 1907, at the Society of Arts, London, attention was directed (Rubber Cultivation in the British Empire) to the length of time which the primary bark could be made to last, a maximum of six years being given. Emphasis was laid upon the danger attendant on the excising of the bark at a rapid rate when it possessed reserve food supplies intended to be of use to the plant. Rare instances of trees which had been killed by too frequent tapping were mentioned.

Fitting recommends the tapping of each quarter-section in one year, so that tapping on the renewed bark can be re-commenced at the beginning of the fifth year, thus allowing a clear interval for bark renewal of four years. But, while emphasizing the necessity of a four years' interval, he rightly suggests that (p. 48, Eng. trans.) re-commencement of tapping after four years should only be permitted if an investigation of the renewed bark proves that the wood and bark cells have been refilled with reserve material. He recognises what many others have not; viz., that tapping—removal of bark—results in the destruction of living matter, and thus confirms the views I enunciated in my Ceylon lectures in 1906 (Science of Para Rubber Cultivation). He showed that soon after tapping was commenced starch disappeared from those parts of the bark next to the cuts—above and below—and that time for its re-formation must be allowed if the minimum injury to the tree is aimed at.

Excision and Incision.

If the area is excised at such a rate that the whole of the bark, at the base, is removed in four years, the oldest renewed tissue, by the time it can again be tapped, may be considered near maturity and can be operated on with comparative safety. About four years is near the minimum time required for the young plants to produce what is considered mature bark, *i.e.*, fit for tapping. The suggestion for less rapid excising is made from a study of the observed effect on Hevea trees in Ceylon. It is a question whether, in some cases, it would not be better only to excise the bark tissues when fresh areas are required for the use of the pricking instrument. It is very doubtful whether the paring of the bark should be looked upon as the one and only operation required to obtain a flow of latex; it might, perhaps, be better regarded as a means of facilitating the collection of the latex obtainable by incising and not excising the milk tubes.

The effect of paring away the outer bark and exposing the internal and more delicate structures to atmospheric influences has in some cases already been detrimental. In a particular case in mind the inner tissues dried up and peeled off in flakes, exposing the whole of the wood. This effect is more noticeable on Ceara rubber trees, but is also known to occur on trees of *Hevea brasiliensis*. It has been suggested that a covering of some waterproof material or of any substance which, while affording protection from rain or sun, will not harbour insects, might be used to cover the tapping area or renewed bark when collecting operations have been completed. The covering might be arranged loosely in the form of a mantle or be wound round the oblique excised areas like an ordinary "puttie" for one's legs. This suggestion is one, however, not likely to evoke much sympathy among practical men.

Pricking and Paring in Ceylon in 1908.

I was surprised to observe the frequency with which trees were being pricked on the occasion of my visit to several well-known Kalutara estates in April, 1908. On two plantations, where previously only the paring operation was adopted, the pricking implement was used as soon as the flow following the paring operation had ceased. On another estate latex was never deliberately obtained by paring; every evening the coolies went round to collect the scrap coagulated in the tapping lines and gently used the paring knife to remove only the outer dead bark and expose a new area below for the pricker; on the following morning the pricker was used on this fresh area and the day's latex thereby obtained. By such a method great economy in bark is effected and the risks accompanying the deep paring method are obviated to a large extent.

The Northway System.

In 1909 Northway invented a new system of pricking. This was reported upon by Willis, then Director, Peradeniya Gardens, who gave the system his approval, stating that it was well suited to young trees. The advantages claimed were: simplicity in operation, quicker and earlier returns, and reduced cost. The system was taken up by many planters, but adverse criticisms were soon made. A reply to these was published (T.A., April, 1909), in which it was pointed out that: The chief indictment was that it encouraged the tapping of immature trees, and that, in consequence, during the next few years a large quantity of inferior or young rubber would be sent into the market from Ceylon. One important point forgotten by some of the critics was that it had not been claimed for the system that it increased the yield of the tree. What had been asserted was that it yielded the same amount of rubber in half the time and at half the cost. For instance, 58 mature trees in 24 days, by the new process, gave 55 lb. of dry rubber, whereas under the old system it took many more days, say, about 55, to secure that quantity of rubber.

The fact that the bark was not stripped was, of course, claimed as perhaps the greatest advantage of the new process. Under the new system not only were the resources of the tree which could be expended in bark-renewal conserved, but the cambium was protected by the bark remaining. Many objections were raised, and the system has, as far as one can judge, not been adopted by planters in Ceylon.

Bad Effects of Pricking.

Fitting, while acknowledging that the use of this implement has noteworthy advantages, states that the effect of the teeth of the pricker on the bark is bad. He found on microscopical examination of tapped areas that where the pricker had not been used, the bark cells were normal; but where used, the bark contained many stone-cells where the teeth of the pricker had penetrated to the cambium. Even when the cambium had not been pricked, the new bark had its laticifers irregularly distributed. He concluded that when the pricker was used, the new bark was uneven and took longer to form; and on these grounds he advised planters to abandon pricking implements. Another observer (T.A., Nov., 1910), states that the effect of the pricker on the cambium passes off after six months.

It may be accepted as true that the use of the pricker in the past has led to the formation of undesirable pimples or warts in the renewed bark. But the system cannot be condemned and dismissed in this manner. No one seems to lay due stress on the fact that in the ordinary paring methods wounds are invariably inflicted; these subsequently give rise to scars, which cannot be appropriately referred to as either warts or pimples but as ugly woody protrusions. Even on the best managed estates where paring only is adopted, one often finds large ugly patches of renewed bark which cannot be tapped with safety for many years, and must therefore be rested. Are these worse than the pimples caused by pricking? My view is that any system of tapping which minimises the loss of bark is deserving of the very best attention. The more rapidly the bark is excised the sooner the latex stores of the tree are depleted; the longer the bark is allowed to remain on the tree, within limits, the larger should be the yield of rubber therefrom. I do not think that the real value of a method such as that which has been expounded by Northway can be determined by scattered trials over a period of a few months. Carruthers pointed out that the prickers so far used have been instruments for making, not a puncture, but a short cut which does considerable damage. The perfect pricking knife has not yet been invented.

Furthermore, stress should be laid on the fact that the much-dreaded but harmless "stone cells" observed by Fitting, and elaborated upon by a few Ceylon enthusiasts, often occur abundantly in the primary cortex of seedlings and in the untapped bark of Hevea trees. These are indicated by Tabor, to whom

I am indebted for the illustrations depicting the anatomy of *Hevea brasiliensis*.

Effect of Tapping on the Periodicity of the Tree.

The treatment meted out to Hevea rubber trees may be said to be less drastic than that adopted in rapidly excising or peeling the bark and cortex off Cinchona trees, and not so rigorous as the cutting off of the stems of cinnamon bushes near the base in order to subsequently secure the dry peeling bark ; nevertheless, where latex extraction is inseparable from rapid cortical stripping, the processes remind one of those adopted, in the past, on many Cinchona plantations.

Then what are the probable effects on the trees which have been tapped in this manner ? It may be considered too early to form any definite conclusions, but what may be regarded as the early effects of extracting latex, and of cortical stripping, should be recorded.

The most striking effect, even on estates where there has been but little excision of the cortex and where the latex has been mainly obtained by the use of pricking instruments, is that on the foliar and other periodicities of the plant. Several tropical trees, even though they are growing in the same garden, often show considerable differences in foliar periodicity ; but untapped trees of *Hevea brasiliensis* growing under approximately the same physical conditions do not generally show very conspicuous differences, as the tabulated results, given elsewhere, have shown.

Tapping and Change in Foliar Periodicity.

Tapped tress do, however, show much variation ; the leafless phase of heavily tapped trees may be passed through during different months of the year. It has been shown elsewhere that the foliar periodicity of endemic, indigenous and even introduced trees in Ceylon is mainly determined by the humidity of the air and soil, the majority of the trees passing through their leafless phases during the period when least moisture is available. A change in foliar periodicity is coincident with changes in humidity, and it appears quite possible that the extraction of latex, involving the removal of almost half its weight in water may, from moisture changes alone, be partly responsible for some of the changes in foliar periodicity. If the change were only more general, this conclusion would be more justifiable. It is the constancy in all periodicities of some heavily tapped trees of *Hevea brasiliensis* which prevents one from making a definite statement on this point.

The changes in foliar periodicity, produced by deliberately mutilating parts of a tree, are only too well known ; probably much of the change in *Hevea brasiliensis* is due to the interruption in the work of the conducting and store cells of the cortex, rather than the removal of water in the latex. If this is the case, the interruption may lead to further irregularities, to a lessening of the vigour of the plant, and even hastening the decay or premature death of various parts.

Effect of Tapping on Seeds.

Reports have been frequently received to the effect that the size and number of the seeds produced have been reduced on some tapped trees, and in particular instances an increase in number of seeds per tree has been noted ; the latter is probably suggestive of more danger than the former. Some statistics appear to indicate that though the seeds from tapped trees are smaller, weigh less per 1,000 seeds, are denser and lose more weight in drying than those from untapped trees, yet they may give a greater percentage of seedlings and preserve their power of germination longer.

Effect of Tapping upon Growth.

Vernet (Journ. d'Agr. Trop., March, 1910), made periodical measurements of trees, one row of ten that had not been tapped for a year being situated between two rows of ten each that were being regularly tapped :—

	Average increase in girth.	
	Tapped trees.	Untapped trees.
	cm.	cm.
8th Sept., 1908, to 1st Jan., 1909	1.48	2.63
1st Jan., 1909, to 9th March, 1909	0.62	1.07
	[Tapping stopped.]	
9th March, 1909, to 21st July, 1909	3.10	1.98
	5.20	5.68

In face of the small number of trees upon which observations were made, the record does not stand for much, yet the result is what one would expect when the functions of a tree are interfered with.

In a recent Ceylon circular (No. 18, vol. V.) it is noted that the trees tapped most frequently showed the greatest increase in girth. This is almost certainly due to the more swollen and turgid condition of the renewed bark, a different matter from increase in growth.

I have recently had an opportunity of studying the growth of trees, tapped and not tapped, in Klang, Sumatra and Java. In every case the incremental growth of the tapped trees is less than that of untapped trees.

Frequent Tapping and Reduction in Yield of Rubber.

That too frequent tapping may lower the yield of rubber there can be no doubt. I have previously pointed out that results of experiments outlined to determine quite different points have shown a common agreement, in so far that, when tapping has been done too frequently or too extensively, the yield of rubber has been reduced, and the bark or source of future latex has gone. In some cases the poor yield from well-developed trees can be associated with the too rapid excising of the bark, and the sooner one realises that the bark is really the "mother of rubber," and that its rapid removal means a reduction in subsequent yields, the better for all concerned.

One might at first conclude that, since the Hevea trees rarely ever run absolutely dry, and most of them (no matter how roughly they have been handled) appear to contain an inexhaustible store of latex, the more frequently the trees are tapped the larger the quantity of rubber obtainable. In one series of experiments, which may or may not be exceptional, this idea was disproved. The trees in one area were tapped every day from September, 1905, and those in another group every alternate day from the same date. The trees which were tapped every day (on 264 occasions) gave about 9 lb. of dry rubber each, and all the original bark had been cut away; those trees which had been tapped every alternate day (on 131 occasions) gave about 11 lb. of dry rubber each, and half of the original bark still remained on the trees.

I inspected these trees in April, 1908 (about two years after the experiments) and was convinced that tapping every day was extremely dangerous and likely to materially affect the future life of the tree.

Tapping at less frequent intervals did not only give a higher yield of rubber per tree, within exactly the same period, but there was sufficient original bark remaining on each tree to last for another nine months. The labour expenses were reduced, the yield increased, and the trees less drastically treated by tapping every alternate day instead of every day. There is some ground for believing that, when incision of the latex tubes is made more perfect than at present, the interval between tapping operations may, with advantage, become still longer and yet be accompanied with a further increase in yield and saving of labour. In view of the enormous variation in the yielding capacity of bark, and the composition of the latex from the same area, it would be unwise to regard these results as being always possible; they are, however, worthy of consideration and may form a basis for further research.

Frequent Tapping and Lowering of Quality.

The inferiority of some samples of plantation rubber may be partly due to the caoutchouc and other constituents being immature. The quality of rubber from the same trees in Ceylon varies from time to time. The rubber from the first tappings is more apt to become soft and tacky than that procured some time later; that from the same trees may, when obtained during the first two or three months' tapping, be of excellent quality, but after a time the quality often deteriorates The deterioration in the rubber obtained after prolonged and repetitional tapping of primary bark, or in that secured from young renewed bark, can probably be accounted for by the changed physical and chemical composition of the latex. The latex obtained under these circumstances generally contains a lower percentage of caoutchouc and other ingredients, and seeing that in the renewed bark a large proportion of the constituents have arisen within a brief period of from three to four years, they can hardly be expected to have attained the same degree of maturity or strength as those in the primary bark of older trees. I am aware that many trees are first tapped when only four years old, but even then the whole of the bark is not affected until two or more years after tapping has been commenced. In the Brazilian and African forests the trees and vines are only tapped during certain seasons, and a long interval is allowed to elapse, which may be partly responsible for the characters of the rubber secured.

The variation in the characters of the components of latex is considerable, especially if one considers different aged parts of the same tree, latex often being abundant in the younger parts, but so constituted as to be uncoagulable. The association of the strength of the final product with the frequency of tapping should be borne in mind.

Reduction of Caoutchouc.

One of the most interesting demonstrations in connection with Hevea trees is the decrease in percentage of caoutchouc in the latex when tapping is too rapidly carried out. The yields on which the hopes of the future have been largely based have been obtained by tapping the original cortex. Success in the future depends, however, on the yields obtainable from renewed bark, formed after repeated excision of the original and succeeding tissues.

On some estates the cortical stripping round the whole of the tree has been effected in one year, and fair yields have been obtained from renewed cortical tissues which were only one year old. It has been demonstrated, however, that tapping young renewed bark is not advisable. Normal latex may possess about 50 to 60 per cent. of water, but that from renewed bark only one year old may under certain conditions possess as much as 90 per cent. of water and very little caoutchouc.

In the discussion following the lecture given by the writer at the Ceylon Rubber Exhibition it was pointed out that the percentage of the caoutchouc in latex might vary from 10 to 32, the latex from trees which had been too frequently tapped usually possessing a very large proportion of water. The caoutchouc is derived from compounds which have been identified in various parts of the plant, but as its production involves a complicated series of chemical changes, a certain time interval must be allowed for the accumulation of the globules and for a particular degree of concentration to be attained.

Ridley, in his Annual Report for 1906, states that in a trial of the spiral method of tapping, he obtained, from a tree in the Singapore Botanic Garden, from the first period of tapping 531 fluid ounces of latex giving 9 lb. of rubber, and from the second tapping, one month afterwards, 433 ounces of latex giving 4 lb. 15 oz. of rubber.

Recent experiments (T.A., Oct., 1910), in Ceylon indicated that during the first few tappings the rate of fall in percentage of rubber in latex was inversely proportional to the length of interval between the tappings. Sooner or later a nearly constant percentage composition of the latex is arrived at; this final percentage is lower in the case of trees tapped at short intervals.

Effect of Tapping in Java.

Dr. Tromp de Haas (Ann. Jard. Bot., 1910, p. 443), gives an account of his experiments to determine not only the effect of tapping, but that of the *method* of tapping on latex. The experiments were made on trees more than ten years old, two systems (*a*) Holloway's and (*b*) full herring-bone, being used. The following figures are given in the published results:—

Date.	Solid matter in 10 grammes of latex.	Ash	Composition of Solid Matter. Proteins	Caoutchouc	Resins
1907		%	%	%	%
4—IX.	5·4	1·25	0·4	90·0	5·82
6	5·1	0·80	0·4	——	——
12	5·0	0·80	0·4	92·4	4·15
18	4·7	0·90	0·3	90·8	6·04
26	3·6	1·00	0·4	90·7	5·66
3—X.	3·3	1·60	0·7	87·1	6·40
10	2·8	1·90	0·6	87·1	6·81
16	3·3	1·70	0·7	85·4	8·24
23	3·3	1·40	0·7	86·5	7·08
31	3·6	1·50	0·7	87·4	5·59

Tromp de Haas concludes that: (1) during tapping, the quantity of solid matter in the latex lessens; (2) the proportions of ash and proteins in the solid matter increases; (3) the method of tapping has an influence upon the composition of the latex. This last conclusion is based upon the following table:—

	Solid Matter in 10 grammes of latex.	Ash.	Composition of Solid Matter. Proteins.	Caoutchouc.	Resins
	grammes.	%	%	%	%
Holloway method ..	43·66	1·1	0·555	90·266	5·1
Full herring-bone ..	35·95	1·35	0·628	89·174	5·7

Abnormal Latex from Ceylon.

Messrs. Schidrowitz and Kaye have pointed out, in the "India-Rubber Journal" of July 1st., 1907, that in a sample of *Hevea brasiliensis* latex from Ceylon "the amount of rubber contained was abnormally small. The weight of the crude rubber present in 750 cc. of latex, after pressing, amounted to only 35 grams, of roughly 4·6 per cent. Allowing for moisture, this would mean that the latex in question contained barely 4 per cent. of dry rubber. The latex, it may be said, was obtained from the primary bark of a five-year-old tree, tapped in a normal manner, and we are not in a position to offer an explanation of the exceedingly low caoutchouc contents." They do not state, however, what quantity of liquid was added when the latex was first bottled in Ceylon.

Stevens, following on this point, states (I.R.J., July 15th, 1907), that he also has made "some tests with separate quantities of latex from Ceylon, to which small quantities of preservatives had been added. In these cases only small yields of caoutchouc were obtained."

"The latex was obtained from trees 6 and 7 years old, and represents either the first or second year's tappings. The contents of the different bottles did not represent the same mixture of latices, but were filled up from different trees as the latex came to hand. I am given to understand that no water was at any time added to the latex." The preservatives added were "cyllin," formalin, a salt of mercury, and chloroform, and the yield of moist caoutchouc in separate samples was 8·4, 8·8, 9·2, 10·0, 8·6, 10·0, 9·7, and 13·5 per cent.

"When allowance is made for the moisture, which is probably not less than 10 per cent., it will be seen that with one exception the yields were in all cases less than 10 per cent. reckoned on the original latex." In these instances, the latices examined by Messrs. Schidrowitz, Kaye and Stevens, do not appear to have been derived from any specially tapped trees, and may indicate the variability of the composition of the latex rather than the effect of excessive tapping.

CHAPTER XV.

TAPPING AND YIELDS IN THE AMAZON REGION.

In the rational treatment and tapping of the trees, the Amazon has been decidedly outpaced by the Middle-East. Since the beginning of the crude rubber industry improvements in Amazon methods have been few; they consist of little more than a lightening of the head of the tapping axe, and the replacing of the older system of gathering latex in a gutter at the base from numerous cuts by the modern cup method. General adoption of up-to-date methods cannot be expected, for each collector disappears daily on his tapping round out of the range of proper supervision. Yet it must not be assumed that chaos rules in tapping operations. The main principles of the modern system, such as it is, are generally followed, and tradition with experience guide all except the unscrupulous, or those beyond any control. When a proprietor leases his concession, he has to face the possibility of tapping being carried on in a fashion that he resents, but cannot prevent; and even when he partially superintends the exploitation, his control over the collectors, who are paid by results, is not so complete as is desirable.

When Tapping is Done.

The time for tapping, in the Amazon region, is in the early morning, beginning at daybreak. Some reasons for this are the same as those ruling in the Middle-East; an additional advantage is that the latex may be collected before the commencement of the frequently-recurring rains of the afternoon. Interference by sun and rain is sometimes avoided by tapping towards nightfall and gathering in the morning. Under ordinary circumstances, breakfast follows the tapping round, and after this interval the latex is collected; immediately after returning the collector begins to smoke the latex. Vice-Consul Temple understood that tapping ended at 9 o'clock; that collecting began at 10 and finished at 1 o'clock; and that smoking ended at 2 or 2.30 p.m. Dunleavy, who accompanied a Bolivian collector upon his round, stated that tapping began at 5.15 a.m. and ended at 10, that collecting went on until 3 o'clock, after which the smoking. Of course the time taken per tree in tapping varies largely. Cibot found that on a Bolivian estrada, fixing from 450 to 500 cups and tapping 150 trees along a path of from 4 to 5 kilometers (2·5 to 3·1 miles) long took from 4 to 5 hours; that is from 1 minute, 36 seconds, to 2 minutes for each tree. On a Rio Negro estrada, according to Bonnechaux, the time averaged one minute.

The Tapping Implement and Size of Cut.

The small-headed, long-handled tapping-axe strongly resembles a tomahawk. Small-headed as it has always been, the tendency in the more accessible regions has been to lessen its cutting-edge, which now averages about one inch in length.

A slanting blow is struck upwards and obliquely. Ule saw the axe, after striking, bent outwards to open the wound and so accelerate the flow. With the smaller axes the length of the cut seems to be about one inch. As regards the depth of the cut, Cross asserted that it was about one inch, and always went into the wood; but the recent practice is more rational now that the danger of cutting deep is well understood. Sandmann mentions a belief held in some quarters that cutting deeply into the wood yields more latex. By Le Cointe it is stated that the cuts are from 5 to 10 mm. (1-5th to 2-5th inches) in depth; Warburg also found that cuts were made down to 10 mm., which he thought was too deep. Vice-Consul Temple's estimate of the thickness of the bark was $\frac{3}{8}$ of an inch.

Effects of Tapping.

As a result of the ill-treatment the trees sometimes receive the tapping area may take on an abnormal and uneven growth, large bosses developing. There is a photograph extant which shows a tree with its tapping area about three times the diameter of the untapped part. Such trees become unproductive for many years, the most severely inflicted blows failing to produce latex except in very small quantities.

Isolated mention is made of attempts to lessen the dangers, at the incised areas, from disease and insect attack. Some collectors carry clay with them to protect the more brutally-made incisions, or even to fill up every incision after the scrap has been pulled off. Pearson met collectors who refused to pick the scrap; they preferred leaving it in the cuts as a protection to the wounded area.

Method of Collecting the Latex.

The older method of collecting the latex is still followed in the more remote regions. The principle is to allow the latex from all the cuts, of which many are made at a time, to run down the bark, previously cleaned and smoothed, into a sloping gutter encircling the whole or only half of the tree's base, and from this into a calabash or other receptacle. In the newer method, a cup is placed below each incision. The cups are of tin, frequently with flat or concave sides for fitting to the trunk; they seem to have supplanted entirely, or nearly so, the older clay cups, shells and bamboo tubes. Their capacity is from $3\frac{1}{2}$ to 7 fluid ounces. A common practice, in fastening the cup to the trunk, is to use clay as a cement, and partly as a conducting channel; in some cases, however, the edges of the cups are pressed into the bark; this was done on Eastern plantations a few years ago.

Method of Tapping.

The carefully-planned excision methods followed in the East are practically unknown in Brazil. Though in 1872 Collins mentioned the full herring-bone system, only isolated and casual trials of the newer or Eastern methods are heard of. It is noteworthy that Dunleavy tried the drastic full-spiral method in Bolivia, and got yields largely exceeding those obtained by the incision method.

At each tapping, cuts are made around the trunk at one level, and at equal distances from one another. A method probably rare is that of arranging the cuts in pairs to form V's. The first ring of cuts is sometimes made at the highest level attainable, and at the next tapping the same number of cuts directly below, and so on until the base is approached. (In some cases the first incisions are made at the base; in other instances at the top and bottom simultaneously.) Later on, a second series is begun at the top, maybe at the side of the first series, or midway between the first and second rows of the first series. These principles are followed to the end of the tapping period, and season after season, for so long as is possible; in course of time, if scarring arises, incisions have to be made where a flow of latex seems likely to be obtained.

High tapping with the help of scaffolding goes on when the bases of the trees are badly scarred. This was noted in Brazil by Ule, Sandmann, Temple, and Pearson, and in Peru by Eberhardt.

The Number of Cuts Made.

Among the numerous accounts of tapping operations on the Amazon, there is not one that is complete, and it is therefore extremely difficult to accurately assess the actual strain imposed upon the trees. Such a detail as the distances apart of the cuts at the end of the season is rarely given, and the tapping history season after season by the same observer is seldom available. It will be noted below how often information on other important points is lacking; for this reason alone many accounts are here omitted, and others are not recorded because they are not reliable.

Upon estradas of 120 to 180 trees, Le Cointe observed that from 500 to 600 cups were needed, each representing a cut made daily. The first incisions were made 35 or 40 cm. (14 to 16 inches) apart, and each day's incisions were 6 cm. (2·4 inches) below the previous day's cuts. After the base was reached, a new series was begun alongside the first and at a level midway between the first and second rings in the first series. Six series might thus be made, so that at the end of the season the incisions would be at a horizontal distance from one another of about 2½ inches. Sandmann found that the first cuts were 44 cm. (7½ inches) apart, those of the next day's being 5 to 7 cm. (2 to 2¾ inches) lower. Tapping was begun at a height of 2 metres (6½ feet), and the ground was reached in 35 tapping days, when a new series was begun at the top about two spans to the side. He remarks that some collectors, against the will of the proprietor, cut three such series. Other statements are still less complete. Warburg asserted that the horizontal distance between the cuts made each day was from 10 to 20 cm. (4 to 7½ inches), and the vertical distance between the successive tappings 20 to 30 cm. (7½ to 11½ inches). Witt's estimate of these distances was 1 to 2 feet for the horizontal and 4 inches for the vertical. The estimate made by Cross—4 to 5 inches apart and 6 inches vertical distance—is forty years old. It is clear from the above that where the horizontal distance is great, the vertical is usually small. Bonnechaux claimed that a vigorous tree, say, 50 cm. in diameter (computed girth about 60 inches), bears 4 cups 10 cm. (nearly 4 inches) apart, though there are rarely more than 5 cups even when the diameter is 1 metre (girth 12½ feet). Clough, who spent some years on the Rio Purus, considered that a tree 12 inches in diameter (girth 38 inches) would carry 6 cups. These details have reference to Brazilian practices; there are few accounts available concerning the upper waters of the Amazon in Bolivia and Peru.

Number of Cuts in Bolivia and Peru.

On the Rio Beni, in Bolivia, Cibot frequently found a distance of 40 cm. (about 16 inches) between the incisions, the tapping being started at a height of 2·50 metres (8 feet); with 45 tapping days before the base of the tree was reached the vertical distance must have been about 2 inches. In 180 tapping days four vertical series would thus be carried down the trunk. During the second year new cuts were made alongside those of the first year. In the third and fourth years the cuts were, in level, between the rings of the first and second years. Then the tree was rested for 5 to 6 years to allow wounds to heal.

The only information on this point regarding Peru is contained in such meagre statements as that of Eberhardt, who found trees carrying three to nine cups, and recorded that a new series of incisions was begun each month at the top.

Number of Trees in an Estrada.

The range in number of trees in a tapping round or estrada is considerable; it is dependent upon their spacing and sizes, the diligence and dexterity of the collector, and also upon whether or not the collector receives any help in placing or emptying the cups, or in scrapping, from members of his family or others. While the number of trees generally ranges between 50 and 200 (except on the Rio Negro and in Bolivia, where the numbers may be higher and the species other than *Hevea brasiliensis*), the average is probably between 120 and 130. Ballivian has drawn a plan of a concession in Peru with the following numbers of trees shown for each estrada: 103, 115, 106, 107, 100, 98, 102, 130, 120, 100, 110, 95, 115, 98, 100, 106, 120, 108, 150, 120, 160, 120, 130, 132, 110, 100, 105, 100, 108, 100. An estrada is arranged so that the tapping round ends near to the beginning; there may be short paths from the main path to exploitable trees.

Distances between the Trees.

Some attempts have been made to find out the distances between the trees in an estrada. Cross gave an estimate of from 10 to 100 yards. Bonnechaux paced the distances upon a Rio Negro estrada, and got an average of 44 paces. In Bolivia, upon the estradas that Cibot personally supervised, the mean distance was 30 metres (32·8 yards). In Peru, on the Madre de Dios, Plane found an average of 33 metres (36 yards); and on the Vista Alegre, a branch of the Madeira, 100 trees were stretched along a path measuring 4,650 paces, say 3,487 metres (3,811 yards), that is, an average of 38 yards between the trees.

How many trees there are per acre is a question that cannot be answered even by the adoption of wide limits, very few estimates having been made and these on only a few acres. Wickham, who was in the Tapajos region, says that six or seven trees, per acre, was the maximum; he doubts very much whether a single square mile of forest exists with 1,500 Hevea trees (equivalent to about five trees per two acres). On the Lower Amazon, according to Sandmann, 120 trees occupy 4 hectares; this is equal to 11 trees per acre. Cibot estimated that an estrada in Bolivia occupied from 5 to 15 hectares ($12\frac{1}{2}$ to 37 acres), there being from 10 to 20 trees per hectare, or from 4 to 6 to the acre.

The Girths of Tapped Trees.

Such details of measurements of the exploited trees as are at hand shew that on the Amazon the trees are generally allowed to attain a greater size before being tapped than is the case in the Middle-East. Of course, the reason is that it does not pay, where trees are so scattered, to include young ones in the tapping round. The diameters of the trees in an estrada situated upon a tributary of the Rio Negro were measured by Bonnechaux, who classified the trees into groups. The average girths given in the following table have been calculated from the average diameters. The height at which the measurements were taken is not recorded:—

Average girth. ins.	No. of trees.	Average girth. ins.	No. of trees.	Average girth. ins.	No. of trees.	Average girth. ins.	No. of trees.
$23\frac{3}{4}$	3	$49\frac{1}{2}$	38	$74\frac{1}{4}$	14	99	6
31	8	$55\frac{3}{4}$	14	$80\frac{1}{2}$	2	$111\frac{1}{2}$	1
$37\frac{1}{4}$	8	62	26	$86\frac{3}{4}$	8	124	1
$43\frac{1}{2}$	22	68	5	93	3		

The lowest of these calculated average girths does not differ very much from Cross's estimate of 18 or 24 inches at 3 feet from the base as the minimum girth for tapping. Sandmann states that the average girth of the Hevea trees in an estrada upon the Lower Amazon was 43 inches. The largest trees recorded, from 10 to 12 feet in girth, seem to have been those found by Wickham. The above statistics refer to trees in Brazilian estradas.

In Bolivia, Cibot found trees below 0·25 metres diameter (a girth of 31 inches) and as large as 5 metres in girth (198 inches).

Upon a Peruvian estrada, the diameter of the trees, according to Plane, ranged between 20 cm. and 1·30 metres (equivalent to a girth of between 25 and 162 inches).

The Minimum Age for Tapping.

Various second-hand statements are available respecting the minimum age, in the Amazon Valley, for tapping. An official Brazilian publication states that trees can be tapped successfully from the tenth year, sometimes from the sixth. From 10 to 15 years in partially-cleared forest, and from 25 to 30 years in the uncleared, were the limits reported by Pearson. Von Dionant understood that tapping operations could be commenced 10 years after the second flowering of the tree.

Duration of the Tapping Season.

In Brazil the tapping season is largely determined by the rainy season. The areas close to the streams are, in the rainy period, submerged and cannot be exploited, though, where it is possible, the collectors may wade in waist-high. The heavy rains may interfere too much with the flow of the latex and dilute it so much that it is very difficult to coagulate. Even the difficulties of transport during the dry season encourage periodicity in tapping. Yet, taking Brazil as a whole, tapping is going on throughout the year, for the end and the beginning of the season vary in different parts ; April is given as the first month for tapping in certain regions and March as the final month in others. Over and above this it must be understood that tapping may occasionally be possible in the rainy season except in flooded areas. The beginning of the season ranges, according to the district, from April to September, and the end from September to March. Its length is from 5 to 9 months.

Of the various accounts of the length of the season published, only some of the most reliable are here given. An official publication records that the season lasts from May to January, with May and September as the best period ; and another official publication records it as lasting from April to September in Matto Grosso. Ule believes that the season lasts six months, at the most eight months, beginning in May or June and ending in January or February ; leaving out Sundays, saint days, and rainy days, about 120 working days remain. Bonnechaux visited the Rio Negro, where the season extends from July to February, the number of tapping days out of the 200 to 250 possible being 100 only. In his lecture at the Rubber Exhibition of 1908, Witt mentioned that on the higher parts of the river tapping is begun in May, but in other parts, as in Amazonas, in July or August. The working days are from 90 to 120.

In Peru, according to Sperber, tapping is not engaged in during the leaf-change from July to September ; it is begun in October and lasts until the end of December. The rains from January to March interrupt tapping, but it is recommenced in April and goes on until the end of June.

In Bolivia, Pearson understands that there are two tapping periods : from April to July, and from October to March, the trees being tapped for three months in each year and then rested. But this is said to refer to the species producing "mollendo" rubber.

Tapping Frequency.

Alternate-day tapping is most frequently mentioned in the accounts of rubber harvesting on the Amazon ; the opinion is frequently expressed that daily tapping does not give paying yields. The principle adopted in alternate-day tapping is to have one collector to two estradas which are tapped in turn. Where a collector works three estradas in turn—mentioned by only two writers—more numerous incisions are made and therefore a heavier strain is imposed upon the trees.

Ule records that on the Madeira daily tapping is carried on, while on the Jurua and Purus two estradas are tapped alternately.

Wound Response on the Amazon.

After wound response had been demonstrated in the Middle-East, some Brazilians passing through Singapore informed Ridley that this phenomenon was familiar to them. In his account of Brazilian rubber-collecting, Sandmann states that every tree is first struck with a long-handled tapping axe at about $3\frac{1}{2}$ metres (12 feet) from the ground, the belief being that this stimulates the flow of latex. Two days later regular tapping commences at the usual height. Two observers note that the flow of latex from the first incisions is small.

Resting of the Trees.

There are a few references to the practice of suspending tapping operations upon a tree for one or more seasons. Pearson records that trees are often rested for a year. Temple was informed that if an exhausted tree was allowed to rest for three or four years, it completely recovered and could be worked again. A writer in the "India-Rubber Journal" stated that in Bolivia the trees were sometimes tapped for two years and then rested for the same period, while others were tapped for six years and rested for six. The statement of Cibot that in the same country the trees were tapped for four years and rested for five or six has already been referred to.

How far the practice of resting the trees is adopted it is quite impossible to learn. It would appear that in course of time the tendency is for the trees to become unproductive through the development of scars. but how long a period this takes must naturally vary greatly. Productiveness after 50 and even 80 years of tapping has been recorded, but one would like to be assured of the reliability of the age determination before finally accepting this statement.

Collection of the Latex.

There is not much to be gained by describing the operation of collecting latex in the Amazon. The flow is said to end in from one to three hours, so that collection may be begun immediately after breakfast. The collecting vessels most favoured at one time appear to have been calabashes or earthenware vessels suspended in plaited work; tin vessels, including the ubiquitous kerosene can, are also now common. Their capacities range, according to the few records available, approximately from 1 to 4 gallons. When emptied, the collecting cups are hung upon branches or sticks, or are placed upside down at the base of the tree. A bag is sometimes carried for holding the scrap; at other times the scrap is stuck upon the edge of the collecting vessel.

The Method of Coagulation.

The method of coagulation has often been described. A wood fire is started in a small oven, and is fed in part with the nuts of certain palms, when these are available. A dense smoke arises, which is directed to one point by placing a metal cone, or chatty, open at both ends, over the fire. The latex having been poured into a shallow open vessel, a paddle-like instrument is dipped into it or some is poured over with a dipping can. Excess of latex is allowed to drip off, and the paddle is held over the smoke, first one side and then the other, two or three circular passes being made each time. Another method is to use a pole, one end of which is supported from the roof or upon a crosspiece, instead of the paddle; the latex is poured over the middle of it, and a large ball of rubber is ultimately made. The formation of a ball may go on for days. Properly prepared balls constitute the "fine hard Para" of commerce; when the rubber is found, on opening, to be imperfectly coagulated, it is classed as "entre-fine," or medium. Scrap rubber taken from the trees and from the ground, and rubber that has coagulated in the cups or otherwise before smoking, is dipped into latex and worked up into chunks, forming "sernamby," "coarse," or "negroheads." Newly-coagulated rubber is very wet, and water drips from it for some days. The proportions of the three grades exported from Brazil are approximately: fine, 62 per cent.; entrefine, 10 per cent.; and sernamby, 28 per cent.

Considerations Affecting Amazonian Yields.

To the planter in the Middle-East, the amount of rubber got from *Hevea brasiliensis* in its native country is a matter of interest, but it is impossible to make other than an approximate estimate. The numerous statements of yield that are available differ very decidedly. They may concern concessions newly opened or others that have been worked to the full for many years. Differences in yield may be expected according to soil and other natural conditions. The collectors vary in diligence, and individually and racially in skill, while dishonesty leads to adulteration and to sales of the rubber to pirates, the latter factor rendering estimates made from the books of estates unreliable. Trees may be tapped daily, on alternate days, sometimes only every three days; the tapping season varies in length; and otherwise there are differences in the strain that is imposed upon the trees. The crop reported is perhaps of wet, newly-coagulated rubber, which may lose even 30 per cent. of its weight by the time it reaches Para or Manaos; or it is of rubber already received there. To take into account only those very few estimates carefully made on certain estates would be wrong, for they appear mostly to have been made in the more accessible regions, where the trees must have been well worked in the past. Other estimates, where they have not been made from estate books, are often slipshod and casual.

Upon first consideration, it would appear the better method, when repeating the statements of the different observers and others who have dealt with the yields from Hevea in the wild state, to include with them such details as are given regarding the number of cuts per tapping day, the tapping frequency, and the number of tapping days; but such details are seldom complete, and it is therefore an advantage to have the statistics of yield compacted together, and as far as possible free from these details.

The estimates of some thirty-five authorities have been examined, but they are not all included here. Where it is not otherwise stated, the weight at Para or Manaos is understood. It will be observed that in addition to the yields per tree, the yields per estrada and per seringuero are frequently given.

Yields in Brazil.

The first estimate to be presented is one that has been criticised on the score of its conservatism. Vice-Consul Temple, of Para, who was given access to the books of concession-owners in Para State, and to other information, computed the average yield per tree per season at between 1 and 1½ kilo (2·2 to 3·3 lb.), and he was of the opinion that very many trees were being worked that gave no larger average yield than 0·5 kilo (1·1 lb.). All these trees were in well-worked regions. Many authorities doubt whether an estate could be profitably worked with such small average yields. Temple also remarks that chance details coming to hand from time to time point to the probability of some trees yielding from 4 to 10 lb. each.

Though Temple's estimate of the average annual yield per tree has been challenged, it does not differ essentially from that made by Pearson, who believed that the amount did not exceed 2 to 3 lb., and was even less in districts that had been constantly worked for a number of years. Yet he elsewhere acknowledges that there are figures shewing a yield of 11 lb. per tree on the Purûs, 15 lb. on the Jurua, and of 9 lb. on the Acre. He also mentions that in the newly-opened Acre territory collectors are able to get from 13 to 55 lb. of rubber per day.

According to Ule, some trees give an annual yield of 2 kilo. (4·4 lb.), but very rich trees may yield 12 kilo. (26·4 lb.), the average being 3 kilo. (6·6 lb). The daily harvest of a collector appears to be 2 and 3 kilo. (4·4 and 6·6 lb.) ; the yearly average is about 300 kilo. (660 lb.). He records a case where two seringueros, working four estradas on the Upper Jurua on alternate days got 1,000 kilo. (2,200 lb.) in a year.

Sandmann found that the day's yield of latex upon an estrada was from 2 to 7½ litres (0·44 to 1·65 gallons), the average being 5 litres (1·1 gallons). In 140 tapping days over two estradas, this equalled 700 litres (154 gallons), from which was obtained 400 kilo. (880 lb.) of dry rubber. The average number of trees in an estrada being 120—average girth 43 inches—the yield per tree works out at 1·66 kilo. (3·75 lb.). Upon the Lower Amazon, especially the islands, the crops are smaller.

Though Bonnechaux records estradas yielding 16 to 20 litres daily, the average yield is only about 8 litres (1·76 gallons) ; from this average quantity 7·150 to 7·500 kilo. of wet rubber can be obtained which on partial drying will be further reduced in weight to 4 kilo. (8·8 lb.). An estrada in a season gives 400 to 500 kilo. (880 to 1100 lb.). Assuming that there are 150 trees, this equals for each tree from 26 to 33 grammes (0·922 to 1·16 oz.) per day, or from 2·6 to 3·3 kilo. (5·72 to 7·26 lb.) per year.

Witt asserts that about 100 trees are tapped, and that an estrada generally gives from 2 to 3 kilo. (4·4 to 6·6 lb.) per day. An experienced collector has been known to obtain 44 lb. per day from 70 trees with alternate day tapping. By examining the cut surfaces of the balls from different regions, for they show stratification partly due to each day's contribution being distinctly shown, he estimated that on the Acre an estrada gave 12 lb., on the Maderia 7 lb., on the Lower Purus 5½ lb., and on the Javary 4 lb. per day.

Vasconcellos puts the average yield at 2½ kilo. (5·5 lb.) and in the Acre territory 4 kilo. (8·8 lb.) of dry rubber.

Upon his famous journey to Brazil, Wickham personally tapped 70 to 80 trees and got 10 lb. per day ; he also stated that an experienced Indian collector could get more.

On the Lower Amazon, according to Ackermann, a collector can get 3 kilo. (6·6 lb.) in a day from an estrada, and easily three times that on the Upper Amazon. In a period of 7 months, from 100 trees, a man is able to get from 400 to 800 kilo. (880 to 1760 lb.).

From these records of Brazilian yields we may turn to those from Peru and Bolivia.

Yields in Peru.

From Plane's work upon the Amazon we learn that on the Madre de Dios, in Peru, the daily yield of a tree 30 cm. diameter (38 inches girth) is 22·5 cm. (0·78 fluid oz.) of latex, giving 15 grammes of humid rubber and 10 grammes (0·35 oz.) of dry. Estradas at Vista-Alegre, Madeira, worked for 40 years, gave in a year not more than 225 kilo. (495 lb.) per estrada and per worker from 100 trees. On the Upper Aripuana, a collector got 450 kilo. (990 lb.) in a season.

A Peruvian estrada of 150 trees, so Eberhardt found, yielded in a day about 2 gallons of latex, giving 4½ lb. of fine hard.

According to Castre, the average production of each tree, in the season of 8 or 9 months, tapped alternate days, is 2 kilo. (4 lb. 7 oz.) of dry rubber.

Yields in Bolivia.

Cibot spent six years upon the Rio Beni, in Bolivia, and has published some instructive details. Dealing first with the particulars of an estrada of 120 trees, he noted that the collector, in 23 tapping days extending from 19th July to 25th August, tapping daily except for an interval of 14 days, got 108·24 kilo. of latex, an average of 4·705 kilo. (10·35 lb.) per day. This latex was all coagulated in one ball, which on the 25th August weighed 73 kilo. (160·6 lb.). By drying the weight was reduced by 2nd September to 66 kilo. (145·2 lb.) He asserts that, when marketed in Europe the rubber is never, in weight, more than half that of the latex whence it is derived. The average yield per tree per day was 39 grammes (1·37 oz.) of latex and 19·5 grammes (0·69 oz.) of rubber marketed in Europe. He proceeded to repeat the particulars of the harvests of 45 collectors working under him, each upon one estrada. The average daily harvest over a period of 14 weeks, which formed one of the two tapping seasons in the year, was 3·08 kilo. (6·8 lb.), weighed one month after coagulation ; deducting 20 per cent. for further drying, this was equal to 2·464 kilo. (5·4 lb.) in Europe. The best of the workers got 5·36 kilo. (11·8 lb.) weighed after one month ; the twelve worst only an average of 2 kilo. (44·4 lb.) There being an average of 130 exploitable trees, the average yield per tree works out at 4·261 kilo. (9·4 lb.) for the season.

In his work upon the Bolivian Andes, Sir Martin Conway reported that nobody counted on less than 3 lb. per tree per year, and no estimates were higher than 7 lb.

On the estate of the Boston and Bolivia Rubber Company, Dunleavy went the rounds with a collector. From 345 trees 19 lb. of rubber were obtained. Sixteen hours after smoking the weight was 5½ lb. less, and twenty days later it had decreased by a further 3½ lb. The amount of the 20-day-old rubber per tree per tapping works out at 0·46 oz.

The Average Yield on the Amazon.

The average amount of wet, newly-coagulated rubber obtained per tree per season in Brazil seems to be between six and seven pounds. Taking into account the contained moisture, this is the equivalent of not more than 3¾ to 4½ lb. of plantation rubber. Such a yield is possible only because many previously untapped trees are each year brought into bearing.

The average yield of from $3\frac{3}{4}$ lb. to $4\frac{1}{2}$ lb. of dry rubber from old trees does not seem at all excessive, and, if correct, can only be explained by assuming that the trees are never taxed to the same extent as they are on Eastern plantations or that they are badly tapped. In the best areas in the Middle-East a yield of one ton per five acres (equal to 4 to 5 lb. per tree) is by no means uncommon, and yet the trees in the East are far younger than most of those tapped along the Amazon. On the other hand, one must bear in mind the fact that trees in the East have only been tapped during the last few years, while tapping in Brazil carries us back over eighty years.

Systematic tapping on anything approximating scientific principles is rarely, if ever, adopted on the Amazon, and it appears quite possible that if proper supervision could be given, a much larger outturn might be obtained from wild trees in the areas herein mentioned.

CHAPTER XVI.

YIELDS IN MALAYA.

Hitherto it has been impossible to give anything like an adequate survey of the yields likely to be obtained from Hevea trees under cultivation in the Middle-East. Now, however, we have detailed information regarding results obtained during the last six years from Hevea trees ranging from $2\frac{3}{4}$ to 25 years of age, growing under very dissimilar conditions and tapped on systems remarkable for their variability in principles. We possess records of yields from exceptionally young and old trees, from trees with a difference of twenty years in age, from individual estates, and lastly from the whole of the tapped trees in the Malay Peninsula during specified years.

The yields obtained during the last five years in Malaya have been largely responsible for stimulating interest, agriculturally and financially, in the rubber-planting industry. There are now about a hundred London companies producing rubber in Malaya alone, and the yields obtained over large acreages as well as from notable trees have so far given every satisfaction.

Early Yields from Trees of Known Age.

The following results (Rep. by Stanley Arden), are of considerable interest, as they show the yield obtained, many years ago, by tapping trees of different ages on 12 alternate days by the herring-bone system :—

No.	Circumference 3 ft. from ground.	Age. Years.	Yield. Ounces.
1	$17\frac{1}{2}$ in.	$3\frac{1}{2}$	1·54
2	$26\frac{1}{2}$,,	4	2·26
3	$26\frac{1}{3}$,,	7	14·27
4	$39\frac{3}{4}$,,	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. Of late years, however, these results have been largely exceeded.

Further results obtained by Ridley 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 specimens ; 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.

Yields from Young Trees in Malaya.

The yield from very young trees is by no means insignificant. An experiment was made in Selangor during 1909 with 2,845 trees which were only 2¾ years old. These were tapped for two months and gave an average yield of 0·297 lb. per tree. Tapping for only eight months 2,843 trees, 3½ years old, gave 1·24 lb. per tree, and in nine months 6,426 trees, 3¾ years old, gave 1·06 lb. per tree.

Another record shows that 6,444 trees, 4¾ years old, gave in two months 0·178 lb. per tree, and 4,420 trees, 5¾ years old, for the same period, yielded 0·248 lb. each. In another field, 400 trees, 4¾ years old, tapped for six months gave 1·107 lb. per tree, and 4,674 trees, 5¾ years old, during the same period, returned an average of 0·961 lb. per tree.

A large number of trees, all 5¾ years old, were tapped during 1909 for two, four and six months, and yielded respectively 0·248, 0·503 and 0·997 lb. per tree, or an increase of approximately 50 per cent. for each two months' tapping.

Some trees 3½ to 4½ years old in the Straits Settlements and in Klang have given at the rate of nearly one lb. of rubber per annum, per tree. The bark of these trees is relatively soft and does not compare favourably with the harder texture of that on trees which have taken a longer time to attain the tappable size.

Excellent results have been obtained on Malay estates by cutting a large V or Y at a foot to eighteen inches from the base of the tree, the V extending half round the tree. When the tree is large enough, a second V is cut on the reverse side. By such a method the young trees can be tapped regularly—almost every alternate day—the rubber is extracted only from the thick part of the bark, and a high yield is obtained from the basal regions.

Yields from Old Trees in Malaya.

In marked contrast with the above are the unexpectedly high yields obtained, in twelve months, from individual trees on various properties. On Jugra estate seven to nine-year-old trees gave 7 lb. per tree, and on Cicely eight-year-old trees gave 8 lb. The Federated Malay States Company possess over 2,900 9½-year-old trees which gave 24,000 lb. of rubber in one year, or an average per tree of 8·2 lb. Twelve-year-old trees on Linggi yielded 10·7 lb. in twelve months, Batu Unjor is reported to have secured 10·73 lb. per tree from 6,800 trees at the age of from 11 to 12 years. A yield of 28½ lb. is also recorded from the 17-year-old trees growing near the churchyard at Parit Buntar. Similarly high yields, equal to one pound of rubber for each year's growth, have been published from time to time, but it is extremely doubtful whether such yields can be relied upon annually In several instances the trees have been growing under exceptionally favourable conditions, and many do not appear to have been tapped until they attained quite a good age.

Yields from Old Trees of Doubtful Age.

The old tree in the Penang Botanic Gardens was tapped during 1908, and yielded 3 lb. 8 oz. of dry rubber, making the total yield since the first tapping over 40 lb.

An old Hevea tree at the Singapore Botanic Gardens was tapped in November and December, 1906, and 4 lb. 4½ oz. of dry rubber obtained ; that made a total of 35 lb. 13½ oz. from the tree since it was first tapped. The tree, which was about twelve years old, reached a greater production in 1905, when 4 lb. 12½ oz. of rubber was obtained.

The report of Mr. W. Peel, the Agricultural Superintendent of the Gardens, on the tapping operations during 1906, showed that though the old tree in the Botanic Gardens which was tapped 14 times between November 19th and December 15th, gave 4 lb. 4½ oz. of dry rubber, the same number of operations on trees on Penang Hill, carried out between July 11th and August 6th, yielded only from 11½ oz. to 2 lb. 14 oz.

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

Yield from Trees 3 to 25 Years Old.

It is eminently desirable that some attempt should be made to determine the average yield, per tree and per acre, from trees of known age. As in other statistics of this character compiled by managers of estates who may not have planted the trees they have tapped, there is a liability to error which cannot be eliminated. The figures in the column headed "age" refer, when no range of age is given, generally to the age of the trees when tapping was first commenced. Where a range in age is indicated, this usually covers the period of tapping for which particulars are given. The total number of tapped trees shown does not necessarily indicate the number tapped during the whole of the year, many trees being added to the tapping round month by month. It is, therefore, fair to assume that the average yields given err on the low side.

Unfortunately, though details of times of planting are available in the prospectuses of many companies, the yield from trees planted in successive years are not always given in the annual reports. In such cases the age of the tapped trees is a matter of conjecture and the available details have therefore been rejected.

The information has been arranged to show the yield from numerous estates from trees of approximately the same age. It should be borne in mind, when dealing with the yields in later years, that these, in most cases, have been obtained from the same trees.

Trees Three to Five Years Old.

Trees in Malaya, 3 to 4 years old, have yielded, within twelve months, from 0·53 to 1·24 lb. per tree, and at the rate of from 104¾ to 148½ lb. per acre, even though every tree has not been tapped regularly throughout the year.

Name.	Age.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre.
F.M.S.	3½	2,483	—	3,084	1·24	—
,,	3¾	6,426	46	6,871	1·06	148
,,	3¾	7,859	60	6,163	0·78	102
,,	4	4,536	33	4,317	0·95	129
Straits Bertam	3-5	23,000	211	12,296	0·53	58
Bagan Serai	3-4	8,536	51	5,669	0·66	111
Straits Rubber	3-5	15,509	89	12,929	0·83	145
Batak Rabit	4	23,400	119	12,457	0·53	105
Sungei Krian	3-5	7,170	—	8,680	1·21	—
Batu Caves	3½-5	56,258	—	95,894	1·70	—

The trees on Batak Rabit were tapped six months only; on Bagan Serai, 7 months; on Straits Rubber Estate, 8 months; on the F.M.S. estates, 8 or 9 months; on Batu Caves, from 8 to 12 months; and on Sungei Krian, 11 months.

Several trees, 3 to 7 years old, on Carey estate, yielded at the rate of 1·84 lb. each. Others, 3-11 years, on Lanadron, gave 4·13 per tree, or at the rate of 448 lb. per acre per annum. Over 15,000 closely-planted trees, 3 to 12 years old, on Pandan (Johore), gave an average of 309 lb. per acre. On Linggi, 151,796 trees, 3½ to 12 years old, yielded 3·59 lb. each, and a further 285,000, 3 to 13 years old, gave 3·08 lb. per tree.

Further details of the Carey estate show that trees 3 to 7 years old each gave 1·84 lb., and in another year those 3 to 8 years gave 1·65 lb. each.

Trees Four to five Years.

In this group tapping does not appear to have been carried out every month of the year. Nevertheless, yields of from 0·46 to 1·68 lb. per tree, and of 42 to 292 lb. per acre, have been chronicled.

Name.	Age.	Hevea Trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre
Castlefield	4-5	34,376	270	18,820	0·55	70
F.M.S.	4-5	8,489	—	—	1·24	—
Banteng (Selangor)	5	5,463	50	6,600	1·21	132
Selangor	4	—	—	—	—	60
,,	5	—	—	—	1·70	90
Klanang	4-5	12,500	140	5,904	0·46	42
,,	4-5	22,500	380	23,446	1·04	62
Bakap	4-5	13,128	—	22,161	1·68	—
Glenshiel	5	3,953	21	6,290	1·59	293
Seafield	4	7,240	120	5,215	0·72	43
,,	4-5	70,790	538	94,519	1·33	175
Jeram	4-5	15,973	254	14,152	0·88	55
Changkat Salak	4	—	99	14,600	—	147
Batu Tiga	4	19,000	—	12,000	0·63	—
Gula Kalumpong	4-5	73,000	—	—	0·75	—

Name.		Hevea Trees. Age.	Number	Acres.	Yield in lb. Total.	Per tree.	Per acre
Batu Unjor	..	4-5	22,472	262	35,638	1·5	136
Sendayan	..	4-5	19,380	174	17,537	0·90	100
Batak Rabit	..	4-5	23,000	—	27,009	1·17	—
Lumut	..	4-5	37,595	—	33,702	0·90	—
Taiping	..	4-4½	50,000	—	52,500	1·05	—

The Castlefield and F.M.S. trees were tapped for nine months, the Banteng for eight, the first group of the Klanang (12,500 trees) for five, and the first group of the Seafield (7,240 trees), for four months only.

Trees Four to Nine Years.

It would not be wise to take an average age for trees ranging from four to nine years old, and separate figures are therefore given showing the yields obtained according to range in age. On Tremelbye nearly half the trees were tapped for a few months only; on Banteng and the Straits Rubber the tapping was mainly basal, whereas on Vallambrosa the yields were from high tapping.

Name.	Hevea trees. Number.	Acres.	Yield in lb. Total.	Per tree.	Per acre.
Four to six years.					
Banteng ..	16,300	200	32,000	1·96	160
Straits Rubber ..	217,000	1,824	209,449	0·97	115
Jementah	—	—	—	1·95	96
Sungei Krian	4,700	—	8,680	1·85	—
Four to seven years.					
Shelford ..	20,000	184	11,548	0·57	63
Chersonese	24,000	—	27,659	1·15	—
Kapar Para	—	800	169,610	—	212
Seremban	36,750	—	68,957	1·88	—
Vallambrosa	—	955	371,316	—	388
Tremelbye	108,761	1,076	101,601	0·94	95
Sengat ..	40,811	—	116,763	2·86	—
Four to eight years.					
Glenshiel	13,000	91	5,679	0·44	62
Four to nine years.					
Glenshiel	64,000	428	48,000	0·75	112
Kinta Kellas	30,000	—	30,085	1·00	—
Bukit Rajah	88,341	720	118,982	1·35	165

There are other yields from trees 4 years old and upwards, which are worth chronicling. The Merton Rubber Syndicate and Allagar obtained from trees, 4 to 10 years old, 160½ and 310½ lb. respectively per acre in one year. Consolidated Malay reported a crop of 3·44 lb. per tree from 99,225 trees, 4 to 12 years old. Inch Kenneth obtained from 621 acres, 4 to 15 years old, a crop at the rate of 277 lb. per acre.

Trees Five to Six Years Old.

Including the experimental work on Jugra, Sempah, and on Highlands and Lowlands, the yield from trees belonging to this class ranges from 0·88 to 2·38 lb. per tree, or 95½ to 296 lb. per acre.

Name.	Age.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre
Jugra	5½	6,820	26	—	0·39	103
Batu Unjor ..	5-6	39,874	—	38,952	0·97	—
Seremban ..	5-6	—	83	20,086	—	242
Cons. Malay ..	Over 5	853,390	683	202,440	2·33	296
F.M.S.	5¼	7,020	—	16,739	2·38	—
Seafield	5-6	21,600	238	38,572	1·79	161
Klanang ..	5-5½	9,564	105	14,072	1·49	134
Kurau	5-6	24,000	220	21,036	0·88	95
Sempah	5-6	6,367	—	4,071	0·64	—
Eow Seng	5-6	7,800	—	9,411	1·21	—
H. & L.	5-6	37,269	406	28,087	0·75	69
Castlefield (Klang)	5-6	67,558	541	72,401	1·06	134
Rubana	5-6	69,000	607	81,921	1·19	114

On Jugra estate the trees were only tapped 39 times, and on Batu Unjor only light tapping was indulged in. On Seafield the trees were tapped for eleven months, and on Highlands and Lowlands about half of the trees were brought into the tapping round in the last six months.

Trees Five to Seven Years Old.

A yield of from 1·36 to 3·93 lb. per tree and up to 405 lb. per acre, per annum, shows a decided advance above the yields previously recorded.

Name.	Age.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre.
Pataling	5-7	—	—	—	—	236
F.M.S. ..	5¼-6¼	6,467	80	18,877	2·92	236
,, ...	5¼-6¼	3,880	101	9,607	2·47	94
Balgownie ..	5½-6½	7,800	—	10,642	1·36	—
Rubana	5-7	107,204	977	245,384	2·29	251
Batu Caves ..	5-7	15,462	—	60,754	3·93	—
Batu Unjor ..	5-7	5,356	46	18,630	3·48	405
Selangor	5-7	—	440	29,750	—	67

On Jugra Island a yield of 400 lb. per acre was reported by Carey from trees planted 10 by 10 feet, though they were only from 5½ to 6½ years old.

Trees Five to Eight Years Old.

The statistics relating to this group are not very numerous; the maximum yield per tree appears to have been less than 4 lb.

Name.	Age.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre.
Rembia	5½-7½	3,750	—	11,000	2·93	225
F.M.S.	5¾-7½	3,287	—	11,654	3·55	—
,, ...	5¾-7¾	4,653	—	17,427	3·74	—
Rembia	5-8	7,500	40	8,361	1·11	206
Shelford	5-8	24,250	184	23,828½	—	129
Selangor	5-8	—	553	70,577	—	127
Cons. Malay ..	5-8	11,348	—	32,693	2·88	—
Bukit Rajah ..	5-8	34,457	—	33,203	0·97	—
Vallambrosa ..	5-8	—	930	156,922	—	169

The crops from the F.M.S. properties were obtained in eleven months of tapping. On Selangor 36½ acres were tapped for the first time late in the year.

Trees Five to Twelve Years Old.

In this division there is naturally a great variation in yield. A maximum crop of 443 lb. per acre is recorded, and one of 3·96 lb. per tree, from Lanadron.

Name.	Hevea trees.		Yield in lb.		
	Number.	Acres.	Total.	Per tree.	Per acre.
Five to nine years.					
Golconda..	—	329	35,103	—	107
Shelford	—	395	33,097½	—	83
Bukit Rajah	88,341	720	118,982	1·34	165
Cons. Malay	17,549	200	63,615	3·62	318
Five to ten years.					
R.E. of Krian	14,000	—	41,200	2·9	435
Bukit Rajah	89,295	800	163,521	1·83	204
Labu	23,000	140	28,775	1·25	205
Lanadron	—	565	249,247	3·96	443
Shelford	65,333	—	103,104	1·58	—
Cons. Malay	34,000	—	111,585	3·28	—
Five to eleven years.					
Selangor	138,600	924	326,654	2·3	353
Bukit Rajah	94,600	950	210,081	2·22	221
Labu	27,670	205	86,763	3·13	423
Cons. Malay	57,145	—	215,893	3·77	—
North Hummock ..	28,476	—	86,561	3·04	—
Five to twelve years.					
Bukit Rajah	125,000	1,250	314,778	2·51	251
Labu	64,000	520	203,696	3·18	391
H. and L.	53,352	720	166,135	3·11	230
Vallambrosa	—	1,172	411,476	—	351
Five to thirteen years.					
Bukit Rajah	128,000	1,470	437,997	3·42	298

Of the 329 acres on Golconda, five to nine years old, 106 were five years old, and this accounts for the relatively low yield. On Labu the trees, five to ten years old, were mixed with other products; and those of a similar age on Shelford included a large number of young trees. The yield from five to twelve-year-old trees on Highlands and Lowlands was partly obtained from high tapping. That given for Vallambrosa was partly from 217 acres tapped for the first time.

Trees Six to Seven Years Old.

Including the first three records, the yield per tree varies from 1 to 5·72 lb., or from 128 to 318 lb. per acre. It is probable that the yield per acre is considerably higher than this on many estates, but particulars are not available for publication.

Name.	Age.	Hevea trees. Number.	Acres.	Yield in lb. Total.	Per tree.	Per acre.
Jugra	6½	5,500	38	4,041	0·73	106
Malacca	6½ to 7	30,000	—	13,000	—	—
Selangor	6	—	—	—	—	140
Klanang	6	16,000	54	13,218	0·83	244
Harpenden ..	6	—	22	3,713	—	168
Shelford	6	9,636	76	6,808	0·77	128
Seafield	6-7	36,053	238	106,886	2·97	224
Klanang	6	18,900	94	30,028	1·60	318
Vallambrosa ..	6-7	6,225	40	6,225	1·00	155
Straits Bertam ..	6 and over	16,782	—	19,781	1·17	—

Name.	Age.	Hevea trees. Number.	Acres.	Yield in lb. Total.	Per tree.	Per acre
F.M.S.	6¼	3,820	45	10,114	2·64	221
,, ...	6¼	6,065	59	15,037	2·47	254
,, ...	6¼	4,915	—	11,969	2·43	—
,, ...	6¼	5,225	61	15,710	3·00	257
,, ...	6¼	3,486	—	8,411	2·41	—
,, ...	6¼	4,208	—	6,858	1·63	—
Anglo-Malay ..	6-7	28,326	—	47,788	1·68	—
,, ,, ..	6-7	5,440	—	18,112	3·32	—

The trees on Malacca were tapped from April to October, and some of those on Shelford for a few months only. The trees on Klanang were planted 12 ft. by 12 ft. apart, and were tapped on the half-herring-bone system. Those on Vallambrosa were originally planted 10 ft. by 12 ft. apart. The Seafield trees were tapped for eight months on the full herring-bone system.

Trees Six to Eleven Years Old.

The range in age is considerable, and it is hardly a matter for surprise that yields of over 4 lb. per tree have been obtained from large numbers of trees.

Name.	Hevea trees. Number.	Acres.	Yield in lb. Total.	Per tree.	Per acre.
Six to eight years.					
Cicely	6,919	—	9,184	1·33	—
Jugra	—	72	—	—	193
F.M.S.	4,807	159	21,680	4·51	136
,, ...	5,383	54	17,426	3·23	319
,, ...	4,493	—	14,324	3·18	—
Golconda..	—	163	18,722	—	114
Six to nine years.					
Perak	18,150	182	34,770	1·91	191
Vallambrosa	152,195	930	225,302	1·48	242
Six to ten years.					
H. and L.	48,823	656	131,252	2·68	200
F.M.S.	3,812	—	19,756	5·19	—
Gula Kalumpong ..	22,000	—	—	4·00	—
Six to eleven years.					
Perak	—	308	115,895	—	376

On Perak 96 acres were nine years old and a higher yield might have been reasonably anticipated. On Highlands and Lowlands 7,128 trees were taken in during the second half of the year.

Trees Seven to Eight Years Old.

The yield from trees of this age is much more regular, as the whole of the trees on each acre are usually in the tapping round. The crop of 555 lb. per acre from such a large acreage on Sungei Kapar can be regarded as above the average, though from 4 to 5 lb. per tree are frequently heard of at the above-mentioned ages.

Name.	Age.	Hevea trees. Number.	Acres.	Yield in lb. Total.	Per tree.	Per acre.
Klanang	7	16,000	54	15,244	0·95	282
Golden Hope ..	7	880	—	2,400	2·9	—
Batu Unjor ..	7-8	36,312	369	89,565	2·46	242
Sungei Kapar ..	7 to 7½	39,276	207	114,970	2·92	555
Lanadron ..	Average 7½	—	567	181,156	2·44	319

Name.	Age.	Hevea trees. Number.	Acres	Total.	Yield in lb. Per tree	Per acre.
Ledbury Estate	Average 7	—	—	—	4·60	285
Sione Estate	7⅓	—	—	—	3·39	246
Jugra	7½	120	—	—	2·06	—
,,	7½	7,068	34	—	1·15	240
Allagar	7 to 8	—	—	—	3·00	—
Anglo-Malay	7 to 8	28,043	—	105,655	3·76	—
Malacca	7½ to 8	12,000	—	46,890	3·9	—
Selangor	7	—	—	—	—	140

In connection with the small yield, per tree, on Klanang, it should be mentioned that the field was planted 12 ft. by 12 ft. The yield of 1·15 lb. per tree on Jugra was obtained from trees tapped 71 times.

Trees Seven to Thirteen Years Old.

Carey has reported a yield of 7 lb. per tree from trees seven to nine years old. This is quite in excess of the average so far recorded over large acreages.

Name.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre.
Seven to nine years.					
Cicely	8,020	—	19,069	2·37	—
Seven to ten years.					
Vallambrosa	—	930	272,741	—	293
Labu	8,000	60	18,977	2·37	316
Ledbury	—	175	28,741	3·08	163
Batu Caves	3,131	—	16,479	5·26	—
Seven to eleven years.					
H. and L.	46,167	656	132,722	2·87	202
Seven to thirteen years.					
H. and L.	58,444	682	224,335	3·84	329

The trees on Labu were among other products, and those on Batu Caves were in coffee. Those on Highlands and Lowlands, seven to eleven years old, included 5,252 trees which were tapped for six months only.

Trees Eight to Nine and More Years Old.

It will be noted that again high yields of 5 lb. per tree and over 400 lb. per acre are common. An eight-year-old tree on Cicely estate has been reputed to yield 8 lb. of rubber in 100 tappings during a period of two months only. Maude also states that 1,470 trees, eight-and-a-half years old, gave 30 lb. of rubber daily plus 8 lb. of scrap.

Name.	Age.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre.
Castlewood	8 to 9	1,508	—	2,934	1·95	—
Selangor	8	—	—	—	—	300
Golden Hope	8	880	—	4,615	5·50	—
Jugra	8	150	—	—	3·56	—
Seremban	8	—	348	109,055	—	313
Vallambrosa	8	4,642	60	12,765	—	212
Klanang	8	16,000	54	18,886	1·18	349
Cicely	8-10	9,000	—	43,696	4·85	—
Jugra	8½	6,060	38	—	2·51	400

Name.	Age.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree	Per acre.
Selinsing	.. 8 to 9	1,400	—	4,330	3·09	—
Jugra ..	.. 8½ to 9	270	—	—	5⅛	—
Sione ..	.. 8½ to 9	5,967	—	8,385	1·40	—
Lanadron	8½ Average	—	565	249,247	3·96	443
Batu Unjor.	.. Up to 9	43,130	425	180,124	4·17	423
Batu Tiga	.. 8-12	—	364	84,000	—	230
Pataling ..	.. 8-13	—	372	205,169	—	548

The trees on Jugra which gave 5⅛ lb. and 3½ lb. of rubber each were in avenues ; those which gave 2·51 lb. were tapped 90 times

Trees Nine to Ten Years Old.

The very large yield, per tree, from Highlands and Lowlands (H. and L.) was obtained from trees planted 30 by 25 feet apart, and it will be noted that the yield per acre was below that from other properties of the same age.

Name.	Age.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre.
Vallambrosa	.. 9	36,301	150	54,451	1·5	363
H. and L.	.. 9	807	16	5,742	7·01	359
Seremban	.. 9	—	348	109,055	—	313
Sione ..	.. 9½ to 10½	6,296	—	15,027	2·39	—
Jugra ..	.. 9½ to 10	270	—	—	8·00	—
Batu Unjor	.. 9 to 10	28,500	196	126,961	4·45	647
F.M.S. ..	.. 9½	2,953	—	24,245	8·21	—
,, ..	.. 9½	2,395	—	9,342	3·9	—
Klanang Produce	9	8,400	54	34,068	4·05	630
Selangor ..	.. 9	—	—	—	—	400

On Cicely estate, 9,000 trees, from 9 to 11 years old, gave a yield of 6 lb. each. The crop of 363 lb. per acre from Vallambrosa was obtained from areas which had been thinned out. The same remark applies to the crop of 630 lb. from Klanang.

Trees Ten to Eleven Years Old.

Yields of 5, 8, and even 9 lb. per tree and from 500 to 700 lb. per acre are recorded for trees of this age.

Name.	Age.	Hevea trees. Number.	Acres.	Total.	Yield in lb. Per tree.	Per acre.
Seremban	.. 10	36,120	348	134,848	3·73	387
Selangor ..	.. 10	—	—	—	—	500
F.M.S. ..	.. 10	2,953	—	27,560	9·32	250
,, ..	.. 10½	3,860	—	31,780	8·24	—
,, ..	.. 10	1,707	—	5,212	3·05	396
Klanang Produce	10	8,400	54	40,026	4·77	741
Batu Tiga	.. 10	3,183	17	9,316	2·93	548
Linggi ..	.. 10	—	—	—	6·5	—
Ledbury (Sione Estate)	.. 10-11	9,655	112	37,477	5·35	221

The 9,000 Cicely trees, when 10 to 12 years old, gave about 8 lb. each in twelve months. On Jebong a yield of 7½ lb. per tree was recorded from several trees 10 to 13 years old.

Trees Eleven to Twelve Years Old.

The same estates are again credited with securing phenomenally high yields from their notable trees. Batu Tiga heads the list with 758 lb. per acre, and the F.M.S. and Batu Unjor are prominent with an outturn of from 9 to 10 lb. per tree.

		Hevea trees.		Yield in lb.		
Name.	Age.	Number.	Acres.	Total.	Per tree.	Per acre.
Seremban ..	11	36,120	350	205,542	5·69	506
,, ...	12	36,120	350	304,620	8·43	870
Selangor	11	—	—	—	—	600
Batu Tiga ..	11	3,183	17	12,887	4·05	758
Singapore Para ..	11	9,000	65	25,547	2·84	393
Linggi	11	—	—	—	8·00	—
F.M.S.	11	3,860	110	35,444	9·18	321
Batu Unjor ..	11-12	6,800	162	72,987	10·73	450
,, ..	11-12	940	12	6,357	6·76	528

The 940 trees on Batu Unjor were tapped for nine months on the half-herring-bone system.

Trees Twelve Years Old.

Twelve-year-old trees at Taiping yielded 3·9 lb. of rubber each in one series of tappings; the length of the tapping period is not given. Other trees of the same age on Linggi estate have given 10·7 lb. each in one year.

Trees Fourteen Years Old.

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.

Trees Seventeen Years Old: Record Yield.

An interesting tapping experiment with eight 17-year-old trees growing near the churchyard at Parit Buntar, in the Krian district of Perak, gave an average of 28½ lb. of dry rubber per tree (Offic. Rep., 1908). The average girth of the trees was 54·87 inches at three feet from the ground, and they have been growing in unweeded land containing lalang and other grasses. The tapping was done on alternate days. These trees appear to have become quite famous, for I was informed later (I.R.J., Feb. 8th, 1909), that one of the trees, then 18 years old, had given no less than 50 lb. of rubber in twelve months. The same yield is also reported by Berkhout (Tropenpflanzer, July, 1910), who points out that, with only 16 trees to each acre, the yield would be 800 lb. per acre, per annum. This appears to be the record yield from any Hevea tree of known age in Malaya.

Trees Twenty-five years Old.

At a recent conference of Malay planters, Baxendale reported a very high yield from one of the trees now growing on Gapis Estate, Perak. In fifteen days, from July 17th to July 31st, 1902, he collected 6½ lb. of rubber from three small cuts close to the base.

After he left Gapis, Mr. Salisbury continued the tapping spasmodically, and the total result in 35 days' actual tapping (between July 17th and Sept. 18th), was 18 lb. of rubber. The tree was 25 years old, and measured 89 inches in girth at one yard from the ground.

Yield per Acre and per Tree.

It is extremely difficult to generalise regarding the yield per acre and per tree from trees of known age in Malaya, owing to the variation in the conditions under which the plants are grown, the number of tapping operations performed, and the bark sections tapped on particular trees. If the abnormal instances are deleted from the preceding tables, some useful data may be formulated. An attempt has been made to do this in the following table, in which actual figures of yield from known estates are used :—

Age in Years.	Per Acre.	Per Tree.
3 to 4	50 to 100	0·53 to 1·06
4 to 5	70 to 136	0·88 to 1·50
5 to 6	114 to 160	1·21 to 1·79
6 to 7	128 to 221	1·60 to 2·47
7 to 8	240 to 319	2·44 to 3·39
8 to 9	313 to 443	3·09 to 4·17
9 to 10	363 to 550	3·90 to 4·45
10 to 11	396 to 630	4·77 to 5·35
11 to 12	450 to 758	5·69 to 6·76

In the above compilation it is clear, since figures from separate but known estates are used, that the increase does not exhibit that regularity which one would anticipate. The figures do not include, as already mentioned, those of extreme cases, but have been selected to show the average variation on the estates already mentioned. It will be quite obvious, for example, that a yield of 6·76 lb. per tree or 630 lb. per acre is not the maximum quantity that can be obtained. It is also clear that the yield per tree may be at the maximum when that per acre is only medium, and *vice-versa*, according to the spacing of the trees.

It is only necessary to remind those who may use this table that the figures represent the yields from trees which, after all, are still young, and which will probably have to suffer repetitional stripping of bark in order to again yield as in the past. Whether the trees will continue to thrive under this treatment remains to be seen. The yields are considerably in excess of those recorded from trees in the Amazon valley.

Successive Annual Yields from Specified Trees.

There are few estates in Malaya which have been in full bearing for several years. Generally a number, small or large, of trees has been added to the tapping-round at irregular intervals during the last few years, thus making a comparison of total annual yields from each estate almost valueless. There are, however, one or two instances which enable us to note the progress in yields from the same trees in successive years.

Name.	Years.	Number of trees or Acres Tapped.	Yield.
Vallambrosa ..	1907-8	930 acres	242 per acre.
	1908-9	930 ,,	293 ,,
	1909-10	930 ,,	399 ,,
Federated Selangor	1907-8	27,483 trees	0·85 per tree
	1908-9	34,072 ,,	1·75 ,,
	1909-10	42,743 ,,	2·67 ,,
Consolidated Malay	1906	11,345 ,,	2·88 ,,
	1907	17,549 ,,	3·62 ,,
	1908	34,000 ,,	3·28 ,,
	1909	57,145 ,,	3·77 ,,
Linggi	1908	79,714 ,,	3·57 ,,
	1909	151,796 ,,	3·59 ,,
	1910	285,000 ,,	3·08 ,,

It will be obvious that in the last-mentioned companies some of the extra trees brought into the tapping-round were young specimens.

Yields from F.M.S. Co.'s Estates.

Some valuable results have been kindly placed at my disposal by the Federated Malay States Rubber Co., Ltd., which show the yield during one year (1st June, 1909, to 31st May, 1910) from trees which had been previously regularly tapped and yielded large crops.

Estate No. 1.

Age of tapped trees.	Number of tapped trees.	Yield per tree per annum.
11 years ..	3,860	9.18 lb
10 ,, ..	2,953	9.32 ,,
6¼ ,, ..	5,225	3.00 ,,
5¼ to 6¼ ,, ..	6,467	2.92 ,,
6¼ ,, ..	3,820	2.64 ,,
6¼ ,, ..	6,065	2.47 ,,
6¼ ,, ..	4,915	2.43 ,,
5¼ ,, ..	7,020	2.38 ,,

These yields are exclusive of earth rubber, which amounted to an average of 0·10 lb. per tree.

Estate No. 2.

Age of tapped trees.	Number of tapped trees.	Yield per tree per annum.
6¼ to 8¼ yerrs	4,807	4·51 lb.
6¼ to 10 ,, ..	3,802	5·19 ,,
6¼ to 8¼ ,, ..	5,383	3·23 ,,
6¼ to 8¼ ,, ...	4,493	3·18 ,,
5¼ to 6¼ ,, ...	3,880	2·47 ,,
6¼ ,, ...	3,486	2·41 ,,

During 1910 this Company obtained the following :—

Number of trees.	Age.	Yield per tree.	Number of months tapping.
66,170	5¼ to 11 years	3·83	12
4,208	6¼	1·62	11
1,707	10	3·05	10
8,489	4 to 5 ,,	1·24	9
14,285	3½ to 3¾ ,,	0·91	8

In the previous year the following crop was secured :—

17,148	9½ to 10½	,,	5·50	12
20,630	4¾ to 5¾	,,	1·03	6
5,033	5¾	,,	0·50	4

A total average yield of 1·98 lb. per tree was obtained from 63,886 trees, varying in age from 3 to 10½ years, tapped from 1 to 12 months during the year.

Annual Yields from Malaya.

Having dealt with the yields from individual trees and estates in Malaya it is now necessary to see what returns have been obtained from the country as a whole and from this to gain some reliable estimate of future production from this area. The Director of Agriculture, F.M.S., reports the following crops :—

	1906. lb.	1907. lb.	1908. lb.	1909. lb.	1910. lb.
Selangor	620,033	1,131,086	1,846,384	3,676,451	7,052,975
Perak	94,848	272,804	383,073	1,060,543	2,962,218
Negri Sembilan ..	146,891	586,864	963,253	1,346,499	2,599,707
Pahang	—	—	—	—	2,483
Malacca	12,000	23,490	52,980	36,865	599,918
Province Wellesley	13,560	82,131	92·600	293,516	445,659
Johore	47,724	182,495	201,632	327,635	664,352
Kelantan and Kedah	—	—	—	—	41,551
Total ..	935,056	2,278,870	3,539,922	6,741,509	14,368,863

If we consider the Federated Malay States alone we find that the total annual yields for the past few years have been: 1906, 935,056 lb.; 1907, 2,278,870 lb.; 1908, 3,539,922 lb.; 1909, 6,741,509 lb.; 1910, 14,368,863 lb These are the figures of production issued by the Agricultural Department. The figures of exports from the Federated Malay States as given by the Federated Malay States Information Agency are generally lower; for 1911 the amount given was 19,695,330 lb.

Trees Tapped in 1906.

The productions during 1906 for Malacca and Province Wellesley are only approximate ; those from the latter include rubber from nine estates in Singapore and six in Penang. The total number of trees tapped, during that year, was 441,488 in F.M.S., 27,076 in the Straits Settlements, and 48,350 in Johore, making a grand total of 516,914. Many of the tapped trees in the F.M.S. were 10 years old and a few even 20 years old. The average yield, per tree, for 1906 was, therefore, 1⅘ lb. of dry rubber.

Trees Tapped in 1907.

In this year 1,300,227 trees were tapped in the F.M.S., Straits Settlements, and Johore. The average yield per tree was 1 lb. 12 oz. In the F.M.S. Selangor had a very long lead with regard to the number of trees being tapped, having 772,656, against

240,401 in Negri Sembilan, and 132,556 in Perak. The average yield, however, was higher in Negri Sembilan and Perak, being 2 lb. 7 oz. and 2 lb. 1 oz. respectively, against 1 lb. 7½ oz. in Selangor. This, however, is not much to go by, as we have no returns of the ages of the trees.

Trees Tapped in 1908.

The average yield per tapped tree all over the peninsula rose from 1 lb. 12 oz. in 1907 to 1 lb. 15¾ oz. in 1908, an increase of 11 per cent. Considering that the majority of the trees tapped were in their first year of bearing, this is a most encouraging figure. The average yield in Negri Sembilan, during 1908, amounted to 3 lb. 2¼ oz., which, being the average of nearly one million trees, is an extraordinarily high figure. This state had much higher yields per tree, because the proportion of trees in their first tapping period was much less than in the other States, but this high figure is interesting as pointing to the averages which may be expected from trees after two or three years' tapping. The yield for 1908 was obtained from a total of 1,954,090 trees, 1,172,383 of these being in Selangor, 251,613 in Perak, 306,376 in Negri Sembilan, 56,846 in Malacca, 65,100 in Province Wellesley, and 101,772 in Johore.

Yield from 1909 to 1911.

The output of rubber during 1909 from Malaya was 6,741,509 lb., and was succeeded by a crop of 14,368,863 lb. in 1910. The Federated Malay States alone gave in 1910 four times the crop for 1908 and 100 per cent. above that for 1909. The output figures given above for the F.M.S. is about 400,000 lb. in excess of those returned by the Commissioner of Trade and Customs. This difference, the Director of Agriculture states, is largely represented by rubber on hand on the plantations. As stated above, the exports in 1911, from the F.M.S. alone, were 19,695,330 lb. The total for the whole of Malaya promises, at the date of writing, to be over 23,000,000 lb.

CHAPTER XVII.

YIELDS IN CEYLON AND SOUTH INDIA.

It is quite manifest from a comparison of the available figures that, up to the present, Ceylon takes a second place, compared with Malaya, in point of annual yield from young trees and from definite acreages of known age, though the recorded yields from old trees in Ceylon are exceptionally high. It is freely admitted that the soil or climatic conditions in Ceylon are less favourable, in the first few years, to the growth of *Hevea brasiliensis*. Whether the moist conditions in Malaya will prove to be so beneficial to old trees as the comparatively dry environment in Ceylon remains to be proved. It must be pointed out that, though rubber in Ceylon may, in the first few years, only have been produced at the rate of 150 lb. per acre, per annum, other products on the same land have returned good crops during the same period.

First Recorded Yields from Ceylon.

The first series of reliable yields, from cultivated trees, were those obtained at Henaratgoda from 1888 to 1896. One tree at Henaratgoda was lightly tapped every second year, and gave for nine years an average annual yield of 1½ lb. of dry rubber :—

27¾ oz. in 1888	51 oz. in 1894
42 oz. in 1890	48¼ oz. in 1896
5 oz. in 1892	

This tree was twelve years old when first tapped, and the annual yield of 1½ 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 50½ inches and was growing with other trees of nearly equal size, distanced 30 feet apart.

Yields From Young Trees.

There are very few, if any, estates in Ceylon where the trees are sufficiently large to permit of tapping under four years of age. In this respect there is a striking difference with Malaya, where tapping is often started as soon as the trees are three years old. Purely as an experiment, some two-year-old trees were tapped in Kalutura, but the yield therefrom was insignificant. In that district quite a number of trees, tapped when four years old, have given over 100 lb. per acre in the first twelve months. A yield of ½ lb. per tree is recorded from 2,119 trees, four years old, on one estate, and of 0·63 lb. per tree from 747 trees of the same age on Mahawale. On Rayigam, 6,000 trees, four to five years old, gave ½ lb. of rubber each, and a further 1,500 yielded 0·41 lb. each. Light tapping of young trees on a well-known Kalutura property gave 1·72 lb. of rubber per tree.

Yields from Old Trees.

At one time a yield of two to three lb. per tree from eight to eleven-year-old trees on Kepitigalla estate was considered good. One tree on Elpitiya, 46 in. in circumference and eleven years old, gave 16 lb. of rubber when tapped on the spiral system. 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. This tree appeared quite healthy in April, 1908.

Individual trees of unknown age (probably 20 to 25 years) on Culloden estate, gave 10, 18, 23, and 25 lb. of rubber in twelve months, tapped on various systems. These trees gave an average of 18 lb. per tree, per annum, for four years.

Several trees at Peradeniya, when 29 years old, gave 6¾ lb. each in eight months, and were still in good condition. Others on the same site gave 3 lb. each in twelve weeks.

Upon the Imboolpitiya estate in the Ambagamuwa district at an elevation of 2,000 feet, several 28-year-old trees were tapped from 18th December, 1905, to 18th March, 1906, and therefore during three very dry months. One tree tapped 17 times gave 3 lb. 7 oz. of dry rubber; two others, tapped 21 times, gave 11 lb. 7 oz.

80 lb. per Tree, per Annum.

The largest yield appears to have been obtained from the old Henaratgoda trees during 1909 and 1910. During that period the largest tree gave 160 lb., or at the rate of 80 lb. per annum: the record, probably, for the world. This, from a tree planted in 1876, gives one some idea of what yield can be obtained from Hevea on very poor soil at thirty-five years of age. It is only fair to add that the trees at Henaratgoda have never been systematically tapped and were not until a few years ago even experimentally operated upon.

Some trees at Henaratgoda, over 20 years old, tapped on the full herring-bone system with knife and pricker, have yielded at the (computed) rate of from 885 lb. to 257 lb. per acre per year when tapped in frequency from daily to seven-day tapping. The system employed was not one recommended for estate work.

Trees 4 to 6 Years Old.

There are fewer Hevea estates in Ceylon with trees of the above age which have been systematically tapped than in Malaya. The following statistics give some idea of what has been obtained:—

Name.	Hevea Trees.			Yield in lb.			Remarks.
	Age.	Number.	Acres.	Total.	Per tree.	Per acre.	
Mahawale	4	747	4	470	0·63	117	
R. Plantations of Kalutara ..	4	2,119	—	1,061	0·50	—	
	4½	5,064	—	3,093	0·61	—	
Rayigam	4-5	6,000	—	2,989	0·50	—	In 10 months
,, ...	4-5	1,500	—	621	0·41	—	,, 10 ,,
Pelmadulla ..	4½-5½	42,777	476	15,075	0·35	31	,, 11 ,,
Bedewella ..	4-6	2,538	288	2,164	0·85	89	,, 9 ,,

The above figures show a yield per tree, from 4-to-5-year-old trees, of from 0·41 to 0·85 lb. and a maximum of 117½ lb. per acre. Most of the trees were tapped on the half-herring-bone system for 9 to 12 months in the year. The yield per tree, from trees 4 years old, varies from 0·50 to 0·63 lb. On Penrith estate 8,726 trees varying in age from 4 to 9 years, planted over 43½ acres, gave in 11 months' tapping 9,725 lb. of dry rubber. This was at the rate of 1·11 lb. per tree or 224 lb. per acre for the tapping period.

Trees 5 to 7 Years Old.

The yield from trees averaging six years shows a very slight increase over those just recorded.

Name.	Hevea Trees.			Yield in lb.		
	Age.	Number.	Acres.	Total.	Per tree.	Per acre.
Rubber Planters of Kalutara ..	5	11,252	—	8,934	0·79	75
Kalutara Rubber Co. of Ceylon ..	56	34,800	—	27,835	0·80	—
Grand Central ..	5	—	1,182	—	—	64
Mahawale ..	5	2,260	11	1,827	0·80	166
Narthupana ..	5	8,100	67	7,000	0·86	104
Mahawale ..	5-6	11,256	56	9,428	0·84	168
Kepitigalla ..	5-7	18,563	—	8,074	0·43	—

The Kepitigalla trees were tapped for 8 and those on Narthupana 9 months. The yield from 5-year-old trees varies very little, the return being from 0·79 to 0·86 lb. per tree. The yield per acre, however, varies from 75¾ to 166 lb. per acre. This is, therefore, a slight increase compared with 4-to-6-year-old trees.

On Suduganga estate, Matale, 10,856 trees varying in age from 5 to over 11 years gave an average yield of 0·92 lb. These were scattered through cacao and tea. The General Ceylon Rubber and Tea Estates also record that from 3,672 trees, 5 to 8 years old, and scattered over 18 acres, a return of 70 lb. per acre or 0·35 lb. per tree was obtained in eleven months' tapping.

Trees 6 to 7 Years Old.

Quite a large number of records are available showing the yields from trees once they have reached their sixth year

Name.	Hevea Trees.			Yield in lb.			Remarks.
	Age.	Number.	Acres.	Total.	Per tree.	Per acre.	
General Ceylon ..	6	5,924	53	10,574	1·78	198	
Rubber Plantations	6	2,000	—	1,481	0·75	—	
Narthupana ..	6	13,000	67	26,000	2·00	388	
Devitural	6	6,727	—	6,779	1·01	—	In 9 months.
Grand Central ..	6	—	427	—	—	105	In 6 months.
Devitural	7	7,215	—	6,960	0·96	—	In 9 months.
Grand Central ..	7	—	249	—	—	200	In 6 months.
Kepitigalla ..	7 to over 10	10,816	—	17,200	1·59	—	In 10 months.

The yield from 6-year-old trees varies from 1·01 to 2 lb. per tree, and 105 to 388 lb. per acre. It will also be noted that the yield from 7-year-old trees is given as 200 lb. per acre (Grand Central), and 0·96 lb. per tree (Deviturai), though tapping was only carried on for 6 and 9 months respectively.

Lochnagar Produce Company report, from 6,200 trees, 5 to 9 years old, 7,645 lb. of rubber, or an average of 1·23 lb. per tree, from areas interplanted with cacao and tea.

Doranakande obtained an average return of 1·27 lb., per tree, from 23,812 trees, 5 to 17 years old. Suduganga cropped 0·97 lb. per tree from 6,503 trees, 6 to over 11 years old, scattered through cacao and tea. Glendon secured, from 43,000 trees, 6 to 16 years old, an average of 1·25 lb. per tree ; Passara Group yielded 2 lb. per tree, from 370 trees, 6 to 13 years old.

Trees 7 to 9 Years Old.

In this group there is still a variation of some importance, though it will be noted that the yield per tree, on estates the majority of which are planted with 200 trees per acre, is between 1 to 2 lb.

Name.	Age.	Hevea Trees. Number.	Acres.	Yield in lb. Total.	Per tree.	Per acre.
Suduganga ..	7-10	3,370	—	4,270	1·27	—
Taldua	7-8	3,500	—	About 2,000	0·57	—
Southern Ceylon	7-9	577	—	614	1·07	—
Dangan	7½-9½	7,700	—	8,378	1·09	—
,, ...	8	4,400	—	3,205	0·73	—
,, ...	8½	5,175	—	5,216	1·01	153
Deviturai ..	8	2,000	—	2,996	1·5	—
Lochnagar ..	8	5,200	150	6,077	1·17	40
Grand Central ..	8	—	112	—	—	234
Deviturai ..	9	5,290	—	9,380	1·77	—
Kepitigalla ..	8-15	10,000	—	30,000	3	—

The Deviturai trees were tapped for 9, and those of the Grand Central Estate 6 months only.

Trees 9 to 11 Years Old.

There are very few trees in Ceylon from 9 years and upwards, but the following statistics are of some interest :—

Name.		Hevea Trees.			Yield in lb.	
	Age.	Number.	Acres.	Total.	Per tree.	Per acre.
Kepitigalla ..	9-10	400	50	339	0·85	60¾
,, ...	10-11	3,370	303	5,000	1·48	—
,, ...	10-11	400	50	382	0·96	—
Suduganga	10	3,370	—	5,000	1·49	—
,, ...	11	3,370	—	4,665	1·39	—
Kepitigalla	11	—	—	—	3 [illegible]	—
A Matale Estate ..	11	499	—	1,596	3	—
South of Ceylon ..	11	255	—	—	5½	—

The trees on the Matale estate were tapped for seven months only. The yield given in the first three series, from old trees on Kepitigalla, is low on account of bad tapping in previous years. The other yields are by no means equal to those from similar-aged trees elsewhere.

Trees 12 to 15 Years old.

The following yields are nearly all taken from the records of one company :—

Name.	Hevea Trees.			Yield in lb.		
	Age.	Number.	Acres.	Total.	Per tree.	Per acre.
Igalkande ..	12	1616	6	2813	1·74	469
Igalkande ..	13	1616	6	2433	1·51	405
Igalkande ..	14	1616	6	2679	1·66	446
Deviturai ..	15	248	—	905	3·65	—

The trees on Deviturai were 15 years and over, but were only tapped for nine months. The soil in this particular area is by no means rich, and I understand that many of the old trees were used for experimental work and the training of tapping coolies. It will also be observed that the trees were closely planted, and that the yield per acre was comparatively large for Ceylon.

Yields Per Acre and Per Tree.

The same difficulties have been experienced in compiling a statement of yields per acre and per tree for Ceylon as were noted when dealing with this subject in connection with Malaya. In the following table figures have, as far as possible, been taken from the records of estates. These do not necessarily give the total range, but the more probable averages, from specified estates, after elimination of exceptional returns :—

Age in years.	Yield per acre.	Yield per tree.
4 to 6	31 to 117 lb.	0·41 to 0·63 lb.
5 to 7	64 to 166 ,,	0·60 to 0·86 ,,
6 to 7	105 to 200 ,,	0·75 to 1·59 ,,
7 to 9	153 to 234 ,,	1·01 to 1·77 ,,
9 to 11	—	1·48 to 3·00 ,,
12 to 15	405 to 469 ,,	1·74 to 3·65 ,,

A point of some importance which is brought out in the above table is that though the yield per tree compares unfavourably with that in Malaya, the outturn per acre is by no means insignificant once tapping operations are in full swing. This is explained by the fact that the areas at present being tapped in Ceylon are very closely planted.

Past Yields Per Acre from Ceylon.

It is now convenient to determine the yield per acre from planted acreages in Ceylon which have been brought to the productive stage. The foregoing statistics justify one in assuming that rubber acreages in Ceylon may be tapped in their fifth year.

In 1901 there were 2,469 acres planted in rubber, alone and with other products; this area, along with some younger rubber, produced 415 tons in 1908, which is at the rate of 1·68 tons per ten acres. By the year 1902, the area was 3,356 acres, from which in 1909 were turned out 679 tons, the rate per ten acres being 2·02 tons. Great progress in planting had been made by the year following, 1903, with 11,630 acres, only a part of which can have been in bearing in 1910, when 1,499 tons were produced, that is, as much as 1·29 tons per ten acres.

If the yields from acreages six years old are considered, they will be found to be almost as much below as those for seven years are above, one ton per ten acres. The average yield of one ton per ten acres appears to have been obtained when the trees were about 6½ years old, taking the island as a whole.

Yields from Ceylon Districts and Estates.
Matale District.

In the Matale District there are estates where an average yield of ¾ lb. of dry rubber per tree from 5,000 trees has been secured in one month's tapping. The average circumference of these trees was 35 inches a yard from the ground.

On another property a yield of 3·2 lb. of rubber per tree has been obtained from 499 trees in seven months' tapping. Another estate, in the same district, has obtained an average yield of 3½ 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. They 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, a 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 implements.

On a third Matale estate the Hevea trees are planted 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 was expected, 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.

The Province of Uva.

The most successful results at high elevations in Ceylon have probably been obtained in the Province of Uva. On Passara

Group estate, *Hevea brasiliensis* is being cultivated up to and over 3,000 feet above sea-level. The trees are of various ages, and one specimen, 13 years old, measured 54 inches in circumference a yard from the ground, and 60 to 70 feet in height, though growing at an elevation of about 2,600 feet. Tapping has been carried on with promising results up to 2,800 feet. From the trees at an elevation of 2,600 feet, varying in age from 7 to 13 years, an average yield of 2 lb. of dry rubber per tree was obtained during 1905. These results are of considerable interest and importance.

A considerable amount of Hevea has been planted in the Badulla, Passara, Monaragala, and Bibile Districts; and in many cases the altitude is considerably over 2,000 feet.

Kelani, Kalutara, Ambalangoda, Rayigam, &c.

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 20 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 was expected during 1906.

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

A well-known old Kalutara company having its Hevea trees mainly planted among tea records the following:—

Hevea Trees.		Yield in lb.		
Number.	Acres.	Total.	Per tree.	Per acre.
8,368	63	13,655	1·63	217
13,330	63	23,803	1·79	378
17,610	83	36,520	2·08	440
28,580	150	57,561	2·01	384
39,912	189	87,779	2·20	464

These trees were from four to ten years old, and the results show that even in Ceylon a yield approximating to one ton per five acres can be obtained over a large acreage of trees which have passed their infancy.

The quantity of rubber harvested during 1905 in Kalutara district was 101·978 lb. from 88,667 trees, which shows an average of about 1·15 per tree. A large number of these trees, about 43 per cent., were tapped for the first time, but as nearly all the older trees in the district were planted in selected spots and at great distances, the Kalutara Association did not, at that time, expect to see any increase in the yield per tree for a considerable number of years. This district is one of the most successful in Ceylon, and the returns obtained by the most advanced estates within its boundaries during 1910 have revived confidence among planters in the island.

Yields on Gikiyanakanda Estate.

The results obtained on the above estate for 1905 are of importance as showing reliable details of yield and dimensions of trees. During the year, 5,598 trees were tapped; of these, 2,207 had been previously tapped. Between January and March 1,346 new trees were operated on for the first time, and again between July and October other 2,045 trees were tapped for the first time. The minimum girth of the trees, which were tapped for the first time, was 20 inches at a yard from the ground, and the census at the end of the year showed that 3,811 out of the 5,598 had a circumference of 24 inches or over. The trees were tapped on the full herring-bone system, each tree being tapped every alternate day. The paring operations were done carefully, the width of excised bark being slightly less than one inch per month. The total quantity of rubber from the 5,598 trees, some of which were tapped from January onwards, others only from October, was 7,592 lb., or 1·34 lb. per tree.

Increase in Yield from Ceylon Estates.

The yields obtained from some estates during the past few years are small but show a gradual increase from the same properties as the tapped trees get older and more young ones attain a tappable size and age. The gradual increase is exemplified in the yields, per tree, obtained on Gikiyanakanda, Neboda, Ceylon, according to the information kindly supplied to me by Mr. Golledge: 1903, 0·59 lb.; 1904, 0·76 lb.; 1905, 1·32 lb.; 1906, 1·78 lb.; and 1907, 1·86 lb.

Rosehaugh Tea and Rubber Co.—The yield of rubber for the twelve months ended 31st December, 1910, was 410,707 lb. For the past three years the yield has been: 1908, 223,859 lb.; 1909, 291,354 lb.; and in 1910, 410,707 lb.

Ceylon Tea Plantations Co.—The yield during 1910 was 118,626 lb. from 140,823 trees, as against 54,548 lb. for 1909. Many of the trees tapped in 1910 were operated upon for the first time. The yield in 1911 was 240,120 lb.

Yatiyantota (Ceylon) Tea Co.—The quantity of rubber secured during 1910 was 39,702 lb., as compared with 14,488 lb. in 1909. The yield from the trees in the old 487 acres of Polatagama was 16,366 lb., as compared with 7,330 lb. in 1909. The balance of 23,336 lb. was obtained from interplanted trees in the tea area. The yield in 1911 was 84,901 lb.

The crop from the P.P.K. (Ceylon) Rubber Estate was 45,474 in 1909 and 62,500 in 1910. An increase from 964 to 2,670 was also shown for the same years in the returns from the Haydella Tea and Rubber Estates.

The Lavant Rubber and Tea Company produced 6,000 lb. in 1909, 19,358 lb. in 1910, and 62,240 lb. in 1911; the estimate for 1912 is 100,000 lb.

The Panawatte Rubber Company obtained 89,204 lb. in 1910 and 181,529 lb. in 1911.

The Pelmadulla Rubber Company similarly showed a large increase, the crop in 1910 being 17,547 and in 1911, 74,556 lb.

The Eastern Produce Company obtained 121,111 lb. in 1910 and 155,280 lb. in 1911. There are many other estates in Ceylon which have shown a conspicuous increase in crop during the past few years, but the above references will be sufficient to emphasize the point under consideration.

Prospective Increases from Ceylon Properties.

There are many estates in Ceylon which in the past have not had large crops of rubber, but which in virtue of their large acreages are destined to play an important part in the future of rubber crops from that island.

Among these may be mentioned Woodend, which gave 7,202 lb. in 1910 from a small number of old trees; Panawal, which yielded 11,005 lb.; and Pantiya, which harvested 23,918 lb. in the same period. On the property of the Ceylon (Para) Rubber Co., tapping operations were commenced in July, 1910. The trees were very lightly treated in the early stages, and it was not until the closing months of the year that rubber was harvested in any appreciable quantity. The total crop was 11,567 lb.

The Grand Central (Ceylon) Rubber Estates recorded for 1910 a rubber crop from the Urumiwella, Nakiadeniya, Durampitiya, Atale, Pallegama and Arandara Estates of 140,367 lb. This Company possesses, in addition to large acreages of young rubber, 788½ acres planted 1900-1904 and 1,182½ acres planted during 1905.

The Kintyre Tea Estates Co. during the year 1910-1911 harvested 40,108 lb. This company possesses 139½ acres of Hevea planted from 1902 to 1905, in addition to some among tea and large areas of rubber planted after 1905.

Yields in South India.

The acreage in bearing in South India is small, and there are but few records available of average crops from estates in that part of the world.

The Travancore Rubber Co., obtained in 1910, from 20,000 trees, 4 to 5 years old, a crop of 6,385 lb. The trees were very lightly tapped, and yielded an average of 0·32 lb. each, or at the rate of 32 lb. per acre over the whole 200 acres.

Mooply Valley in 1910 harvested 6,600 lb. from trees planted over 45 acres in 1905. This was obtained during a few months' tapping only.

The Rani Travancore Rubber Co. obtained in 1910, from 79,800 trees, then 5 to 6 years old, 41,983 lb. of rubber, equivalent to 0·53 lb. per tree. It should be pointed out that a large number of the trees only reached the tapping stage towards the end of the year.

The Periyar Rubber Co. secured in 1908, from 238 acres of Hevea, then six years old, 11,340 lb. Since that date the yield per acre has been increased considerably.

Old Trees in Malabar.

Some old trees planted between 1883 and 1885 at Poonur in Malabar, were recently tapped (T.A., March, 1910). They were planted 135 trees per acre, and many of them measured seven feet at over three feet from the ground. During several months' tapping, the trees are said to have yielded at the rate of 1 lb. of dry rubber per tree, per month, a cooly collecting about $3\frac{1}{2}$ lb. per day.

Yields at High Altitudes.

On Hawthorne Estate, Shevaroy Hills, the rubber trees are growing among coffee, at an elevation of 3,000 to 3,500 feet, and in a climate having only about 50 inches of rain annually. The photographs of the rubber on this estate show fairly good growth, most of the trees having been allowed to produce tall and slender stems. Early in 1906, 91 Hevea rubber trees, twelve of which were seven years old and the rest five and six years, were tapped, and an average yield of $\frac{1}{4}$ lb. of dry clean rubber per tree for one month was obtained. In conjunction with this it must be remembered that at an elevation of 2,600 feet in Ceylon, in a relatively dry climate, a yield of 2 lb. of rubber per tree has been obtained during 1905.

Experimental tapping was also commenced on Glenburn estate (T.A., May, 1909), in the Nilgiris, 3,500 feet above sea-level; 745 trees were tapped in comparatively dry weather and in six days twenty-one men obtained 45 lb. 2 oz. of latex, which yielded 15 lb. 11 oz. of dry rubber.

Ten trees planted in Cachar, North-East India (Agr. Jour. India, July, 1907), amongst tea, in 1897, were tapped from December, 1906, to March, 1907, and yielded 10 lb. of rubber.

CHAPTER XVIII.

YIELDS IN THE DUTCH EAST INDIES, BORNEO, AFRICA, ETC.

At the present time Malaya and Ceylon are the principal producers of plantation Para rubber, and when the statistics regarding yields from those countries have been dealt with this part of our subject is almost completed. There are, nevertheless, enormous areas in the Indo-Malayan region, outside the countries already dealt with, where large numbers of Hevea plantations have been established, the more notable being Sumatra, Java, Borneo, and Africa. It is, therefore, desirable to deal with the records of crops from plantations in these parts of the tropical belt.

Yields in Sumatra.

Sumatra is, from the standpoint of acreage under Hevea, the most important country in the Dutch East Indies Unfortunately, the number of old or bearing trees is insignificant; but there is a considerable amount of information available regarding the yields from trees of a known age which may prove useful in compiling estimates of future output from these areas.

Name.	Age.	Hevea Trees. Number.	Acres.	Yield in lb. Total.	Per tree.	Per acre.
Sumatra Para ..	3–4	—	—	—	—	200
United Sumatra	3–5	1,850	20	1,600	0·87	80
do. ..	3-5	6,000	55	4,300	0·72	78
do. ..	3–5	1,200	10 }			
..	5–7	9,200	85 }	17,300	1·70	182
do. ..	3–5	12,000	115 }			
..	5–7	11,500	110 }	50,500	2·15	224
Sialang ..	4–6	12,000	151	16,767	0·92	111
Anglo-Sumatra ..	4–6	3,676	29	3,282	0·89	113
do ..	4–7	49,796	432	54,252	1·09	126
Serdang Central ..	4–7	12,500	100	6,830	0·54	68
United Serdang ..	4–7	74,094	—	67,828	0·92	—
Serbadjadi ..	4¼–5	13,000	—	4,504	0·35	—
Sungei Kari ..	5–6	18,211	151	16,767	0·92	111
Deli Moeda ..	5–7	9,000	—	17,600	1·95	—
Bandar Sumatra..	5–7	10,944	—	18,000	1·73	—
United Serdang ..	5–7	111,500	976	218,530	1·95	221
Tapanoeli ..	7	25,006	—	12,500	0·50	—

In several instances, notably Sialang and Serdang Central, the trees were only tapped for 6 or 8 months. In United Serdang only 5638, and on Tapanoeli 3,035 trees were in the tapping round at the commencement of operations. On the property of the United Sumatra the Hevea was mixed with coffee, which was finally removed. On Bandar Sumatra the number given represents the average tapped throughout the year, there being only 6,300 trees tapped at the beginning and 15,000 at the end of the year.

The yield obtained from young trees, five years old, in Sumatra is shown in the returns from Glen Bervie Estate. At the beginning of the financial year 1,200 trees were tapped, 6,337 in the middle and 10,000 at the end of the year. The yield obtained was at the rate of approximately 1 lb. per tree, per annum.

The above yields compare very favourably with those from young trees in Ceylon, but are not equal to the yields from Malaya. The main reason is that most of the Hevea trees were growing on old coffee land.

Yield from Old Trees in Sumatra.

Arbuthnot does not regard a yield of 2 lb. per tree as very satisfactory, and points out that on the property of the United Sumatra company there are several old trees which have yielded from 9 to 25 lb. each. Eighteen trees, 10 years old, gave 9·2 lb. each; when 11 years old, 15 lb.; at 12 years, 18·8 lb.; at 13 years of age, 25 lb. each; thus proving that the yield from well-established trees in Sumatra is comparable with that in Malaya.

On the properties owned by the Sumatra Para company there are many old trees. It was stated at the last annual meeting by Mr. Arbuthnot that the trees planted in 1898-9 yielded at the rate of 900 lb. per acre, and that the 1902 planting gave 700 lb. per acre, the ages of the trees on these two blocks being about 12 and 9 years respectively.

Yields from Notable Sumatra Estates.

There are several estates in Sumatra, notably those owned by the Sumatra Para, United Sumatra, and other companies, which have given good yields in the past few years.

The Sumatra Para company in the year 1907-8 tapped about 20,000 trees, some of which were 4 to 6 years old, and the remainder —9,109—8 to 9 years old, the yield therefrom being at the rate of 3·13 lb. per tree, per annum. In the following year, from the same trees, together with an additional 14,000 young trees, a yield of 2·17 lb. per tree was returned. In 1909-10, from approximately 9,000 trees 10 to 11 years old, and 28,000 trees up to 8 years old, an average yield of 3½ lb. per tree was obtained. For 1910-11, it was reported that over the whole tapping area of 450 acres some 475 lb. per acre was got from trees 4 to 12 years old.

During the year 1910-11 the United Sumatra Company obtained about 2 lb. per tree from trees up to 9 years old, with some 17 older trees.

Yields from Hevea in Java.

Though the acreage under Hevea in Java is now large, there are very few estates which have been tapping for a year or longer. The Algemeene Belgisch-Javische C.M. report that 5,000 trees scattered over 122½ acres, only 4 years old, gave a yield of 0·8 lb. each, equivalent to 33 lb. per acre. The Belgischo-Nederlandsche C.M. state that 35,000 trees over 420 acres, when 3 to 5 years old, gave 1·03 lb. per tree or 86 lb. per acre. The Fransch-Nederlandsche Koloniale C.M. obtained from trees 4, 5, and 6 years old respectively 0·52, 0·92, and 1·42 lb. of dry rubber per tree, per annum.

At Buitenzorg, where several trees are growing on poor soil, those 8 years old have given 1 lb. 7 oz. per tree, per annum, the tapping having been done every alternate day, the pricker immediately following the parer on every occasion.

Yields in British North Borneo.

As in Java, there are few estates which possess large trees in bearing. The only trees which appear to have been tapped for a considerable period are those on Sekong and Sapong estates and at the experiment station, Tenom. The following table will serve to show the probable yields on good soil in Borneo :—

	Hevea Trees.			Yield in lb.	
Age.	Number.	Acres.	Total.	Per tree.	Per acre.
4-5	26,947	—	22,990	0·85	—
4-6	6,723	22	9,560	1·42	432
5-6½	60	—	107	1·8	—
4-10	22,367	74	35,134	1·57	473
8 & over	6,700	—	10,395	1·55	—
10	11,317	—	32,723	2·98	—

The British Borneo Para Rubber Co. inform me that 32,000 trees, averaging 5 years in age, yielded 12,011 lb. in the first period of tapping.

Yields in the Gold Coast.

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.

The amount of rubber yielded by Hevea and Funtumia trees (Johnson's Report, 1905), 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 ..	,, 1903 ..	0	4

Regarding the yield from *Hevea brasiliensis*, Johnson remarks that it must not be taken as a criterion of the anticipated yield from 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.

Tudhope states that in 1908, at Aburi, 14 trees, with an average girth of about 19¼ inches, were tapped on the half-spiral system, 3 times a week from 19th November to 31st December, 1908. A yield of 2 lb. 8½ oz. of dry rubber was obtained.

The Director of Agriculture, in his annual report for 1909, states that thirty trees, 5½ years old, and with an average girth of 24 inches, were selected for the purpose of tapping, and a yield of 5 lb. 14 oz. of dry rubber obtained therefrom, which shows that it will well repay planters to cultivate this species of rubber tree in that colony. Three blocks containing 15, 15 and 14 trees respectively were tapped at Aburi, and the results, 2 lb. 5½ oz., 4 lb. 5½ oz., and 4 lb. 5¾ oz., are very encouraging. The third block was tapped in the previous year, and yielded 2 lb. 8½ oz. of dry rubber. The tapping at Tarquah was stopped after twelve cuts had been made, but it was continued at Aburi, and the results were better than in the previous year. Tapping on Block I. was stopped after fourteen incisions had been made, as the V knife appeared to cause considerable damage to the trees. Blocks II. and III. were continued until the 22nd December, when the Harmattan set in, and it was decided to stop tapping for a time. Twenty cuts had been made, and a yield of 4½ oz. and 5 oz. per tree obtained.

Yields in Cameroon, Togo, and Nigeria.

The following yields (Tropenpflanzer, Dec., 1910), have been recorded from three 10-year-old trees in the Cameroon, tapped daily; in the first two there was an interval of six months between the two series of tappings :—

Tree.	Girth.	Method of Tapping.	No. of Tappings.	Total Yield. ozs.
1	3 ft. 5 ins.	Full herring-bone	59	20·98
2	do.	Separate oblique cuts	56	25·16
3	3 ft. 7 ins.	Spiral	20	8·80
				54·94

The separate oblique cuts—4 inches long—were made in rings around the stem, and each day a new ring of cuts was made 2 inches below the previous one.

In Togo (Tropenpflanzer, Dec., 1910), a tree seven years old, with a girth of 24 inches, was tapped for 12 consecutive days in three spirals eight inches apart, and yielded 14⅗ oz. of dry rubber.

In Nigeria (Ann. Rep., For. and Agr. Dep., 1909), 100 trees, 8 years old, were tapped and yielded, in 23 tappings, 6½ oz. per tree; others 15 years old gave 1 lb. 4 oz. in 26 tappings.

Yields in the Congo Free State.

At Mayumbe, some 10-year-old Hevea trees each gave (Rub. Exh. Handbook, 1911), in 30 tappings, 296 grammes (10½ oz.) of dry rubber; others gave 99 grammes (3½ oz.) in 10 tappings. Ten-year-old trees in poor soil at Boma, where there is a well-defined dry season of from 5 to 6 months, each yielded 188·5 grammes ($6\frac{1}{2}$ oz.) in 28 tapping days. Trees of the same age at Coquilhatville, in 40 tapping days, yielded 1,499 grammes (3 lb. 5 oz.). At Tlambi, 11-year-old trees, tapped 11 times, gave an average per tree of 140 grammes (5 oz.). On another occasion, tapped 10 times on alternate days, they averaged 227 grammes (8 oz.) per tree.

Yields in Burmah, Indo China, New Guinea, and Queensland.

According to Snow (I.R.W., Jan., 1911) several trees in Lower Burmah, when five years old, measured 27 inches in girth at a yard from the ground, and yielded $\frac{3}{4}$ lb. of rubber each.

The New Guinea Company report (Gummi-Zeitung, Feb. 3rd, 1911) that several eight-year-old trees, measuring 60 cm. (24 inches) at one metre from the ground, produced 279 grammes (9·8 ozs) of rubber in one month.

Several records of yields in Cochin China are available. One record (J. d' Agr. Trop., July, 1907) states that seven 9-year-old trees at Suoi Giao, from one tapping, gave $1\frac{1}{2}$ oz. of rubber. The same authority states that the average quantity of latex obtained from each of the 7 and 9-year-old trees, when tapped 145 times, was respectively 2,256 and 3,331 c.c. The mean amount of caoutchouc in the latex being 31·3 per cent., the yields of rubber were 1·55 lb. for the 7-year trees, and 2·30 lb. for those 9 years old. Ten trees planted in 1898 (Str. Bull., Jan., 1910), gave, in 1909, when tapped every day, the equivalent of about $2\frac{1}{2}$ lb. dry rubber.

At the Kamerunga Station, Queensland, ten trees about 8 years old, with average girth 21·3 inches, were tapped irregularly, some nearly every day, others almost alternate days, an average of 41·5 times between 19th February and 23rd May, 1907. Various methods, including the full spiral, were used. The average yield per tree per tapping was 0·315 oz., which at 180 tapping days, equals 3 lb. $8\frac{3}{4}$ oz. per year per tree.

Yields in Surinam.

There are several old Hevea trees in Surinam which have been somewhat experimentally tapped and have given encouraging yields. In 1908 (Rep. Dep. Agr.) ten trees planted at Waterland in 1897, and therefore about 11 years old, gave an average of 2·4 lb. each, consisting of 1·8 lbs. of first grade and 0·6 lbs. of scrap. A year later a yield of 3 lb. per tree was reported from 300 ten-year-old trees in the same district.

CHAPTER XIX.

GENERAL CONSIDERATIONS AFFECTING YIELDS.

When dealing with the question of yields of dry rubber from 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 trees greatly influence the quantity and quality of the rubber, and it is to be regretted that more yields over large acreages for several years in succession are not at hand. Nevertheless, we do possess information of the yield from particular trees during certain years and from large acreages of known age for a limited period; 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.

Natural Variations.

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. At Henaratgoda, where the trees range in age from 15 to 30 years, and where tapping has been done on various sections of the trees from the base to 6, 16, 20, 30, and 50 feet, the opportunities to observe the variation in yield of latex and rubber have been numerous. The first six feet from the base, though tapped over the same area, in the same manner, and with the same implements, gave from $\frac{6}{25}$ oz. to nearly two ounces of rubber per tapping per tree. Other parts of the stems of individual trees have varied in their daily yield of rubber from $\frac{3}{5}$ oz., $5\frac{1}{5}$ oz., and $\frac{9}{40}$ oz., to $\frac{33}{40}$ oz. In one case, where the tree has been regularly tapped from the base to a height of 50 feet, the yield of dry rubber has sometimes been as high as $8\frac{3}{4}$ oz. per tree per tapping, and on other occasions as low as $\frac{1}{4}$ oz. Such variations can, in most cases, be mainly attributed to internal conditions rather than external climatic forces.

Variation in yield from individual trees has also been reported by Pearson (I.R.World) in the Amazon, some trees there bleeding freely and others reluctantly. Several trees furnish thick creamy latex, others yield thin watery latex and several gave no latex at all

Estate Conditions Affecting Yields.

It is apparent from the foregoing chapters upon yields of rubber from Hevea trees in various countries, that considerable variation must be allowed for. The external factors which are responsible for this variation are numerous. Some—distance in planting, frequency of tapping—have already been recognised; others—such as humidity and atmospheric pressure—are still obscure. It is therefore necessary to consider the more important estate conditions which appear to have an effect on yield.

Yields in Different Countries.

The most striking differences in yield are seen between the two leading countries—Ceylon and Malaya. Elsewhere it has been shown that, whereas the yields in Ceylon from trees six to seven years old may range from 0·75 to 1·59 lb. per tree per annum, those in Malaya range from 1·60 to 2·47 lb. per tree per annum from trees of approximately similar ages. Tapping in Ceylon cannot usually be commenced before the middle of the fifth year; in Malaya many trees have yielded from one to two pounds of rubber each before attaining that age. This variability in yielding capacity renders estimates, experiments, and observations in Ceylon of little value for Malaya. The soils, climate, and methods of cultivation in Ceylon are unlike those in Malaya; and as on these depend the growth and ultimate yields of rubber, the sooner the differences are acknowledged by Ceylon enthusiasts the better. Manuring in Ceylon will undoubtedly compensate for many of the drawbacks in that country. This, combined with cheap production, will enable planters in Ceylon to successfully compete with their fellows in most parts of the tropics.

Rate of Growth and Ultimate Yields.

It seems almost incredible that Hevea trees may take from three to seven, and even nine, years to reach the producing stage. This variation in bearing age is very large, but covers a multitude of conditions under which plants are at present cultivated. Trees in bearing at three years are frequently to be seen in Province Wellesley, Selangor, and Serdang; others in Uva, Ceylon, at least 2,500 feet, and in Southern India at about 3,000 feet above sea-level, may take the longer period. In many circles it is accepted that a fair proportion of the trees grown alone on a clearing can be tapped when four years old in favoured parts of Malaya, at five years in other parts of Malaya and Sumatra, and at six years in most Ceylon districts; where the trees are planted among old tea, coffee, or cacao, eight years is often required before successful tapping operations can be carried out. If a difference of two years, or even one year, is ultimately to be associated with Hevea trees in the areas enumerated, it is a matter of the utmost importance to all. This difference is not merely one of the age at which trees can be tapped for the first time; it indicates the probability of a much reduced total yield from trees requiring the maximum period for attainment of maturity. Where the trees take six years to reach the tappable stage there must, on account of inferior soil, unfavourable climatic or other conditions, be a much slower average rate of growth during what may be termed the first cycle; as the slow-growing trees get older they will not have a better chance of increasing their rate of growth above those characterised by more rapid development, and the secondary and subsequently renewed barks will probably require a similarly longer period to mature. In other words, there will be less renewed bark available on the slow-growing trees after a given period. And the bark is the mother of rubber. It may be argued that quantity, and especially thickness, of bark is not the only criterion of total yield; it is granted that in some circumstances thin-barked trees yield as much per area of bark excised as others with thicker bark, especially when the former trees are older. But, taking trees of the same age, there seems every reason to expect that those with more rapid rates of growth and thicker bark tissues will be capable of yielding larger quantities of rubber in the future.

In some instances the trees have not reached the productive stage at an early age on account of bad methods of cultivation; in such cases the subsequent growth may be quite equal to that on the better-class estates.

Effect of Intercrops on Yields.

The effect of most intercrops on yields is similar to that of weeds or of poor soil. The growth of the Hevea tree is considerably slower, and the ultimate yield of rubber is therefore less. Hevea intercropped with tapioca and cultivated in the native fashion is often two years behind in growth. This should be allowed for in estimating rubber crops.

Crops such as Indian corn, tapioca, sugar, pineapples, are known to have a very exhausting effect; others, such as coffee and cacao, are less detrimental, especially when properly distanced; finally, there are a few, of the indigo and banana types, that are reputed to improve the fertility of the land. The effect of intercrops on the available food supplies in the soil is, however, generally admitted. They undoubtedly absorb food which might otherwise have been used by the growing rubber trees.

In many cases they preserve the soil moisture, a consideration of some importance in dry districts of Ceylon, India, and Java, but negligible in many parts of Malaya, where the water-level is very near to the surface all the year round. Intercrops also shade the trunks of the Hevea trees and thus check whatever influence sunlight may have on the trees or the latex. This effect is limited, with low-lying crops such as coffee and tea, mainly to the early morning and to the evening, though with cacao it is in force the greater part of the day. Many of the intercrops often interfere with direct supervision during tapping, though this can be remedied by proper spacing of both classes of plants.

It is obvious that, despite the unfavourable effect that intercrops have upon the growth of the Hevea trees and upon the ultimate yields, they may, by necessitating a much wider distance for the Hevea, be instrumental in effecting a great improvement in later years. Many estates plant the Hevea trees, if without intercrop, from 15 to 20 feet apart. If intercrops are used, the distance between the Hevea trees is increased to 20 or 25 feet, a difference which ensures much larger and better developed rubber trees in the future.

In a general way it may be stated that the lowest yields have hitherto been obtained in countries or upon estates where intercrops were regularly cultivated. The maximum crops have been obtained in Malaya and Sumatra, where Hevea has been grown as a single product. Whether or not this is due to mismanagement of the intercrops remains to be proved; meanwhile, the tendency in Malaya and Sumatra is to remove them from estates upon which they have been planted. On the other hand, mainly owing to the high prices ruling for sugar, coffee, and other catch-crop products, many planters prefer to cultivate such crops among the rubber in the belief that the total net profit over a number of years from rubber and other products will be greater than from rubber alone.

Yield and Distance in Planting.

For several years planters have not been able to decide the question of the best distance in planting, many believing that the closely-planted trees would yield more per acre than those widely planted. During 1906 some very good results were obtained on estates where trees were widely planted; on closely-planted properties much difficulty was experienced in thinning-out the undesirable trees.

Yields on Vallambrosa Estate.

The following statement of approximate yields from the older fields belonging to the Vallambrosa Rubber Company was compiled from the manager's report and presented by the Directors in their Annual Report for 1906-07:—

Acreage of fields	Distances trees planted apart.	No. of trees tapped.	No. of times tapped.	Yield per tree.	Total Yield.	No. of trees per acre tapped.	Yield per acre	Remarks.
	Feet.			lb.	lb.		lb.	
60	24 x 12	4,642	3	2¾	12,765	77	212½	Planted 1899 (about 150 trees per acre).
150	10 x 10	8,000 28,301	3 2	1½	54,451	242	363	This field was planted through coffee in 1898, and thinned - out to 260 270 trees per acre.
40	12 x 10	6,225	2	1	6,225	155	155	Planted 1900. Thinned to 250 trees per acre.
680	12 x 10	10,000 60,820	3 2	1	70,820	147	117½	Planted from 1899 to 1901. Thinned to 250-270 trees per acre.
		29,113	1	oz. 5	9,097			
930		147,101			153,358			

Caledonia Estate.

Some trees were planted on Caledonia estate many years ago, more, it is said, with the idea of filling in an unsightly swampy piece of ground than with an eye to profit. For several years this block, of a few acres in extent (planted 10 by 10), was pointed out as an awful example of the effects of close planting. The trees were tall, weedy in appearance, and of small girth. Moreover, they were subjected to all kinds of experiments in the way of pruning, lopping, and tapping, and the soil, according to experts, was by no means specially suitable for rubber. That block of trees, however, yielded at the rate of 900 lb. per acre in one year; previously it had given 378 lb. per acre in twelve months.

Yields on Highlands and Lowlands Estate.

The Annual Report of the above Company for 1906 gives some interesting information in favour of widely-planted trees. The report made by Mr. R. W. Harrison states that there is one block of trees, 16 acres in extent, containing 807 trees planted 30 by 25 feet. These trees, nine years old, were tapped three times during 1906 and gave 2,500 lb. at the first, 1,469 lb. at the second, and 1,773 lb. at the third tapping, or a total of 5,742 lb. from 807 trees, equivalent to a yield of over 7 lb. per tree. These may be exceptional results, but they certainly indicate that satisfactory returns can be obtained when the trees are not closely planted.

As pointed out by Etherington, the distance of 30 by 25 ft. allows 2,250 cubic feet of soil to each tree and an average spread of foliage of 750 square feet; under these conditions the food-producing and absorbing power of each tree must be considerable.

Permanent close planting has, after seven or eight years, an effect similar to that of impoverished soils. The trees do not make the same growth, the bark takes longer to renew, and the yield does not increase as it does on widely-planted or thinned-out properties. Future yield is therefore to be correlated with the rate of the trees' growth.

Yield and Size of Tree.

Ridley and Derry in their Annual Report for 1904 published some figures showing ratio of yield to the size of the tree.

The following table was given :—

Girth at 3 feet from ground.	Comparative yield per inch of girth at 3 feet from ground.
Under 2 ft. girth	Under $\frac{1}{4}$ oz.
From 2 ft. to 2 ft. 6 in.	$\frac{1}{4}$ oz.
From 2 ft. 6 in. to 3 ft.	Under $\frac{1}{2}$ oz.
From 3 ft. to 3 ft. 6 in.	$\frac{1}{2}$ oz.
From 3 ft. 6 in. and over	Over $\frac{1}{2}$ oz

Ridley and Derry believe that the best growing period is between the 6th and 15th years, during which time trees may increase from about 24 inches in girth to 60 inches or more, thus showing an annual increment of from 3 to 6 inches. They claim to have shown that trees closely planted do not make a satisfactory increment of growth, and that the yield of rubber increases with the size of the tree from under ¼ oz. of dry rubber to the inch of girth for small trees to over ½ oz. for large ones; to further emphasize the error of close planting they have submitted the following statements taken from the figures of their experiments:—

No. of trees tapped.	Average girth per tree. ft. in.	Aggregate girth. ft. in.	Dry Rubber. lb. oz.	Remarks.
40	2 3	90 7½	18 7¼	Tapped 18 times.
20	4 2	83 7¼	25 6	
50	1 9	88 7¼	18 8¼	
15	5 8	85 7	33 8	

Yield and Water in Soils.

The yields of rubber which are now being chronicled throw considerable light on a problem which has engaged the attention of cultivators for many years. It was originally supposed that Hevea trees throve best on the banks of rivers where, in addition to a good supply of available plant food, there was always abundance of water and an occasional flooding of the land. As previously pointed out, it was in consequence of this that botanical authorities in the East recommended planters to select similar areas for their new clearings in the belief that to imitate Nature would be the safest and probably the most remunerative plan. When it was subsequently reported that Hevea trees flourished not only along the river banks, but on the low hills of the interior of Brazil, doubt was expressed as to the wisdom of planting on areas subject to periodical inundation.

As a result, we have in the Indo-Malayan region Hevea rubber trees planted on all classes of soil, some very dry and others exceedingly damp. It is well known that the majority of the Perak and Selangor estates now in bearing are on land where the water-level is only one or two feet from the surface. In Ceylon, Sumatra and Java, the majority of rubber estates are not so abundantly supplied with water. The one fact which vividly impresses tourists in the East is the nearness of the water-level to the surface on many Malay estates. Now, everyone recognises that the highest yields have been obtained from these estates, though the lateral roots are more or less immersed in water, the taproots have disappeared and the trees are growing under what would normally be regarded as unnatural, if not unhealthy, conditions. The water factor appears to be of more importance during the first eight years of growth than most experts imagine.

Atmospheric Pressure and Yields.

The effect upon yields of variation in the pressure of the air is as yet unknown. The behaviour of the tree at high altitudes cannot serve as a guide upon the question, for there many other factors come into consideration. The atmosphere must exercise its pressure upon the latex in two opposing directions: against the stream flowing out of the cut ends of the latex vessels, and upon the trunk of the trees. This latter force must help the latex out of the vessels, with the aid of the force exercised by the tissue tension. At first glance it would appear very much the greater, for it is applied to a larger surface, over the trunk, while the other is applied to only the small cut ends of the latex vessels. But the resistance of the partly unyielding bark to the pressure of the air must render the difference in intensity of the force less in amount. One would welcome observations upon this factor of atmospheric pressure. The variations from day to day in the yields of trees are sometimes marked, and as it does not seem possible to refer them always to changes in moisture conditions it would be worth while to determine this point. It must, of course, be admitted that the information will not be of an immediate practical value, since atmospheric pressure is beyond our control, but it may throw light upon estate operations wherein pressure is or can be brought into force.

Yield and Length of Time Latex Flows.

The length of time that latex flows from a freshly-made cut has a direct connection with the yields on estates. It is unfortunate that the latex flows only for minutes, instead of hours. The length of time that latex flows is dependent upon many factors, some—the anatomy of the plant, the tissue tension, and atmospheric pressure—are beyond our control, whilst others, such as the water content of the latex, can be modified during collecting operations. The time is shortened by the dryness of the air, by heat and by sunlight. The former, along with thickness of the latex, often necessitates the stopping of tapping operations in dry seasons, but can be partially controlled by the use of water from drip-tins to retard the coagulation of latex at the cut ends of the latex tubes. The bad effects of heat and sunlight can to some extent be minimised by choosing certain times of the day for tapping and by combining this with compass tapping ; some intercrops, especially cacao, shade the trunks of the trees throughout the day. Atmospheric humidity depends almost entirely upon the location of the estate, but something might be done to influence this in normally dry districts by the retention of a definite proportion of the original forest to serve as a wind break, or by planting wind-belts or bushy intercrops that will have a similar effect. By thus impeding the circulation of air, there will be a partial retention of moisture that has come from the soil and from the leaves.

In some reports of tapping on the Amazon and in the West Indies, reference is made to the renewal of the flow by picking off the scrap before it has become too thick ; a second and even a third flow can sometimes be obtained by this means. Hart reported this in some of his Trinidad experiments, and Vernet also appears to have "refreshed" the cuts twice on a certain day, with a gradually decreasing yield, though it is doubtful as to what extent the knife was used by him. In these experiments time enters as a factor, the interval being sufficiently long to permit of an accumulation of latex, of varying richness in caoutchouc, towards the cut ends of the latex tubes.

This subject is not so trivial as it may on first consideration appear. The larger the quantity of latex obtained per incision, the greater is the bark economy effected. So far the only feasible operation appears to be to maintain open latex tubes by the passage of water alone, or water containing ammonia, along the tapped surfaces as soon as the flow begins to lessen.

Yield and Superposition of Incisions.

Vernet (Journ. d'Agric. Tropicale, April, 1910) experimented to find out what was the effect of superposition of incisions upon the yield. It is to be expected that an upper incision will to some extent prevent the downwardly-flowing sap from reaching and providing with nutriment the area around a lower incision. And if the two incisions are near enough, though at what distance we cannot yet say, they must drain not only the same systems of laticiferous vessels, but also the same reserves of nutriment. Vernet made a single V incision upon one side of ten seven-year-old trees. Upon the other side he made two V incisions, so that one was as much higher than the V on the other side as the other was lower. The incisions were renewed six times :—

70 double incisions gave 909 c.c. of latex.
70 single incisions gave 620 c.c. of latex.

Had each of the double incisions yielded at the same rate as the single incision there would have been 1,240 c.c. of latex. These results, of course, do not throw any light upon the second of the above questions, seeing that Vernet does not tell us the distance between the double incisions. Indeed, he does not mention this point, but it is probable that he made the cuts far enough apart to prevent one influencing the other as far as proximity was concerned.

Factors in Yields from Individual Estates.

There are numerous factors which have an important relationship not only to the composition of an estate's crop, but to the total yield from a particular property. Regularity in tapping, systems of coagulating, washing, and other operations on the estate have their effect on the total yield. Among one of the factors is that of thickness of bark shavings and cleanliness in picking scrap.

Rubber from Bark Shavings.

A few years ago, when bark parings were frequently $\frac{1}{10}$ of an inch in thickness, and the picking of coagulated scrap from the tapping lines was not carefully attended to, a considerable yield of rubber was obtained from shavings. It is customary to collect all shavings and accumulate them in tanks containing water with or without chemicals. These shavings, when thoroughly steeped, are washed in a macerating machine and the rubber extracted therefrom shipped as washed scrap. In the early tapping days, it was estimated that the shavings from 100 coolies' work would give about 25 lb. of washed rubber. A yield of 7 per cent. of washed scrap rubber from bark shavings was by no means uncommon in Ceylon and Malaya. The actual quantity of rubber in the thin shavings now cut away is very small; much more is attached to the strips of bark. A high yield from bark shavings generally denotes lack of supervision during paring and picking operations.

Earth rubber collected from the ground is usually very impure and does not always figure in the classified rubber from estates; on some large properties it amounts to a considerable figure in the course of a year.

Percentage of Scrap in Total Crop.

The percentage of scrap in the total dry crop varies on different estates, even where the same system of grading is in vogue. First quality crêpe or sheet should be from 70 to 80 per cent. of the total; in dry districts 60 per cent. is sometimes considered fair.

A Ceylon planter (T.A., December, 1908), after making enquiries, estimated a range of from 5 to 40 per cent. scrap. Where it is said that no scrap is obtained, the explanation probably lies in the conversion of all such rubber into dark crêpe, but even then the product should be, and is usually, marketed as crêpe-scrap.

At a recent meeting of the Malay Planters' Association, it was concluded that 70 per cent. first quality was a fair average. Mr. Burn Murdoch gave 75 per cent. of No. 1 as the result of his observations. Mr. Baxendale thought 60 per cent. represented the average of the low country in a dry season. In the further course of the discussion, Mr. H. T. Fraser read the following figures relating to a series of experiments lasting over six months :—

	First three months.	After six months.
	%	%
No. 1	85	83
Lump	1	3
Scrap	10	10
Shavings ..	4	4

Some figures are given by Cramer of the composition of the crop upon a Malayan estate :—

	Old Trees.	Young trees.
	%	%
No. 1	74·64	74·77
Lump	8·52	5·83
Scrap	10·58	11·73
Shavings ..	6·26	7·67

Rather high proportions of lump and bark rubber are shown.

The Klanang Produce Company reported that their crop for 1910 consisted of 33,882 lb. of sheet, 29,931 lb. of number one, and 29,852 lb. of number two crêpe. Other five Malayan estates with which I am acquainted show the percentage of scrap rubber in the total crop to be 18, 20, 22, 34, and 55 per cent.; the last was from an estate possessing a large number of young trees.

In the annual report of the Golden Hope Rubber Estates, Ltd., the crop, consisting of about 51,420 lb., was divided into:

number 1 fine crêpe 75 per cent., number 2 fine crêpe 10 per cent., number 3 scrap 10 per cent., and bark-scrap 5 per cent.

The proportions of grades in the 1910-11 crops of the Brieh Rubber Estate were 24,939 lb. of No. 1 sheet and crêpe, and 8,974 lb. of No. 3 bark-scrap.

Crop Periodicity in Ceylon.

One is accustomed to the seasonal crops from the Amazon and is apt to imagine that on the contrary the plantation industry will show a constant increase in output month by month and year by year. This, however, is not really the case, as there are certain factors operating in most of the rubber-growing areas in the Middle-East which prevent tapping operations from being carried out with that regularity characteristic of the rest of the year. While it is true that the majority of mature Hevea trees yield latex on tapping during every week of the year, in some districts there are periods when, on account of the small yield obtainable, tapping is partially if not entirely suspended. Some companies have even considered the stopping of tapping operations during the greater part of the dry period in each year. It has been previously pointed out that in many of the Hevea districts of Ceylon there is a marked dry period extending in each year from January to April. Furthermore, during this season the trees drop their old leaves and produce new leaves, and subsequently flowers, this foliar change being particularly noticeable during February and March. During this period the yield of latex, and generally also of dry rubber, per tapping, is small; and it has become a custom on many estates to allow the trees to rest. On the other hand, the interference with tapping operations by rains is indicated at two periods of the year, the first about June, the second in November. Of course, there is some degree of variation from year to year in the incidence of the seasons, and between different districts.

Monthly Returns from Two Ceylon Estates.

The periodical decreases in yield are demonstrated by the following returns from (1) an estate in the Kelani Valley and (2) an estate in the Matale district :—

Monthly Yields of Rubber.

1909.	Kelani Estate. lb.	Matale Estate. lb.	1910.	Kelani Estate. lb.	Matale Estate. lb.
January	—	2,744	January	500	3,055
February	—	2,375	February	—	2,232
March	174	2,343	March	70	1,911
April	351	1,309	April	910	2,277
May	180	1,096	May	1,322	567
June	44	752	June	1,085	5,566
July	70	1,269	July	1,664	3,517
August	412	2,166	August	1,783	3,965
September	1,274	2,019	September	2,210	4,106
October	1,280	2,342	October	2,598	4,702
November	1,001	1,610	November	3,070	4,174
December	1,230	2,897	December	4,146	4,728

The crops from the Kelani Valley estate decreased greatly during the first three months of 1910. A recovery followed in April and May; this was in turn followed by a set-back in June, one of the rainy months. During the rest of the year there was a steady increase with the increase in age and number of tapped trees. Note the fall at the beginning of 1911. If one goes back to the yields for the year 1909, one can see how marked has been the effect of the first rainy season about the months of June and July, and how the second rainy season has interfered with tapping in November. The returns from the Matale estate are less instructive, owing to some irregularity in tapping arising partly from the enforced resting of trees. The typical dry-season decrease is shown at the beginning of each year, but in 1909 there was no recovery shown in the April returns, and the decrease was continued to the rainy month of June, after which was a recovery. In the year 1910, tapping in the month of April showed an improvement after the dry season, and from the rains the crops during the month of May suffered the most; but there is an inexplicable return for June, after which there is a gradual rise in the crop. In both years the November crop has been affected by the rains.

While it is impossible to predict the actual percentage of the year's crop that may be expected during any specified part of the year until the whole island is in full production, it seems fairly safe to estimate that the produce from the same trees will probably be approximately 35 to 40 per cent. for the months from January to June inclusive, and 60 to 65 per cent. from July to December.

Crop Periodicity in Malaya.

On many estates, even in Malaya, with its less marked climatic variations, tapping is not so vigorously carried on during February and March as at the end of the year, on account of the prevalent belief that the trees, while passing through their change of leaf, yield less and require comparative rest. As a matter of fact, the food reserves drawn upon during active leaf production are more likely to be those in the twigs and branches than those in the trunk of the tree. The turgidity of the cells, upon which a copious flow of latex largely depends, is probably most irregular during this period on account, firstly, of the check to transpiration due to the death and fall of old leaves, and, secondly, on account of the rapid increase in transpiration from the young leaves which usually appear within a few days of the fall of the old ones.

We cannot expect to find so marked a variation in the Malayan crops, for the good reason that seasonal changes have a much smaller range; the rainfall is more equally distributed, so that the variation in outturn from month to month is comparatively little. And the range of variation being so comparatively small, such disturbing factors as the irregular resting of trees and the bringing of young trees into the tapping round make the statistics somewhat erratic.

Monthly Returns of Representative Companies.

To discover what are the variations, the monthly returns of some 31 Malayan companies turning out large crops have been totalled. Of these companies the returns for three years—1908-1910—have been available in four cases, for two years—1909-1910—in six cases, for one year—1910—in twenty-one :—

	Total Crops. lb.	Increase or decrease. lb.		Total Crops. lb.	Increase or decrease. lb.
January ..	857,258		July ..	1,139,817	+ 135,295
February ..	843,876	— 13,382	August ..	1,140,359	+ 542
March ..	955,795	+ 111,919	September	1,174,497	+ 34,138
April ..	921,444	— 34,351	October ..	1,233,159	+ 58,662
May ..	949,553	+ 28,109	November	1,290,285	+ 57,126
June ..	1,004,522	+ 54,969	December	1,468,286	+ 178,001

There is a fall in February, with a strong recovery the next month, and a fall in April. Yet, in spite of this, April shows a good advance upon January, presumably owing to the increase in number and size of the tappable trees. From April onwards a rise increases in force until August, when it receives a setback, starting again and increasing its impetus, as it were, to the end of the year. Not shown in the table is a decrease that occurs in January as compared with the December crop, of which the decrease in February is a continuation.

The fall from December to February can be correlated with a decrease in the rainfall—though the latter is not very marked—and at the end of the period with the occurrence of wintering and with the shortness of the month of February—a holiday month. But why there should be such a great increase in March is not explainable, even by allowing for the rest which the trees receive in February owing to holidays. The decrease in April may be due to excessive rains. Suitable moisture conditions permit of better crops being obtained in May, June, and July; but the dry season, if not the setting of the fruits, affects the August crop. After this month the upward move is resumed, not to any great extent during the rains in October and November, there being a slight hesitation during the latter month; then comes a big advance in December, a more desirable month for tapping.

Monthly Returns of Two Malayan Companies.

To take the returns of separate companies only is to increase the possible disturbing effect of other factors, but by so doing we are able to include some returns for the first three months of last year. There is a purpose in this, for it enables us to illustrate the depressing result on the yield exercised by such unprecedented drought as that through which Malaya was then passing.

1910.	Labu.	H. & L.	1911.	Labu	H. & L.
January ..	12,863	43,176	January ..	20,089	49,492
February ..	9,300	40,724	February ..	17,872	44,936
March ..	16,000	47,273	March ..	14,717	37,402
April ..	14,750	42,265	April ..	14,569	37,157
May ..	17,185	38,648	May ..	20,744	44,431
June ..	19,134	37,471	June ..	20,635	44,701
July ..	16,626	39,266	July ..	23,510	49,433
August ..	15,426	39,847			
September ..	20,648	43,173			
October ..	20,000	48,253			
November ..	20,000	49,477			
December ..	20,500	45,908			

These returns are alike in that in 1910 the months of February and April show decreases on the preceding months, though it must be understood that this is far from being the case with all the companies whose crops have been totalled in the preceding table. The first of the two companies had an actual decrease in August, following another in July; the other shows merely a hesitation in the rise. Upon passing to the statistics for 1911, we find on the whole an increase in January, but afterwards a very marked decrease, the respective managers cabling home that the drought was severe. Of course, this is an exceptional condition, but the figures serve to drive home the fact that moisture conditions affect crops.

Producing Capacity of Plantations.

The following tables should prove useful when estimates are being made of future plantation crops :—

Approximate Yield per Acre.

Distance.	Number of trees per acre.	¾-lb. per tree.	1-lb. per tree.	1½-lb. per tree.	2-lb. per tree.	3-lb. per tree.	4-lb. per tree.
feet.		lb.	lb.	lb.	lb.	lb.	lb.
10 by 10	435	326	435	652	870	1,305	—
10 by 15	290	217	290	435	580	870	1,160
15 by 15	193	145	193	—	386	579	772
15 by 20	145	109	145	217	290	435	580
20 by 20	109	82	109	163	218	327	436
20 by 25	87	65	87	130	174	261	348
25 by 25	70	52	70	105	140	210	280

Table Showing the Producing Capacity of Plantations.

Acreage.	At 1 cwt. per acre. tons.	At 2 cwt. per acre. tons.	At 3 cwt. per acre. tons.	At 4 cwt. per acre. tons.
100	5	10	15	20
250	12½	25	37½	50
500	25	50	75	100
1,000	50	100	150	200
10,000	500	1,000	1,500	2,000
50,000	2,500	5,000	7,500	10,000
100,000	5,000	10,000	15,000	20,000
200,000	10,000	20,000	30,000	40,000
350,000	17,500	35,000	52,500	70,000

The second table may be serviceable when yields from countries having a known acreage under Hev a are being estimated.

CHAPTER XX.

PHYSICAL AND CHEMICAL PROPERTIES OF LATEX.

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. In the opinion of most, it is strictly comparable with an emulsion.

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; they can be reduced by incising instead of excising the laticiferous tubes. In several instances the latex, by mixing with such exudations, becomes neutral, and 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.

SPECIFIC GRAVITY OF LATEX.

The chemical composition of latex varies considerably and a difference in specific gravity is therefore to be expected. Muspratt gives the density at 1·012; Ule quotes 1·041; Henri 0·973; Seeligmann 1·019; while Bamber states that the specific weight of latex of *Hevea brasiliensis* containing 32 per cent. of caoutchouc is 1·018 at 60°F.

By Beadle and Stevens (Indiarubber Exhibition Lectures, 1908), it was stated that one of them determined the specific gravity of a large number of samples of latex from 8-year-old trees. The average was 0·975, the lowest record being 0·973, and the highest 0·980. Kaye made a number of determinations, and found a maximum of 1·0046 and a minimum of 1·0030. According to Girard and Lindet, the density is 0·986. In the case of latex collected in the Manaos district, Bonnechaux found a density of 0·905.

The density of the caoutchouc itself varies, though the differences observable in that compound are insignificant when compared with those of the mineral, protein, or resinous contents.

THE CHEMISTRY OF THE LATEX.

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 ; 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.

The mechanical impurities present in most samples of latex in the field consist of pieces of bark, fibre, sand, &c., and 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, proteins, sugars, gums, insoluble substances, and mineral matter. The amount of water in pure latex varies considerably, but it is usually estimated at 50 to 60 per cent. 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 per cent. of water being present. The latex collected during the dry months of February and March at Henaratgoda contains much less water than that obtained from the same trees in the rainy season. The following table will serve to indicate the general range in composition according to the analyses of Seeligmann (Indiarubber and Gutta Percha, by Torrilhon, Seeligmann, and Falconet), Lascelles Scott and Bamber (Circular R.B.G., June, 1899) :—

	Seeligmann.	Scott.	Bamber.	
	%	%	%	%
Water	55 to 56	52·32	55·15	55·56
Caoutchouc	32	37·13	41·29	32·00
Proteins	2-30	2·71	2·18	2·03
Resins	Traces	3·44	—	2·03
Ash	—	0·23	0·41	—
Sugar	—	4·17	0·36	—

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 accepted it as being not far from the truth for our species. There is an indefiniteness about several of the constituents grouped under such general heads as proteins, resins, etc.

Variation in Composition of Hevea Latex.

The latex from parts of the same tree at different times of the year shows considerable variation, and minor ingredients, normally absent, appear on certain occasions. It has also been shown elsewhere how the composition and character of the latex from the same tree varies during different parts of the same season, according to the frequency of tapping, conditions of humidity, and the age of the cortex whence the latex is extracted. Schidrowitz, Kaye, and Stevens have shown how certain samples of latex from trees of *Hevea brasiliensis* in Ceylon vary, and have pointed out that in those which they characterised as abnormal only from 4 to 10 per cent. of caoutchouc occurred.

It will be noticed that the caoutchouc, according to the above analyses, varies from 32 to over 41 per cent., and the other constituents such as resin, sugar, insoluble substances and 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.

The Caoutchouc Hydrocarbon.

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, of which turpentine is a member. The percentage composition—$C_{10}H_{16}$—is the same for turpentine as for the caoutchouc hydrocarbon, though the degree of condensation, as indicated by the molecular weight, is much higher in the latter. Caoutchouc is insoluble in water. According to Weber it 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.

Henri states that microscopic examination of the latex reveals the presence of a large number of globules, some with a diameter of nearly 0·002 millimetres, others smaller, the latter exhibiting extremely intense and persistent Brownian movements. The number of globules in a latex indicates its richness and may be easily determined; in the operation a suitable diluent—20 per cent. solution of sodium chloride—is added, which arrests the Brownian movements, without precipitating or coagulating the latex; the globules can then be counted, and in one case an average of 50 million globules per cubic millimetre was estimated.

According to Seeligmann, the average diameter of the globules is 0·0035 mm. This size seems to be greater than that of the globules in any other latex. Henri asserts that the diameter varies only between 0·0005 mm. and 0·002 mm.

The origin of caoutchouc in latex has been investigated by many authorities, and considerable doubt still exists in the minds of chemists regarding this; nevertheless, it is generally admitted that Harries has fairly well established a close relationship between the caoutchouc and the sugar-like products—lævulinic acid—in the plants.

Resins and Sugary Substances.

The resins, gums, and oil 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 an integral part of the rubber, and the extraction from the latter by the manufacturers in Europe is a difficult and tedious task.

Spence (Indiarubber Lectures, 1908), remarks that at one time it was believed the resins were derived from other sources than the latex tubes, and he admits that this may be true to a certain extent, particularly when tapping is carelessly done; but in most cases the resins in the coagulated rubber are derived from the latex, although in what form he had not been able to determine. They are probably dissolved in the caoutchouc in the latex. He believed that they would eventually be shown to be related to the caoutchouc itself and derived from this, either as a by-product or as an intermediary one in the building-up or breaking-down of the caoutchouc by the plant. They have been shown to contain oxygen, an element that the caoutchouc hydrocarbon very readily takes up, and recent investigations have shown that in some cases the resins extracted from indiarubber resemble, in elementary composition at least, certain resinous products prepared by the oxidation of rubber in a current of air.

The sugars are rarely present in large proportions, and a maximum of 0·5 per cent. may be taken as correct. They are dissolved in the liquid in which the globules of caoutchouc and resins are suspended; in the washing of the freshly-coagulated rubber they are generally removed.

Starch granules of peculiar shape exist in latex.

Protein Matter.

Our knowledge of the chemistry of the proteins in latex is not very clear, especially in regard to the soluble nitrogenous products which remain in the mother liquor after coagulation; these are probably quite different from the complex proteins which are coagulated and form part of ordinary raw rubber. Spence states (I.R.J., Aug. 16th, 1907), that though the nitrogenous products which occur in the latex after coagulation are peculiar in origin and constitution they are in all probability simple products of protein metabolism.

The protein or albuminous matter, about which more will be said, varies from 1·9 to 2·7 per cent. of the fresh latex, or approximately 3 to 4 per cent. 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 protein matter is of a complex nature, and, alone or with the gums, sugars, and enzymes, may be responsible for the development of bacteria on the finished product which lead to putrefaction or "tackiness." The use of formaldehyde in connection with elimination of the protein matter will be considered when dealing with coagulation.

When the rubber is prepared by simple coagulation the insoluble protein becomes 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 proteins from commercial rubber, though sometimes desired, is almost impossible. In the perfecting of mechanical processes and the use of antiseptic re-agents for dealing with the protein in the latex as it comes from the tree lies a considerable amount of important profitable work for planters in the tropics.

Enzymes in Latex.

The latex of Hevea has not been completely examined for its enzymes (ferments), and some oxidising enzymes are all that have been discovered. These oxidising enzymes are very important factors. They are partly responsible for the latex turning acid on keeping. They have been accused, without good reason, according to Spence, of inducing "tackiness" in the dry rubber. But what they can justly be associated with is the darkening of prepared rubber through their oxidising action upon the proteins. Spence points out that the enzymes merely accelerate a reaction that can take place without them, though much more slowly. Experiments by Fickendey have shown that oxygen is essential to the darkening.

Mineral Matter.

The inorganic matter found in most latices consists of compounds containing calcium, potassium, iron, sodium, and magnesium; these are combined with mineral or organic acids. The concentration and nature of the salts found in the latex influence its coagulation.

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 chapters concerned with the components of commercial rubber and the purification processes.

Effects of Physical and Chemical Agencies.

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 affect a separation of the caoutchouc of normal Hevea 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 neutralizing the acids as soon as they are formed, and the latter by acting as an antiseptic and preventing the decomposition of the protein 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 XXI.

PRODUCTION OF RUBBER FROM LATEX.

Having briefly described the physical and chemical properties of latex, the operations upon which the production of good rubber from latex depends can now be dealt with. If 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 re-agents and 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.

KEEPING THE LATEX LIQUID IN TANKS.

On small estates where few and widely-scattered trees are being tapped the planter is often compelled to resort to the production of rubber on a small scale. This frequently involves the use of much petty hand labour. The latex can, however, be kept in a liquid condition for several days or even weeks without doing much harm to the finished product, and the rubber can be manufactured on a big scale when a sufficient quantity of latex has been accumulated.

If it is necessary to keep the latex in the liquid condition, this can be done by the addition of formalin, ammonia, sodium carbonate, or other alkaline chemicals which are readily soluble in cold water. It is better to use either ammonia or formalin and to avoid any of the mineral salts; the former can be readily removed and may even escape on exposure to the air in the ordinary processes of preparation.

In one invention, not much used on estates, the latex is kept in covered settling tanks supplied with (1) a drip-tin apparatus filled with chemicals to retain the milk in an alkaline condition, and (2) with a paddle to keep the latex in motion. If a receptacle containing ammonia is exposed to the air, the re-agent will evaporate and the latex coagulate within a few days. If, however, the receptacles are covered or sealed, the ammonia cannot easily escape and the latex can be accumulated in a liquid state almost indefinitely.

Formalin has a similar effect, as it stops putrefaction and therefore prevents the development of acidity. The ammonia probably neutralizes the acids as they are formed and thus maintains the latex in an alkaline or neutral state, thereby preventing coagulation. By the use of such re-agents and apparatus a great saving of labour may be effected.

It is reported by Messrs. Clayton Beadle and Stevens that the use of formalin in the latex does not affect the quality of the rubber. But Schidrowitz and Kaye have a different opinion.

Effects of Diluting the Latex.

It has been asserted that the protein and resin content of the prepared rubber can be kept low by dilution of the latex before coagulation. This can only refer to proteins and resins of such kinds as remain in the mother liquor after separation of the rubber, and which also, of course, are present in the water (mother liquor) retained in the rubber itself. When the rubber is dried, they are left behind in it. The effect of dilution is to lessen their concentration in the mother liquor retained in the rubber, so that they are left behind in smaller quantity on evaporation of the water. Yet an evil effect of dilution is apparently a loss in quality of the rubber.

Straining Latex: Centrifugal Machines.

Before any steps are taken to effect coagulation, the planter should see that the latex is quite free from any mechanical impurities; it is first necessary to filter the latex through porous cloth or horsehair sieves or to remove the visible impurities by means of some mechanical apparatus.

A very important reason for straining latex in the field is that the coagulated scrap will thereby tend to be on the whole cleaner; furthermore, the prompt exclusion of mechanical impurities in the field appears to be accompanied by a reduction in the quantity of scrap normally appearing in latex as irregular coagulated lumps.

At the Ceylon Rubber Exhibition two centrifugal machines were exhibited for this work, and the following is the account given in the Official Handbook of the Exhibition.

"Both machines are rotary, and with the exception of the central basket or drum, are of the same design, but with the one type of drum only the larger and lighter impurities can be removed, whilst with the other type only those particles of sand and grit, etc., are eliminated which are of a greater specific gravity than that of the latex.

"Mr. Macadam's exhibit, *i.e.*, the one which removes the larger and lighter impurities from the latex, is a 12-inch self-balanced centrifugal machine with a rope drive; it is composed of a cast-iron pedestal surmounted by a cast-iron casing with a dished bottom and outlet lip, the top being fitted with a cover having a funnel in the centre for the purpose of feeding the machine. Inside this casing a basket or perforated drum revolves, being actuated by a vertical shaft whose bearings are in the neck and foot of the pedestal. The basket is not compelled to revolve about a fixed centre as in other machines, but is permitted to find its proper centre of rotation by the use of elastic bearings, thus reducing to a minimum the power required to drive the machine as also the amount of vibration transmitted to the casing of the machine. The vertical shaft is driven at the rate of three thousand revolutions per minute by means of a rope drive from a small countershaft carried by swing bush bearings mounted on a cast iron frame. The shaft is also fitted with fast and loose pulleys for belt driving. The lubrication of the swing bush bearings of the countershaft, as well as of the bearings in the machine proper, are most efficient, the former being self-oiling and the latter being fed from an oil cup and tube outside of the casing and pedestal. The machine is fitted with a suitable foot brake to enable the operator to stop the process at any moment. The machine was thoroughly tested by passing latex which had been freely and well mixed with sand, lumps of earth, chips, twigs, bark, etc., through the funnel in the top lid of the outer casing and into the centre of the revolving basket or perforated drum. Inside the latter is placed a linen or cloth bag, and it is through this that the latex is rapidly strained, leaving the lighter and large impurities behind it. The strained latex then passes into the outer casing and finally issues from the pipe at the side into a receptacle bowl. By this means large quantities of latex can be strained in a very short time.

"The machine takes about 1 H.P. to drive, and its output is 50 gallons per hour."

The writer was informed, when at Culloden in April, 1908, that the machine, though useful, had not been much used by Mr. Macadam—or any other planters in Ceylon.

"The machine shown by Mr. Kelway Bamber is much the same as that exhibited by Mr. Macadam, except that no cloth bag is used and that the bottom and the periphery of the drum are solid, and the top also is partly closed.

"The latex is poured into a funnel in the lid in the same manner as that described in the other machine, except that it has to be very carefully and slowly fed into the centre of the revolving drum. The heavier particles of the impurities in the latex are thrown centrifugally against the periphery and are there collected and retained, being helped somewhat by means of short partitions, whilst the pure latex rises over the top of the drum into the outer casings and then finally issues from a pipe into a receptacle below. The output of the machine is roughly estimated at 20 gallons per hour." Having secured latex free from any mechanical impurities the first step towards the production of crude rubber is coagulation.

Sieve Pails.

Where centrifugal machines are not used the majority of estates collect the latex in enamelled pails provided with tight-fitting lids. The latter are furnished with metal sieves, having a very small mesh, which are effective in removing mechanical mpurities from the latex. Sieves of this description are expensive, and are liable to be clogged with small particles of coagulated rubber. Hence the necessity to clean them regularly at the end of a day's work.

Transport of Latex to the Factory.

The latex collected in the enamelled pails may be conveyed in these receptacles to the factory or accumulated in larger vessels and transported as latex or coagulated rubber to the factory. The idea of preparing the latex in the field, small sheds being provided with the usual apparatus for straining and coagulating, is by no means new. It was first suggested to me by Mr. Golledge in 1908. The object is to reduce the transport difficulties by removing the water, or as much of it as possible, on the spot. Even then the transport of the freshly-coagulated rubber may occasion some difficulty on large estates provided with only one central factory. On Lanadron and other estates in the East, the monorail has been used for transporting latex from the field to the factory; on other properties light railways have been constructed to do the same work. Where monorails are not used, it is often found convenient to convey the latex in large metal tanks supported on two wheels—the whole being easily pushed by one cooly.

Monorails and Light Railways.

The system known as Caillet's monorail has found favour on many plantations. This is intended as an intermediary between carts and the lightest of double rail systems. It is essentially a system for small traffic, and the maximum limit of its economical working varies from 150 to 200 tons per day, according to local conditions. It is especially economical where long distances have to be traversed and the traffic amounts to only a few thousand tons per annum.

It consists of a single rail of light section supported by steel sole-plates at intervals of a few feet, and is laid down direct on the surface of the ground, without sleepers, ballasting or other special preparation. One horse is required for each truck, and can draw a load of $1\frac{1}{2}$ to 2 tons over a line where the gradient does not exceed about 5 per cent. Several trucks can be coupled together, thereby reducing the number of drivers.

The cars for hand traction are light and easily manipulated, and one man can work 10 hours per day transporting loads of 6 cwt. The bottom of the cars being only a few inches above the rail, it is impossible for them to run away or to overturn.

A light section of rail is used, a 9-lb. rail being sufficient for all cars on two wheels with a load up to 15 cwt. and for bogie cars with a load of about 20 cwt. As the weight of the load presses directly upon the top of the rail, only sufficient strength is required to resist any permanent bending of the rail. For trucks loaded up to 30 cwt., a 12-lb. or 14-lb. section is employed according to the amount of traffic per day. The 14-lb. section is also strong enough for bogie trucks carrying a 4-ton load.

Light railways have also been laid down in Java which are said to be serviceable as a means of transporting large cans of latex as well as the finished product.

Natural or Spontaneous Coagulation.

If latex is allowed to stand exposed to air, coagulation takes place after an interval of from 6 to 24 hours. The coagulated substance carries, or becomes mixed with, the suspended globules of caoutchouc and other bodies, so that the whole process is more or less one of clarification, the liquid left behind usually containing only those ingredients of the latex which have remained in solution. Coagulation occurs 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.

The natural method of coagulation depends upon the formation of acids by bacteria from proteins and carbohydrates present in the latex.

It has been asserted that the rubber made by the natural method is less elastic. Other objections, viz., the slowness of the method ; the gathering of impurities ; and the putrefaction that is begun in the rubber and is an essential condition for the process of coagulation, have been raised. Furthermore, the mother liquor is often quite turbid owing to its containing a quantity of caoutchouc. If such mother liquor is thrown away, there is considerable waste. The caoutchouc can be obtained from such liquids by the addition of acetic acid.

Artificial Methods of Coagulation.

There are numerous mechanical and chemical processes by means of which rubber can be obtained from latex.

Until the various theories outlined elsewhere have been definitely proved and accepted, we can best regard—in a work such as this, which is written for the guidance of the practical planter—some of the protein substances as playing an important part in coagulation. Certain proteins remain in solution even after coagulation ; others are capable of being converted into an insoluble form and occur in all rubbers.

Heating Methods.

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 *Hevea brasiliensis* is unaffected by boiling. If the undiluted latex is boiled, water is driven off, and the thickened milk may then become charred. The separation of the caoutchouc of Castilloa, Ficus and Landolphia latices is often effected by boiling on a slow fire.

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

Natural Heat.

Explorers who have visited American and African rubber-producing areas report that the natives frequently collect the latex and rub it over their arms and chests and allow the heat of the body and the feebly acid perspiration to aid in the production of rubber. The thin particles thus obtained are gathered and made up into balls for export.

Addition of Water.

The addition of pure water to the latex of *Hevea brasiliensis* does not hasten coagulation, but, as in the case of many other latices, delays the formation of a solid clot for a considerable time. It is worthy of note, however, that the caoutchouc of Castilloa is sometimes agglutinated by the addition of water, and one report states that the same result is sometimes obtained when the latex of *Funtumia elastica* is similarly treated. The caoutchouc in both these latices can be creamed or separated by means of a centrifugal machine.

Addition of Plant Juices.

Organic or mineral acids bring about the coagulation of the latex of *Hevea brasiliensis*. In parts of Ceylon some very interesting results have been obtained by the use of clear aqueous solutions of citrus, tamarind, and other commonly-occurring acid fruits. Samples of perfectly dry plantation rubber, obtained by adding plant juices to the latex, have possessed remarkable strength. In parts of tropical America and Africa these re-agents are largely used, and many believe that the strength of the coagulated rubber is much improved thereby.

The plants used in different countries differ considerably in their botanical relationships, but the watery extracts from most of them now in use have an acid reaction. There are a few which are said to have an alkaline reaction.

According to Jumelle, the natives in French Soudan use four liquids for coagulating *Landolphia Heudelotii*: (1) juice of citron, made by crushing ten fruits in a litre of water; (2) water acidulated with the fruit of *Adansonia digitata*, one ripe, macerated fruit being sufficient for one litre of water; (3) water acidulated by the leaves or calyces of the Rozelle plant—*Hibiscus Sabbariffa*, 500 grams of leaves and fruits being used in one litre of water; (4) infusion of fruits of *Tamarindus indica*, 2 handfuls of fruits being required for one litre of water. All these plants are abundantly distributed and cultivated in many parts of the tropics and can easily be tried by planters. In Ecuador and the Belgian Congo, the juice from the stalks of "bossanga"—*Costus Lukanusianus*—is largely used as a coagulant. The watery extract from the macerated stalks of *Calonyction speciosum*—which, according to Preuss, is alkaline in reaction—is also used in Ecuador and Central America generally. Another plant which has received considerable attention as a source of an effective coagulant is *Bauhinia reticulata*, a species now established in most of the botanic gardens throughout the tropical world. It is largely used in the production of rubber from the latex of *Funtumia elastica*.

According to Mountmorres a handful of the green leaves and young shoots is placed in two gallons of water, and boiled for about fifteen minutes, the filtered infusion being poured, while hot, into about one-and-a-half gallons of fresh latex.

It is obvious that aqueous extracts of parts of plants such as those mentioned above may contain a number of useless as well as useful ingredients. It is therefore difficult to ascribe the good physical properties of the coagulated rubber to any definite substance or substances until these have been chemically investigated. The plants used for this purpose are among those most commonly met with in tropical areas, and the subject is therefore one which should arrest the attention of all rubber planters.

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 coagulation ; the other substances, particularly the creosote, are absorbed, the latter acting as an antiseptic in preventing the rapid decomposition of the albuminoids present.

Coagulation by Chemical Re-agents.

In coagulation by chemical means the object is to use re-agents which, while effectively and rapidly precipitating the coagulable material, will not have a detrimental effect on the rubber produced.

Many compounds, such as picric acid, would rapidly induce coagulation, 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 unnecessary to do more than mention those which have, from practical experience, been proved more or less acceptable to planters.

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 coagulation of the latex while cold. The commercial article varies in strength and the quality should be noted by the purchaser. The rubber produced by means of this coagulant is, according to Henri, of inferior quality.

Formic acid.—This, though similar to acetic acid in its effect, is more expensive, weight for weight. The advantages of using this re-agent are (1) that less is required than of 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 just to precipitate the albumen in the latex.

Formic acid is less pleasant to handle than acetic. Spence (I.R.J., April, 1908), has experimented with formic acid, which he prefers to acetic. The rubber obtained was of good quality and was pale yellow in colour; an acetic acid prepared specimen from the same latex was dark-brown.

Tannic acid.—This is, according to Weber, the most powerful of the acids which can be used for this process; 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 chloride.—Corrosive sublimate effects coagulation while the latex is cold, and also acts as an antiseptic. It is very poisonous, and if used, a small quantity of the salt is unavoidably left in the rubber. Rubber prepared in this way can perhaps be put on the market, if it is made perfectly clear to the buyers how it has been prepared. Though such rubber appears to be of good quality, some further tests are necessary before any definite recommendation can be made.

Carbonic acid gas.—The use of this gas is proposed, and a patent method of employing it—Pahl's—is now on the market, but not sufficient information is at hand of its behaviour or of the quality of the rubber obtained.

MIXTURES.

The following mixtures produced samples of rubber of excellent quality at the Ceylon Rubber Exhibition in 1906:—A. 1 dram of cream of tartar, dissolved in 1 oz. cold water, added to a panful of latex of about 48 oz. B. ½ dram cream of tartar, dissolved in 4 oz. of fresh rubber whey added to a panful of latex of about 48 oz. Mr. J. A. Bird is said to have originated the mixtures.

The following is the formula of a coagulating mixture that has been devised by Morisse:—

Solution A.—Carbolic acid, commercial, 4 grammes; alcohol in sufficient quantity to dissolve it; water, 80 grammes.

Solution B.—Sulphuric acid, commercial, 2 grammes; water, 20 grammes.

When mixed, these quantities are sufficient to coagulate instantaneously, with the aid of a little agitation, a litre (1¾ pints) of latex. Morisse points out that to coagulate 1,000 litres of latex, it takes 2 litres of sulphuric acid and 4 of carbolic, which in his opinion makes the method a very inexpensive one. Some rubber prepared in this way, exposed to the air, light, and dust during twelve years, was as good in July, 1901, as it was when prepared in February, 1888. Under the influence of a little free sulphur in the coagulating solution, it had become veritably vulcanised. In March, 1908, this sample was in the same perfect condition. In this connection we may recall the fact that Spence found rubber coagulated with sulphuric acid to deteriorate, though it must be noted that he did not add an antiseptic.

PROPRIETARY COAGULANTS.

There are a number of patent or otherwise secret compositions on the market, but one cannot learn of the extent to which all are used. Hydrofluoric acid is sold under the name of "Purub," and under that of "Coagaline" is retailed a mixture of the following composition: tartar emetic, 3 per cent.; formaldehyde, 0·5 per cent.; carbolic acid, 0·5 per cent.; and water, 96 per cent. We have also the Elias process, the Pinto process, and that of Dern, among others.

AMOUNT OF ACETIC ACID TO BE USED.

The quantity of acid required is believed to largely depend upon the proportion and condition of the albumen in the latex. According to Weber, the latex from Hevea trees in the Amazon contains only about 1·5 per cent. 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 rapid and complete coagulation. The behaviour of the latex with acids is due to the fact that it is, when fresh, usually slightly alkaline or neutral, and the protein substances are insoluble in a feebly acid solution but soluble in alkaline or strongly acid solutions. It has been asserted that the protein matter is insoluble in a neutral solution, but on several occasions the fresh latex from the Henaratgoda trees remained liquid, though the reaction with litmus paper did not indicate acidity or alkalinity. Only a small quantity of acid is required to neutralize or acidify the latex, and therefore lead to coagulation. It is a mistake to add excess of acetic acid, as the proteins or their derivatives would be partly re-dissolved and would, therefore, still remain in solution. Instead of protein being the agent in coagulation, an idea held, as already mentioned, is that latex behaves as an emulsion in the presence of an acid.

QUANTITY OF ACETIC ACID USED ON ESTATES.

In the last edition the following remarks were made:—

"Every 100 volumes of pure Ceylon latex require about 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. On Culloden estate three drams of acetic acid are added to each gallon of latex, no matter in what condition the latter arrives at the factory; the acetic acid consists of three parts water and one part glacial acetic. On Gikiyanakanda one dram of acetic acid is used for each gallon of latex. If the acetic acid is added until the mixture becomes feebly acid after stirring very little harm will be done. The addition of excess of acid may bring about a re-solution of the proteins and coagulation be thereby delayed. It is very rare that the latex on a large scale is heated before treatment with acetic acid."

On Glenealy estate one fluid drachm of a 10 per cent. solution is added to each quart of latex; that is, one part of pure acetic coagulates 3,226 parts of latex. Coagulation takes place in two hours.

A Recent Research: Quantity of Acid.

The above differences in the quantities of acid employed have been commented upon by Crossley (I.R.J., 27th May, 1911). The first-mentioned quantity being 100 volumes of latex to 1 of acid, he points out that on Culloden 1,706 volumes of latex are coagulated and on the Gikiyanakanda 1,280 volumes, while Weber's estimate equals 320 volumes. He suggests that these differences are explicable by different degrees of dilution and by variations in the amount of fermentation acid already present. Working with a Sumatran latex to which formalin had been added, and which probably had been diluted with water three or four times, he determined the limits in quantity of acid that could be used. In the case of this particular latex the minimum proportion of pure glacial acetic acid producing efficient coagulation was one part by weight of acid to 1,176 parts by volume of latex. But the fermentation acids were already present, and played some part in coagulation. Allowing for these, and assuming that their coagulating power in the aggregate was equal to that of the same quantity of acetic acid, the true coagulating power of the total acid present—fermentation plus added acid—was one part by weight of acid to 575 parts by volume of latex neutral in reaction. In view of Parkin's declaration that "the percentage of acid necessary is proportional only to the original volume of latex present, and is independent of its dilution with water," Crossley made a series of experiments with the latex diluted in different degrees, when he found that the statement held good over a long range of values. After plotting out the results in the form of a curve, he computed that a minimum of 0·7 c.c. of pure glacial acetic acid would be necessary to coagulate 100 c.c. of pure fresh latex. Determinations were made to show what was the maximum quantity of acid that could be used to produce coagulation in the above sample of latex; as far as these experiments went, they proved that, ignoring the fermentation acid present, it was 20·4 times the minimum. Taking the fermentation acid into account, that is, basing the calculation upon the total acidity of the latex, it was 10·4 times the minimum. The relation between the minimum and maximum quantities of acid varies with the dilution; the "factor of safety," or difference between them, must be much less in the case of undiluted latex than it was in the latex experimented upon.

Time Required for Coagulation.

The completeness of coagulation 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; where special machines are used the latex is coagulated in three to ten minutes. On Culloden estate, without the use of any apparatus, the latex is completely coagulated in ten minutes; on Vogan in a couple of hours; and on another estate in the same district half-an-hour was generally allowed for complete coagulation.

Advantage of Rapid Coagulation.

The variation in time allowed for coagulation is still considerable, though the opinion is gaining ground that the more rapidly the latex can be coagulated, the more satisfactory are the results. It is maintained by some planters that the more quickly the latex is coagulated and put through the washing rollers, the more rapidly the rubber dries, a point of practical importance, especially where hot air is not used in the drying sheds. Furthermore, when latex has to be collected over widely-scattered acreages, some time often elapses before it can be delivered, as such, at the factory. Under such circumstances it appears advisable to effect coagulation in the field, providing the process can be carried out in a proper manner in the absence of the usual supervision.

Methods of Determining the Quantity of Acetic Acid Required.

It has been contended that many inventions which have recently been brought forward necessitate dilution, to varying degrees, with water, ammonia, and formalin, and that such dilution prevents the planter from knowing how much latex the coolies collect, and how much acetic acid will be required in the process of coagulation. It is quite true that the latex so treated will contain varying quantities of rubber, but when one considers the variation in composition of ordinary samples of undiluted latex from different trees, or when obtained at different times of the year from the same trees, it is obvious that the same difficulty has ordinarily to be overcome. The objection is, therefore, not a very serious one so long as latex is not sold by volume.

The application of the same quantity of acetic acid to the same volume of latex on every occasion cannot be recommended except for expediency. The acid should be added in order to neutralize or faintly acidify the latex ; it is better to determine the exact quantity required than to add too much.

The amount of acid required can be determined with ease. Let the coolies pour the diluted latex from the different trees into a settling tank or ordinary receptacle and fill up to a known level, so that the exact volume will be known. After thoroughly stirring the mixture take a small sample of known volume and add dilute acetic acid of constant strength, drop by drop, from a burette or graduated glass tube, until the whole mixture after stirring is neutral or faintly acid. On measuring the volume of acetic acid used, the amount required for complete coagulation of the latex in the settling tank can be easily calculated and added. Litmus paper can be used to determine when sufficient acetic acid has been used ; the resultant solution should be only faintly acid or neutral, blue litmus paper becoming faintly red and red litmus paper remaining unchanged respectively in such solutions.

Such a method may involve the accumulation of the latex in receptacles of known capacity and provided with mechanical means for keeping the latex in a liquid state. Some such apparatus may or may not be required as the trees on the various rubber estates are more frequently tapped.

On this subject Parkin (I.R.J., 1911), remarks :—"It seems to me that the proper way to control the coagulation would be to test first a small quantity of the large volume of diluted latex awaiting treatment. This could be so arranged as to occupy only a few minutes. A spirit lamp, a few test tubes, and one or two other simple chemical devices are all that would be required. Heating brings about the coagulation much more rapidly, hence the value of the spirit lamp or some similar contrivance. The quantity of acid required is the same in either heat or cold. A simple calculation from this preliminary test will give the amount of acid to be added to the large bulk of dilute latex, the volume of which has been previously measured.

"The supervisor of this part of the proceedings in the factory would soon have a good idea of the quantity of acid needed, so that the test for each lot of latex would be carried out very quickly as a rule, serving more as a precaution or check than anything else. The strength of the acetic acid employed must also be known, as I imagine that pure (glacial) acetic acid will be rarely used on the estates."

On theoretical grounds Schidrowitz doubts very much Parkin's assertion that the quantity of acid required is the same in heat or cold.

The suggestion made by Dr. Schidrowitz for fixing the amount of acid required is as follows : "On the whole, I think that the best method of estimating the quantity of acid to be added would be that of adding varying quantities of acid to a number of samples of bulked latex and noting the minimum quantity which gives a good result, and also the dry weight of rubber obtained in each case. This should be repeated say once a week, and gradually in this way the plantation manager would accumulate statistical material which would enable him to judge with comparative ease how any particular batch of latex (according to rubber content, time of year, plot from which derived) should be handled. As an additional safeguard, the litmus test could be used constantly as a rough check."

Advantages and Disadvantages of adding Chemicals to the Latex.

It has been frequently contended that manufacturers object to the use of chemicals in coagulation, particularly mineral and vegetable acids, on account of the fact that even after thorough washing and pressing some of the acid may still remain in the rubber and subsequently prove harmful in the manufacturing processes. The retention of a large proportion of foreign chemical ingredients is said to lead to the production of bubbles and blow holes and to be occasionally accompanied by early deterioration of the prepared rubber.

On the other hand, it can be shown that the addition of re-agents such as formalin, creosote, or acids such as formic and even hydrofluoric, have a preservative effect on the rubber when used in infinitely small quantities. When one considers the chemicals which are incorporated in rubber of good repute prepared by the natives in the Amazon district and the inert characteristic of rubber itself, the objection to the use of minimum quantities of re-agents such as acetic acid and creosote seems to be less tenable. But apart from the preservative action of some of the chemicals used, there is a much more serious advantage, to the producer, accompanying the use of the required quantity of acetic acid, viz., the rapidity and completeness of the coagulation effected.

Why Acids Should be Used.

In one experiment about $1\frac{1}{2}$ gallons of ordinary latex were poured into a large glass beaker and allowed to coagulate naturally. At the end of two days a large cake of rubber had formed at the top of the liquid, but the mother liquor was still quite milky; the cake of rubber was removed, and subsequently thinner cakes appeared at the surface and were removed; after six days the mother liquor still remained turbid, and a further quantity of rubber was prepared from it by treatment with a small quantity of acetic acid and heating. The completeness of coagulation, when the latex is allowed to set untreated with acids, does not always take such a long time, but it is probable that the same phenomenon may repeat itself, and thus necessitate considerable delay and perhaps waste; certainly it would involve considerable irregularity to the producer. The use of acetic acid, on the other hand, effects coagulation in a few hours, and the mother liquor becomes perfectly clear in less than a day; the precipitation is complete, and there is therefore no waste of rubber.

If the planter is compelled to stop using acetic or any other acid for assisting coagulation, and has to produce his rubber by simply allowing the latex to slowly ferment, there are other difficulties in the way. It is obviously to the advantage of the producer to reduce the proportion of scrap in his rubber and to keep the latex flowing as long as possible, and the use of ammonia and formalin to accomplish this is being adopted on many estates during tapping operations; the presence of these re-agents in the latex tends to prevent coagulation, and they would, therefore, further aggravate the question of delay necessary if the natural process of coagulation were compulsory; a long period of time would be required for the necessary acidity to develop in presence of either of these re-agents.

In the absence of definite information from manufacturers, the use of minimum quantities of acetic acid, determined by the simple methods previously described, is likely to be continued by the producer in the tropics. For the present the application of the correct quantity of acid, followed by thoroughly washing and rolling, may be adopted, but care must be exercised not to add excess, and every effort be made to subsequently expel the re-agent by suitable mechanical processes. One of the most marked examples that has been recorded of the evil effects of excess of acid was a sheet of rubber, quarter of an inch or more thick, that, as a result of over-dosing with acetic, was perfectly rotten and could be torn like cardboard.

Effect of Acid on Quantity of Protein in Rubber.

In order to determine if the quantity of protein in the rubber was affected by the quantity of acid used, Crossley (I.R.J., 27th May, 1911), made a series of determinations, using an acetic acid solution containing 0·0543 grammes of acid in each cubic centimetre :—

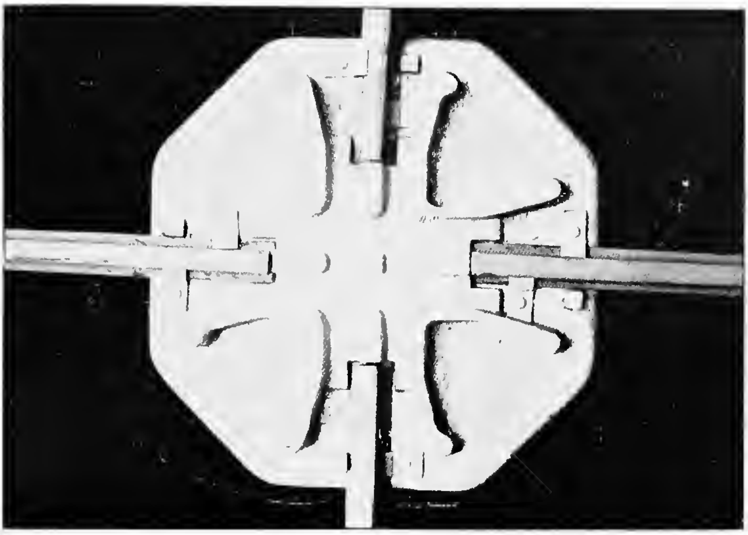
Acid used for 20 c.c of latex.	Protein found in Rubber.	Percentage acidity of medium in which coagulation took place.
0·36 c.c.	3·19%	0·184%
0·60 c.c.	3·20%	0·245%
0·90 c.c.	3·49%	0·320%
1·20 c.c.	3·92%	0·392%
6·00 c.c.	3·99%	1·322%

The series shows that it is an advantage to add the minimum quantity of acid.

Receptacles for Coagulating the Latex in Bulk.

Having shown that many different processes are in vogue in various parts of the world, and that on plantations the use of acetic or other acids is desirable, the next step is to determine the most suitable receptacles wherein the latex can be kept during coagulation. If ammonia is used in the latex, copper receptacles cannot be used. The best materials are glazed earthenware or enamelled troughs. If these are shaped similarly to a bath and are provided with an outlet pipe at the bottom for running off the mother liquor, they should meet the requirements. It is necessary that the receptacles be made of material which can be kept clean and which will not rust. It is, furthermore, advisable to supply a sieved funnel, through which the latex can be poured and filtered, at one end of the receptacle. A lid should also be provided to keep out dust. The size depends upon the quantity of latex daily harvested ; the number is dependent upon the same factor, and whether the latex from fields of different-aged trees is kept separate or not.

In cases of emergency, planters use empty kerosine oil tins or wood barrels. The former are, however, liable to rust, and the latter to hide and encourage the accumulation of mechanical impurities ; both should therefore only be regarded as temporary expedients. The above are for latex when crêpe is the form of preparation intended. When sheet or biscuits are made, enamelled trays, rectangular or circular, are used. The trays vary in depth from 1¾ to 4 inches. The rectangular trays are in various sizes,



CROSSING PLATE.

Lent by Monorail Port. Rail. Coy.

A MONORAIL IN USE.

12 by 8, 16 by 10, 6 by 18, 10 by 18 and 9 by 18 inches ; the circular trays are usually from 9½ to 12 inches in diameter.

Rapid Coagulation by Mechanical and Electrical Means.

It may appear to be quite unnecessary and perhaps inadvisable to unduly hasten coagulation, seeing that, by the use of acetic acid in specified quantities, this work can be effectively carried out, in bulk, in less than an hour. It may, however, be possible to effect coalescence of the caoutchouc globules without the use of acids or other chemical re-agents, though all the inventions so far on the market, with one or two exceptions, appear to be dependent upon the use of re-agents at some stage of the process. Several mechanical, electrical and mechanical-chemical inventions have been placed on the market.

French Spray Patent.

In this process (Journ. Soc. Chem. Ind., Vol. xxx., No. 19), invented by Hamet and Mounier, the latex is forced from a vessel by means of a pump, through a tube, ending in an atomising-jet within the domed lid of a coagulating chamber ; simultaneously a jet of steam, hot water, or acid or formaldehyde solution, delivered from a second vessel, and similarly atomized, is caused to impinge upon the latex-spray. The coagulating vessel is provided with a perforated false bottom, by means of which the coagulated rubber is strained off from the mother liquor and added liquid, and upon which the rubber can if necessary be washed before being removed, pressed and dried. The coagulating chamber has an uptake for the escape of vapours.

Biffen's Centrifugal Machine.

Biffen recognised that in latex the indiarubber 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 was a modified form of the ordinary centrifugal milk tester capable of being rotated 6,000 times per minute. The caoutchouc of Hevea latex is said to be effectively separated in a few minutes and to consist of the pure article, free from mixtures of proteins, resins, etc. Weber strongly recommended such a process of treating the latex for eliminating protein 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. It is certainly not essential to remove all traces of these substances.

Experiments in Ceylon.

Furthermore, several small experiments carried out in Ceylon have proved that the caoutchouc in Hevea latex is not rapidly separated by a centrifugal machine, even when the speed is as high as 11,000 revolutions per minute. In these experiments various heavy chemicals were added to the latex after the formalin; the chemicals used did not show an acid reaction, and considerably increased the density of the alkaline mother liquor. The whole of this mixture was placed in the "Aktiebolaget Separator," and then subjected to centrifugal force for over an hour, and yet the caoutchouc globules were not effectively separated from the other constituents; the apparatus was perhaps too small.

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 and heavy substances, and then causing a separation of the caoutchouc globules by mechanical means, is one which cannot be too strongly impressed on the experimentalist.

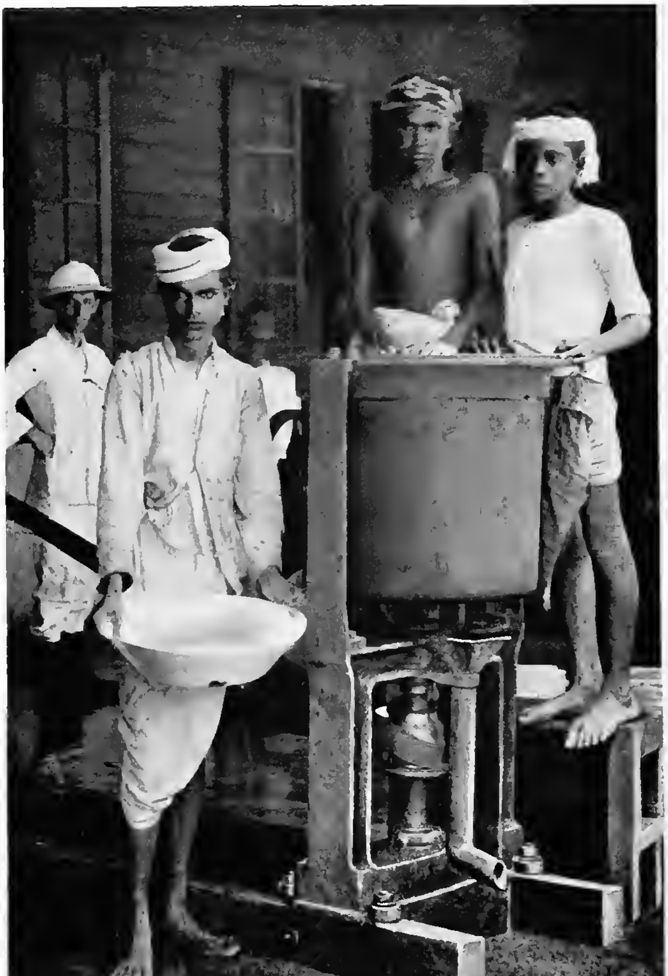
The Michie Golledge Machine.

Construction.—The Michie-Golledge rubber coagulating machine consists of a revolving cylinder, with angular ribs on its inside, and curved blades which are fixtures. The latex is poured into the cylinder, which is then set in motion. The revolving cylinder and its ribs force the latex forward on to the blades, 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. 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 per cent., 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 part between the 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, in the fresh state, very spongy, and is torn into irregular pieces which are pressed between the rollers of a mangle; the irregular cakes, obtained by passing the spongy mass through the rollers, are then cut into worm-like 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

Lent by Walker & Sons.

CUTTING FRESHLY-ROLLED RUBBER INTO "WORMS."



Lent by Walker & Sons.

MICHIE-GOLLEDGE COAGULATOR.

portion of which may be partially removed by repeatedly washing the rubber during the rolling process.

Mathieu's Coagulator.

With this apparatus heat is the coagulant and formalin the antiseptic. The latex flows through two adjustable slits in the bottom of a receptacle upon the surfaces of two revolving drums, these surfaces being kept at a temperature of 120° to 130°F. by a hot-water jacket. What makes the apparatus impracticable is the fact that, to maintain this temperature, hot water has to be introduced from time to time into each drum. The formalin is sprayed on. When the coatings of the drums are one quarter of an inch thick, they are cut across and unrolled in sheet form.

The K.L. Coagulator.

A coagulator invented by Mr. Harvey, of Pataling estate, and known as the "K.L. Coagulator" was exhibited at an exhibition at Kuala Kangsar. Compared with other inventions, this was said to require only a fraction of the amount of coagulant ordinarily used, and to be capable of turning out sponge-rubber, ready for further manipulation, in from 6 to 10 minutes, according to the age of the trees from which the latex was taken.

Mr. Harvey, in describing his machine, wrote to the Federated Engineering Company, Limited, as follows :—

1. This machine occupies very little room, and effectively does away with the need for coagulating pans and racks, thus saving space and labour.

2. Latex can be strained directly into the machine immediately it arrives from the field, and a perfect coagulation can be effected in five minutes. Thorough bulking of latex is assured.

3. By the use of this machine all decomposition of the proteins contained in the latex is rendered impossible, and when the coagulated rubber is washed through a machine, there is an entire absence of that unpleasant odour associated with new rubber which has been coagulated naturally in pans.

4. The outturn of dry rubber will be found to be more even in colour.

5. The large machine is capable of dealing with 50 gallons of latex at one time, while the smaller size treats 30 gallons.

6. It can be worked easily by one cooly, and needs no pulleys or belts. Nor is it necessary to set the machine in concrete.

7. The machine is portable, and can be cleaned with ease, with fair usage it is impossible to get out of order or broken.

8. The price is less than one-third that of any other coagulating machine on the market, and its capacity is four times greater.

Instructions for Use with "K.L. Coagulator."

The following solution of acetic acid has been found to give good results for coagulation :—

6 of water to 1 of glacial acetic, and
$1\frac{3}{4}$ fluid oz. of this solution to every 4 gallons of latex.

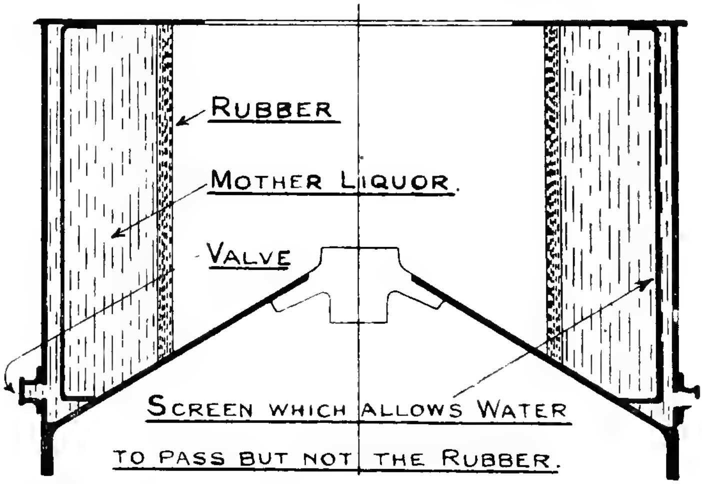
Having strained the latex into the coagulator, turn the handle slowly while pouring in the solution ; the latter should be poured in slowly, so as to be as widely diffused as possible throughout the latex.

The solution having all been poured in, continue to turn for about five minutes ; a medium pace should be maintained and the handle occasionally reversed for a turn or two.

If there are about 35 gallons of latex in the coagulator, coagulation starts in about five minutes, and when once this is the case, it is best to let it stand and then turn again in alternate spells of short duration ; quantities of 30 to 50 gallons of latex may be coagulated in about six to seven minutes.

Smith's Centrifugal Machine.

This apparatus, for which it is claimed that Castilloa latex can be satisfactorily treated, has been experimented with upon Hevea latex. The drum is deep, and the sides are lined by a screen of cloth covered on both surfaces by layers of perforated metal. After the apparatus is started, some water is run into the



VERTICAL SECTION THROUGH SMITH'S MACHINE AFTER SEPARATION OF RUBBER.

drum and becomes spread over the inner surface of the screen, where it forms a wall through which latex cannot escape. Next, the latex is run in, and spreads itself in turn on the inside of this wall. After a period, while the drum is still revolving, the water and the mother liquor which have separated from the film of rubber are allowed to escape through holes in the side of the drum. This allows the rubber to pass outwards and apply itself to the inner surface of the screen. Continuation of the motion removes some water from the rubber, which is finally removed in the form of sheet by slitting across the band of rubber applied to the screens. It is to be noted that acetic acid has to be added to the latex previous to treatment. An apparatus has been sent to Malaya for testing.

Main's Centrifugal Machine.

The form of this is like that of a vertical turbine, the blades being supposed to direct the caoutchouc globules inwards, where four curved plates, which do not revolve, pass them on to the centre. Here a spongy cylinder of rubber is formed, this rubber being removed by hand as it collects. Again, acetic acid must first be added.

Cockerill's Electrical Coagulator.

Cockerill has adapted the principle that caoutchouc is deposited from the latex upon an electrical anode. In the earlier form of his apparatus a continually moving anode is formed by an endless belt coated with graphite. Above it, with its free end half-an-inch from the belt, is a metal cathode. Latex running on to the belt has its caoutchouc attracted by it, and the residual serum runs into drip-pans below. The film of rubber is scraped off the belt and afterwards is run between rollers to press out some of the water remaining. In the later form, both anode and cathode take the shape of endless belts, one above the other, built up of metallic sections hinged together. The lower belt composes the trough which carries the latex and is made water-tight, while there are provisions for keeping the latex from overflowing and for preserving its contact with the surfaces of both electrodes. Means are provided for the removal of the serum, and for the washing and branding of the rubber sheet.

Coagulation in the Field or Factory.

On most estates the latex is collected in the field and despatched to the factory in pails carried by hand or in tanks along a monorail, where it is almost immediately coagulated. It is obvious, however, that a large quantity of water is thus transmitted; in order to effect economy several planters have suggested that coagulation should be done in the field and only the freshly-coagulated rubber need then be carried to the central factory. Mr. Golledge, Gikiyanakanda, informed me that he proposed to erect small sheds each equipped with a coagulating machine on every hundred acres of land; the coagulated rubber from each shed could then be carried to the factory for final manipulation.

Proteins, etc., in Coagulated Rubber.

Whenever rubber is prepared by ordinary coagulation, either by the smoking method or the use of familiar chemical re-agents, hot or cold, it is obvious that the rubber must contain the proteins together with the suspended globules of caoutchouc, resin, &c. Analyses of well-dried Para rubber show only a small percentage of substances other than caoutchouc—practically from 4 to 6 per cent.—and it may at firs 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 re-agents have been used the percentage of protein 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 re-actions with the tests for proteins. The amount of protein in the clear liquor may, according to Bamber, be as much as 50 per cent. of the original. It may be asserted that a great part of these substances generally occurs in the prepared rubber, and their presence along with other substances leads in many cases to putrefaction.

Use of Antiseptics.

If the local conditions are such that the rubber cannot be prepared by any method other than coagulation, and the protein 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 re-agent which has antiseptic properties, such as creosote or corrosive sublimate, and quickly drying the rubber after effectively washing and pressing the freshly-coagulated material. It must be recalled that the acetic acid method, as first devised by Parkin, included the use of creosote.

Creosote is a mixture of many substances, some of which are slightly soluble in water, others entirely insoluble. Of those that are slightly soluble are such antiseptic agents as carbolic acid and cresols, one of the latter having been tried alone, with what result has not yet been made public. Parkin recommends the use of a weak aqueous emulsion, added to the latex before, or preferably with, the acetic acid.

At the Ongyêm station, in Cochin China, 1 c.c. of formalin is added with the coagulant to every 1,000 c.c. of latex, which is diluted. After the last passage of the rubber through the washing machine, it is washed in 4 per cent. formalin.

Moisture, Washing and Putrefaction.

In some cases it is doubtful whether it is even necessary to add antiseptic re-agents if it is intended to turn the rubber out thoroughly dried, as decomposition is more or less 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 ; too much water cannot be used. In the washing processes the water may carry away a considerable portion of the soluble protein 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, judging by the reports of European firms on the ondition of various packages of plantation rubber which they have received. Dilution of the latex before coagulation might also reduce the proportion of protein in the prepared rubber. The more quickly and effectively the rubber is dried, the less likelihood is there of putrefaction or tackiness setting in.

Removal of the Protein from the Latex.

But it is not beyond the ingenuity of the chemist or planter to treat the latex with some re-agent which will keep some proteins in solution while the caoutchouc globules are segregating ; those which form part of the rubber can be expelled by subsequent pressing, macerating, and washing. Henri, Spence and Dunstan believe that coagulation can be effected after the removal of all protein substances from the latex.

Weber, as the result of experiments mainly with 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 protein matter in prepared rubber :—

"To every gallon of the rubber latex, from ½ oz. to 1 oz. of formalin 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 re-action.

"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 india-rubber.

"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 so obtained should at once be taken, cut into strips, and subjected to a thorough washing upon an ordinary rubber washing machine." The formalin acts more as an antiseptic to prevent the decomposition of the protein than anything else, and does not affect the specific gravity of the mother liquor.

Johnson made several attempts, when Director on the Gold Coast, to separate rubber from Hevea latex in the manner above suggested, but failed in each instance, although the latex stood, in one or two trials, 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 re-agents, *e.g.*, ammonia, &c., will keep the latex in a liquid state for a very long time, and might be used with advantage in such experiments.

Darkening of Rubber: Proteins and Enzymes.

It being very desirable that rubber should be sent to the market in as pale a condition as is possible, some attention has been given to methods of destroying or removing the substances causing the darkening. Bamber (Straits Bulletin, August, 1908), states that :—

"The discoloration is due to oxidation, by means of an oxidising enzyme, of soluble organic bodies allied to tannin in the latex, and is intensified by a warm temperature and exposure to the air. Thorough washing of the freshly-coagulated caoutchouc will remove much of the soluble matter with the enzyme, but it is difficult or impossible to remove it all, and other means have to be adopted to prevent the darkening on drying which almost invariably occurs. This is done by destroying the enzyme by means of heat before oxidation occurs, with the result that the rubber dries a clear pale yellow colour, and of perfect uniformity from day to day. The heating can be done in different ways before or after coagulation : 1st. By passing steam into the bulked latex until the temperature reaches 80°C. (or 167°F.), and maintaining this temperature for 15 minutes or longer, according to the thickness of the rubber. 2nd. By immersing the biscuits or sheets, etc., in water of this temperature for some minutes immediately after passing through the above rolling machine ; then re-rolling to the requisite thinness, and immersing again for a shorter time to ensure destruction of the enzyme. 3rd. Hot water can be employed in the washing machine, and if necessary steam-heated rollers as well."

A different position is taken up by Spence (Indiarubber Exhibition Lectures, 1908), who, to begin with, considers that the dark-coloured bodies are formed by the oxidation of proteins by means of an oxidising enzyme, and who, further, denies the efficiency of the methods suggested by Bamber. He admits that, as shown by his own experiments, on heating an extract containing the enzymes, say, at 80°C. for 5 minutes, they are destroyed. But he points out that all enzymes arise from bodies known as zymogens, which are resistant even to boiling. Thus, after treatment of crude rubber by heat for the destruction of the enzymes, new enzyme is formed. Yet the aggregate activity has been lessened by the process. The heating method, as applied to some latices, may possibly ensure light-coloured rubber, but as applied to the latices from old trees, it is doomed to failure apart from the injury that may be done to the rubber by heating the latex. He recommends that if light-coloured rubber is desired, the enzymes and proteins be removed from the latex by suitable methods of washing before the rubber is finally coagulated. By this he evidently implies washing the rubber during the early stages of coagulation, when it is in the form of flakes, a process that he claimed to have carried out. But no proposals have yet been made for following out the process on a commercial scale, and Spence himself (I.R.J., April, 1911), has recently admitted that the removal of the proteins from crude rubber is a matter of much difficulty. A private communication from Crossley is to the same effect.

It is worthy of note that Messrs. Lewis and Peat, in their 1910 circular, remark that the trade generally now look far more to the quality and strength of plantation rubber than to colour.

Discoloration of Biscuits.

The government mycologist, Ceylon, reported that in 1909 various cases of discoloration to rubber biscuits, e.g., red patches, black spots, and biscuits with a brown film, had been examined as far as possible. Some of these discolorations appear to be due to bacteria and yeasts, and can be avoided by scalding the various utensils used in the factory ; others appear to be due to chemical differences, and these are now being analysed.

When this trouble makes its appearance, all collecting cups should be boiled, and the dishes, pails, etc., scalded with boiling water. It has been found sufficient to do this once, but it would be a wise precaution to scald the dishes and pails periodically, as part of the general routine of the factory. If the infection is introduced with the water-supply, the above treatment will not stop it, because the dishes will be re-infected. To determine whether the water supply is at fault, biscuits should be made, using water which has been boiled and cooled, and these should be compared with biscuits made with the unboiled water.

According to Brooks, the red patches are due to infection by *Bacillus prodigiosus.*

Moulds on Rubber.

An examination of the rubbers from various countries was carried out in Ceylon (Annual Report, 1906), in order to determine their comparative resistance to moulds. The mould which grows on prepared rubber in Ceylon is apparently *Eurotium candidum.* It seems clear as a result of the inquiry that the development of the moulds depended upon the moisture content of the rubbers, the driest rubbers escaping attack.

CHAPTER XXII.

THE THEORY OF COAGULATION.

The physical and chemical changes involved in the phases of coagulation already recognised are numerous and complex, and many theories have been put forward to explain the phenomenon. It may be argued that the practical planter does not need to trouble himself about the changes which lead to the separation of rubber from the latex, since this is so easily accomplished. The writer is of the opinion, however, that the methods adopted on Eastern estates still leave much to be desired, and if a better knowledge of the changes incurred during coagulation can be gained, planters of an inventive frame of mind will quickly effect improvements. For these reasons, it is proposed to study the phenomena of coagulation in some detail, and to consider latices from species other than *Hevea brasiliensis*.

The latices from different species alike possess quantities of resins, proteins, caoutchouc and inorganic substances, but the behaviour of these to the same agencies—heat, moisture, centrifugal force, preservatives, acids, and alkalies—is widely different. The phases of coagulation of latices from distinct botanical sources require separate and detailed investigation. Heat, though it coagulates many latices, has no such effect on that of *Hevea brasiliensis*. Formaldehyde, though acting as an anti-coagulant with Hevea latex, appears to coagulate other latices. Alkalies, which help to maintain some latices in a liquid condition, hasten the coagulation of others. Mechanical means, while allowing one to effectively separate large-sized caoutchouc globules from some latices, are almost useless when dealing with the latex of *Hevea brasiliensis*.

The Theory of Coagulation.

The changes that are essential in the production of an elastic mass of indiarubber from the latex have been variously explained, but only two views will be here referred to. Some hold that the necessary factor is the formation of a network of coagulating protein that brings the globules together as it contracts. Others maintain that coagulation is independent of the proteins, can take place in their absence, and is explicable only by modern physico-chemical theories of the suspension of colloid particles in an emulsion. That the coagulation of the protein is responsible seems a very attractive explanation when one recalls the clotting of ordinary milk under the influence of rennet. But this view of coagulation has been strongly attacked by, among others, Spence, Dunstan, and Henri.

The term "coagulation" was originally applied to the coagulation of protein, but it is now generally used to denote the separation of the caoutchouc globules and all those processes which lead to the production of a mass of rubber from latex.

Proteins and Coagulation.

Dunstan (Bull. Imp. Inst., Vol. IV., No. 4, 1906), has pointed out that the original view taken of the process of coagulation—to the effect that it was dependent upon protein coagulation and the separated proteins carrying the rubber globules with them—cannot now be accepted. Dunstan asserts that "there are peculiarities connected with the coagulation of latex which are opposed to the view that it is wholly explained by the coagulation of the associated proteins. Experiments, made with latex from India, led them to the conclusion that 'coagulation' can take place after removal of the proteins, and that in all probability it is the result of the polymerisation of a liquid which is held in suspension in the latex and that on polymerisation changes into the solid colloid which we know as caoutchouc. There is little room for doubt that the coagulation is due to the 'condensation' or polymerisation of a liquid contained in the latex. What is the nature of this liquid from which caoutchouc is formed?"

Physico-Chemical Theory of Coagulation.

Henri (Le Caoutchouc, May 15th, 1907), who carried out a series of experiments with the latex of *Hevea brasiliensis*, pointed out that in connection with the coagulation of latex there exists a series of bodies which cause coagulation in some samples, but have no effect on others; he also remarks that the coagulation of latex has been compared with that of albuminoids, it even being surmised that these substances are essential to the process. He maintains, however, that latex is really a suspension of very fine particles in aqueous liquid more or less rich in saline or organic bodies, is of the nature of an emulsion, and that the same laws rule as in the precipitation of colloids from emulsions. The fact that rubber, owing to its lightness, rises to the surface instead of being precipitated does not affect the comparison. Having electrically tested Hevea latex, he found that the globules were negative as to the serum. And, as he points out, the precipitation of negative emulsions, or rather, of the suspended particles, is brought about by acids or the salts of bi- and tri-valent metals, without any distinction as to the nature of the acids of these salts; while the precipitation of positive emulsions is brought about by alkalies or the salts of bi- and tri-basic acids, the nature of the metallic bases of these salts being of no importance. This close analogy with an emulsion he regards as of great significance.

Fickendey on Protective Colloids.

By Fickendey (Zeits. Chem. Ind. Kolloide, 1910), the term "coalescence" is preferred to that of "coagulation." The stability of latex emulsions, that is, their power of retaining the caoutchouc globules in suspension, he ascribes to what he calls the protective colloids, the proteins, as in Hevea latex, or the peptones, as in Funtumia latex. The first phase in coalescence, really comparable to creaming of the globules, depends directly upon the behaviour of the colloids. Protein precipitants cause separation of the rubber in latices containing proteins, as in Hevea latex; peptone precipitants cause separation of rubber in latices containing peptones, as in Funtumia, where formalin is a coagulant because it is a peptone precipitant. If freshly-separated rubber cream from Funtumia latex is shaken up with peptone solution, a stable emulsion is formed. The same happens if cream from Castilloa latex is shaken up with albumen solution. The second phase of coalescence has been regarded as one of polymerisation, though experimental proof is wanting. It is accepted by him that liquefaction or destruction of the separate globules precedes the transformation of the liquid caoutchouc into the elastic modification. He cannot confirm Schidrowitz's statement that the globular form persists in the crude rubber.

Polymerisation of the Caoutchouc.

This question of polymerisation of the caoutchouc hydrocarbon during the production of the rubber is still a matter of debate. Polymerisation is a chemical change, but not one involving any alteration in the relative quantity of the constituents, being merely what may roughly be called a condensation, a substance of higher molecular weight being formed. Probably, this chemical change, if it takes place, is accompanied by a physical change, to a more solid condition.

Some investigators hold that the caoutchouc, as we find it in the crude rubber, is already formed as such in the latex, but others differ. Weber believed that in the latex caoutchouc exists as a thin, oily liquid.

Apparently the only investigations bearing upon this question of polymerisation are two in number. Hinrichsen and Kindscher find that the caoutchouc has already, in the latex, a very high molecular weight, a fact that is against the idea that polymerisation takes place during coagulation. Harries got colloidal solutions by treating fresh latex with ether—another indication of high molecular weight.

It must not be assumed that polymerisation is an incident only in coagulation, or that it necessarily takes place at that stage. Harries apparently believes that polymerisation may take place during the drying and smoking of the rubber.

Phases of Coagulation.

As the result of his experiments Henri concluded that "On adding different reagents to the latex one of three things may occur :—

"1. There is no reaction.

"2. Isolated flakes, varying in size, are formed which either rise or sink, but do not unite, being readily separated by stirring. This may be termed the agglutination of the latex.

"3. A network of long threads encircling all the globules of the latex is observed. On stirring, the threads reunite, forming a solid elastic coagulum. This is the true coagulation of the latex."

Agglutination or coalescence of the caoutchouc globules is therefore the first stage in coagulation. It is conceivable, when the caoutchouc is entirely separated from the other constituents of the latex, that this may also be the only and therefore final stage.

Effect of Re-agents on Latex.

Henri performed his experiments upon dialysed latex, that is, latex from which the salts and other crystalline bodies were removed. A large number of re-agents, singly and in mixtures, were tried with the following results :—

"Methyl, ethyl and amyl alcohol produced no reaction. Hitherto alcohol has been considered a coagulant, but its action is evidently due to salts present in the latex. Sodium, potassium, and ammonium salts also have no effect. Salts of calcium, barium and magnesium in sufficient quantities cause agglutination. Salts of iron, manganese, nickel, cobalt, copper, zinc, lead, and aluminium all produce agglutination, the size of the flakes increasing with increase in concentration of the solutions, but one never got an elastic clot. Hydrochloric, nitric and acetic acids all cause agglutination ; very dilute sulphuric acid also has the same effect, but if more concentrated, coagulation commences. Trichloracetic acid, even when very dilute, produces a remarkably elastic coagulum. Acetone also is a coagulant."

" Regarding the action of mixtures, as a rule alcohol added after a salt produces agglutination or coagulation.

"On studying the influence of alkalies on coagulation, it was found that an extremely small quantity interfered with the reaction ; a ten-thousandth normal solution was sufficient to prevent agglutination or transform coagulation into agglutination. Thus magnesium chloride and alcohol produce coagulation, but if the latex is rendered even very slightly alkaline, only isolated flakes are formed, again showing that the passage from agglutination to coagulation is gradual, and that one may be considered as a higher stage of the other."

Generalisations by Henri from his Experiments.

Some of the deductions made by Henri from his experiments are as follows :—

1. Coagulation by mixtures is much superior to that by single substances.

2. It is by the association of acids with the salts of bivalent and trivalent metals that the best results are obtained.

3. Coagulation by mixtures should not be too rapid, otherwise some parts are less efficiently coagulated than others. Agitation helps coagulation.

4. The temperature at which the coagulant is added is of importance. The best results are in certain cases obtained by first adding a very small quantity of the mixture, not enough to produce coagulation, and then raising the temperature to 25° or 30° C. The rubber obtained is very homogeneous, of good nerve, elastic, and generally of superior quality. Evaporation of water is here, of course, one of the agents in coagulation.

5. The mixtures giving the most elastic rubber are not those giving the best rubber for solution in benzene.

Comparative Coagulating Power of Different Chemicals.

The coagulating power of chemical substances varies within fairly wide limits, and in the table below Parkin (Science Progress, April, 1910), gives the weight required of different re-agents to coagulate completely 100 c.c. of Hevea latex.

	Grammes per 100 c.c. of latex.
Sulphuric acid	0·1
Hydrochloric acid	0·1
Nitric acid	0·3
Acetic acid	0·95
Oxalic acid	0·2
Tartaric acid	0·25
Citric acid	0·5
Corrosive sublimate	0·8
Formic acid	0·45
Acid potassium tartrate	0·16

It will be observed that acetic acid is the least powerful of these re-agents; but, leaving all other considerations out of account, this has its advantage in that greater freedom is possible in the amount of acid used.

Structure of Crude Rubber.

Torrey (I.R.J., Nov., 1907) points out that Henri gives a series of plates showing the structure of the rubber obtained by coagulation of the latex with different re-agents, and shows that the same latex yields products of totally different character (as to length of fibre, elasticity and life) according to the re-agent by which it is coagulated. Sometimes the rubber separates in the form of fine flecks which show little or no tendency to unite with other coagulants, the flecks either unite to form larger flecks, or one obtains at once a deposit which from the first has a lace-like structure. In these latter cases the product is very elastic; in the first case it is notably less so.

Some years ago Torrey observed that "petroleum naphtha solutions of a number of crude unwashed rubbers gave characteristic figures when a few drops were allowed to evaporate on a white surface. The solutions consisted of 5 grams of each rubber in 100 cc., petroleum naphtha boiling at 60 deg. to 90 deg. C. I recall that Fine Para and Matto Grosso were the two South American grades; and among the Africans were Lapori, Red Kasai, Upper Congo Ball, Ikelemba and Bussira."

"Fine Para gave always a fine regular lace-like pattern; Matto Grosso gave a very similar one, but not so fine and not so regular. Some of the African gave the same general type of figure, but much coarser. Others deposited the rubber in the form of one or two nebulous spots, shading away very gradually toward the edges, and connected by a few rather faint filaments which were usually disposed between the two spots in the form of a single mesh of a coarse network—the mesh being approximately circular in form. The most characteristic case of this kind was Lapori. On the whole, the difference between the figures corresponding to different rubbers was so great that even an untrained observer could, without difficulty, identify almost any one of the varieties under examination by its figure."

These results seem to be explained differently by the experiments of Fox (I.R.J., January, 1909). A large number of samples representing the most important of the wild and cultivated species were tested according to Torrey's method. Fox was able to show that the pattern of the films left after evaporation of the solvent depended entirely upon the viscosity of the solution. This in turn depends mainly upon the concentration of the solution and partly upon the degree of impurity of the crude rubber.

Influence of Coagulant on Strength of Rubber.

The observations of Henri regarding the influence of the various coagulants on the strength of the rubber are extremely important to planters. If the re-agents which are now so largely used on Eastern estates produce an inferior rubber, others should be taken up. Henri claims to have proved that "the structure of the coagulum varies with the nature and concentration of the substances employed for coagulation. A weak coagulant produces a pulverulent or flaky precipitate; a strong coagulant, on the contrary, leads to the formation of an elastic curd with reticular structure. When the structure of the reticular curd obtained by different coagulating agents is considered it is seen that the smallness of the meshes varies with the coagulant and speed of coagulation. The elastic properties of rubber obtained by coagulation of the same latex vary much with the different coagulants employed."

And it may be taken in a general sense that a tougher rubber, but one with less distensibility, results from a more rapid coagulation.

The curds which Henri obtained by coagulation of latex were rolled out in sheets, dried, cut into strips and mechanically tested. The following were his results. (The last column gives elongations at moment of rupture) :—

Mode of Coagulation.	Rupture Stress per millimetre.	Elongations.
Heat 80 deg. C.	150 g.	8·5
Heat 25 deg. C.	190	7·2
Weak acetic acid	175	7·5
Strong acetic acid	210	7·1
Trichloracetic acid	325	6·8
Acid + salt 1	310	6·8
Acid + salt 2	380	6·8
Acid + salt 3	660	6·5

"The elastic properties of rubber are therefore considered to be in relation with the fineness of the reticular structure of the curd, and the latter depends upon the coagulant employed." Thus with the same latex Henri showed that rubbers with different values can be obtained, a most important determination to all rubber planters.

Henri's observation—that the fineness of the reticular structure depends on the nature of the coagulant and the rate of coagulation—has been confirmed by Spence for Funtumia rubber (I.R.J., August, 1907), who states that the elastic properties of rubber may vary with the coagulant employed. This is a point which should be well studied by all planters who are anxious to improve the physical properties of their rubber. If the acetic acid so largely used on Eastern estates produces an inferior rubber, its use should be discontinued and the latest results of science given a practical trial on a large scale. There is no time to be wasted in this direction, especially on plantations where all the trees are young. Spence is of the opinion, from his analyses of *Funtumia elastica* latex and rubber, that if the nitrogenous compounds in latex could be broken up in a particular manner, the quality of the final rubber might be considerably improved. Is this also likely with Hevea latex ?

Further Observations on Effect of Coagulation on Strength.

Without mentioning the methods of coagulation employed, Schidrowitz (Rubber, 1911) mentions that in a series of three samples of Funtumia rubber prepared by different methods, the best sample had a viscosity value of 17,400 and the poorest one of 12,800, that of benzene being unity. In a series of ten samples, all the product of different methods, the limits were 18,500 and 11,400. These figures enforce the importance of our determining carefully the best methods of production.

In an earlier communication that he made along with Kaye (I.R.J., 23rd Sept., 1907), wide variations were found in samples of Funtumia rubber coagulated in different ways, as by heating, and with calcium chloride, acetone, etc. The pure caoutchouc, that is, the soluble rubber free from water and resin, ranged in quantity from 77·6 to 94·32 per cent. of the latex. The tensile strengths (breaking strains) varied between 217 and nearly 500 ; elongation at break was between 3·8 and 6·6 ; the range in resiliency was from 54 to 100 per cent.

COAGULANT AND STRENGTH OF VULCANIZED RUBBER.

Frank and Marckwald (Gummi-Zeitung, XXV., 1911, pp. 193 and 877), prepared Ceara and Funtumia rubber by numerous methods, varying the methods of drying and after-preparation as well as those of coagulation. All the samples were vulcanized, and then tested for elongation at break and the breaking stress; the viscosity was also determined, and the free and combined sulphur. A very wide variation in mechanical qualities and in behaviour under vulcanization was shown.

Messrs. Clayton Beadle and Stevens (Chemical News, November 22nd, 1907), state that though the method of coagulation may affect the physical properties (nerve) of raw rubber, the difference in reticulation recorded by Henri may have no effect on the properties of the ultimate vulcanized product. At the temperature of vulcanization they maintain that all traces of structure disappear, even if they have not already been obliterated in the process of mastication. They should not lose sight of the fact, however, that raw rubber is sold by producers on its physical properties alone. Too much stress cannot be laid on the importance of preparing plantation rubber in such a manner that its nerve shall, if possible, be equal to that of fine hard Para.

The same authors, in the same contribution, point out that there is some striking proof of the influence of the conditions under which crude rubber is prepared on its physical properties in the "apparent" specific gravity of the rubbers examined by them. The specific gravity of one biscuit was low corresponding with a low tensile strength. That of a block was lower still owing to the presence of a large number of air bubbles. Heating a block reduced its tensile strength; freezing a block for one week improved the tensile strength without materially affecting the specific gravity.

CHAPTER XXIII.

PURIFICATION OF RUBBER, AND WASHING MACHINES.

Having dealt with the properties of latex and the various methods of preparing rubber therefrom, it is now necessary to consider the important details of the processes through which rubber passes in purification, and its condition when it enters the market. 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, apart from the usual shrinkage, it undergoes no changes during transit if it has been properly prepared.

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

Purification by the Manufacturers.

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, &c., flying out of the softened rubber when it is stretched and torn between the rollers. These impurities are loosely embedded in the rubber, and if the temperature is raised too high the resins may be converted into sticky substances, which cement the rubber and mechanical impurities and thus render it impossible to remove the latter by washing.

Loss in Washing Wild Rubbers.

The actual loss in the washing process is often surprising. The loss on washing some of the Para rubber collected in the Amazon district varies from 10 to 40 per cent. 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 0·29 per cent. of ash. The loss from fine Para is from 10 to 20 per cent., whereas that from plantation biscuit, sheet, crêpe, &c., is only about 1 per cent. Weber states that fine hard Para from the Amazon district shows a loss on washing of from 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. Cameta loses 40-50, Peruvian ball or Caucho, 20-40, Mangabeira (Hancornia), 30-40, Red Kasai (Landolphia), 20-30, Gaboon balls, 25-35, Upper Congo, 10-30, Panama (Castilloa), 15-30, and Pontianak, 10-50 per cent. on washing.

Different brands show a variation in the composition of the impurities and the loss on washing as indicated below; the composition of the impurities is clearly put forward by Weber:—

Brand.	Loss on Washing.	Oily and Resinous Substances.	Ash.
	%	%	%
Ceylon	1	3·0	0·5
Para, hard cure	15	2·1	0·5
Para, soft cure	17	2·5	0·3
Ceara	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. The crude rubber is weighed both before washing and after drying, the percentage loss then being calculated. 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 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.

Many persons assume that the percentage of resinous matter in indiarubber is an indication of the care bestowed upon it by the producer. This is not correct, for the resinous matters exist in the latex as the latter flows from the trees. The variation in resin in different samples 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 latices of different qualities.

High Loss Undesirable.

If the loss on washing is beyond a certain amount the rubber will be naturally classed as inferior. In a paper (I.R.J., July 20, 1903) 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 10 to 12 per cent., this rose within the last ten years from 12 to 16 per cent., and in the last five years had 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.''

Washing Rubber on Plantations

When plantation rubber was first sent from the East it was shipped as clean biscuits or sheet obtained by filtering the latex through cloth, adding acetic acid to hasten coagulation, and thoroughly washing the soft freshly-coagulated rubber with clean water. Such methods of preparation, while useful from the standpoint of purity in composition and ease in packing, are not applicable when estates are harvesting several tons each month; the use of separate trays, for biscuits or sheets weighing only a few ounces each when dry, must give way to a more practical method for dealing with large crops.

The use of machinery is bound to become more general when more rubber is collected; the means adopted for straining, purifying, and coagulating the latex will minimise the loss which normally occurs in the manufacturing process.

Characters of Washed Rubber.

If the washing process has been properly carried out, the rubber should dry rapidly and give a pale amber-coloured final product. The unevenness depends upon the cut of the rollers and the number of times the rubber has been operated upon. Often the rubber has been torn and stretched beyond all requirements. Thoroughly-washed rubber does not usually show any signs of mould or tackiness; crêpe—probably on account of the washing to which it has been subjected—is rarely known to arrive in Europe in a mouldy condition; this cannot be said of most other forms. Where machinery is defective, the strips of crêpe may have dirty or oily patches which disfigure the consignment; these defects can, however, be remedied.

Practical Points in Washing Rubber.

Properly washed plantation rubber is now sometimes being passed through the manufacturing processes without being submitted to the preliminary washing usual with wild rubbers. Of course the washing of sheet rubber is only a perfunctory process and affects merely the surface. Furthermore, the passing of large lumps of coagulated rubber through washing rollers converts the product into a shape in which it can be easily handled in far less time than when separate trays are used for each sheet or biscuit of rubber. The fact that by the use of washing machines on plantations the planter is able to successfully deal with his large crop, is probably quite as important, to him, as the purification effected in the rubber.

Removal of Acids by Washing.

An important reason for thoroughly washing the rubber immediately after coagulation is that the residual acid is harmful to the rubber, and interferes with vulcanization, and must therefore be removed as far as is possible. Some of the acid remains adsorbed on the surface of the caoutchouc globule, and experience has shown that it is impossible to remove such adsorbed acid by mere washing. But it is desirable that the quantity of acid retained should be small, for, as Spence shows in the case of sulphuric, the residual acid is harmful to the rubber and may induce tackiness. Brindejonc has demonstrated the evil effects of acetic acid upon the keeping qualities of rubber. Crossley has shown that the quantity of acetic remaining in the clot is small

Another good reason for washing is the removal of all soluble substances that may serve as food for bacteria and moulds.

Further, it has been found that sheets and biscuits, which are not really washed, have a tendency to deposit on the rollers of the mixing machine a sticky substance that causes the mineral matter of the compound to adhere and form hard scales or flakes.

Mr. P. M. Matthew, of the Victoria Rubber Company, Edinburgh, suggested that immediately after coagulation the rubber should be thoroughly cleansed by maceration in pure water.

Washing Machines for Plantations.

Less than ten years ago washing mills were hardly known on Eastern plantations. I understand that the introduction of washing machines was largely the result of conferences between Mr. Tarbet (late Editor, India-Rubber Journal), Mr. P. J. Burgess, at that time attached to the Agricultural Department, F.M.S., and Mr. Francis Pears, then Manager of Lanadron Estate, Johore. Burgess, at an agricultural conference in Malay, about seven years ago, read a paper to planters in which he outlined the main features of washing mills he had seen working in England; he definitely advised their use on plantations. Very soon Ceylon and Kuala Lumpur firms advertised washing machines supplied with rollers of quite a miniature type, but fitted with feeding troughs and gears of an enormous size; since that date, Eastern engineers have much improved their machines. British and Continental firms have also entered the market, and have entirely changed the mechanical features of this department of factory work on estates.

Types of Plantation Washing Machines.

Washing machines on plantations are constructed on the same principles as those for factories in Europe. The main difference is in the sizes of the rollers and component parts, and, therefore, in capacity. Some countries have not yet adopted washing mills and a brief description of their construction and working is therefore necessary.

A typical machine consists essentially of two chilled cast-iron or 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 about one inch to contact. The adjustment is effected by turning a screw at each end of the roller or at one end only. The fittings of the rollers are so arranged that, in the event of large stones being introduced between them, either the fittings readily give way or the rollers stop. Safety bushes, the screws of which break if any stones get between the rollers, are usually supplied. The rollers may revolve at the same or different speeds. The axes of the two rollers may be on the same horizontal plane ; more usually, the back roller is slightly above the other. A stream of hot or cold water flows over the surface of the rollers all the time they are in use.

Fresh soft rubber is placed between the rollers, and is passed through them several times, the rollers being brought close together until the strip of sheet or crêpe is even in thickness and comparatively hard. If scrap or bark rubber is used, and the rollers are running at different speeds, pieces of bark, wood and dirt are ejected as a result of the stretching and tearing to which the mass is subjected. The stream of water, supplied from a jet immediately above the middle of the rollers, thoroughly washes away any mechanical and readily soluble impurities in the rubber.

Each machine is usually provided with a trough into which the soft or scrap rubber is fed ; below is a perforated tray to catch fragments of rubber and yet allow water and finely pulverised impurities to escape.

It is, therefore, obvious that, apart from the fact that the machines enable the planter to deal rapidly with large quantities of rubber, their use also ensures the removal of mechanical impurities, the washing of all parts of the rubber by clean water, and the production of a thin sheet of fairly uniform thickness and length convenient for subsequent drying and packing.

Types of Machines Required by Planters.

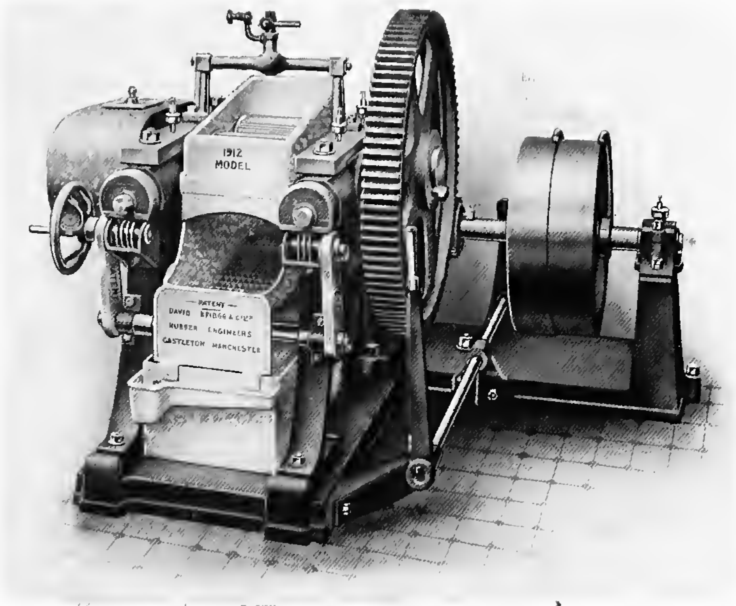
There are usually three types of machines required by planters, which are conveniently described as sheeting, crêping and macerating mills.

Sheeting Machines.

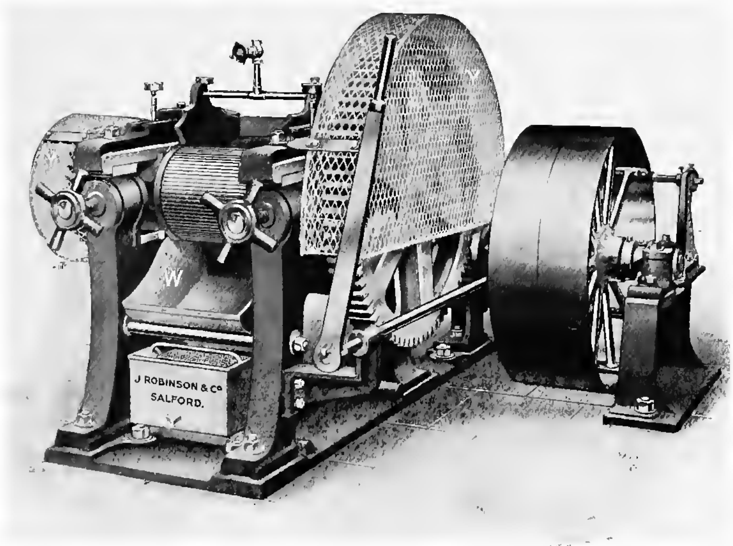
Sheeting machines are supplied with perfectly smooth rollers which revolve at nearly even speeds, the differential speed usually being only one tooth difference. The rubber is therefore not subjected to much tearing or stretching, and is not washed, internally, to the same degree as crêpe. These machines are used for making sheet rubber and for binding rubber which has been repeatedly passed through crêping or macerating machines. Sheet rubber can be more easily impressed with an estate mark than crêpe.

Crêping Machines.

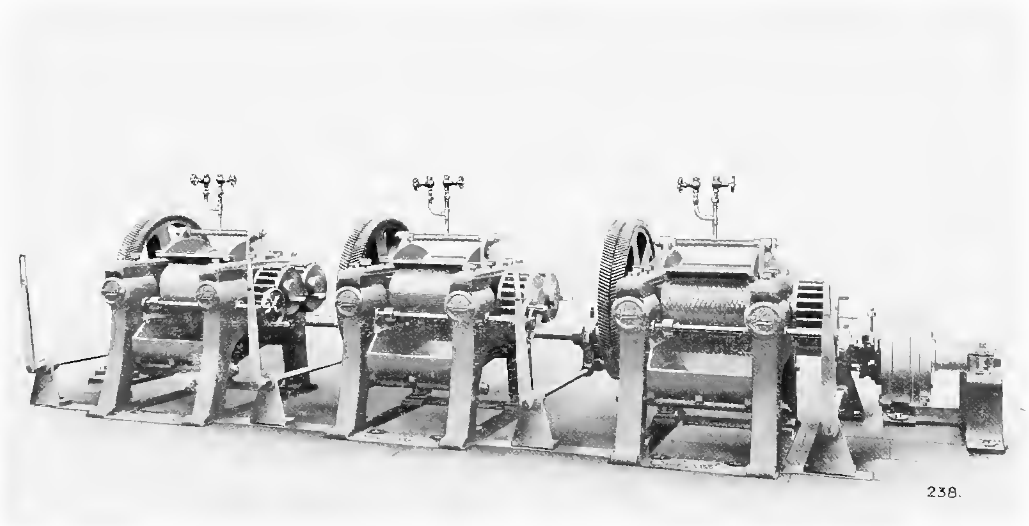
Crêping machines are supplied with grooved rollers, the flutings or grooves sometimes being horizontal, at other times square or diamond-cut and sometimes spiral. On some estates these machines are supplied with one roller smooth and the other



BRIDGE'S BELT-DRIVEN WASHING MACHINE.



ROBINSON'S WASHING MACHINE.



SHAW'S COMPLETE SET OF MACERATING, CREPING AND SHEETING MACHINES.

grooved. The rollers run at uneven speeds, 5 to 4 and 3 to 2 being common speed ratios; on some properties a much higher differential rate of revolution is preferred. It is obvious that rubber prepared in a crêping machine is better washed and generally subjected to far more stretching and tearing than that prepared between even-speed sheeting rollers. This difference is so great, and the effect on the rubber so pronounced, that many manufacturers have cautioned estate managers against their use. It is, however, possible to achieve the desired results without risking deterioration of the rubber. This is being done successfully on many estates.

Crêping machines are used primarily for the production of long strips of crêpe rubber which can be rapidly dried. They are also occasionally used for macerating bark shavings and washing scrap.

The grooves in the rollers vary in distance from each other according to the pattern adopted, and also in depth and width. The groovings give a definite appearance or pattern to the crêpe, which sometimes makes the impressing of an estate mark difficult on this class of rubber.

Bertram's, Ltd., state that they have supplied single spiral even-speed machines for finishing purposes, having the grooves in the same direction so that they cross at the nip of the rolls, thereby marking the rubber so as to form a diamond pattern when held up to the light. If the machine used for this purpose is supplied with double spirals it is found that the diamond impression on the one side of the rubber shows on the opposite side and thereby gives a confused impression instead of a clear diamond as given by the single spiral roll.

Macerating Machines.

These generally differ from crêping machines in having rollers set at a greater differential rate of revolution, a speed ratio of 3 to 2 and 2 to 1 being adopted on some estates. The machines are used primarily for tearing and stretching bark shavings and scrap rubber. They are also used for shaping freshly-coagulated rubber before passing it through crêping or sheeting rollers, one rolling usually being sufficient for this purpose. It is advisable that one macerating machine shall be set apart for dealing with dirty rubber and scrap, in order to avoid contamination of the purer grades. Even then it is necessary to clean the machines more frequently than the others if the best results are to be obtained. The groovings are usually spiral or zigzag, and are deeper and wider than those on crêping rollers. It is usually necessary to immediately pass the rubber, when freed from all impurities, through smooth sheeting rollers, in order to get the benefit of any binding effect which such treatment may afford; frequently the rubber when finished in the macerating machine is in such a state that re-binding is impossible or extremely difficult.

Sizes and Chilling of Rollers.

The first washing machines used on plantations were comparatively small—rollers 8 to 9 inches long—but there is now a pronounced tendency to adopt sizes somewhat similar to those used in Europe. For small estates rollers 18 in. long by 9½ in. diameter, and for large estates 18 in. by 12 in. are now usually recommended. The common stock sizes for plantations are 6 by 12, 7 by 12, 9 by 18, 9½ by 18, 12 by 15, 12 by 18, 14 by 21 and 16 by 28 inches, the smaller figure being the diameter. Most firms supply chilled cast-iron rollers, as it is believed that these last longer than those not chilled. They are not, as many planters seem to think, rust-proof. The deepening or re-cutting of the grooves when worn down is by no means an easy task. Chilling increases the durability of the rollers, and the grooves are not, therefore, worn as speedily as they would otherwise be; but it is being doubted in many quarters whether chilling really pays. Rollers for sheeting machines, made of hard, close-grained, cast iron are said to be quite good. Cochrane's supply rollers which are said to be hard and non-rusting. The rollers for plantation machines are generally solid; Warner's recently made hollow rollers for plantations which could be heated in order that softening prior to blocking could be effected.

Speed of Rollers.

As previously indicated, the speed of the rollers varies according to the type of machine, sheeting machines running at almost even speeds and macerating machines at the maximum difference. Bridge's are of the opinion that the most economical speed of rollers in macerating, crêping and sheeting machines for newly-coagulated rubber is 60 feet per minute, though they have run machinery at higher and lower speeds. At a higher speed, the machine is running too fast for the attendant. When hard rubber is being rolled, 40 feet per minute is advisable. They also find that if the rollers are running at the ratio of 1½ to 1, and even up to 2 to 1 for macerating, 4-teeth friction for crêping, and 1 tooth-friction for sheeting machines, satisfactory results are obtained.

Bertram's, Ltd., also advise a surface speed for rollers of 60 feet per minute for all machines on plantations. They adopt the following frictions: macerating machines, 6 to 9; crêping machines, 6 to 7 or 6 to 8; and even-speed for sheeting machines, 6 to 6. The rollers are usually run at a speed of about 20 revolutions per minute.

Cochrane's inform me that in all their machines the back rollers run at 24 revolutions when 9 in. in diameter, and at 18¼ revolutions per minute when 12 in. in diameter. The front rollers revolve in macerating machines at 18 to 23 per minute when 9 in. diameter, and 15 to 18 revolutions per minute when 12 in. diameter rollers are used. In crêping and sheeting machines with rollers 9 in. in diameter, they run at 20 to 23 and 20 to 24 respectively.

Shaw's, as well as other firms, have the rollers running at different rates according to size. Rollers 18 by $9\frac{1}{2}$ in. have the back rollers running at 24 revolutions per minute, the front rollers running at 19 (for macerating), $21\frac{1}{2}$ (for crêping), and 24 (for sheeting) revolutions per minute. With rollers 18 in. by 12 in., the back roller is run at 20 revolutions per minute, the front running at 16 (for macerating), 18 (for crêping), and 20 (for sheeting) revolutions per minute.

Dimensions of Grooves.

The depth, width, and distance apart of the grooves vary according to the pattern of flutings selected. The grooves are generally nearest to each other in diamond-cut rollers, and at the greatest distance, when disposed horizontally; it is probably on account of this that diamond-cut rollers wear out sooner than other types.

Various firms appear to adopt different dimensions. Bertram's, Ltd., make macerating rollers with grooves $\frac{3}{16}$ in. wide, by $\frac{1}{8}$ in.deep, or $\frac{1}{8}$ in. wide by $\frac{1}{8}$ in. deep; for crêping the grooves are $\frac{1}{8}$ in. wide by $\frac{1}{8}$ in. deep, or $\frac{1}{8}$ in. wide by $\frac{1}{16}$ in. deep.

Bridge's prefer grooves on spiral macerating rollers to be V-shaped, $\frac{3}{16}$ in. wide, $\frac{3}{32}$ in. deep, and $\frac{5}{8}$ in. pitch; on the coarse diamond cuts the size of the diamond is $1\frac{1}{4}$ in. by $\frac{3}{4}$ in. with sizes of grooves as above. Grooves on crêping rollers are made in diamond-pattern V-shapes, $\frac{3}{32}$ in. wide, $\frac{3}{64}$ in. deep, and the sizes of the diamond $\frac{3}{4}$ in. and $\frac{1}{2}$ in. Straight-cut rollers, for macerating or crêping, are made with grooves $\frac{5}{8}$ in. pitch, $\frac{1}{16}$ in. by $\frac{1}{8}$ wide and V-shaped.

Cochrane's make their spiral, horizontal and diamond grooves on macerating and crêping rollers $\frac{3}{16}$ in. wide with a pitch varying from $\frac{5}{8}$ in. to 1 in., and the depth from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. In diamond-cut rollers the grooves are $\frac{1}{16}$ in. deep, $\frac{1}{8}$ in. wide, and from $\frac{3}{8}$ in. to $\frac{3}{4}$ in. pitch.

Robinson's make the grooves in all fluted rollers of definite dimensions, but vary the latter according to the size of the rollers. The grooves are $\frac{1}{16}$ in. deep, $\frac{1}{16}$ in. wide, and have a pitch of $\frac{3}{8}$ in. for rollers 4 in. by 6in. and 6in. by 10 in. The depth is $\frac{1}{8}$ in., width $\frac{3}{32}$ in., and pitch $\frac{1}{2}$ in., for rollers 8 in. by 12 in., or 12 in. by 16 in., and $\frac{3}{16}$ in. deep, $\frac{3}{16}$ in. wide, and pitch $\frac{1}{2}$ in., when rollers are 14 in. by 26 in.

Shaw's make the grooves in spiral and diamond patterns, on macerating rollers with 1 in. pitch, the depth in the former being $\frac{5}{32}$ in. and width $\frac{1}{4}$ in., while the depth in the latter is $\frac{1}{4}$ in. and width $\frac{5}{32}$ in. For crêping machines, diamond-pattern, the grooves are $\frac{3}{32}$ in. deep and wide and $\frac{1}{2}$ in. apart. In their sheeting-machines the horizontal grooves are $\frac{1}{32}$ in. deep, $\frac{1}{16}$ in. wide, and $\frac{1}{2}$ in. apart.

Hand-Power Washing Machines.

On estates which are only commencing tapping operations, it is not usually deemed advisable to go to the expense of erecting the heavy types of washing machines mentioned in the foregoing pages. An ordinary wooden mangle has been used on many estates having monthly crops of a few hundred pounds. Where the monthly crop is larger than this, wooden rollers are soon worn out, and it is usual to replace them with metal. The hand-power washers now being sent to the East are supplied with metal rollers, and can be worked by two coolies each turning a handle. These mangles are also supplied with a pulley in order that at a later date they can be driven by belt.

In the hand-power washing machine turned out by Shaw's, the rollers can be altered from the horizontal position for washing to the vertical for rolling sheets and biscuits, and they may be run at even or at friction speeds.

Machines for Bark Shavings and Scrap.

Bark shavings are usually mixed with varying quantities of scrap rubber, and, in addition, contain rubber which has coagulated internally. To macerate the bark tissues and enable the operator to effectively separate the rubber therefrom, macerating machines are employed. The bark shavings are usually first steeped in tubs or tanks of water for several days in order to soften the tissues; the bark may, perhaps advantageously, be more rapidly destroyed by the use of small quantities of caustic alkalies. Before rubber can be effectively separated from the shavings, it is generally necessary to pass the whole mass through the rollers many times. The rubber finally obtained from bark shavings is generally dark in colour, and even though it may have been well washed, has a tendency to become sticky on the surface. Smoking the rubber over a wood fire is an improvement which is more necessary with this than with any other kind of rubber from plantations.

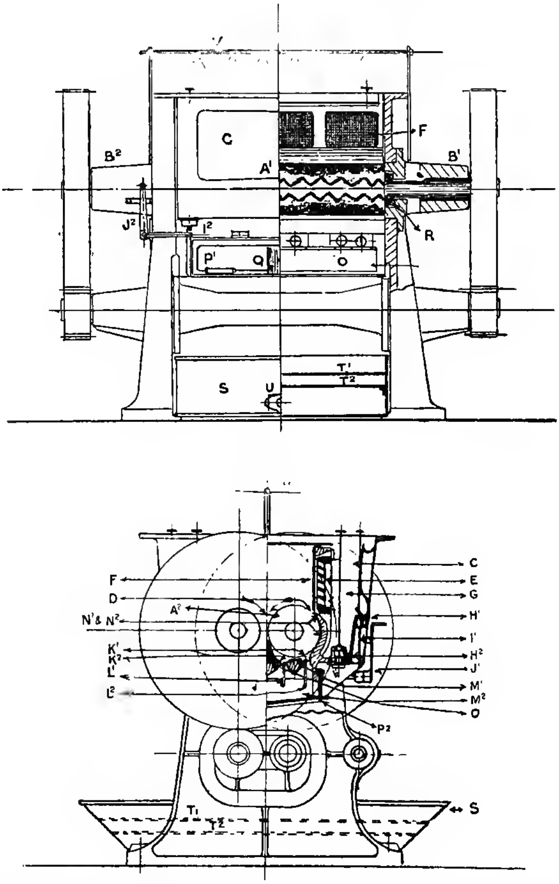
The Valour and Guiguet Machines.

Comparatively little attention has been paid to the provision of special machines for dealing with bark shavings. Usually the shavings are accumulated until there is sufficient to justify the using of an ordinary macerating machine. And certainly the quantity of bark parings requiring treatment on all except the largest estates scarcely justifies any considerable capital expenditure upon special machinery. One of the simplest of these machines is the "Valour," a drum revolving on a horizontal axis, and containing a number of loose heavy metal bars that crush the bark to fine particles.

A more elaborate machine is the "Guiguet." In this the bark is reduced to a paste between a fixed and a rotating plate, each provided with teeth. The paste passes to agglomerators, which consist of cones, with helicoidal grooves, revolving in sleeves with grooves of opposite sign, a current of water carrying bark away, and the rubber collecting into masses. These masses are carried into a revolving drum, in which there is further separation of bark, and are then treated in a second agglomerator.

A New Type of Washing Machine.

The "Universal" rubber washer, made by Messrs. Werner, Pfleiderer and Perkins, has been designed mainly to avoid injuring the nerve of rubber by too severe a mechanical working. Objections to the ordinary type of macerating machine are that the force of the rollers is concentrated upon a narrow strip of the rubber to its detriment; that the crushing and splintering action



A^1A^2, rolls; B^1B^2, their bearings; C, trough; D, ledges in C; E, gratings; F, sliding frames in C; G, jacket of C; H^1H^2, valves in G; I^1, outlets; J^1J^2, levers for valves; K^1K^2, slots; L^1L^2, shakers in slots; M^1M^2, ledges; N^1N^2, saddles for opening out rubber; O, sand box; P^1P^2, flaps for flushing out O; Q, outlet for draining O; R, packing; S, straining vessel to catch impurities; T^1T^2, sieves in S; U, outlet to S; V, spray pipe.

upon contained sand and bark hinders the purification, for the particles become embedded in the rubber and are difficult to remove, so that prolonged washing is necessary; that the quantity of rubber that can be manipulated is small, as it is limited to what the operator can handle; and that the loose scrap needs constant shovelling up from the ray below.

In the "Universal" washer, two very deeply corrugated rollers—the ridges large and wide apart, and of a zigzag pattern—revolve in a double-walled trough, above which is a spray-pipe. The rollers are not set close together, and are carried in fixed bearings instead of adjustable ones, as is usually the case, and this, with the deepness of the grooves between the ridges, prevents undue compression of the rubber while it is being opened out under water and the impurities rejected. The bottom of the trough is in the form of two semi-cylinders in each of which is one of the rollers, a space being left between the rollers and the trough.

On account of the peculiar formation of the rollers, the rubber, as it is fed in, is immediately gripped and carried downwards between them, being opened out at the same time, and passes next between the rollers and trough bottom, where, owing to the formation of the bottom, the opening out is continued, the rubber being automatically brought to the surface again. Guides are provided to turn the rubber towards the centre again as it comes to the top, and in this way it is continuously carried round until thoroughly cleansed.

A striking feature of the machine is the provision made for getting rid of the impurities. The finer of the heavy impurities pass through two slots beneath the rollers that are provided with shakers into a sand-box, while the pebbles, nails, etc., are thrust over a ledge on each side almost level with the tops of the rollers. In the walls of the inner part of the trough are wire-screens through which may pass wash water containing floating impurities, rubber particles being retained. The level of the water may be raised so that wood and similar large floating impurities may pass over the ledges mentioned, or it may be raised level with a gutter near the top into which they may pass. These are only the salient features of the machine.

This machine can be used for washing any kind of rubber, including jelutong, guttapercha, and balata, in addition to scrap and bark shavings. It can also be used by planters to free the freshly-coagulated rubber from acid and soluble substances which harbour bacteria and moulds, and owing to the large output capacity of the larger machines, considerable economies in space and labour can be secured. Also the particularly gentle action of this machine is a big point in its favour when manipulating the rubber in this early stage, for too great care cannot be taken to ensure the safety of the "nerve" of the rubber.

Large quantities of freshly-coagulated rubber are quickly worked by this machine into a convenient shape for handling and putting through sheeting and crêping machines.

The types being made for plantations require from 8 to 10 H.P.; large types require up to 25 H.P. each, but these deal with up to 100 lb. of rubber at a time.

Drives for Rubber Factories.

Most up-to-date factories in the East are now arranging for their washing-machines to be driven direct from the main engine by means of gearing, each machine being put in and out of gear by means of a clutch fitted to the pinion working into a spur wheel on the main-line shaft. Belts are therefore dispensed with, and in this alone there is a great saving.

When washing-mills were first used in Ceylon, each machine was usually supplied with a loose and fast pulley, and was driven by separate belts from overhead shafting. This was the most economical arrangement and necessitated fewest alterations in the factories then existing and being worked in connection with the manufacture of tea, coffee, sugar, etc.

At a later date, the same plan of belt-driven machines was followed even when new rubber factories with sides of corrugated iron were built. The expense necessary to strengthen the walls of the factories and erect brackets was, however, found to be excessive. Subsequently, the machines were driven from counter-shafting carried from brackets on the floors. This, however, was soon found to be inconvenient, and to require more space than could always be afforded.

In the direct-gear methods now being adopted, the shaft, driven direct from the engine, runs under or at the back of the line of machines, and is raised about 15 inches above the floor-level. Preference is given to shafting at the back of the mills, on account of the gear being clear of the operator. This system of direct driving where each machine is supplied with a friction-clutch has many advantages apart from saving in space. It also permits of extensions being easily made by fixing extension-shafts on either side of the engine. The only disadvantages appear to be the higher initial costs, and the somewhat complicated apparatus replacing the simple pulley and belt arrangement.

Driving Arrangements in Recent Installations.

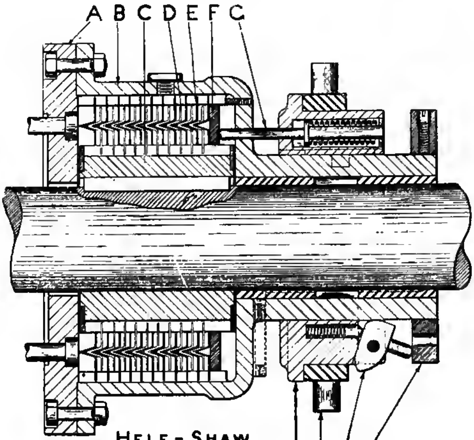
The driving arrangement is sometimes modified, as in a double machine, similar to that made by Shaw's. In this case both machines are driven by a single belt, and only one overhead pulley is required, each machine being worked independently of the other by means of friction-clutches. In a recent installation of plant on a Sumatra estate (I.R.J., Oct. 28th, 1911), the line-shaft driving the machinery is driven direct from the crank-shaft of the engines by belting, a coupling being placed between the two driving-pulleys on the main-shaft, so that the machines can be driven by either of two engines positioned together near the centre of the line of washing-mills. To give flexibility of drive each pulley is mounted on a friction-clutch so that the engines can be started before the line-shaft is put in motion.

Shaw's recommend for transmitting power from the engine to the line-shaft a belt-drive with a pulley mounted on a friction clutch, or double helical machine-cut gears fitted with a clutch.

Clutches and Gearing.

Various types of friction-clutches are used on the machines turned out by different firms.

In Shaw's machines each mill is operated by a Hele-Shaw patent friction-clutch



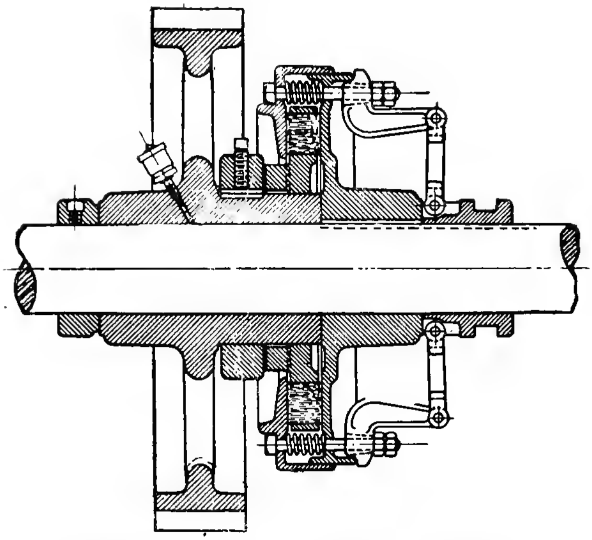
Hele-Shaw Clutch.

A, end cover; B, clutch case; C, core; D, inner steel plates; E, outer bronze plates; F, presser plates; G, presser pins; H, presser box; J, actuating ring; K, triggers; L, adjustable trigger ring.

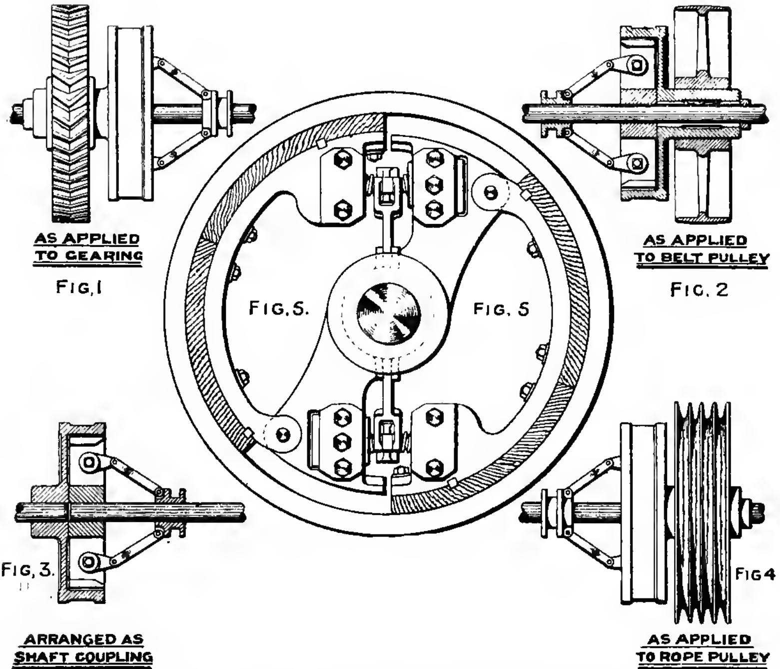
through double helical machine-cut gearing. The Hele-Shaw clutches (of which a section is illustrated) are totally enclosed and are unaffected by the dirt inseparable from rubber washing. The friction plates run in oil, and thus allow for easy adjustment, and a gradual taking up of the load.

Bertram's, Ltd., supply a simple friction-clutch, the essential features of which are the facility of adjustment, and the ease with which the clutch can be refilled on the spot, the filling consisting of hard wood blocks. In the accompanying illustration a section is shown of the clutch applied to a spur wheel; the adjustment is made by tightening the two nuts shown at the right-hand side of the disc. (See page 365).

Bridge's, who many years ago recommended driving plantation machinery direct from the engines by gearing and friction-clutches in order to avoid the objectionable slipping of belts, have specialised in what they term the Heywood-Bridge patent friction-clutch. This clutch is operated by means of two right and left hand screws, fitted with bell crank lever, and links actuated by hand lever and shaft, worked from any position to suit the operator. They are lined with wood, iron, or special quick-grip frictional material that can easily be renewed on the



BERTRAM'S SECTION FRICTION-CLUTCH.



HEYWOOD AND BRIDGE'S FRICTION-CLUTCH.

spot. These clutches are very tender in their action when starting machines, and can be instantly disconnected by the operator in case of accident.

Cochrane's supply in addition to belt-driven machines, others driven direct through a claw-clutch and moulded gears, and a third type driven by a friction-clutch and double helical gears with the shafting at the back of the mill. The gears are put into motion by an expanding type of friction-clutch.

Outturn of Rubber from Washing Machines.

It is extremely difficult to get reliable statements regarding the average working capacity of washing machines on plantations. In most factories one or more of the mills are not running, and those being worked are used for the preparation of different forms of rubber in the wet state. Hence the difficulty in estimating the maximum outturn of dry rubber per day from any particular machine, even when the rollers are all of the same size. Shaw's estimate that each machine, with rollers 18 by 12 inches, can turn out 45 lb. of dry rubber per hour, and those with smaller rollers, 18 by 9½ inches, from 30 to 35 lb. per hour. It is well known that a much larger outturn can be obtained if all the machines are kept working throughout the day, and especially is this so if the minimum time is spent in finishing sheet rubber. Cochrane's estimate that with quick work a washing mill should turn out 800 lb. of wet rubber per day. Bertram's, Ltd., estimate that machines with rollers 12 by 15 inches will turn out from 200 to 300 lb. of dry rubber per day of ten hours. Robinson's estimate an outturn of 25 lb., 50 lb., and 100 lb. of dry rubber per hour from rollers 8 in. by 12 in., 12 in. by 16 in., and 14 in. by 26 in. respectively. Bridge's point out that the outturn largely depends on the finish given to the rubber, but that an average output of 30, 40, and 56 lb. per hour may be expected from rollers 9 in., 12 in., and 14 in. diameter respectively. While these estimates of output differ, it must be understood that the amount of rubber that can be dealt with by a machine is influenced by the width of the rollers and their peripheral speed.

Power for Driving Machines.

Various types of engines, including steam, oil and suction gas, are now used for driving rubber machinery. The power required depends upon the number of machines in use, their respective sizes, and the condition of the rubber dealt with. On Eastern estates it is generally advisable to have several small-power engines than only one capable of driving the whole of the machinery, owing to the time taken in effecting repairs, the general lack of spare parts and competent engineering officers. A breakdown on a plantation many miles from an engineer or works would be very serious if only one engine were installed. The usual washing-mills now in use on estates each require from

8 to 12 H.P., but provision is often made for the addition of other machines (as the crops increase in quantity) to be driven by the same engines. The engines are usually provided with self-starters, the Government in some countries insisting upon their being supplied in all factories.

On one estate, supplied with three washing mills having rollers 12 by 18 inches, two engines, each of 32 H.P., were supplied, the object being to drive all three machines with one engine when necessary to do so, or to drive a total of five washing machines with both engines at some future date. On another property, with three machines each having rollers 12 by 15 inches, a minimum of 24 H.P., and a maximum of 36 H.P., were found workable. On a third property, three washing-mills with rollers 15 by 12 inches were run by two oil engines each capable of developing 22 H.P., and therefore of driving two machines.

Filter Beds and Presses.

The water supply, in respect of quantity and purity, is of great importance in the factory. Apart from the use of water-power, it is necessary to have an ample supply of water for cleansing, tapping, and collecting tools and for thoroughly washing all rubber during the washing process. It is known that rubber can absorb a moderate quantity of acetic acid sometimes used in irregular quantities. Furthermore, rubber contains a fair proportion of putrescible substances. It is, therefore, necessary that large volumes of water be available, and that these be as pure as possible. The use of impure water has often led to discoloration and tackiness in rubber. Every means should therefore be adopted to ensure a satisfactory water supply. On some estates filter-beds have been constructed through which the water is allowed to pass before being transmitted to the factory.

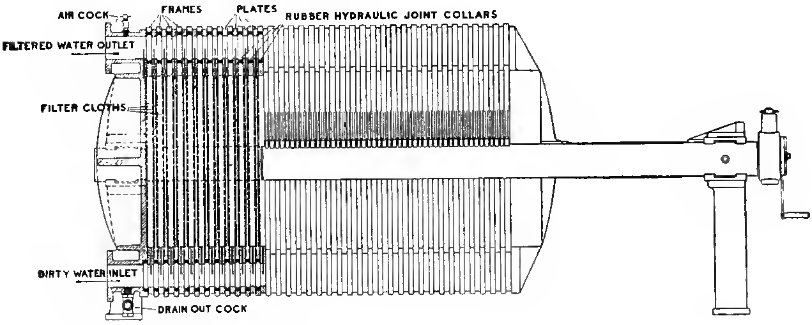
There are several filter-presses which can also be used for this purpose ; some have been constructed not only for clarifying ordinary water, but also for affecting the same change in dirty water from the washing machines, so that the same water can be used several times. This is of more than passing importance to planters in districts with a limited water supply.

Johnson's Water Filter.

This apparatus consists of a number of square cast-iron plates and distance frames or rings. The plates have a facing on each side all round the outer edge. When the plates and frames are placed side by side in position and the press tightened up, a feeler $\frac{4}{1000}$ in. thick cannot be inserted between the joints. The flat surfaces of the plates circumscribed by the machined surface is studded all over by small truncated square pyramids evenly spaced.

The plates and frames have lugs at the top and bottom. When the plates and frames are placed alternately, there is a series of hollow chambers between the plates. These chambers each communicate with the bottom passage by means of a port cast in each distance frame, and from these the dirty water enters each chamber. Each plate has a corresponding port connecting from both sides thereof to the top passage, and this is the only means of exit for the water when forced into the chambers under pressure.

A filter-cloth is placed over each of the plates and securely gripped between the machined joints when the press is tightened up ; the water must pass through the filter-cloths in order to reach the outlet passage. It is by this means entirely freed from all



JOHNSON'S WATER FILTER.

matter in suspension, which remains as a deposit upon the surface of the cloths. As this deposit increases, due to the accumulation of the solid matter removed from the water, the rate of filtration will gradually diminish and eventually cease.

The filter-press must be frequently opened and the cloths removed and washed, after which they can be replaced and filtration continued.

Pumps and Piping.

Even when a factory has a water supply close at hand, a considerable length of piping for use between boilers, washing machines and the various storage tanks is required, and should be kept in stock on all estates. Where the water is some distance away, expenditure under this head is increased. On many estates the water necessary for boilers, cooling tanks, and washing machines, has to be pumped from a distant place many feet below the level of the factory site. Pumps are therefore necessary for this work. Double-acting pumps capable of raising from 600 to 10,000 gallons of water per hour through any height up to 150 feet, or single-acting pumps for supplying from 300 to 1,000 gallons per hour adapted for belt driving are made. The water is usually carried to a tank upon a steel-framed tower from which it is led to the factory.

Hot and Cold Water.

It has been the custom to use hot water on many rubber estates in the hope of removing a larger proportion of chemical impurities and destroying those organisms responsible for darkening of rubber on keeping. Its use also helps to maintain the rubber in a softer and more workable condition during the washing process. Quite recently, however, several firms have expressed their objections to the use of heated water because they believe it has some bad effects on the nerve of the rubber.

It is the custom to supply spray pipes, positioned above the rollers, with steam and water valves in order that water at any temperature can be used during washing.

The use of hot water for this purpose necessitates the erection of steam boilers or other heating apparatus. When these are introduced, the further possibility of using the exhaust steam for heating pipes in the curing room should be considered.

CHAPTER XXIV.

THE DRYING OF RUBBER.

The treatment to which freshly-coagulated rubber is subjected in the various types of washing machines has been described, and we must proceed to consider further processes through which rubber has to pass before it is placed on the market. The changes which washed rubber subsequently undergoes are associated with loss of water and the absence or presence of certain preservatives; hence the necessity to consider the importance of these and the methods adopted in drying and smoking the raw product.

WATER IN WILD AND PLANTATION RUBBER.

Most of the rubber exported from African and American ports contains a large proportion of impurities. Even fine hard Para and Lagos lump frequently possess over ten per cent. of water alone on their arrival in Europe. Many of the wild rubbers exhibited in the London saleroom can, by means of hand pressure alone, be made to eject water in considerable quantities; other rubbers arrive in a comparatively dry, though otherwise impure, state. This variation in the moisture content naturally affects the proportion of caoutchouc, the value of the rubber to the manufacturer, and therefore the price realized. In marked contrast to this is the dry rubber received from Eastern plantations. This freedom from moisture and consequent constancy in composition is largely responsible for the agreement in average prices realized for consignments of plantation rubber from innumerable estates in Sumatra, Borneo, Java, Ceylon, and Malaya. The production of rubber free from moisture may involve the erection of machinery and necessitate a certain amount of delay in delivery; but this is fully compensated for by the results obtained.

REMOVAL OF MOISTURE FROM PLANTATION RUBBER.

The desirability of removing the water from plantation rubber has been discussed in many quarters and the subject raises numerous points of interest. In the first case it should be remembered that the difference between wild and plantation rubbers is not one of moisture alone; a series of factors such as the proportion of putrescible matter and its state of preservation, the age of the trees whence the rubber is obtained, etc., all play a part in giving to wild rubber its general characteristics.

Some time ago it was suggested that the extra moisture left in fine Para "smoke-cured" rendered it fit and strong enough for all purposes, and accounted for its not deteriorating after being kept for any length of time. To this the Editor of the "India-Rubber Journal" (April 9th, 1906), replied "if this is so, why do the manufacturers, as soon as possible after there arrives in the factory a delivery of rubber, put it through the washing machine, and prefer to stock it as dry sheet rather than in the state in which it arrives? The answer is simply that thoroughly-washed and dried rubber under suitable conditions will not deteriorate until after a very long lapse of time. The manufacturers' dried rubber contains no moisture at all, and in the old days it used to be stocked for two or three years before being used for special purposes. It cannot therefore be on account of the lack of moisture that the rubber deteriorates." What is true regarding Para rubber from wild Hevea trees is probably equally so for rubber from the same species under cultivation.

Mr. C. Devitt stated, in 1906, that "one of the most important points in the packing of plantation rubber is to get it absolutely dry and quite free from surface moisture before shipping, as any dampness, even if it is only on a few biscuits or sheets, is likely to ruin a whole caseful. We very often find where moisture has been left, the rubber has turned white and decomposition has started, making it unsightly, weak, and evil-smelling." Past experience in the East has proved the desirability of shipping the rubber in as dry a condition as it is possible to get it.

Effect of Moisture on Strength of Rubber.

After giving the analyses of various rubbers, it is stated in the Official Handbook to the Ceylon Rubber Exhibition, that "A careful study of the figures shows how difficult it is to form deductions as to what gives actual strength in the rubber, for the strongest rubbers have not necessarily the most caoutchouc, though the difference of 1 per cent., in such high numbers as 93 to 95 per cent. would have very slight effect."

It was further stated that: "The theory that more moisture left in the rubber would add to its strength is apparently not borne out by the above figures." In view of this statement it is difficult to understand the claims subsequently made by the authors of the above in connection with the preparation of wet creosoted rubber described below.

Reduction of Moisture and Increased Strength.

Schidrowitz and Kaye, in their paper (I.R.J., Sept. 23rd, 1907) on "The Influence of the Method of Coagulation on the Physical and Chemical properties of *Funtumia elastica*," point out that as might have been expected, the method of coagulation has an important bearing on the chemical and physical properties of Funtumia. It is worthy of note that the reduction in moisture from, in the highest case, 12·64 to a mere trace results in every instance in an appreciable increase in tensile strength and distensibility. This is of particular interest in view of the fact that fine hard Para contains considerably more moisture than any of these moist samples. It is probable that in this moist Funtumia the water is present in a quasi-molecular state whereas in fine hard Para it is merely mechanically admixed. The dry samples gave in some cases very high figures for the physical tests. It has been sometimes asserted that to dry rubber too much makes it harsh and brittle. These results show that if this is so, it is not due to the removal of the moisture, but to the manner in which it is removed.

The extent to which moisture should be removed must depend on the class of rubber being treated and the method of coagulation. It does not necessarily follow that rubber which is packed somewhat moist will on arrival and after washing and drying give worse results than material which is shipped very dry. It depends largely on whether the conditions of preparation of the crude rubber are such that an appreciable quantity of moisture is dangerous as regards mould formation or not. The same remarks apply, in the main, to plantation rubber from Hevea trees. On chemical and physical grounds there is, therefore, no reason why anyone should recommend planters to ship their rubber in the wet state; it should be easily possible to improve upon the native methods in Brazil.

Water in, and Price of, Rubber.

There is also the ordinary commercial aspect of the case to be borne in mind.

It is obvious that when rubber varies in its water content the price paid for the crude material will also vary, and only when the rubber is free from all impurities and of relatively constant composition will the price be at all constant. It is the habit of some buyers of crude rubber to test the samples for their water and grit by hand only, though no one doubts the impossibilty of thus accurately estimating the percentage of moisture in samples from various sources. The loss in weight of fine hard Para and other wet grades, due to the evaporation of water, is sometimes very great, especially when, during transit, the rubber has been stored in the hottest part of the ship. The present prices for fine hard Para and plantation Para are 4s. 4d. and 4s. 8d. per lb. respectively; the former contains up to 20 per cent. and the latter less than 0·9 per cent. of water, so that the price paid for fine hard Para is, pound per pound of dry rubber, more than that paid for plantation. The increased price paid for fine Para may be owing to its superior qualities compared with that from ordinary plantations and its established position in the manufacturing industry; it does not mean that plantation rubber is getting a lower price on account of its not possessing water; the difference paid is no reason why any person should have suggested the shipping of plantation rubber containing a higher proportion of water.

Creosote and Wet Plantation Rubber.

At the Peradeniya Gardens (Circ. Jan., 1907), experiments were carried out to test the possibility of sending home undried rubber preserved with the aid of creosote. Acetic acid and a mixture of creosote in methylated spirit were added to the latex; as soon as coagulation was complete, the mass was cut up and washed, and then blocked for two or three hours in a wooden mould in a screw press. The block so prepared contained from 8 to 9 per cent. of water, but the authorities thought that this might be reduced to 7 per cent. if necessary.

Samples prepared in the above manner were valued at 5s. 6d. per lb. It was thereupon pointed out that as ordinary Ceylon plantation rubber contains less than 1 per cent. of moisture, the price obtained for the experimental samples was equivalent to 6s. a pound for the actual rubber they contained. The actual sales on the same day were "Culloden" 5s. 9¼d. and on seven other estates 5s. 7¼d. The rubber therefore obtained a price 3d. better than the exceptionally good lot sent from Culloden; this compared very favourably indeed with any previously realized, though it was not up to that of fine hard Para. It was not, apparently, known to the experimentalists that later consignments proved to be unsaleable, and that their appearance on the market was strongly objected to.

The following analyses were given to show the composition of the wet rubber after drying ten days, and the average of good Ceylon biscuits :—

	Creosoted Wet Rubber. per cent.	Average Ceylon Biscuit. per cent.
Moisture ..	7·06	0·45
Ash	0·18	0·34
Resin ..	1·92	2·01
Proteins ..	3·67	2·37
Caoutchouc ..	87·17	94·83
	100·00	100·00
Nitrogen	0·58	0·37

Messrs. Bamber and Willis concluded that planters were removing too much from their rubber, especially in the way of moisture, and that in future it would be advisable to block rubber in the wet condition, provided it was rendered antiseptic by the use of creosote or other preservative. This conclusion was quite unwarranted, and in order to test its value the opinions of leading manufacturers were obtained.

Manufacturers Against Wet Plantation Rubber.

It will be generally admitted that the users of plantation rubber are, in virtue of their long association with rubbers of many kinds, able to exercise sound judgment on such a question. The "India-Rubber Journal," in the issue dated September 23rd, 1907, gave the following account of the opinions of manufacturers on plantation rubber in the wet and dry state.

The question put before the manufacturers was whether they preferred to receive plantation rubber in the pure and dry state or with water and creosote. If manufacturers will pay a price for wet plantation rubber which will give the planter a return equal to or better than that realized for the dry material it will be a great advantage, and will allow the producers to turn out their rubber in the minimum time.

The following are the replies of several firms in reply to the question given above :—"Dry state"; "Pure and dry"; "Pure and dry state"; "Pure and dry state most decidedly." This unanimity among manufacturers using the rubber for entirely different purposes came as a surprise. Not a single firm replied to the effect that they preferred the rubber in the "wet and creosoted" condition; they plumped for the "dry and pure state." If only planters in the East will realize how important it is that their rubber is always at the top for price, purity, and constancy, even if the maintenance of that reputation necessitates what, for the present, appears almost unnecessary expenditure, they will be well advised. The cheapening of the processes of production does not tempt those proprietors who know the value of keeping their product in the front rank in every respect; it is hoped that no recommendations will be again issued until the opinions of manufacturers have been secured on the samples submitted.

Since the above experiments were made no one has seriously attempted to ship rubber in the wet state. In fact, competition has been exceptionally keen among planters and engineers in the improvement of methods of drying the raw product, and numerous inventions and systems of drying are now being tried throughout the middle East. It is with these methods of drying that we must now concern ourselves.

Methods of Drying in the East.

There are four methods of very unequal merit by which rubber is dried on plantations in the East: (1) Exposure in the open; (2) Drying indoors in currents of unheated air; (3) Drying indoors in heated air; and (4) Drying in vacuum. All except the first involve the erection of commodious factories, with which it will therefore be necessary to deal in this chapter.

Exposure in the Open.

This is a method that does not require any machinery, but it is one which cannot be recommended on account of the liability of the rubber to turn soft and sticky on exposure to the sun. It is only practised by native owners of very small plantations.

Cold-Air Currents.

The second method is that of drying the rubber in dark rooms kept at ordinary temperatures. The length of time required to dry the rubber under such conditions is determined mainly by the circulation of air through the room and the thickness of the rubber. Under ordinary conditions, with rubber prepared in thin sheets or crêpe an interval of weeks or months may be allowed for this process. This is obviously a very slow method, though it is used by persons who believe that a better product is obtained by allowing the rubber to dry very slowly. It is not in the planter's interests to thus keep the rubber in the store, because, apart from financial considerations, it is liable, when exposed for such a long period to become tacky or mouldy.

It is, however, not advisable to spend huge sums of money or to go to the trouble and risk of erecting complicated machinery when estates are just beginning to yield. The experience gained on a small scale, even if it is limited to mouldiness and tackiness, is of considerable value when large crops are anticipated. Managers having about 1,000 lb. of rubber per month can easily deal with their produce in a corrugated iron factory, supplied with wooden reapers, 1½ by ½ in., stretching across the width of the building. It is not absolutely necessary that a fan or heating apparatus be provided; it is, however, advisable to provide such a chamber with an ample supply of fresh air. Under these circumstances it should be possible to turn out dry rubber within a week if the air is maintained at a little over 90° F.—a by no means unusual temperature for iron-roofed buildings in the East. As a matter of fact, simple buildings of this type are to-day used on estates with very large monthly crops and no serious difficulties are encountered.

In one type of cold-air factory the floor is laid with open joints to enable air to pass through, and a ventilator is provided in the roof to ensure a continuous current.

Burgess stated that it was possible to dry rubber without any artificial heat, by the use of some agent that will dry the air. For this purpose he suggested 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 it, and the calcium chloride becomes moist and eventually absorbs so much water that a syrupy liquid results. It can be recovered from the wet state by simply heating and thereby driving off the moisture. It is not, however, used on estates at the present time.

Hot-Air Rooms.

The third method is that of using hot-air chambers provided with shelves or poles over which to spread or hang the rubber. The temperature is maintained at from 90° to 100° F. by means of hot air which is drawn through the building by means of a fan. The heating is generally effected by hot air or steam pipes placed around the building. In one form of drying-shed the pipes run below the open floor. Whenever artificial heat is resorted to, care should be exercised and the temperature never allowed to rise above 120° F., owing to the adverse effects of high temperatures on rubber. Weber asserted that certain brands of 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 rubber begins to soften varies according to the percentage of resinous and oily substances present ; many samples of good Para rubber pass into a more or less fluid state at about 170° to 180° F.

Hot air buildings are usually, but not always, two storeys high, and are fitted up with heating apparatus of a special character. The various contrivances adopted can best be dealt with in that section of this chapter dealing with factories. On many tea and cacao estates in Ceylon the rubber is dried in the withering and curing-sheds respectively. Such an arrangement is, however, only advisable when the rubber crops are insignificant. When the rubber is harvested in regular and increasing quantities, separate factories must be built for dealing with the crop.

Factories on Plantations.

It is, for obvious reasons, necessary to provide on estates with large areas in bearing some building wherein the rubber can be protected during the coagulating, washing, drying, smoking, and packing stages. The washing machines and engines, with the necessary shafting, are usually of a heavy type ; these, together with driers, fans, and other appliances, necessitate the construction of buildings of a substantial and permanent character.

Selection of Site.

The selection of a suitable site requires, in some countries, considerable thought. On hilly estates it is customary to select some area as low, while as central, as possible. This generally enables the manager to economise in transport and sometimes to use water power. On such properties sites which are swampy, liable to flood, or unhealthy, should be avoided. It is often much cheaper to select a site at some altitude, and pump water up to the factory, than to choose a place convenient only for water and transport. In considering the site in relation to transport, it should be borne in mind that carrying the latex—which may contain more than 50 per cent. of water—to the factory is more expensive than the subsequent transport of dry rubber to the nearest cart road. The selection of a site is also partly determined by the accessibility of the area for passenger and cart traffic, proximity to a good clean supply of water, exposure to wind, and the character of the subsoil. In Ceylon and other hilly rubber districts the subsoil is usually safe for foundation work, but in the wet, flat, and somewhat swampy plains, in parts of Malaya and Sumatra, the difficulty of making reliable foundations is often accentuated.

One difficulty frequently experienced, especially when artificial heating apparatus is not employed, is that of getting a good supply of cool air through the building. This defect is often due to the site not being at a sufficient altitude and to the building being closely surrounded by forest trees of the Hevea type. A site sufficiently large and free from trees is therefore desirable. In gently undulating country a slight altitude is all that is required to ensure a good circulation of air through the building.

Types of Factories Required.

The type of factory to be erected depends upon many factors, such as the amount of the crop and the methods of curing and washing.

In order to meet crop requirements care should be taken to ensure that extensions can be easily and economically made from time to time. This is particularly the case where small acreages come into bearing regularly each year for many years in succession. Where the whole of the area is in bearing, the building need not provide for extensions to the same degree, though an annual increase in yield per acre must be allowed for.

The method of curing also has a bearing on the type of factory required. If vacuum driers are used the size of the factory can be reduced. If artificial heating apparatus is provided, the rubber is dried more quickly, and less space is therefore required in the curing section. The installation of heating apparatus, fans, etc., generally necessitates the erection of a two-storey building. Smoking must also be considered, though in many cases a separate building is erected for this phase of the curing process. Frequently, however, the rubber is smoked while being cured, in a part of the factory permanently set aside for this work.

The kind of washing machine and position of shafting must also be considered in the construction of the walls and floor of a factory. There are some washing machines which have double or treble the working capacity of others, and which demand comparatively less space. Shafting, if overhead, may require wall brackets, which frequently necessitate an entirely different construction. Floor shafting, on the other hand, may be erected more or less irrespective of the materials used in the construction of the building.

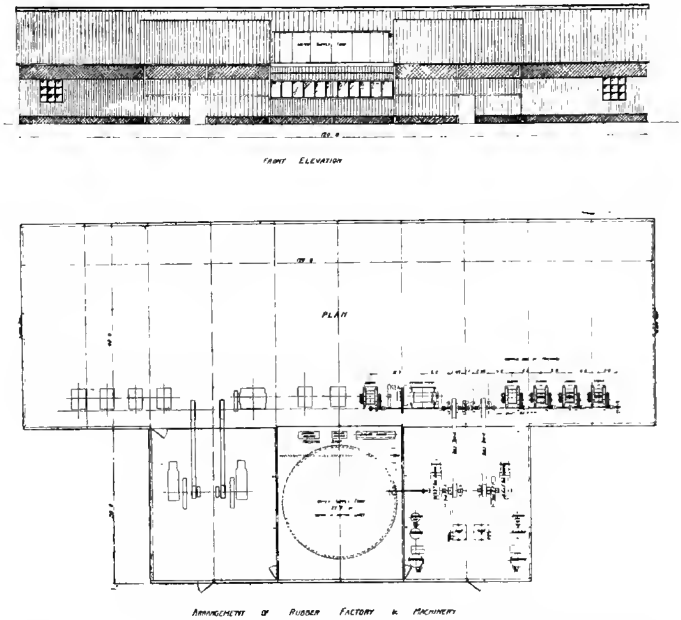
Types now Used on Plantations.

Though in types of factories now used on plantations there is considerable variation, there is some ground for hoping that standardisation will ultimately be recognised. If rubber plantation factories were standardised, the cost would be appreciably lessened, and additions more easily made. A width of forty feet with bays ten feet, has been suggested (Davidson, Souvenir, I.R.J.) as the standard to adopt.

On Eastern estates the factories are either: (1) entirely on ground floor, (2) two-storeyed (or more) throughout, or (3) two-storeyed only in the curing section. They are provided with a space for the engines inside the factory, or a separate building adjoining the factory is reserved as the power station.

One-Storey Factories.

The first type—one storey only—is recommended by many firms if land is available. Messrs. Francis Shaw recently (I.R.J., October 28th, 1911) erected one of this pattern on Sennah Estate, Sumatra. The main building was 120 feet long and 40 feet wide, having a height to eaves of 12 feet. An engine-house and engineering shop was also provided, 72 by 30 feet, adjoining the main building. Ventilation was partly provided for by means of



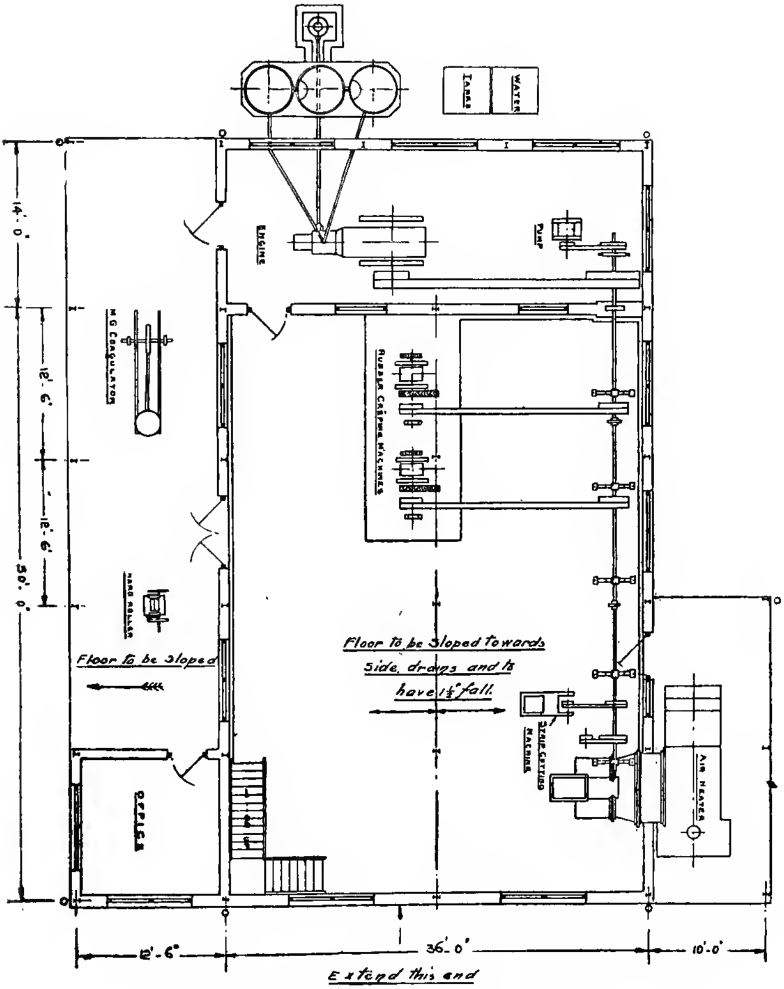
ELEVATION AND GROUND PLAN OF FACTORY (MESSRS. SHAW).

expanded metal all round the building at the floor-level and similar metal under the eaves of each span. In factories of this kind, the washing, curing and packing sections must be screened off so as to avoid, as far as possible, the introduction of mechanical impurities while the rubber is in course of preparation.

The expense of erecting lifts for conveying the rubber to and from the drying-room and of building staircases is avoided, and carting is generally simple with one-storeyed factories.

Two-Storey Factories.

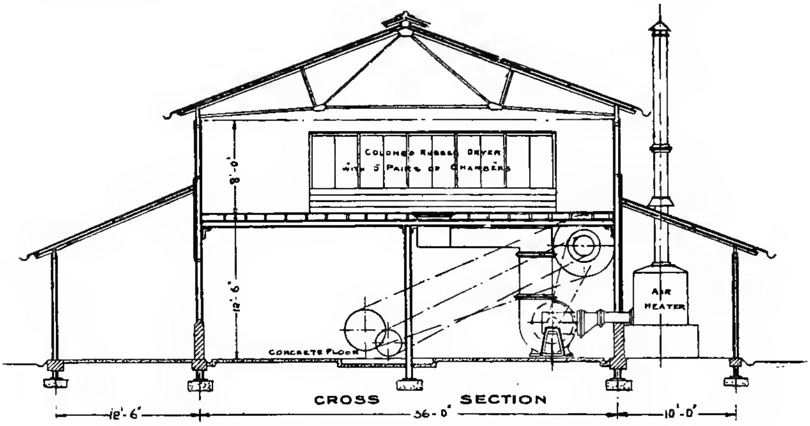
The second type—two storeys throughout—has often been recommended by planters with long experience in Ceylon, where tea and cacao curing-houses of this kind have been in use for many years. In the Souvenir number of the I.R.J. there is an illustration shewing the construction and plan of a building recommended by Mr. L. Davidson (retired planter), after consultation with leading planters and engineers in the East. In this class of building each department is carefully spaced; a verandah for receiving scrap and latex, despatching and box-marking is provided. It



PLAN OF FACTORY RECOMMENDED BY WALKER AND SONS.

will also be noticed that on the ground floor is a vacuum-drying and blocking section, if such is required, in addition to a second storey reserved entirely for curing. The building stretches about 160 feet in length and 50 feet in width, apart from the separate areas occupied by the engine-house (30 by 40 feet) and boiler and fuel verandah (10 by 30 feet). A complete factory such as this is capable of turning out from 800,000 to 1,000,000 lb. per annum. The factory was designed so that it could be built in sections, commencing with one engine and three washing machines.

Messrs Walker Sons and Co., have supplied me with blocks showing the plan of the ground floor of a two-storeyed factory now being recommended by them. The capacity of the factory is estimated at 1000 lb. of dry rubber per day of ten hours, though some extension of the building may be necessary, when the maximum output is reached, for hanging the rubber in crêpe form for a few days before packing. The plan of this factory is shown on page 379.



SECTION OF FACTORY RECOMMENDED BY WALKER AND SONS.

The capacity of the "Colombo Rubber Dryer" shown on the above plan is also estimated at 1000 lb. in an ordinary day, with a possibility of turning out nearly double that quantity, in ten hours, when their own process of curing is adopted.

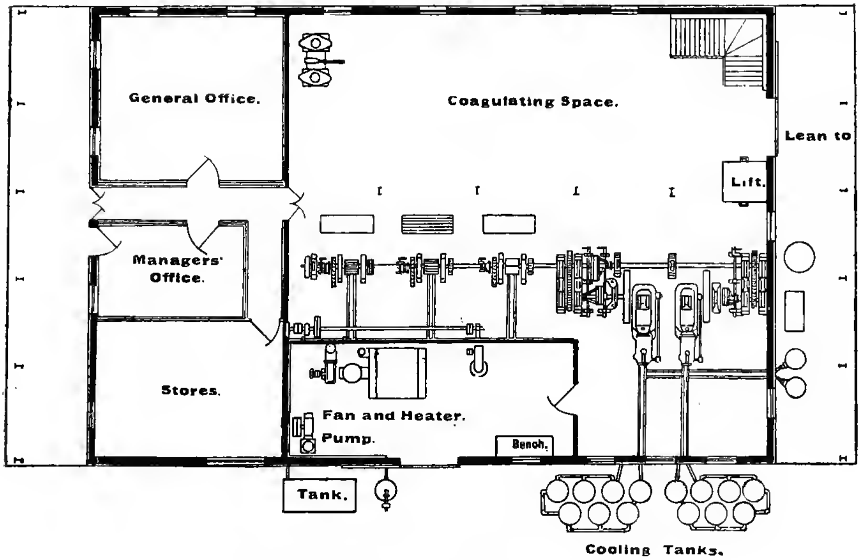
Another type of two-storey factory is shown in the plans supplied by Messrs. W. H. Cochrane and Co. In this the upper storey is devoted to curing by artificial means and to packing. On the ground-floor, offices, lift and engines are spaced out, and a lean-to is provided at each end of the building. The factory, illustrated on the opposite page, is 70 by 35 feet, the height from the ground to the first floor being $13\frac{1}{2}$ feet, and from the first floor to the eaves-level 10 feet. The height of the roof is equal to one-fourth of the span. There is a lean-to on one side on the ground-floor, 70 feet long and 12 feet wide, and also an open lean-to, 10 feet wide, across each end.

A factory has been erected according to the above plans in Sumatra and is working successfully.

Two-storey factories are cheaper per square foot of floor space than buildings all on the ground floor. They are generally rectangular in shape, though some have been erected circular in outline with the object of mitigating damage during squalls or hurricanes, frequent in Samoa and Sumatra.

Two-Storey Curing Section.

The third type—two storeys for curing-section—is occasionally adopted on Eastern plantations. Such an arrangement allows the manager to effectively instal and work artificial heating apparatus, owing to the difference in elevation of the curing-section. The second storey may extend along one-third to



PLAN OF COCHRANE'S FACTORY.

half the length of the ground-floor building, and is reserved entirely for drying or smoking the rubber, steam or hot-air pipes being used for the former. The upper storey is generally well ventilated. A lift, in addition to a staircase, usually connects the two floors.

Materials Used in Construction of Factories.

Most factories are steel-framed and covered with galvanized corrugated-iron sheets. Where the roof is not provided with a timber ceiling the air is apt to get very warm in the tropics. The sides, or walls, are usually made of corrugated-iron sheets similar to those used for the roof. On some estates timber is sometimes favoured, in which case it is advisable to use wood which has been impregnated with creosote in order to preserve it against the attacks of white ants. Brick walls, between the iron columns, are not often erected though they are always cool, durable, and neat.

Ventilation of Factories.

Apart from health reasons, there are many others why rubber factories should be well ventilated. Rubber contains a proportion of putrescible matter, and if the air is not kept pure, bacteria may appear in large numbers and lead to deterioration of the rubber during curing. Furthermore, drying is, even in dry weather, expedited if a good draught of fresh air is maintained through the building. The majority of factories rely upon open windows and doors, together with a fan, for their supplies of fresh air ; expanded metal, which is so constructed as to allow of air currents, is now used, near the eaves or floor-level.

Floors of Factories.

The ground-floor is, for durability and cleanliness, usually made of cement. It is, however, not uncommon to find white ants boring their way through thin layers of cement, and it is therefore necessary to see that all floors are properly made. In order that water may be carried rapidly away from the washing machines and drip racks, channels should be freely provided. The floor requires washing at regular intervals (preferably with water containing some cheap disinfectant) and it is therefore necessary to construct it with a slope of, say, one in eighty, to hasten drying.

Where one-storey buildings are installed with artificial heating apparatus, a raised timbered floor is often necessary. This may be provided with spaces for the passage of air, and be raised above the level of the ground to enable steam or hot-air pipes to be laid and to create a hot-air chamber in this region.

Light and Windows in Factories.

The bad effect of light on rubber, and the necessity of having abundance of light in the machinery sections, require the adoption of a different arrangement in various parts of the factory. There can hardly be too many windows near the engines and washing mills. These should, therefore, be provided and constructed so as to open inwards for draught purposes.

In the curing room, however, windows must either be supplied with red glass, or curtains, to stop the chemical rays from reaching the rubber, or with wooden or corrugated iron doors—which can be opened from the inside to allow light to enter during inspection of the rubber. It is necessary that the rubber in the curing room be frequently inspected in order that the development of moulds and tackiness may be arrested in the initial stages ; hence the desirability of having even the curing room well supplied with light but under control.

Doors and windows should, whenever possible, be made to close on the inside in order that draughts of fresh air can enter the building without check.

Timber in Factories.

It is not only necessary that all timber used in the factory should be well seasoned to avoid warping, and of the most durable kind, but it is also advisable to protect it in every possible way against wet and dry rot and various pests. In most tropical areas white ants do an enormous amount of damage, and in order to mitigate this evil some estates have insisted on all the timber being creosoted, not only externally, but also internally. The use of such timber in the curing-house is an obvious advantage. When used for flooring it may be troublesome to the bare feet of the coolies. Instead of creosote, " Jodelite " is being used on some plantations.

The drying poles, reapers, or shelves, in the curing-room are not necessarily very expensive. Jungle and bamboo poles free from splinters are extremely useful; otherwise, planed reapers similar to those used in ceiling work are generally supplied.

Heating Apparatus.

Various forms of heating apparatus are supplied to estates; each is usually associated with the name of the inventor or firm interested in it.

It is apparent that, in the production of heat, material may be used which will emit dense volumes of smoke capable of being used in the smoking as well as drying of rubber.

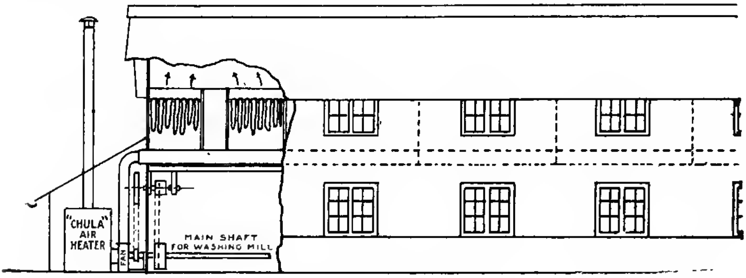
In Cochrane's system the heat is developed in iron trucks on the ground-floor. Three or more of these trucks, each provided with regulating grate bars and fitted on wheels, are used. They can be easily cleaned, and the fire started outside the building. The heat is driven by a fan through ducts to the drying-rooms. It then rises through expanded metal meshwork laid under each rack in the drying-room, and is drawn over the rubber on the racks by the opening of adjustable ventilators.

The "Chula" Rubber Drying Plant.

The "Chula" patent air heater used in connection with rubber drying and curing is one which has been developed largely in connection with tea-drying. It consists of a large number of tubes placed above a furnace through which the air to be heated circulates.

In its application to rubber drying several methods are possible. One is to divide the drying-loft up into, say, six sections, and by means of a large fan to draw hot air through a system of light steel piping fitted with numerous outlets controlled by shutters. The first day's rubber is placed in the first section, and the following day's production goes into the next chamber, and so on until the seventh day, when the first chamber is emptied and re-filled. Once started this process is, therefore, continuous, and a day's manufacture of rubber is turned out every day dried, and, if necessary, also smoked. Using thin crêpe, and with the fan running during the day only, two days have been found sufficient to thoroughly dry the crêpe, although, to get it heavily smoked, it should remain from four to six days in the chamber.

Another method of applying the "Chula" heater to a curing-loft is to have one large chamber with the fan at one end and the heater at the other. At both ends of the building ducts are pro-

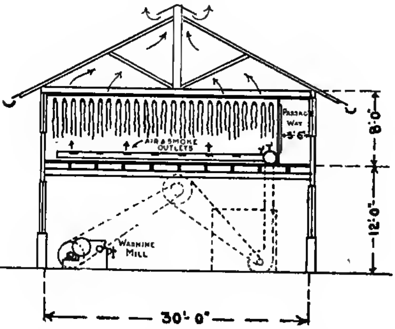


ELEVATION (WITH SECTION) SHOWING APPLICATION OF "CHULA" HEATER.

vided to cause an even current of hot air or smoke through the building.

Temperatures of from 100° to 110° F. are used, and the air or smoke is arranged to pass through the drying-room from six to eight times per hour.

The same apparatus can, as in the previous case, be used for supplying hot smoke and air to the drying-room. Valves are provided above the tube chamber by means of which the fumes from the furnace can, if desired, be allowed to escape and mix with the hot air. When smoke-dried rubber is desired, the fire is fed with suitable green fuel on a low fire. (Albizzia wood and leaves are used in Ceylon and Lantana in S. India.) The dense smoke



SECTION THROUGH DRYING CHAMBER.

rising among the air-heating tubes is cooled down by the air circulating through the tubes, and when allowed to escape through the valves at the top of the heater, is practically at the same temperature as the hot air from the tubes. The mixture of hot air

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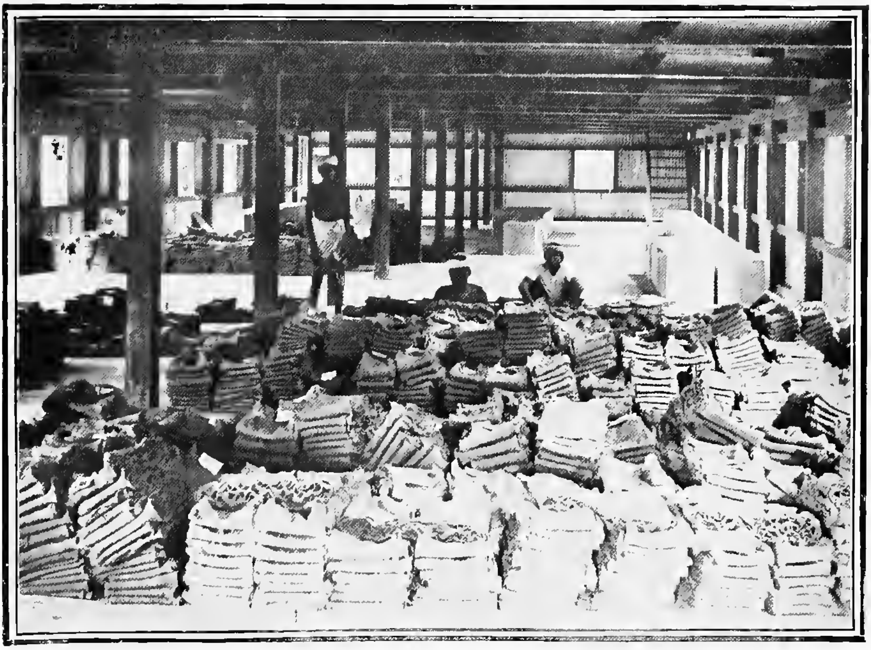
DRYING RUBBER ON THE ESTATE.



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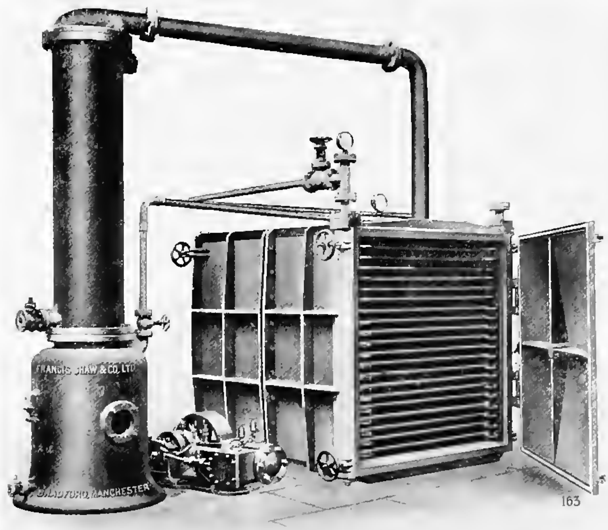
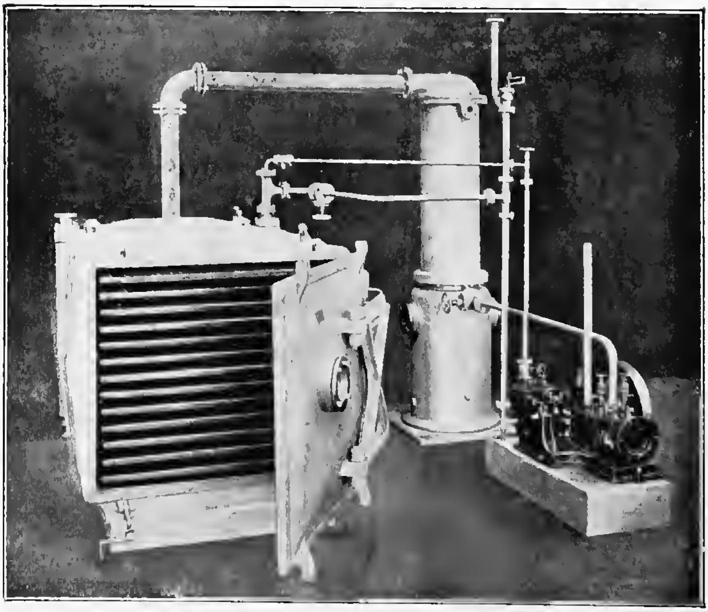
SORTING AND PACKING RUBBER ON THE ESTATE.



SHAW'S VACUUM DRIER.



PASSBURG'S VACUUM DRIER.

and smoke is then drawn off by a fan and delivered to the curing-rooms in a suitable manner. The crêpe or sheet is hung in the usual way and the drying room filled with smoke at a slight pressure which is distributed evenly throughout the chamber by means of outlets in the piping. Each section of the drying-chamber can have its smoke-supply cut off by means of a valve. For producing pale dry rubber the smoke valves on the heater are closed and the chimney valve opened and, of course, a dry fuel used in the furnace. Pure hot air only is then obtained for passing over the rubber.

"Sirocco" Drying Plant.

The "Sirocco" drying plant can also be used on rubber plantations. It consists of a "Sirocco" air heater placed in an air-tight chamber in the centre of the ground-floor of the factory. The stoking is effected from the outside, as this obviates the necessity of bringing fuel into the factory itself, and permits the latter to be kept clean. A volume of air, suitable to the requirements of the curing-rooms, is driven by means of a centrifugal fan into the air chamber. Having been heated to a desired degree, it passes into a horizontal duct extending the whole length of the first floor of the building. By means of valves the warm air can be admitted from the duct into any of the curing-rooms, which are kept under a slight pressure due to the fan or the natural draught. Temperatures of from 80° F. to 160° F. can be employed.

Fans in Drying Factories.

Though an adequate draught of fresh air is frequently obtained in curing-rooms without the use of fans, these appliances are being used with advantage on many estates. When artificial heat is used, fans are invariably adopted to drive hot air into the building or to draw off the hot, moisture-laden air. Even where no heating apparatus is employed the use of a fan is found necessary when large crops have to be cured in the shortest time possible. When fans are used the rubber is much more quickly dried and the danger of moulds and other objectionable developments lessened. The capacity of different-sized fans is given in various engineering catalogues.

Vacuum Drying.

The fourth method is that of drying in vacuum-chambers. In the previous methods large spaces involving the erection of factories are necessary. In this method the minimum space is required. It is maintained that drying in vacuum is accomplished rapidly, only low temperatures are necessary, and a great saving in fuel, space and labour is effected. The vacuum-drying chambers are generally rectangular or cylindrical in form and fitted with plate shelves or shelf coils inside. A vacuum chamber usually consists of a large iron box, of from 100 to 200 cubic feet capacity or even larger, fitted inside with shallow trays having perforated bottoms, and heated with steam pipes ; the interior is connected by an iron pipe with an exhaust pump. For heating, live or exhaust steam may be used, or even hot water. The temperature of the chamber is raised to 90 or 100 F., and after the air has been drawn through the drier for a few hours the rubber is usually sufficiently dry for most purposes. Most manufacturers and planters have not adopted drying in vacuum as they believe the rubber is softened too much, and the nerve more or less permanently injured. They prefer to dry the rubber gradually in dark warm rooms.

This most rapid method of drying can be applied to all kinds of rubber—biscuits, sheets, or crêpe—and enables one to manufacture rubber nearly dry in a sound but soft state, ready for making up into blocks. The rubber is allowed to remain in the vacuum chamber until only about 1 per cent. moisture is left in the rubber. When in that condition it should be removed, as if allowed to remain until the whole of the moisture is extracted the rubber seems very liable to resolve itself into a soft treacly mass. The temperature and pressure inside the chamber, can, with a little skill, be easily regulated, and providing the whole of the moisture is not extracted, good results may be anticipated. The quantity of rubber which can be dried in a given time by means of a vacuum chamber depends upon the capacity.

There are many kinds of vacuum driers now on the market, notably Passburg's, Shaw's, Bridge's and Robinson's.

Method of Working Passburg's Drier.

In working Passburg's drier, the rubber remains in the chamber from 1¼ to 2 hours. About 10 lb. of wet rubber are spread upon each tray, the chamber supplied to plantations usually receiving 190 lb. per charge. The steam supply is shut off about a quarter-of-an-hour before the rubber is dry. The heat in the metal of the chamber completes the last stage of the drying. When the vacuum is about 28½ inches, the temperature of the rubber remains at about 90° F. until the greater part of the moisture has been removed. It then slightly rises, and the rubber is taken out when the temperature reaches about 120° F. The pump requires about 1 H.P., but the exhaust steam from the steam cylinder is more than sufficient for heating the shelves of the chambers.

In the Federated Malay States a very low steam pressure in the shelves is used—from 1 to 4 lb. only—and on some estates the rubber may be left in for 1½ to 2 hours. When planters desire more output from a chamber they will probably increase the steam pressure and shorten the drying time. At the end of the drying process the rubber is hot and relatively soft, and is specially suitable for cutting into strips and conversion into block. One can make satisfactory dry blocks with using the vacuum chamber, as it not only gives a dry, but a soft product, easily manipulated. The warm rubber on cooling sets into a hard block.

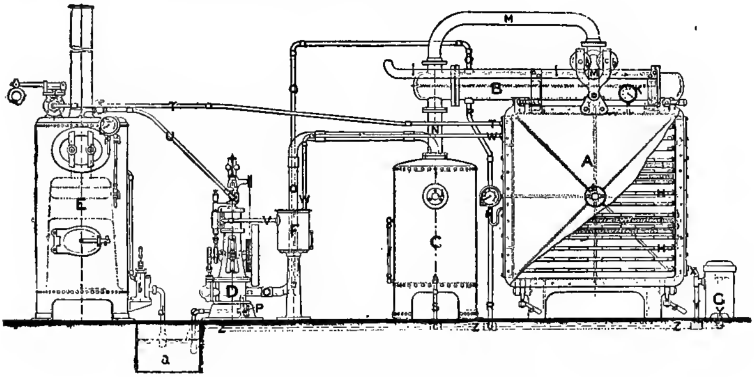
Shaw's Vacuum Drier.

Shaw's make special sizes of vacuum stoves for plantations. Each stove contains 20 shelves; the size may be 4 in. by 4 in., 6 in. by 4 in., or 8 in. by 4 in., these respectively taking 84, 126, and 168 lb. of rubber per charge. Five charges per day can be dried, so that the output from a single stove may be considerable. The installation is provided with a pump, condenser, and receiver capable of operating two stoves, so that a second can be added when found necessary without incurring double expense.

Messrs. Jas. Robinson and Co., Manchester, also make vacuum driers of a special type.

Bridge's Vacuum Drier.

The stoves in Bridge's vacuum driers contain 14 shelves. Three sizes of stove are made, all of the same width inside, but of different depth from front to back, the depths of the shelves being 1 foot, 3½ feet, and 5¼ feet respectively. From experiments made at their works they find that a square foot of moderately thin crêpe weighing, say, ¼ lb. to the square foot, can be dried in 30 minutes, working at a temperature of, say, 90° F.



BRIDGE'S VACUUM DRIER.

Bridge's mention that the great point in using vacuum driers is to see that the rubber is evenly crêped, so that one part does not dry more quickly than the other. After vacuum drying the rubber is not fit for the market, but it can be readily made so by passing through dry rollers once or twice to re-crêpe it, or several thicknesses can be put together through the dry rollers and made up into blanket, or the rubber may be blocked. This firm think that thick blanket and block are the best when vacuum drying is adopted.

General Remarks about Vacuum Drying.

Vacuum drying is generally resorted to when it is advisable to rapidly remove the moisture without subjecting the product to a very high temperature.

It has been argued that with drying in vacuum chambers there cannot, owing to the absence of air, be any oxidation ; this is to some extent a wrong view to take as a small quantity of air will probably remain in the vacuum chamber however excellent the exhaust.

It is obvious from these considerations that the vacuum method is one by means of which rubber can be dried in the shortest time, and material turned out approximately pure and uniform. On some estates vacuum driers have been described as "useless," and on others as "indispensable." The success with which such a complicated piece of apparatus is used depends, very often, on the engineering skill of the planter in charge. Where skilled supervision has been provided, vacuum driers have been quite a success.

In amplification of some remarks on a previous page, attention may be drawn to some recommendations made by Mr. J. Darnley Taylor in reference to complaints against the tendency of vacuum-dried rubber to become nerveless and tacky. According to him (Tropical Life, April, 1910), this is because the rubber is allowed to remain in the chamber, subjected to the heat of the shelves, with the inside temperature rising, after the superfluous moisture has been removed, so that a cooking or roasting action takes place. He submits that it is unnecessary and even harmful to make the rubber "bone dry." The last 2 or 2½ per cent. of moisture is the most difficult to remove, and requires somewhat severe measures. Taylor recommends leaving it in, when the vacuum chamber is used, as he believes that it prolongs the life of the rubber, and gives greater elasticity. He mentions that the first indication of the rubber being sufficiently dried is when the temperature begins to rise, further corroboration being the cessation of the dropping of condensed vapour into the receiver. Then is the time to stop drying.

It is well known from experience on many plantations in the East, that by means of vacuum dryers rubber can be cured at the rate of 200 to 330 lb. per two hours ; this represents an output now anticipated on many properties. But as to whether the rubber is in any way damaged by such rapid drying, opinion seems to be divided. The replies received from manufacturers who have been consulted as to whether they would recommend planters to dry their rubber slowly or in vacuum chambers are all against rapid drying ; they all state that the best rubber is obtained when it is slowly dried.

When rubber is rapidly dried an impervious skin may form on the surface owing to the superficial layers being dried before the internal portion ; when one is dealing with very thin sheets or crêpe this drawback against rapid drying is not very formidable.

At the conference held during the Rubber Exhibition of last year, Dr. Esch condemned vacuum drying in any case, in spite of the good results sometimes obtained.

Bubbles and Vacuum Drying.

Attention has been called to the number of air and steam bubbles occurring in some samples of sheet rubber dried in vacuum chambers. Many explain this by stating that when the wet sheets are placed in hot chambers a film forms on the surface, which, to some extent, prevents the escape of air or steam; if the temperature is then lowered very suddenly the air or steam may never escape, and the bubbles therefore remain to disfigure the rubber. Slowly-dried, thin sheets do not usually show this disfigurement to the same extent, and one may conclude that the method of drying is at fault. These bubbles occur just as abundantly in an average lot of crêpe rubber cured in vacuum chambers, but when the rubber is presented in this form the bubbles do not show up very conspicuously. The steam bubbles are formed as soon as a partial vacuum is secured, the water boiling under the reduced pressure at a comparatively low temperature. This feature in vacuum-dried rubber cannot be regarded as a very serious obstacle, especially if the planters must convert the hot, dry rubber into loaves or blocks in the minimum time.

Michie-Golledge Process of Rapid Drying.

I am indebted to Mr. Michie, of Walker, Sons & Co., London, for the following description of the Michie-Golledge curing process, which enables planters to turn out dry rubber in the minimum time without the use of vacuum-driers. Rubber cured by this process is ready for despatch in one or two days after the latex is taken from the trees.

Latex is coagulated in three to four minutes by means of the Michie-Golledge hand-driven coagulating machine, these machines being placed in sheds at places where latex from the various fields can be conveniently collected. Immediately after coagulation the rubber, while still in a plastic state, is passed through a small hand-roller and rolled into sheets. These sheets are taken to the factory or curing-store, and are at once cut into strips by a special machine. The strips, spread on wire trays, are placed inside drying-chambers, through which slightly heated air is drawn or forced by a fan. When smoke-cure is required, smoke is passed with the air through the strip rubber during the drying process. One or two hours suffice to thoroughly dry-cure the "strip," which is then, if the rubber is to be finished in crêpe or sheet form, passed through the crêpe or sheet mills.

I have seen this process in working order, and consider it one of few complete systems capable of rapidly drying rubber without the use of vacuum driers. It is a simple and yet very effective process. The process is followed upon such estates a St. George's, Panawattee, Udapolla, Neuchatel, and Periyar.

Drying of Air in Refrigerating Chamber.

In a recent patent by Marlow, the rubber is hung in a dark chamber, which is exhausted to a vacuum of two inches of water;

an air-blower is then inserted, and through it the previously dried air is passed, this air having been dried in a refrigerating chamber, after which its temperature is raised again.

It has been pointed out, by some authorities, that no suggestion has yet been made for drying the air by cooling it to the condensation point of the bulk of the contained moisture.

CHAPTER XXV.

THE SMOKING OF RUBBER

A great part of the rubber from plantations is shipped without being in any way smoked. In fact, some forms of plantation rubber, especially well-washed crêpes, are never subjected to this treatment. Nevertheless, this process has been adopted with advantage by many planters, and is worthy of consideration at the present juncture.

When dealing with yields and preparation of rubber from the Amazon, mention has been made of the smoking method adopted in that region. Furthermore, we have just seen how in many factories recently erected in the East, a separate part of the building has been set apart for smoking only.

Advantages of Smoking.

The benefits to be derived by smoking rubber depend upon the thoroughness with which the raw material is impregnated with the antiseptic and preserving substances contained in smoke, upon the condition of the rubber being so treated, and whether the rubber is smoked internally or externally.

The most apparent effect of smoking is reduction in the number of cases showing tackiness and moulds. Properly smoked sheet rubber, if packed dry, can be stored for many months without becoming soft or mouldy. Crêpe, not smoked, keeps equally well, probably because the substances on which the development of moulds and tackiness largely depend have been almost entirely removed during the washing process through which all such rubber passes.

Smoking and Strength of Rubber.

Apart from the good effects on the keeping properties, smoking appears to improve the strength of the rubber, especially when effected internally. The better physical properties of fine hard Para compared with the average plantation product have for many years been associated with the smoking process in the Amazon. This might well be the case seeing that readily decomposible substances are, during coagulation, covered with preservatives contained in the smoke, the liability to internal decomposition and degeneration being thereby minimised. If this is the correct view, it would certainly appear worth while smoking even crêpe, washed scrap, and any other forms of washed rubber, especially as this can be done at very little extra cost.

Demand for Smoked Rubber.

That there is a decided preference for smoked rubber from plantations is evident from the fact that this type has been acquired by the payment of substantial premiums over the unsmoked plantation product. This premium has been maintained for several months in succession, and though it will in all probability diminish or disappear when smoked rubber is available in large quantity, its existence i good testimony to the opinion in which it is held by buyers.

A most striking acknowledgment to smoked rubber was paid at the Rubber Exhibition, 1911, when the "India-Rubber Journal Shield" and "Grenier's Trophy" were offered for the best plantation rubber in the world. Both prizes were won by one exhibitor of smoked rubber, and those exhibits nearest the winning lot were smoked. The value of this verdict was very great. It appears that separate groups of technologists, manufacturers, and rubber brokers were selected to examine the exhibits for each of the two awards. Though the methods of the two groups of judges were quite unknown to each other, the smoked rubber from the same estate gained the highest number of marks in each competition. This decision, strengthened by the fact that nearly all the runners-up in each competition exhibited smoked rubber, was regarded as a definite pronouncement in favour of smoked as against the unsmoked plantation product.

Of course this, as well as other kinds of plantation rubber, is subject to the laws of supply and demand. In fact, at the moment of writing, merchants are asking planters to make crêpe in preference to smoked or unsmoked sheet ; but this is on account of the market condition in relation to forward contracts for these classes of rubber.

Methods of Smoking.

There are various methods of smoking adopted in wild and plantation districts. In the Amazon region, and also as the basic principle in many of the recent inventions designed for use on plantations, the rubber is smoked internally as the latex is being coagulated, this being considered to have a better effect on the physical properties of the finished product.

On most plantations smoking is external only and is comparable, to some extent, with the surface-smoking of common food stuffs in this country both in respect of method of procedure and effects. The rubber when smoked externally is suspended on racks or poles, in a chamber filled with smoke from a smouldering fire, until it has been thoroughly covered with the smoke, the final stage being determined by colour and smell.

The rubber may be placed in the smoking-chamber in the wet or in an almost dry state ; it is usually transferred to the smoking-shed after being allowed to drip for a day or two, and is kept there until thoroughly dry.

Smoking Coincident with Other Processes.

It will, therefore, be quite clear that whether internal or external smoking methods are adopted, certain other changes are in progress during this stage. In the internal methods, coagulation is proceeding hand-in-hand with the smoking of every particle. When surface-smoking is adopted, drying is generally accomplished in the same period. In the former method, the rubber is usually, but not always, shipped in the wet and unwashed state; in the latter, the rubber is washed before being smoked, and is generally shipped in the dry condition. It is this connection between the smoking methods and the coagulating, drying and washing processes that leads to such entirely different factory arrangements in rubber-producing areas.

The Amazon Method.

The method adopted in the preparation and smoking of fine hard Para can be taken as the standard. Most of the new inventions are based on the principles of the method employed by the natives in the Amazon region.

In Brazil the latex is poured into a shallow basin 60 cm. to 1 metre in diameter and 20 to 30 cm. deep, and pieces of bark, dirt, &c., removed. A fire is then made of wood and resinous substances, and is kept going either with green branches of *Mimusops elata*, or with palm nuts from *Attalea excelsa* and *Maximiliana regia*. These palms are usually grown in botanic gardens in various parts of the tropics, the latter species being more commonly known as the "Cocurito" palm. A chatty, open at both ends, or a cone, is placed on the fire and the smoke allowed to issue from the upper aperture.

A paddle-like implement is then dipped into or covered with the latex, and held over the smoke until the latter is coagulated. It is stated by Bonnechaux that 8 litres of latex are completely coagulated in about 1½ hours by these means. The same principle is said to be adopted in parts of the Congo in the preparation of Landolphia rubber.

The Constituents of Smoke from Attalea Nuts.

These have been partly determined by Frank and Gnadiger. On combustion of the nuts, there are obtained 10·08 per cent. of tar, 46·4 per cent. of watery distillate, 29·10 per cent. of charcoal, and 14·51 per cent. of gases. Neither the tar nor the watery distillate differ greatly in composition from the similar products obtained from beechwood. In the tar were identified methylpyrogallol, dimethyl ether, coerulignol, cresol, guaiacol, homopyrocatechol, a sesquiterpene, and pyridine derivatives. In the aqueous distillate were large quantities of formaldehyde and acetone, and in addition xanthogallol, homopyrocatechol and formic, acetic and propionic acids.

Other Internal Smoking Processes.

Ridley (Straits Bulletin, 1910), devised a novel method of smoking. Spindles, flat and towards the centre broad, were used; these, when made to revolve, dipped into the latex and passed through a smoke chamber. Samples of the rubber were submitted to a manufacturer for testing. The loss in washing was 13 per cent. compared with 18 per cent. for fine hard Para. The rubber was extremely like the latter in tensile strength and power of recovery, but was slightly softer and required a different vulcanizing heat. Tests of the elasticity and tensile strength made at different times during the experiments show that at the proper vulcanizing heat it was as durable as fine hard Para.

Sutton's Apparatus.

This also is based upon the Brazilian method of smoking upon paddles. There is a series of paddles revolving in a circuit, and each is made to dip in turn into a vessel containing the latex, making two or three turns in it. After a paddle has thus received its coating of latex, it passes through a chamber filled with smoke generated by a specially constructed creosote apparatus. The paddles are kept revolving until each has a sufficiently thick coating which is cut off and forms a sheet. It is claimed that one man can attend to several machines, and that the temperature is under complete control. A small-sized machine with six paddles is being tested in the East, but machines with many more paddles can be made.

The Derry and Bertram Methods.

In both of these an endless band is made to dip into the latex and to run during part of its course through a smoke chamber. The coagulated rubber is cut off in the form of long sheets. Derry's apparatus has been tried in Malaya; the method is highly spoken of, and the rubber obtained is said to be excellent. Bertram's apparatus has various modifications, one of which is the introduction of a roller which revolves continuously in the latex and is in contact with the band, which does not itself dip into the latex, but receives it from the roller. This apparatus is driven by hand.

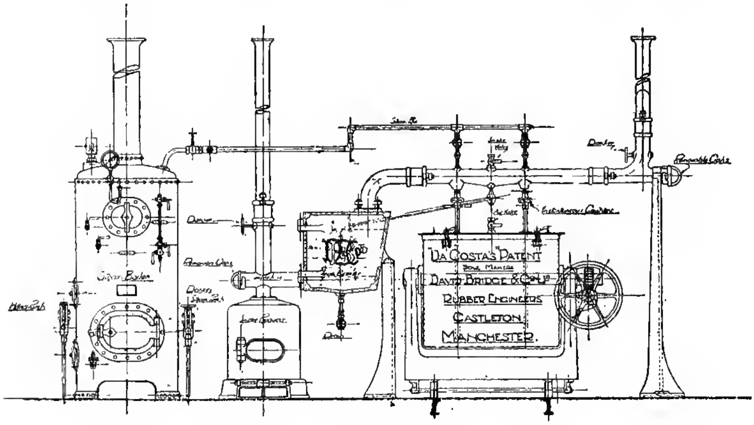
Wickham's Smoking Process.

In this apparatus dense smoke is produced in a furnace, this being effected by burning oily nuts of palms with charcoal. The latex is poured into the lower portion of a cylinder and the latter is then rotated. The smoke is passed through a hollow axle of the cylinder. When the cylinder rotates, the bulk of the latex will remain in the lower segment, but a thin film will adhere to the inner surface of the cylinder and be carried round with it and exposed to the smoke which cures and coagulates the rubber, forming a skin of solidified rubber on the inner surface of the cylinder. During the next rotation a fresh film of latex is carried round on the surface of the first skin and in its turn cured and coagulated, and this may be continued till a ring of rubber of considerable thickness is formed which can be pulled out of the cylinder. The setting of the rubber films can be observed through the opening in the side of the cylinder, and the speed of rotation regulated accordingly. By this means the whole of the latex treated is exposed in successive thin films to the action of the smoke, and a well-cured and homogeneous rubber is obtained.

This method was devised to closely imitate the Amazon method, but there are no reports available regarding its wide adoption on Eastern plantations.

Da Costa Smoking and Coagulating Plant.

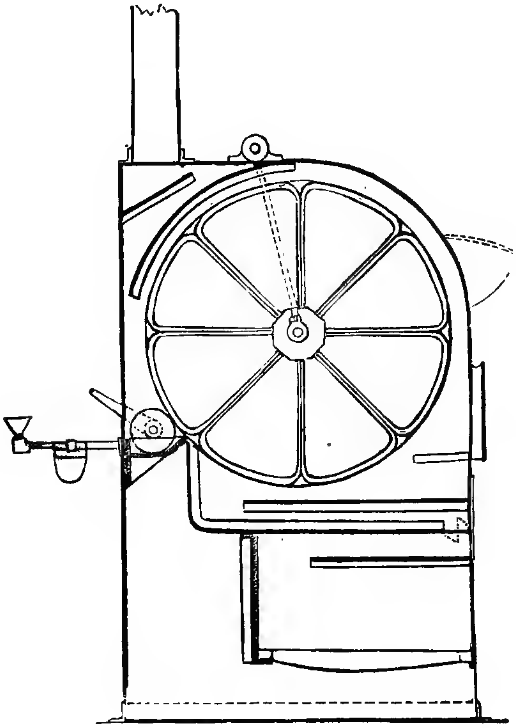
This process for coagulating latex and at the same time incorporating creosote with the rubber was put on the market by Messrs. Bridge and Co., and depends upon the injection of smoke directly into the latex by means of steam, compressed air, or with a jet of water. The plant consists of boiler, smoke-producer,



smoke-sifter (or soot-filter), and coagulating trolley bearing the coagulating-chamber, together with the necessary piping, fittings, etc. The smoke is made from any kind of wood, leaves, twigs, etc., and is thoroughly sifted by baffle-plates to extract all particles of soot previous to its being injected into the latex. To ensure its even distribution, the smoke is diverted from the soot-filter to two pipes. The latex chamber is mounted on a trolley and is fitted with a tipping arrangement actuated by worm gear and hand wheel. An instantaneous connection can be made between the pipes fixed to the coagulating chamber and the pipes leading from the smoke producer. While the coagulating process is going on, another coagulating chamber on its trolley is being discharged of coagulated rubber and re-charged with latex. The force of the injection violently agitates the latex, and during this operation every particle is reached by the smoke. In a short time the whole mass coagulates and the floating rubber can be removed. It may be prepared as crêpe, or be blocked.

Dickson's Smoker Coagulator.

The smoke is generated in a small furnace below the coagulating chamber, and before passing into the latter filters between baffle-plates. In the coagulating chamber is a large drum in



contact with a roller which is partly immersed in a shallow pan containing latex. The roller is turned by hand or power, when it causes the drum to revolve, depositing on it at the same time a continuous film of latex which is coagulated by combined heat and smoke. When there is a thick deposit of rubber, the smoke is shut off by a damper, and a door in the coagulating chamber is opened through which, after slitting across with a knife, the rubber is withdrawn in the form of a large sheet.

Shaw's Smoking System.

In this apparatus (I.R.J., April, 1911), coagulation is effected by forcing smoke through the latex by means of compressed air led from a belt-driven air compressor. The advantages claimed are: (1) latex is coagulated at a definite temperature that can be ascertained and adhered to; (2) live steam at a high temperature is not brought into direct contact with the latex; (3) the smoke is cooled by the compressed air before reaching the latex. This apparatus may commend itself to those who are nervous about the use of live steam. The tanks are now made of porcelain with aluminium covers to ensure cleanliness and are made in standard sizes to hold 25 and 50 gallons of latex each. They are water-jacketed, the water being heated to a constant level to ensure coagulation being always effected under similar conditions.

The "Fumero" Apparatus.

Van den Kerckhove has patented an apparatus, called the "Fumero," designed for use on plantations where the smoking of rubber is desired. The "Fumero" is about 80 cm. (32 in.) in height, can be transported by hand from one place to another, and when lighted emits smoke containing creosote. The inventor states that coagulation is effected without the addition of acid, and the rubber can be made up, finally, in the form of sheets, biscuits, balls, etc. It was explained by the writer at the Ceylon Rubber Exhibition that hot smoke, from smouldering logs of wood which had been previously steeped in creosote, brought about coagulation of the latex through which it was passed.

Krebs's Patent Smoking Apparatus.

Here, instead of allowing the fumes to come directly into contact with the latex, they are passed through water, which traps some of the constituents, this water being added to the latex to produce coagulation. To generate the fumes, wood is slowly burned in a forced-draught furnace and they are driven through the water by means of a hand or mechanically-propelled fan. The residual fumes may be passed on to the drying-room.

Surface-smoking on Estates.

The foregoing methods are all based on the Amazon system of impregnating every particle of rubber with the constituents of smoke. In the surface-smoking methods which predominate on Eastern plantations, smoking is almost entirely superficial. Various systems are adopted, the smoking chamber sometimes being of a temporary character and at other times a fixed part of the factory. In the latter case the smoking section may be in a compartment attached to, or be an integral part of, the main building.

Sources of Smoke.

The smoke is obtained from various sources. On Klanang estate, where smoked sheet of first-class quality is turned out, coconut husks, with a small quantity of hard wood, are used to generate the smoke. The freshly-washed sheets, after being allowed to drip, are exposed to the smoke and are said to be dry and ready for packing in about one week.

On other estates old railway-sleepers, or timber soaked in creosote, are allowed to smoulder. A dense smoke is obtained from such material, though the addition of creosote is said to sometimes raise the temperature and lead to too rapid combustion. On other properties certain common native woods, known for the dense smoke they emit while smouldering, are used. Waste coconut-dust and sawdust have sometimes been used, but have been abandoned on account of their frequently giving off sparks of wood which settle on the surface of the rubber and also increase the fire risks.

Fires and Supervision During Smoking.

It appears to be the general practice, where the smoking chamber is not a part of the main building, to have the fire-places sunk in the floor or placed on the bare earth. Under these circumstances the kiln principle appears to be the safest. By means of baffle-plates the smoke can be delivered to any part of the chamber where the rubber is hanging.

There is very little supervision required, and the danger from fire is generally small.

The safest principle of all, and one allowing almost perfect control, is to have a smoke-generating apparatus outside the building, such as the "Chula" type.

Under ordinary circumstances, the timber or coconut shells are allowed to smoulder all day, the fires being renewed at frequent intervals. The smoke should be dry for the benefit of the rubber and the coolies working in it. There are certain risks from fire, but these can be minimised if the fire is sunk in the ground and smouldering only—which does not increase the temperature greatly—is permitted.

The rubber should be turned over occasionally, so that it may be smoked as evenly as possible. If this is not done, the part of the rubber touching the pole or support will remain pale in colour and thus spoil the appearance of the sheet.

Creosote-Generating Apparatus.

A creosote-generating apparatus has been recently brought forward by Sutton, based on the vaporisation of creosote by allowing it to drip upon a heated surface. The creosote drops through small nozzles fitted with needle-valves upon a pan heated by a paraffin oil-lamp. Should the creosote upon the pan take fire, the supply is shut off automatically. Should the lamp go out, the overflow of unheated creosote is provided for. The apparatus is placed in the drying or smoking-room. It can be easily managed by a native.

Buildings for Surface-Smoking.

On many estates the smoking-house is constructed of mud and timber or of timber only. The plan is often extremely simple and the cost of erection small.

Upon an estate, the smoked sheets from which realize very nearly the top prices at the auction sales, three houses differing somewhat in construction are used. The first is a square house 12 ft. by 12 ft., with bars running across the open top, which is 14 feet from the ground. Above the fire, three feet from the ground-level, is hung an iron sheet, and above it again is stretched wire netting to prevent any rubber falling into the fire.

The second house is built 12 ft. by 12 ft. and 16 ft. high, with a pit 5 ft. deep. This house has a covered-in top, a small hole being left in the centre to allow the smoke to escape. Three feet from the ground-level sheets of iron are hung over the fires, and 1 foot above this is the bottom of the first drawer. There are many drawers, each 6 ft. by 6 ft. by 6 in., laid on top of one another as far as the roof. They draw to the outside, a platform being erected to allow of their being filled. There are four tiers of these drawers, 56 in all, and they are formed of a framework of wood with wire-netting stretched across the bottom. Smaller sheets are smoked in this house.

The third house is a corrugated iron building, 40 ft. by 25 ft., and 25 ft. high. In a chamber on the ground-level, 10 ft. wide at the bottom and 22 ft. at the top, the fires are placed. At 10 ft. from the ground is a wooden ceiling (the floor of the chamber above) in the centre of which is a space 6 ft. wide and 30 ft. long, covered with wire-netting, for the upward passage of the smoke. Rattans, the width of the building, are stretched across the upper chamber 10 ft. above its floor to support the rubber when drying. The fires below are protected with sheet iron as in the other forms of houses. Ordinary green wood from the new clearings is used, and sawdust is kept caked upon the top to prevent the formation of flames.

Smoking-House at Singapore.

Ridley (I.R.J., April, 1911), has given the following description of a building which he found useful at the Botanic Gardens, Singapore :—

"The building is 55½ ft. long and 19 ft. wide, oblong in shape, and made of ordinary planking with a high roof. The plank walls are 8 ft. high, and the roof of attaps, 15 ft. high in the centre. The floor is cemented, with concrete below. There are two or three windows, which can be opened when required, and one entrance door. The building is erected on a slope of about 1 in 12, and drains run down the side to carry off rain water ; inside are wooden posts sunk in the ground between which run thin rattans stretched tight over which the rubber is hung. Near the door are sunk in the concrete and cement floors circular pits 1 ft. wide and 3 ft. deep in which the fire is put, and then are covered with iron cones with a flat perforated top. These cones are 22 in. high. They have a small oblong opening at the base to admit air to the fire. Three of these fireplaces keep the room full all day, but there are others at the upper end of the building which can be used to increase the smoke, if required, either for exceptionally heavy smoking or when the building is quite full of rubber. The newest made rubber is put nearest the fires so as to get the most smoking and moved further up the slope as it gets drier.

"All smoke contains a certain proportion of water, and this, with the free creosote and naphtha, are practically absorbed by the woodwork and attaps, so that the rubber is not covered with a wet unpleasant layer. At one time a brick smoking-room with a corrugated iron roof was built. In this house the fire was outside and the smoke was conducted in by a tube, but it was soon found that there was deposited on the floor and elsewhere in the rooms a thick brown liquid consisting of naphtha and water. This stuff got, too, on the rubber, but is quite absent from the wooden drying house. Though the woodwork gets dark brown or black from the deposited products of the smoke, the rubber is dry and of good colour."

Smoking in the Main Building.

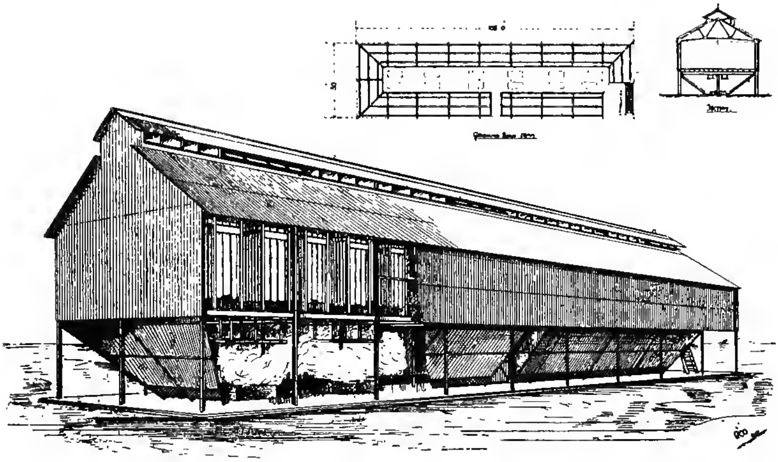
On many estates the smoking compartment is a part of the factory. Where the building is all on the ground floor, the smoking section is at one end, generally projecting—almost as if it were a separate structure—from the line of the main building. When the factory is two storeys high, the smoking department is again usually at one end of the upper storey, the rest of that floor being used for packing and weighing. When such arrangements are adopted, the smoke is obtained by various methods, the simplest being by perforated buckets containing the smouldering substances. In other cases the smoke and hot air are obtained from furnaces placed outside the building.

The risks from fire in a part of the main building, especially when smoking is carried out on the second floor, are sometimes considerable. In a private catalogue is shown the division of the upper storey of a factory erected by Cochrane. The drying and smoking-room is supplied with smoke as described in a previous chapter.

Smoking-Houses.

Some managers prefer to have a separate building wherein the rubber can be smoked and dried. This is believed to minimise fire risks, and to enable the managers to organise the rest of the factory operations more economically. The disadvantage is the distance which such a building is usually from the washing-mills and packing rooms. Considerable hand labour and exposure is involved in taking the freshly-coagulated rubber from the main factory and in carrying the smoked and dried rubber to the weighing and packing rooms.

In a type of smoking-house built by Francis Shaw & Co., the floor is about 6 feet from the ground, and below are the fires, which



ELEVATION, PLAN OF LOWER CHAMBER, AND SECTION OF SHAW'S SMOKING HOUSE.

are enclosed in a chamber with sides sloping in towards the bottom. The floor boards are laid with open joints to allow the air and smoke to pass through, and below the floor are smoke-distributing plates. A ventilator is fixed in the roof as shown above.

Continuous Treatment in Central Factories.

Having now described the separate processes of coagulating, washing, drying and smoking, and seen how much time and factory organisation is necessary in connection with each of these processes, we can now consider other aspects. In the foregoing chapters it has been shown how independent each process is or may be of the other, and how, in the event of one section failing for a short time, the others may be proceeding. For instance, drying or smoking, or both, may be going on during the night when the others are stopped. Similarly, the other processes may be going on when the drying and smoking compartments are empty. In many instances, rubber is washed only, or is cured only, for a neighbouring estate not fully equipped for complete preparation. There is, therefore, usually ample provision made for each process in factories on estates in an advanced stage. In some instances it has been thought possible to effect economy by using a central factory for several estates, large spaces and the necessary machinery and apparatus being provided for each process in the preparation of the finished product. Such a system may make each participant very dependent on the successful running of every department of such a factory, though it is obvious that economy is more possible under such a scheme providing everything is maintained in perfect working order. A step has been taken in this direction by the newly-formed "Kajang Curing Company," that has been formed with the object of curing, in a central factory, the rubber from the Inch Kenneth, Glenshiel, Balgownie, Cheras, Kajang, and Sungei Parau estates in Malay.

A System for Continuous Treatment.

Somewhat allied to this is an invention taken out in the joint names of Da Costa and Bridge for an elaborate installation of apparatus at one end of which is fed the latex and at the other is turned out the finished, marketable rubber. From a receiving trough the latex is led through a pipe by gravitation or by pumping into the coagulating tank of a Da Costa Smoker Coagulator. In this coagulation is brought about by a mixture of smoke and steam, or by one of smoke mixed with heated or cold air driven in by an air-compressor or drawn through by a blower, etc. The coagulated rubber may be conveyed by various means proposed (worm conveyor, vanewheel, etc.) to one or a series of pairs of rollers—macerating, crêping, or sheeting—between which it passes downwards and is deposited upon an endless belt. This carries it towards a table, upon which it may be cut into, say, sheets, which are then placed within a heated drying chamber. In this chamber may be a number of endless belts, preferably of lattice work, arranged one above another, and the rubber placed upon the uppermost, drops from one to the other. In place of the series of belts, a single conveyor belt may be used in the drying chamber. Instead of a simple drying chamber, a vacuum chamber can be employed. Provision for surface-smoking is possible. After drying, the rubber may be prepared as sheet, crêpe or blanket, and may further be finished as block, arrangements being made even to run the trolleys carrying the rubber to the presses directly into them so that transference is unnecessary.

This process may strike the planter as imaginary; it has the merit of originality, and may lead to practical suggestions later.

In the previous chapter on the drying of rubber, page 389, a full description of a continuous system—the Michie Golledge—has been given.

CHAPTER XXVI.

FORMS, BRANDING, PACKING, AND HANDLING OF PLANTATION RUBBER.

In the foregoing accounts of the methods of preparing plantation rubber it has been shown that the finished product may be presented in various forms. In the production of each kind special means and apparatus are employed and certain general rules followed in order to meet market requirements. The principal form of plantation rubber—in first-quality grades—now on the market are: biscuits, sheet, crêpe, worms, and block (scrap being in the form of crêpe, slabs, or blocks). All except crêpe and, perhaps, block rubber may appear in the smoked or unsmoked condition.

Merchants have aided the standardization of plantation grades by contracting, in forward sales, for rubber in the form of (1) smoked or unsmoked sheet, (2) crêpe, not smoked, (3) block, (4) scrap. Forward contracts have been made for 1912 and 1913 in which plantation rubber may be delivered in the form of crêpe or sheet at the option of the sellers. This may suggest that the two forms are approximately of the same value.

Biscuit Rubber.

Biscuit rubber, the original form of preparation in Ceylon, is now not so commonly met with, as most estates have machinery installed for turning out other forms. It is prepared by allowing the latex to set in shallow, circular receptacles after acetic acid has been added, and by washing and rolling the cake of rubber that appears at the top. The biscuits are, therefore, more or less circular in outline.

In many instances they curl up at the edges on drying and present an objectionable appearance. This can to some extent be overcome by pressing them in a vessel of definite outline before subjecting them to the rolling process. After rolling, the cakes partake of the shape of the vessel in which they have been pressed. If the margins of the coagulating receptacles are correctly made, the tendency to curl and become wavy in outline is not so noticeable.

Biscuits (and sheets) are usually very pure, and can, without washing, be used for "solution" work by the manufacturers; the material is practically ready for the naphtha bath on its arrival in Europe. It has been stated that the material from Ceylon shrinks about 1·4 per cent., 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 Hevea 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.

Biscuits are made from $\frac{1}{16}$ to $\frac{1}{8}$ inch in thickness and 10 to 14 inches in diameter.

Sheet Rubber.

This is prepared by coagulating the latex in special oblong dishes and passing the rubber between smooth rollers running at even speeds or at a very low differential rate. Sheet rubber does not get the thorough washing that crêpe receives, though it has the advantage of being less worked mechanically. It is generally admitted that plantation sheet finished in the machine by a squeezing as opposed to a tearing or disintegrating action, involved in making crêpe, has, so far as manufacturing experience goes, given the most satisfactory results.

It is considered a great improvement to run the sheet finally between diamond-cut rollers, or other patterns. The resultant ridging of the surface allows for ventilation between the sheets, so that mould develops less easily. It also prevents them sticking together to any extent. This form of rubber is very frequently smoked on the plantation.

Sheets measuring at least 24 by 12 inches and one-sixteenth to one-eighth in thickness are received with favour in Europe.

Crêpe Rubber.

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 uneven in thickness, and like lace and flake rubber, dries very rapidly. On account of its purity it has been well reported upon in Europe.

Lewis and Peat stated in 1905 that "manufacturers are still prejudiced against any rubber that has been washed or otherwise treated, as a certain amount of the natural fibre and elasticity is lost in the process, and the true quality of the rubber is much more difficult to tell in this form; but the prejudice seems to be wearing off." That the prejudice has worn off is witnessed by the free and considerable market in crêpe. In their circular for 1910, in addition to smoked sheet, the same firm recommend the preparation of fine, thick, gristly blanket crêpe.

Crêpe rubber may be prepared in lengths of from 3 to 9 feet, width about 12 inches, and be graded according to colour. To the thicker preparations the term "blanket crêpe" has been applied. Messrs. Gow, Wilson & Stanton, in their report for 1910, noted a marked tendency to roll out crêpe very thin to hasten

Photo by Ivor Etherington.

DRYING BISCUIT RUBBER.

Photo by C. H. Kerr.

PREPARATION OF BISCUITS.

drying, and remarked that it was desirable that crêpe in the finished form should be thick and even in texture, say $\frac{1}{8}$ in. thick, prepared by running together between the rollers several layers of thin crêpe. It is a mistake to attempt to turn out thick crêpe in one operation.

Worm Rubber.

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

By passing the dry worms through ordinary washing-rollers they are bound together into a characteristic form.

Samples of "worm" rubber have, up to the present, received good reports, the concensus of opinion being that the rubber so prepared is very clean and contains very little moisture.

Lace Rubber.

Lace rubber was for a time prepared by Holloway in Ceylon. It consisted of very thin perforated sheets of considerable length. The porous sheet was very thin, of a pale amber colour, and was easily pressed into biscuits or sheets of any desired thickness. The "lace" came out of the machine in a continuous strip, and was cut into pieces 6 feet long as it ran on to wire trays. It was maintained that it could be turned out ready for drying within seven minutes of the arrival of the latex at the factory. The time taken for coagulating the latex, conversion into lace rubber, and drying ready for despatch was stated to be 48 hours.

Flake Rubber.

Flake rubber was first made by Mr. C. O. Macadam, Culloden, Neboda. It was prepared by placing small pieces of freshly-coagulated rubber in a small rolling machine or washer, the corrugations of which ran horizontally. The rollers were close together, and the cut rubber issued as thin strips. The strips or flakes were thin, and could be easily smoked and packed in any form. The sample I saw was pale amber in colour, free from mechanical impurities, and possessed good physical properties. It is apparent that the very thin flakes can be rapidly dried, and in this respect compare very favourably with crêpe or lace rubber. This form is seldom seen on the home market ; the same remark applies to "lace" rubber.

Scrap Rubber.

Scrap rubber is mainly the coagulated rubber obtained from the collecting cups, tapping utensils, and 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. Scrap rubber, if free from bark, dirt, and other impurities, obtains a high price. Hand-picked scrap is preferred to the washed material by some buyers.

Having regard to the opinions of manufacturers as to the desirability of securing dry pure rubber in preference to wet, and bearing in mind the objections which others raise against the use of machinery in the preparation of crêpe, the "India-Rubber Journal" asked manufacturers whether they preferred scrap rubber to be sent as purified scrap, crêpe or block, instead of in the usual impure form containing a large proportion of water, bark and other mechanical impurities. Only one firm suggested that the scrap should be sent in the condition in which it arrives at the plantation factory. All the other firms agreed that the purification of scrap rubber was a thing to be desired, and are thus consistent in their demands for pure dry rubber of the first grade.

Block Rubber.

It is well known that block rubber has been most successfully prepared on Lanadron Estate, Johore. I have, in my office, exposed to light, dust and various temperatures for over five years, two blocks of first-grade and scrap block rubber made on Lanadron by Mr. Francis Pears. They appear to be just as good as when originally received. It is obvious that when rubber is made into six-inch blocks weighing 25 lb. to 50 lb. they are likely to be comparatively uniform in section and to expose the minimum surface to air and light. These advantages, together with the ease of manufacture and packing, are such as to make this form one of the most desirable.

Block rubber is usually made by placing the soft pliable crêpe from the vacuum drier into presses. When rubber leaves the vacuum chamber it is of a consistency which permits of easy handling and pressing into any shape; on cooling, the rubber hardens and retains the shape of the receptacle in which it has been pressed while cooling.

Block rubber may also be made from biscuits, sheets, scrap, or worm rubber by pressing the material while in the soft condition as it is when removed from the heated vacuum chamber, or by pressing freshly-coagulated wet rubber. The blocks may be made into cubes or rectangular slabs and in all cases present only a relatively small surface to air and light.

Owing to the arrival of parcels of wet block, many manufacturers have shown a disinclination to purchase rubber in this form. Many of them have gone back to the old form of sheets or the later form of crêpe.

A Recent Opinion upon Block.

Interviewed during the course of the 1911 Exhibition, Schidrowitz remarked that, with regard to block, it seemed that no particular progress had been made. Manufacturers perhaps found it an awkward form; they usually preferred a method of preparation which would enable them to detect impurities immediately. On the other hand, there was at least one mark of block for which manufacturers had a regard, and in this case the quality was always so uniformly high that it could be purchased without risk. He thought that when one had a sufficiently hard rubber to stand the heating in the blocking press necessary for perfect block, and very efficient superintendence, block could not be beaten. He looks upon block made by compressing smoked crêpe as the ideal form; crêpe is not, however, generally smoked.

Size of Blocks.

The original Lanadron blocks were about 10 by 10 by 6 inches. Mr. Francis Pears advocated the preparation of blocks about one cubic foot in size, so that two could go to a case, with a thin partition between them. Such a block would weigh about 50 lb., and would therefore be equivalent to about 200 biscuits. The reasons which Mr. Francis Pears gave in support of the idea of making such large blocks were (1) the thinner the blocks, the more the hydraulic presses required, or less time must be given to pressing each block; and (2) several thin blocks or slabs packed in one case would be firmly stuck together on arrival in Europe and would require considerable effort to separate them. Several London firms, however, have suggested that the blocks should not be so thick and state that rectangular slabs would be welcome. The thinner blocks are handled with more ease.

Many persons prefer thin block, say, from 1 to 1½ inches thick, that can be taken by the washing or mixing machine without being previously cut up. It is admitted that making blocks so thin is a nuisance; it may be better to make them large and cut them into sections on the plantation.

It has been asserted by a manufacturer that blocks 12 in. by 12 in. by 2 in. are convenient for packing and in every way suited to the requirements of most manufacturers.

One may note that thin blocks or slabs can be tested for impurities by holding up to the light.

Blocking Dry Rubber.

Block rubber, of a kind, can be made by pressing freshly-coagulated rubber, or the partially dry and soft rubber fresh from the vacuum driers; but it is also possible to make a block by pressing biscuits which have been kept in the dried state for several months. On one occasion some biscuits, ten weeks old and perfectly dry, were placed in a mould and subjected to enormous pressure in a large hand-screw press; the pressed biscuits were kept in this condition for two nights and one day—36 hours in all—and then removed; the block was fairly good, all traces of the separate biscuits being superficially destroyed and only feebly distinguishable when the block was cut in two. If the dry rubber is passed through heated rollers it is softened and in a condition fit to be blocked.

Presses for Blocking Rubber.

Freshly-coagulated rubber is soft and spongy and can be blocked without the use of complicated machinery. On some small properties a letter press has been effectively used in the preparation of small samples of slab or block rubber, but on estates where the daily output is at all large, the use of a press is essential for blocking rubber. The presses first brought before the planters were usually so constructed as to be capable of being worked by hand or power, and a large number have already been found to be very defective when required to give a pressure equal to one or two tons per square inch. The use of hydraulic presses is generally viewed with favour and already machinery of this type has been placed on the market. Presses of various types have been tried and a description of some of these will not be out of place.

Shaw's Blocking-Press.

Messrs. Francis Shaw and Co. have placed on the market a compact hydraulic press. It is claimed that, in their press, there are no working parts liable to get out of order, which is a great consideration when the native labour usually employed is taken into account. The top is hinged for charging and emptying, and can be arranged to produce any size of finished block. Name plates are supplied to fit the cavities by means of which the name of the plantation is impressed on each block of rubber produced. The press is operated by a small hand pump, fitted with a safety valve which allows the water to circulate as soon as the required pressure is attained in the press. For smaller plants machines of smaller construction and made for driving either from line shafting near the floor-level, or by means of belting from overhead shafting, are supplied. The blocks are made to any size, but 12 by 12 by 1½ inches seems to be preferred by them.

David Bridge's Presses.

Messrs. David Bridge and Co. have designed a blocking-press which can be worked by hand or otherwise. It consists of a screw fitted with a machine-cut worm wheel, driven by a steel-cut worm by fast and loose pulleys. A reversing motion is arranged for the quick withdrawal of the platten. This is carried on two strong steel columns, bolted to the base. The platten proper has a detachable platten cottered to it, on which are letters for branding the block rubber. The box is detachable, therefore any number of boxes can be used with the one press. Each box is fitted with two strong wrought-iron bridles, with four powerful screws. After the crêpe rubber has left the vacuum-dryer it is pressed in the box, and when under pressure the bridles are brought over to an upright position. The bottom of the box is hinged and allows the block to be forced out by four vertical screws.

This press is also fitted with a hand motion, which is quite satisfactory in the absence of mechanical power. The power required to drive by belt is from 2 to 3 H.P. The boxes are of different sizes. The total weight of this press is about 17 cwt., with one box.

The same firm has patented a hydraulic block-press which appears to be useful for blocking rubber. By the use of hydraulic pressure, a known total pressure can be put upon the rubber being pressed, and the pressure can be regulated exactly in accordance with requirements.

The machine consists of a hydraulic cast-iron ram, fitted into a strong hydraulic cylinder, with U leather packing arranged to work at a pressure of 1,200 lb. per square inch. The base of the cylinder is arranged to carry an improved design hydraulic pump, operated by hand-lever, with relief valve and hydraulic pressure-gauge.

A strong cast-iron rising table is fitted upon the top of the ram, and an extra strong cast-iron head, fitted with lifting eye and mullet or ram of sufficient length, secured to same to admit of its passing into the box when placed on the table, and so press the rubber to the necessary thickness. The cast-iron head is supported by four turned steel pillars, secured by hexagonal nuts to the head and cylinder mentioned.

The table is arranged to receive interchangeable boxes 14 in. by 12 in. by 9 in., which are fitted with runners on rails secured to the pillars, and quickly run away to any part of the works, Each box is arranged to run on wheels, and fitted with two strong wrought-iron bridles, with four powerful screws.

Comparison of Present Plantation Forms.

The various forms which have been here described have now been known to manufacturers for several years, and the advantages and disadvantages of each publicly discussed on several occasions.

The "India-Rubber Journal" published the views of manufacturers on this subject in the latter part of 1907, and pointed out that though the experimental phase in the preparation of rubber in various fancy forms was almost past, and crêpe, sheet, block, and biscuit were the predominating types on the London market, yet the original biscuits still appealed to certain manufacturers, apparently because they could be easily examined to ascertain their purity ; sheet similarly appealed to many manufacturers in virtue of its purity and the fact that it had not been subjected to any mechanical treatment. At the present moment the demand is mainly for thick, blanket crêpe or clean, smoked sheet.

As far as the producer is concerned, biscuits and sheets are prepared in the same manner and at the same cost, but the rectangular form is preferred for convenience in packing. Biscuits and sheets, owing to the very long time required to effectively dry them, are not popular, except on small estates. To the planter there is another strong objection to biscuits and sheets : they must generally be prepared in small pans by the slow-setting process, requiring big factory space and a waiting period of over twelve hours, whereas the whole of the day's latex can be converted into rubber in one receptacle in the space of a few minutes. The manufacturers who still prefer biscuits request that these pancakes be as thin as possible. Those who prefer plantation rubber in the form of sheets specify that the sheets should be fairly thin; one firm also suggests that they should be from two to three feet wide by two to three yards long.

Branding of Plantation Rubber.

Manufacturers have strongly advised planters to brand all their rubbers. They demand, and planters have every reason to respect their request, that plantation rubber must not be variable in appearance, composition, or physical properties. They advocate branding the rubber from every estate, because this is the only way in which they can overcome the difficulties consequent on the acknowledged variability of plantation rubber. First-quality rubber from one estate known to the manufacturer by its mark is bought and used by the same firm for the same purpose time after time. There is less variability in first-grade qualities from one estate than from several plantations, and if the manufacturer cannot get his rubber from a plantation the mark of which is already known in his works, there is bound to be confusion and trouble in the near future. Several plantation companies have already made their name, and their mark is a guarantee of quality and uniformity to manufacturers; there will be less difficulty in disposing of the produce from such estates than from properties without a name or reputation.

At present, speaking generally, block, sheet, and biscuits are marked, but in the case of crêpe, scrap and other forms, the mark is usually only on the packing case. Block rubber may readily be impressed with the necessary mark on one or both surfaces in the process of blocking. Biscuits and sheets are stamped before they are dry, and when the rubber almost resembles dough. With crêpe it is different, because when it comes out of the machine it is hard, and therefore very difficult to make an impression upon. Yet it is stated that it may be distinctly marked by being passed between metal rollers, on one side of which the desired mark or name has been cut. The marking of the packing cases alone is as likely to aid as to prevent fraud.

A branding press for sheets, biscuits, etc., has been put on the market by Messrs. Shaw & Co.

Proposed Grading of Plantation Rubber.

A suggestion has been made that plantation rubber should be graded as No. 1, No. 2, and No. 3 latex, and be sold as such without the estate being specified. The object is to enable forward sales to be made. This will, it is mantained, if successful, tend to class all sheets, crêpe, etc., as of one value. If manufacturers are going to use plantation rubber as fast as it is produced, it is absolutely necessary for them to know what they are getting when they buy, so far as high qualities are concerned. At present they can specify marks for which they are willing to pay a premium; but, if in the future they can only buy No. 1 latex, they will not know exactly what they are getting, as any lot of this grade may include the produce from a number of estates.

Packing of Rubber.

In packing plantation rubber, the cases should be strong and well hooped. When, as happens sometimes in Ceylon, the rubber is sent to the shipping-port packed in weak tea-chests, it should be repacked in stronger cases. This is not always done, and there are serious complaints of exposure of the rubber to deteriorating influences through breakage of the cases. It is of interest to know that most of the rubber shipped from Para is put into cases made of imported American pinewood. The inside of the cases should be perfectly clean, smooth, and free from sawdust and splinters. Lining with paper or cloth or dusting with fuller's earth is undesirable.

Sheet and crêpe should be packed flat and folded to fit the usual size of case. It is not advisable to roll sheet and crêpe for purposes of packing, though a few estates do so.

Shape and Weight of Cases.

The shape of packing-case that undergoes handling the most satisfactorily is that which is almost cubical; the measurements of a typical case are 19 by 19 by 24 inches. Oblong cases seem generally to fall to pieces, and on arrival at the wharf may be found tinkered up with odd pieces of wood. A case of the above size will weigh about 20 lb. It is the practice on some estates to enclose the case in gunny, which renders the detection of pilfering simple. Another provision against pilfering is to use wooden instead of steel hoops.

The Ventilation of Cases.

The desirability of ventilating cases in which plantation rubber is shipped appears to be questionable. Some manufacturers have suggested that planters should ship their rubber in air-tight cases, but, on the other hand, a few planters have had cause to regret having adopted that system, owing to the arrival of their rubber in Europe in a heated condition. It is obvious that block rubber has an advantage over sheet and crêpe in so far that proportionately less surface is exposed to the air; one might, therefore, feel inclined to argue that packing in air-tight cases, to minimise oxidation, would be advantageous. But one must realize that it is impossible to ship rubber in vacuum cases; air must always be present. To lock up rubber in an air-tight case may simply result in imprisoning foul gases during transit, and if there is any tendency towards tackiness at the time of packing the whole consignment may arrive as a treacly mass.

Bearing upon this point is the history of samples of rubber that were taken from block rubber prepared on the Lanadron Estate, and were carried about by Mr. Jas. Ryan for two and a half years. One that was allowed to remain loose in a kit-bag or suit-case, seldom being wrapped even in paper, retained all its qualities. The other, fixed to the lid of an air-tight metal case, began to degenerate within three weeks and became hopelessly tacky.

Fractions of a Pound.

The exact weight of rubber in each packing case is also a point worth considering. Fractions of a pound of rubber in a case are always in favour of the buyer, no allowance being made for such to the seller. It would therefore appear to be advantageous to the seller to carefully weigh the cases before shipment, and after allowing for the average loss in weight during transit, to add a few ounces of rubber in excess of the full pound. It is obviously better for the seller to receive payment for 200 lb. and ose the value of two or three ounces in excess, than to receive credit for only 199 lb. and lose the value of twelve or fifteen ounces through a deficiency of a few ounces below a full pound. A wharfinger to whom this idea was suggested gave it as his opinion that it would be almost an impossibility for the shipper or packer to put in the few odd ounces suggested. Practically all rubber loses a certain amount of weight between the time of shipment and arrival at its destination. These losses vary very much according to the description and quality of the rubber, and though as a rule with most estate rubber the loss is fairly regular, it would, in his opinion, be impossible to calculate it to such a fine point as would be required by my suggestion.

Sorting During Packing on the Estate.

It is very important that the lots sent home be uniform in quality and not of a mixed character, and though, on the other hand, subdivision into very small lots is a disadvantage, this is a less important consideration. Lower prices result if there is want of uniformity either in individual packages or in lots. Different colours should be kept separate, and, where it is practicable, rubbers from trees of different ages. All mottled or otherwise damaged pieces should be kept together in a separate lot. Where efficient sorting of the rubber results in smallness of lots at any time, the best plan is to accumulate the particular grades until they are sufficiently large in quantity to be marketable. As a matter of fact, rubber delivered against a forward contract (London) must be presented in lots each of not less than ten tons.

It will amply repay planters to grade their rubber better than they have done in the past. This point is one which brokers, too, might bear in mind, as we have reason to believe that more care might be bestowed by them in the offering of rubber of variable colour in the same lot. In the past brokers have sometimes been able to obtain small premiums for a difference in colour, and in such cases every care has been taken to keep the colour-grades separate ; now, and in the future, when premiums for novelties in colour and thickness cannot be obtained, there may be a tendency to offer lots of a mixed character—a course which is obviously likely to do considerable harm to the grower.

Packing of Tacky Rubber.

It is most necessary to isolate all rubber as soon as symptoms of tackiness are presented, otherwise the condition may spread and affect large quantities of rubber in the factory. Dipping tacky rubber in a 2% solution of formalin is said to check the spread. All tacky rubber should be sold as soon as possible, and not be allowed to accumulate in the factory. In packing, care should be taken to remove any samples of rubber presenting sticky surfaces or spots. All such material should be packed in separate cases.

Small Lots of Rubber.

Representations have been made regarding the difficulties which some brokers experience in disposing of small, classified lots of rubber frequently received from individual estates in the Federated Malay States and Ceylon. Planters appear to be very anxious to keep all grades in separate packets, a principle which should be continued, and against which no objection can reasonably be made. But it is, in the sale room, very difficult to provide space for, and to dispose of, very small quantities of graded rubber to the best advantage as separate lots, and before long it is anticipated that brokers will be compelled to sell such consignments, from each estate, as one lot or accumulate small lots until they have about 1 cwt. of each grade. In one instance there were no less than six grades in a consignment from one estate though the total weight was only 1½ cwt. Up to the present time many brokers have been able to dispose of their small lots in separate batches, according to grades, but when numerous estates begin to tap their rubber trees the difficulty may, especially during the next couple of years, become a very serious one. It has been suggested by some brokers that planters would be acting wisely if they agreed to the sale of their small lots as one lot ; it would certainly be to the convenience of brokers and buyers. Each small lot could be packed separately, according to quality, and these placed in one box without any difficulty.

It is generally desirable to keep back the lots until there are 2 or 3 cwt. of each ready for shipment.

Rubber in the Wharves.

A statement is necessary regarding the treatment to which rubber is subjected on arrival at, and while stored in, the London wharves.

The cases of rubber are lightered up from the import ships to the quays of the various warehouses, and are immediately deposited on the floor of the warehouse, the latter having certain floors set apart for the purpose. The gross weight of each case is then determined as a check against the weights marked on the cases or in the specification. The cases are then emptied and the rubber inspected and sampled. This is done in buildings usually well lighted, and provided with fire-proof floors; the contents of each box are kept separate. Care is taken to keep the rubber clean and free from impurities, such as chips of wood, dust, etc. The samples are selected to represent the contents of each case, and are forwarded to the selling brokers, the cases being then coopered, tared, re-filled and weighed, and then stored in vaults or cellars reserved exclusively for this purpose. It should be noted that almost all grades of wild rubber except Para arrive in bales.

In the work of emptying, sampling and re-filling, some wharfingers prefer a top light, others a well-lit floor without a top light. Where top floors are used, the temperature and light, especially in hot weather, may lead to discoloration and excessive loss in weight. The rooms are usually maintained at a uniform low temperature and well ventilated and not too dry. Dryness may with wet, wild rubbers encourage a great loss in weight due to evaporation of water, a point of some importance if and when the rubber has to be stored many weeks or months.

Sorting at the Wharves.

The rule in re-filling (after taring and sampling, is that the rubber is made up again in exactly the same lots and cases. When so instructed, the rubber from several cases is repacked into a single box by the wharfinger, who may not use his discretion as to what lots may go together.

If, on sampling the rubber, it is found to be mixed in quality and colour, the attention of the merchants or the selling-brokers is called to the lack of uniformity. Usually, orders are then given to sort the rubber to quality or colour as the case may be, but this is never done by the wharfingers in the absence of instructions to that effect. It is obviously necessary that the sampling and sorting be done by those having an adequate knowledge of the article so as to detect those differences in quality and colour which represents even a small difference in value; experienced men are engaged on this work.

It is worthy of note that the regulations of the insurance companies do not allow rubber to be stored on the working-floors, neither do they allow other produce to be worked on the floors set apart for rubber. The rubber is taken away to the special vaults as soon as possible after it has been worked and sampled.

CHAPTER XXVII.

PLANTATION RUBBER: ITS CHARACTERS AND COMPARATIVE VALUE.

Having discussed the various methods of preparation and the present forms in which plantation rubber is now shipped, I propose to deal with the characters and comparative value of plantation rubber from Hevea trees. This is advisable in view of the diverse opinions expressed by leading authorities on the uses to which Hevea rubber from plantations can be applied. It is necessary to take into consideration the composition of plantation rubber, and to detail the results of various physical tests on it. The first of these subjects is more fully dealt with in the chapter dealing with the chemistry and physical properties of rubber.

Composition of Hevea Rubber.

The most striking feature of plantation Hevea rubber is its purity, and therefore the small loss on washing, compared with fine hard Para. Samples of plantation Hevea from Ceylon, Malaya, Africa, and the West Indies have been shown to possess from 93 to over 95 per cent. of caoutchouc; the resins have varied from 1·6 to 5·83 per cent.; and the proteins from 1·25 to 4·20 per cent. The water in plantation samples rarely exceeds 0·6 per cent., whereas in fine hard Para it may vary from 10 to 20 per cent. It is on account of the small quantity of moisture in plantation rubber that the loss in weight during transit from the East to London rarely equals 1 per cent., an allowance of ½ per cent. being usually sufficient. This high standard of purity applies to all except scrap grades, and gives to the plantation product the high reputation it deserves. Notwithstanding the small loss on washing, plantation Hevea rubber has not always secured a premium over comparatively wet fine hard Para. A higher price per pound is, in my opinion, bound to be paid for plantation grades when they dominate the market in point of quantity as well as quality.

Physical Characters of Plantation Hevea Rubber.

It has on many occasions been asserted that chemical analyses alone do not give any indication of differences in physical properties and when used in reference to plantation rubber may give rise to erroneous conceptions. Elsewhere it has been shown that rubber from Hevea trees in Ceylon, varying in age from 2 to 30 years, showed only small differences in chemical composition, though the physical characteristics of the various samples were widely different. It is, therefore, necessary to use additional tests, of a physical character, in determining the value of plantation as against fine hard Para, though it is not impossible that it will ultimately be shown how the physical properties are associated with the quantity and character of the substances indicated in the chemical analyses.

It is seldom that the valuation of plantation rubber is based on chemical analyses alone. On the other hand physical characters are sometimes of very little value. For instance, colour cannot be accepted as a guide, some manufacturers giving preference to pale amber and others to dark, smoked rubber. Only in the case of really bad samples can odour be taken as indicating quality, as the best samples have often a cheesy, putrescid smell which is more or less transient.

Early Tests with Plantation Rubber.

Clayton Beadle and Stevens published (Chemical News, July 26th, October 18th, and November 15th, 1907) an account of their experiments with plantation rubber. They vulcanized samples of plantation and fine hard Para rubber; the products from the former were clear, transparent, yellow to brown shade when viewed through sheets 1 mm. thick; the latter were much darker and less transparent. The average tensile strength of vulcanized plantation samples was 3,187, and that of vulcanized fine hard Para 3,013. The average elongation at the moment of rupture for the plantation lots was 13, and for fine hard Para 12·7. The elongation under a strain of 1,500 grammes, less than that necessary to rupture, was 8·9 and 9·3 respectively. Beadle and Stevens therefore concluded that the plantation product would prove equal to Amazonian Para. They also subsequently proved in their tests on vulcanized plantation rubbers prepared from block rubber containing mineral matter, that the addition of mineral matter had the effect of increasing the tensile strength while reducing the elongation.

These results are very interesting, but at the outset it should be pointed out that probably the best block plantation rubber on the market was dealt with. A persual of the results gives one the impression that plantation rubber is at the present time quite equal to, if not better than, hard fine Para. Manufacturers, whose experience in this regard is surely unique, are not all of this opinion. It is, nevertheless, believed that latex obtained from mature plantation Hevea trees, and coagulated in the proper manner, is not, in the long run, likely to prove in any way inferior to wild Hevea latex. The reasons why there is lack of "resiliency" or "nerve" in much of the plantation product must be looked for in other directions, particularly in the tapping of immature trees, and the employment of methods of coagulation, washing and curing which are not quite suitable.

Tests made by the same chemists on a sample of Ceylon biscuit did not give such good results as those made upon block rubber, though they were even then not very different from the results found in the case of fine hard Para.

Beadle and Stevens also published the results of their tests with hard-cure which had been washed and dried by a manufacturer and was therefore in the exact condition in which it would be used by the manufacturer himself. The hard-cure Para supplied by the manufacturer yielded lower figures for tensile strength than the plantation rubber. The average elongation at rupture was greater and the elongation under a stress of 1,500 grammes was also greater. They concluded that different forms of plantation rubber differed materially from one another, and suggested that planters would require to consider carefully whether the form in which they were shipping their rubber was that which gave the best results to the manufacturer.

Tests by Schidrowitz and Goldsborough.

Schidrowitz and Goldsborough (Journ. Soc. Chem. Ind., Jan., 1909), examined samples of Ceylon plantation rubber from trees of different ages, submitting them to mechanical tests and determining their viscosity in benzene solution, the latter quality being, it is said, indicative of "nerve." A sample of fine hard Para was also examined :—

Age of Trees.	Result of Broker's Hand Test.	Elongation at break.	Breaking strain. *	Co-efficient of resiliency. *	Calculated viscosity (Benzene = 1).
A. 8 yr. trees	Weak	4·5	58	21·6	1,000
B. 6-13 ,,	Fairly strong	8·0	52	24	6,653
C. 30 ,,	Very strong	9·75	218	57	8,843
Fine hard Para	Fair, but old	10·0	406	75	7,253

* Grammes per sq. mm. of cross-sectional area.

The authors made the following comments :—"The general superiority of C and the Brazilian specimen over A and B is obvious. The inferiority of B is not so marked, however, in regard to viscosity as with respect to the other factors, and we suggest that it is possible that we have here a case where a rubber is relatively weak as regards its mechanical structure, but fairly satisfactory with respect to the chemical or physical structure of its mass. It will be noticed also that, whereas C is inferior to the Brazilian specimen with regard to breaking strain and resilience, its viscosity is superior to that of the latter. We think that in the case of the Brazilian product there is not the slightest doubt that a considerable proportion of its mechanical strength is due to purely mechanical causes, and that comparing it with C the viscosity figures are probably a better criterion of the relative 'nerve' of the actual rubber substance of the two specimens than the tension results.

"Another point of interest is that the specimen A, which is inferior to B in every other respect, shows a rather higher figure for breaking strain. We think the explanation of this point is not far to seek. This specimen (A) contained a good deal of insoluble matter, and experience has led us to know that the presence of a certain type of insoluble matter in rubbers indicates that they have gained somewhat in toughness at the cost of elasticity and resilience. In such cases the breaking strain may be comparatively high, but the elongation and resilience are always low."

To these viscosity determinations can now be added others made later by Schidrowitz (Rubber, 1911) :—

				Viscosity.
Plantation, from young trees,		crêpe	decidedly "short"	1,000
Do.	do.	do.		1,400
Do.	do.	do.		1,400
Do.	do.	thin crêpe		4,400
Do.	do.	biscuit		8,800
Do.	from old trees,	block		10,000
Do.	do.	thick crêpe		7,000
Fine hard Para,	rather poor and old			9,000
Do.	good specimen			12,000-14,000

Tests by the Continental Rubber Co.

At the last International Rubber Exhibition eight samples of plantation rubber on exhibit were tested along with one of fine hard Para by the Continental Rubber Company of New York. Only two of the series—unsmoked sheet from Glenealy Estate coagulated with acetic acid, and some spindle rubber prepared in the Brazilian fashion at the Singapore Gardens by Mr. Derry—were comparable with fine hard Para :—

	Breaking Strain.		Resiliency.		
	Weight lb.	Extension inches.	Pull lb.	Pull after 5 minutes lb.	Permanent set after 5 minutes extension & 5 minutes rest.
Singapore Spindle	58	9½	21	17½	10
Glenealy Sheet ..	64	8¾	25	21½	10
Fine hard Para ..	58	9½	19½	17	8

The breaking strain was 6 lb. more for Glenealy sheet than for fine hard. Resistance to pull was greater in the case of both plantation rubbers, 5½ lb. and 1½ lb. respectively ; and 3½ lb. and ½ lb. after five minutes. The figures represent a permanent set of 7·81 per cent. for both plantation rubbers and 6·25 per cent. for fine hard Para, an advantage in favour of the latter of 1·55 per cent. Thus, the plantation rubbers were the tougher, and the Brazilian the more resilient. The Glenealy sheet was from trees 12 years old or younger, and the acetic acid used in coagulation was in strength equal to 0·31 per cent.

Two other samples of smoked sheet from 20-year-old trees, and smoked biscuit, both from the Singapore Gardens, were also tested. The results were quite dissimilar :—

Time of Vulcanization. minutes.	Breaking Strain. Break. lb.	Unbroken. lb.	Extension. inches.	Resiliency. Pull lb.	Pull after 5 minutes. lb.	Permanent set after 5 minutes extension and 5 min. rest.
Smoked sheet :—						
50	—	39	9½	13	10½	11
55	47	—	10	15½	13	24
45	—	41	10¼	13	10½	15
Smoked biscuit :—						
50	—	41	10	12½	10½	14
55	40	—	9½	13½	12¼	12
60	75	—	9¾	19	17	8

The smoked sheet was therefore incapable of giving good results with any vulcanization period, while the smoked biscuit, when the right period was found, gave very good results. No information was available as to the probable causes of difference between the two rubbers.

Tests made in New York.

Samples of plantation rubber from Malaya were examined independently by a number of chemists in a New York laboratory, and among the conclusions arrived at were the following (Straits Bull., March, 1910) :—

(1) The potential strength of the plantation product was inferior to that of fine hard Para.

(2) The stretch was satisfactory for all practical purposes.

(3) The plantation product has slightly less resin than fine hard Para.

(4) Plantation rubber has slightly less mineral matter.

Does Age of Trees Affect Quality?

Schidrowitz tested a series of samples from trees varying in age from 6 to 30 years, and found unmistakable differences among them. The samples from older trees were remarkably good, and for manufacturing purposes were equal, if not superior, to fine hard Para. The same can be said of samples from 2 to 30-year-old trees examined in Ceylon.

A more recent series of tests made in New York, in the laboratory already mentioned, upon rubber from trees 4½, 5, 9, 10, 17, and 27 years old respectively, justified the conclusion that rubber from young trees is not materially different from rubber from older trees. And Beadle and Stevens appear to believe that the quality of the rubber is not affected by the age of the tree which yields the latex.

Plantation Rubber in 1907.

The use to which manufacturers put plantation rubber is probably the best testimony. It is now bought at the rate of over 15,000 tons per annum, and must be used by someone even though the users may regard it as inferior in some respects to fine hard

Para. The "India-Rubber Journal" (Sept. 23rd, 1907), in order to obtain a definite pronouncement on this subject at a time when plantation rubber was not well known, circularised manufacturers and asked them if they would state for what purposes they found plantation rubber (a) useful and (b) useless. One firm replied that they found plantation rubber useless in the manufacture of elastic thread, and that they had no special purpose for which plantation rubber could be used; whilst another firm, which frankly pointed out that competition in business did not permit their informing the public for what special purposes they found plantation rubber useful, hastened to state that for several purposes they found this class of rubber useless! Other firms replied that they found plantation rubber useful in the making of buffers, soles and heels for boots and shoes, motor tyres, etc.

These replies were received when plantation rubber was only available in small quantities, and at a time when prominent firms had not seen the advantage of taking up the product from Eastern plantations. We can now detail the advances which have been made in the use of plantation rubber.

The Manufacturer's Point of View.

So far in this chapter attention has been paid mainly to what the scientist has to tell us. Now we may consider those points which appeal to the manufacturer and may learn the very little that he chooses to divulge regarding the behaviour of plantation rubber in the factory.

The purity of plantation rubber and its dryness, with in most cases its lightness of colour, have been prominent factors in gaining favour for it. The saving in buying a purer and drier rubber—a treble saving when washing in the factory is not added to the cost of manufacture and depreciation of "nerve" during this process is avoided—has enabled the plantation product to hold its own against fine hard Para when the tapped trees have been comparatively young, when small and uneven lots have been sent to the market, and when, speaking candidly, the planter has been serving his apprenticeship in the production of rubber from latex.

Solution appears to have been at one time the destination of most plantation rubber, but the sphere of usefulness of the latter is enlarging as the quality improves and as the conservatism of the manufacturer is dispelled. He has often, in the past, had just grounds for complaining of plantation rubber, but that the justification for these complaints is disappearing is evident from the testimony given below of the increasing adoption of plantation rubber. Unfortunately, the hands of the manufacturer are in many cases tied by clauses in contracts that specify the use of fine hard Para.

The old complaints regarding the keeping qualities of plantation rubber are now becoming rarer, especially in face of the thorough smoking so often practised.

Upon the question of the keeping qualities of the vulcanized rubber one public declaration has been made which it would be desirable to have confirmed or otherwise by the manufacturers. It has been stated by Dr. Esch that cold-cure goods made from some kinds of plantation rubber cannot be stored in the shop for a period of many months. He also asserted that some large manufacturers in Germany and Russia, giving a five years' guarantee with their goods, cannot use plantation rubber, though they can use sernamby.

Upon the question of mechanical qualities there are differences of opinion. It is difficult to learn what is the real state of affairs, for the manufacturer as a rule will not give us his confidence; only scattered references are therefore available. In this connection one may direct attention to the results already given in this chapter of mechanical tests carried out in the laboratory. When one reads that plantation rubber vulcanizes badly, or that the ultimate product is inferior, one wonders to what extent the methods suitable for fine hard Para have been modified to suit a rubber prepared in a different fashion.

Lack of Uniformity in Plantation Rubber.

Upon the question of uniformity in qualities and in behaviour during vulcanization complaints have frequently been made, and certainly they have often been justifiable.

A serious disadvantage that may attach to any lot or to any grade of rubber from the manufacturer's point of view is uncertainty as to its behaviour during vulcanization. This matter requires the careful attention of the planter upon whom lies the burden of acquainting himself with the nature of the complaints.

One complaint is that made by Mr. A. D. Thornton, of the Canadian Consolidated Rubber Company, Montreal (I.R.J., Oct., 1910), who thus expresses himself: "If you will permit, I would like to give you the reasons why we, as large manufacturers, are forced to use "fine hard" in preference to "plantation." We have used plantation rubber from the time it first came on the market, and we are still large users of it, but we realize that while improvements have been made, it is still far from what it should be. I refer to its lack of uniformity. At the moment I have in mind a ten-ton lot we are using at present. It comes as No. 1 biscuit; there are many shades in colour, the resinous extracts vary considerably, the tensile strength (when vulcanized) varies very considerably, but most serious of all is its variation as to vulcanizing. With five samples selected from one case, we mixed the same amount of sulphur and litharge, and vulcanized it in moulds at the same time, and it shows unreasonable variations in the results; some were fully vulcanized, some over and some under-vulcanized."

This was followed up by Mr. Thornton with a further expression of opinion: "We have tried large and small parcels;

the result is not satisfactory. I enclose two biscuits taken from the same case. You will note the branding is identical, yet they differ in colour, elasticity and time for vulcanization. The swell in benzene shows a still greater variation.

"If a dark biscuit is of a different nature to a light biscuit, that difference prevails all through the process of manufacture. We don't object to the shade as a shade, but because it represents differences in composition, consequently many vexatious troubles for the technical man in the factory. Para is not uniform. I know it, but it is reasonably so, whereas plantation grades are not."

The two biscuits were shown to the head of one of the principal broker's houses in London, and he expressed surprise that two samples differing so widely in colour should have been sold in the same case.

An endorsement of Mr. Thornton's statements was made (I.R.J., October, 1910) by Mr. Brierly, F.C.S., manufacturer and chemist, who remarked that, with very few exceptions, his firm was experiencing the same difficulty and variations, and that the uncertainty and fluctuating vulcanization of plantation rubber appears to be an increasing evil both in the hot and cold-cure, so much so, that his firm was seriously curtailing its use of it and was going back to the old standard wild rubbers.

Another authority, after having visited America, and who previously had considerable experience in testing plantation as well as other rubber, gave it as his opinion (I.R.J., October, 1910) that the variation was more pronounced with rubber used in the United States, and probably also in Canada, than it was in Great Britain. He noticed when in the States that plantation lots which manufacturers there had were of a very mixed description, biscuits and sheets of various qualities and colours being all mixed up in one and the same case. Many manufacturers with whom this subject has been discussed agree that the plantation product varies very widely in regard to strength.

On the other hand, Stevens, who pointed out that fine hard Para itself is by no means absolutely uniform, stated that two good samples of plantation rubber, of different origin, and giving distinctly different results when vulcanized under uniform conditions, were submitted to a large manufacturer who reported that they did not differ from one another more than two samples of fine hard Para taken at random.

He cites also a case similar to that described by Mr. Thornton. Considerable difficulty was experienced in some rubber works in obtaining uniform results, on vulcanization, of articles cured in moulds under apparently uniform conditions. In this case, however, the rubber, although a Hevea rubber, was not a plantation product, but one of the well-known South American brands.

He maintains that both in colour and time of vulcanizing certain grades of Hevea rubber from Eastern estates with a wide reputation exhibit great uniformity.

Causes of the Variability.

Upon the causes of this variability one chemist has suggested that merchants on this side were probably mixing up odd lots and were sending them across to America. He was satisfied that, on the whole, the trouble lay here and not in the East. This point has been cleared up by enquiring into the methods of dealing with rubber at the wharves, where, on instructions, the contents of several cases may be repacked into larger cases for shipment abroad.

Mixing of Lots on Small Estates.

Now, biscuit and sheet rubber is frequently prepared by planters when dealing with small crops ; and it may be accepted that the mixing up of odd lots is one natural result of the small crops that are being turned out as yet from some young estates. That an improvement can be expected, so far as this factor alone is concerned, is certain when large estates are producing considerable quantities of rubber. We may take it that time will lead to improvements and that the range in variability in any lots put on the market will be within the limits desirable in manufacture. At any rate, with such large crops as will be available in the future, manufacturers will be able to supply their needs, keeping to particular brands with which they are familiar.

Factors Causing Variability.

Some of the factors causing variability will, in the course of nature, or as a result of improved methods, become equalised ; others are beyond equalisation or can be dealt with only slightly. On the one hand, there are those inducing inequalities in the latex ; and on the other, those arising during preparation of the rubber. The first group includes age of trees, altitude of estate, soil, moisture, and climatic conditions, the quality of the water used for dilution, and natural variations among the trees. The second includes the length of time elapsing between tapping and coagulation, the time taken in coagulation, the strength of coagulant used, the nature of the coagulant, the time elapsing between coagulation and washing, the amount of mechanical treatment during the washing operations, variations in drying methods (rate and temperature) and the pitch to which they are carried, and such personal factors as the attention of the operators in the factory. Though the first group is beyond our control, the age factor—probably the most important of all—will remedy itself in course of time. The second group is to-day under continuous observation and improved methods are being daily effected, especially in the use of acids and thorough washing without undue tearing and stretching.

Direct Use of Plantation Rubber.

The question of the direct treatment of plantation rubber for mastication and mixing is one of considerable importance. If the latex is properly coagulated, and the resultant mass thoroughly washed and dried on the plantations before exporting, it would appear superfluous for the manufacturers in this country to go through the whole process a second time, especially when the rubber arrives in the excellent condition in which it is now being received from well-equipped estates. This would save the manufacturer the trouble of softening in warm water, followed by the washing and drying operations, the latter being a particularly slow process, especially if the rubber has to be stored for the purpose of allowing it to regain the peculiar physical condition in which it yields the best results on vulcanization.

The above remarks have been borne out by actual experience in the factory, and plantation rubber has in some cases been directly used. For reasons before explained, this does not apply to biscuit and sheet, but only to thoroughly washed rubbers.

Behaviour During Mastication.

It was asserted by Esch at the 1911 Exhibition Conference that most of the plantation rubber on the market was unable to stand much mastication. But it was at once pointed out that it is not an unusual thing when two samples differ in their behaviour on the mill, one breaking down more readily and undergoing the milling less perfectly, to have the two after vulcanization of equal quality.

At the same conference, Jaques, who has had several years experience in rubber-mills, took up a somewhat different position to Esch. He remarked that a few plantation kinds do not soften readily on the rolls, and that it is impossible often to get good calendered sheet. But he admitted that there are other kinds that are more amenable on the mixing rolls than hard-cure Para, which behave as well in calendering, vulcanize more readily, and are stronger. When vulcanized under the proper conditions, the finished product, like fine hard, improves with keeping. He considered that the tensile properties of vulcanized first-quality plantation rubber are sometimes equal to those of fine hard Para. On the other hand, there are some smoked and pale kinds that are of better quality than the average hard-cure.

Plantation Rubber for Solutions.

Plantation rubber is said to be preferred by many manufacturers for "solutions" on account of their being able to use it directly without purification. Coal-tar and mineral naphthas are used as the solvents. Fine hard Para, if masticated, appears to be dissolved quicker by naphtha. Biscuits from plantations are sometimes more difficult to dissolve than washed masticated crêpe. Plantation rubbers, if pure, are gaining in favour among manufacturers for this purpose.

Elastic Thread the Highest Test.

It is generally acknowledged that rubber in the form of elastic thread is subjected to the severest of tests. Elastic thread represents one of the highest classes of rubber goods. Upon this point (I.R.J., Nov., 1908), it has been reported that an English manufacturer, who had made a quantity of elastic thread from Lanadron block, found that the results were equal to those obtained from average fine hard Para. He further stated that he saw no reason why plantation rubber in general, when prepared under the best conditions, should not be capable of giving results equal to those obtained with fine hard Para. Another sample of this thread was submitted to a firm of elastic webbing manufacturers, who ultimately described it as "very satisfactory."

This view is not held by another manufacturer, Mr. P. M. Matthew (I.R.J., Feb., 1909), of the Victoria Indiarubber Mills, Edinburgh, who said that he was aware that it was the view of some experts that plantation rubber could be used for any purpose, and that splendid thread rubber could be made from it, but this was not his opinion. He further asserted that there is no doubt that if properly treated, plantation rubber can be successfully employed for most purposes for which wild Para is now used and possibly in time to come it may be used in the manufacture of thread, which is probably the highest test of quality to which it can be subjected. He had made many experiments with the object of determining the relative merits of fine Para and cultivated rubber, with the result that the latter, though available for most purposes, could not be substituted for the former in such goods as elastic thread.

The moral of these two statements appears to be that all plantation rubber is not as excellent as Lanadron block.

Though Mr. Matthew could not admit the availability of plantation rubber for elastic thread, at a later date (I.R.J., Oct., 1910), he claimed for it a utility for most purposes. He pointed out that there are some purposes for which it is still found necessary to employ fine Para in preference to plantation rubber, but not for reasons connected with its durability. The difference in the method of coagulating and curing the two rubbers necessitates different treatment in the various processes of manufacture, but when this is thoroughly understood Mr. Matthew believed that for nine-tenths of the purposes for which wild Para is now used, the best plantation rubber could be employed with equal advantage. He had subjected plantation rubber to severe tests, including those for durability prescribed by the Admiralty and the War Office, and had obtained satisfactory results.

Plantation Rubber for Wire Covering.

Though there is some obscurity in the following extract from a letter by Mr. Henry A. Morss, Boston (I.R.J., Nov., 1910), it is clear that some plantation rubber as at present prepared has at least one limitation. Morss bought a small amount of crêpe rubber in Singapore, and experimented with it, comparing it with South American Para. So far as his own business is concerned, which is the making of rubber-covered wires and cables, the rubber that he bought was not satisfactory. However, he had some further experience with plantation rubber, having bought several small lots, mostly from Ceylon. His experience was that, while plantation rubber is clean, and on the whole has good mechanical qualities, only smoked rubber is suitable for his use. He had been unable to make a compound with acid-cured rubber which would withstand the searching electrical tests necessarily applied. On the other hand, he had been able to do fairly well with smoked Ceylon, although, owing to varying quality, it could not be depended upon for the highest class of work.

Though Mr. Morss is obviously under a misconception as to the method by which smoked plantation rubber is prepared, the fact remains that, in his opinion, it is not entirely suitable. It will be noted that it does fairly well, presumably in withstanding the electrical tests, but beyond this is the objection of varying quality.

Plantation Rubber and Cut Sheet.

At the last International Exhibition Conference, 1911, Esch asserted that the results of experiments carried out by him for a large German rubber factory showed that good cut sheet could be manufactured from second-grade Caucho ball, but they had not been able to make it from the best plantation light crêpe. Yet he admitted that some kinds of plantation rubber could be used; apparently some manufacturers fear that they will not be able at any time to obtain lots sufficiently large for their purpose, lots of a size that they may obtain again as their requirements demand. Terry added to this by saying that it was a well-known fact that plantation rubber did not produce good cut sheet. He also remarked that card-cloth manufacturers used fine hard Para only, and not plantation rubber.

Clayton Beadle and Stevens (Rubber, p. 105) state that not only are lower grade rubbers being used in admixture with fine hard Para for second-grade sheet, but special pale cut sheet is now being made from plantation rubber stronger than that of first quality made exclusively from fine hard Para. They report that plantation rubber, despite its purity, is for cut sheet generally washed by the manufacturer before being used for this purpose.

Plantation Rubber for Tyres.

The reputed inferiority of recently manufactured articles, such as tyres, has been lately emphasized, the imputation being that plantation grades have been used, and that these are inferior to fine hard Para. It has also been stated in my hearing that a well-known Continental manufacturer publicly announced that plantation rubber was not used in the manufacture of tyres made by his firm. We have further been assured by other manufacturers that they have not yet used plantation rubber for tyres. The gentlemen making these statements are connected with some of the very best firms in Europe.

There is, it will be noted, not a single definite statement that plantation rubber cannot be used for tyres, and I do not know of any evidence of its unsuitability as determined in practice, nor of any reason why it should not be used when properly prepared, excepting, of course, rubber from young trees. Had there been any serious objection to its use, one would have heard much more definitely of this. Tyre rubber passes through most severe tests in practice which demand, in a high degree, all the essential qualities of a rubber.

At the last International Rubber Exhibition, one firm manufacturing tyres proclaimed its adhesion to the use of plantation rubber for this purpose. At the conference, Esch stated that in Germany manufacturers are unable to extensively use plantation rubber for tyres, the reason being that very large mixing machines are used, the quantity of rubber necessary to keep them going not being available of sufficient uniformity. Yet he also stated that all large manufacturers who use hard-cure rubber could not use plantation rubber for goods, such as tyres, that have to undergo attrition.

CHAPTER XXVIII.

CHEMICAL AND PHYSICAL PROPERTIES AND TESTING OF RUBBER.

The preparation of rubber from latices having been fully described, it is, before considering the uses to which rubber is put, advisable to discuss the chemical and physical properties of the raw product. The characteristics of Hevea rubber obtained from different parts of the tropical world are of primary importance, and are here considered first. The composition of other rubbers of various kinds from the East, Africa and Brazil is then dealt with.

Composition of Rubber from Malaya.

Variously prepared forms of rubber from the Federated Malay States were analysed at the Imperial Institute (Bulletin V., No 3), with the following results :—

	Moisture.	Ash.	Resin.	Proteins.	Caoutchouc
	%	%	%	%	%
Crêpe, pale yellow	0·22	0·16	2·75	2·27	94·60
Large, thin biscuits, pale ..	0·36	0·29	2·23	2·31	94·81
Thin sheets, pale, opaque ..	0·54	0·48	1·64	2·66	94·68
Crêpe, almost white ..	0·26	0·34	3·58	3·18	92·64
Ditto, dark brown	0·60	0·56	2·89	2·50	93·45
Sheet, very pale	0·38	0·36	1·78	3·08	94·40
Crêpe, almost white ..	0·32	0·18	2·83	2·99	93·68
Large biscuit, pale ..	0·42	0·46	1·38	2·13	95·61
Crêpe, light brown ..	0·28	0·23	2·82	2·10	94·48
Sheet, dark	0·44	0·35	2·45	1·94	94·82
Ditto, pale	0·38	0·28	1·83	2·36	95·15
Ditto, rather dark	0·36	0·34	2·07	2·36	94·87
Ditto, pale	0·52	0·43	2·57	3·06	93·42
Crêpe, yellow	0·42	0·14	3·01	2·90	93·53
Thin sheet, pale	0·22	0·21	1·87	1·35	96·35
Sheet, pale	0·38	0·27	1·75	2·13	95·47
Minimum values ..	0·22	0·14	1·38	1·35	92·64
Maximum values ..	0·60	0·50	3·58	3·18	96·35

Analyses of Ceylon and S. Indian Rubber.

The following are some of the analyses of Hevea rubbers as published in the Official Handbook of the Ceylon Exhibition of 1906 ; the first four rubbers were gold medal samples :—

	Moisture.	Resin.	Ash.	Proteins.	Caoutchouc
	%	%	%	%	%
Duckwari biscuits	0·68	2·32	0·36	3·00	93·64
Arapolakande smoked biscuits	0·28	1·84	0·20	2·12	95·56
Syston sheet	0·30	2·74	0·20	2·25	94·51
Lanadron block	0·36	2·44	0·20	3·31	93·69
Hawthorn Estate, S. India, biscuits	0·60	3·02	0·40	2·82	93·16
Typical weak sheets ..	1·04	3·34	0·36	2·82	92·44
Typical weak biscuits ..	0·68	2·14	0·24	3·00	93·94

Taking the whole of the prize samples, the range of variation was as follows: moisture, 0·18 to 1·18 per cent.; resin, 1·18 to 4·84 per cent.; ash, 0·20 to 0·84 per cent.; proteins, 1·25 to 7·31 per cent.; caoutchouc, 91·89 to 95·93 per cent.

As far as the chemical composition of the rubber goes, there seems nothing to account for the differences in the strength of various plantation and other rubbers. The splendid Duckwari biscuits and "typical weak biscuits" show practically no difference in chemical composition, the percentage of moisture and proteins are identical, and the weak rubber contains less ash and less resin but more caoutchouc than the gold medal sample.

Typical weak shee contains, according to the analyses, more moisture than any of the samples.

The best plantation samples at the Ceylon Rubber Exhibition contained practically no moisture in the majority of cases, there being less than 1 per cent. present, while a typical sample of weak Para sheet contained 1·04 per cent. of moisture.

Messrs. Schidrowitz and Kaye, in the Journal of the Chemical Society, have dealt with the composition of Ceylon biscuits of various thicknesses. Other analyses by the same chemists show that rubber prepared from Ceylon latex possessed from about 86 to over 90 per cent. of caoutchouc, when the moisture ranged from 5 to 9 per cent.

Chemical Composition of Hevea Plantation Rubber.

The following analyses, in some cases averages of analyses, are given by various authorities, including the Imperial Institute, Bamber, etc.:—

	Ceylon.	Bukit Rajah.	Penang.	Straits Rubber, old.	Gold Coast (average).	South Nigeria (average)
	%	%	%	%	%	%
Caoutchouc ..	95·50	95·37	95·00	93·22	95·74	93·0
Resins	3·00	3·02	4·08	1·76	3·58	2·6
Proteins ..	1·25	1·24	?	4·20	?	2·0
Ash	0·25	0·37	0·05	0·32	0·22	0·3
Moisture ..	—	—	0·15	0·50	0·57	2·1

	Nilgiris (average).	Mergui (average).	Martinique (average).	Trinidad (average).	Dominica.
	%	%	%	%	%
Caoutchouc.. ..	91·7	95·2	90·5	91·1	93·0
Resins	3·3	1·6	4·24	3·4	4·2
Proteins	3·3	2·4	3·38	2·1	2·1
Ash	1·1	0·3	0·30	0·5	0·3
Moisture	0·6	0·5	1·58	2·9	0·4

The high percentage of caoutchouc in Hevea rubber, grown in different countries, is so far very satisfactory. It has been shown that whereas the rubber from Hevea under cultivation may contain over 95 per cent. of caoutchouc and less than 4 per cent. of resinous matter, the native African rubber (*Funtumia elastica*) contains less than 90 per cent. of caoutchouc and over 8 per cent. of resinous compounds. From the foregoing analysis it may safely be asserted that *Hevea brasiliensis* bids fair to beat many rubber trees indigenous to tropical areas. Resins in large quantities, proteins, and ash constituents are not required, and in many articles of commerce are injurious.

Composition of Other Rubbers.

It will be seen from the analyses below how much richer Hevea rubber is in caoutchouc than are the rubbers from other plants. Compared with that from Ceara and Castilloa trees, Hevea rubber is much less resinous. Such differences are reflected in the physical qualities of these rubbers. Taking the analyses as a whole, and noting the inferiority in quality of some of the kinds as indicated by their market values, one is compelled to acknowledge that chemical analyses have some real value in such instances.

Ceylon Hevea, Ceara and Castilloa Rubbers.

The chemical characteristics of rubber from Hevea, Manihot (Ceara), and Castilloa trees grown in Ceylon are exemplified in the following analyses (Comm. Agr. Expts., Nov., 1905) :—

	Hevea.	Ceara.	Castilloa.
	%	%	%
Caoutchouc ..	94·60	76·25	86·19
Resin ..	2·66	10·04	12·42
Proteins	1·75	8·05	0·87
Ash	0·14	2·46	0·20
Moisture	0·85	3·20	0·32

African and Eastern Wild Rubbers.

The essential differences in chemical composition between various wild rubbers obtained from Africa and the East are manifest from the numerous analyses published in the Bulletins of the Imperial Institute, London.

The following are a few typical examples :—

	Landolphia Kirkii.	Landolphia Petersiana.	Landolphia Watsoniana.
	%	%	%
Caoutchouc	80·1	67·7	67·2
Resin	6·9	11·1	11·9
Dirt and insoluble matter	5·3	3·4	8·0
Ash included in dirt ..	0·31	1·2	1·3
Moisture	7·7	17·7	12·9

	Species of Ficus.	Ficus elastica.	Urceola esculenta.	Rhynchodia Wallichii.
	%	%	%	%
Caoutchouc	19·6	84·3	80·5	86·5
Resin	49·9	11·8	9·8	6·5[1]
Dirt and insoluble matter	2·1	3·1	5·7	4·2
Ash included in dirt ..	0·79	0·8	1·16	0·48
Moisture	28·4	0·8	4·0	2·8

Relationship Between Chemical and Physical Characters.

It has been previously pointed out that the physical characters of various oils, gums and resins can generally be associated with differences in chemical composition. A slight change in the proportion of certain chemical ingredients, or reduction or oxidation of components in a mixture, often appreciably affects the physical properties of the products under observation. The same may, to a limited extent, be said of various rubbers which regularly appear on the market. An increase in the percentage of resinous constituents may change the rubber to a brittle or sticky mass, and it is already possible to group some rubbers according to their chemical composition and associated physical properties. Chemical analyses, even as submitted to-day in their undoubtedly empirical and undesirable form, allow us to distinguish sometimes the botanical sources of certain latices and rubbers, though the plants yielding them may not at the time be available for botanical verification. But no one can deny that the analyses of rubber as at present submitted often give no indication of the physical differences which exist between samples of rubber obtained from Hevea trees of different ages. This does not necessarily disprove that a correlation exists between the chemical composition and physical properties of the rubber, but suggests that the analyses do not distinguish the differences between the components of the groups enumerated. It is not sufficient to merely state the percentage of resinous, protein, and caoutchouc contents in samples of rubber. This grouping of most of the constituents and the calculation of caoutchouc by difference does not give us any idea of the differences which we are led to believe exist between the proteins involved in the phases of coagulation and those which appear in solution after the complete separation of the caoutchouc; neither does it give us a clear conception of the differences between the components in each of the other groups or between the individual resins and caoutchouc globules in trees of different ages, and in the latex from different species.

Dunstan, in his address before the British Association in 1906, pointed out that the chemical analysis of raw rubber as at present conducted is not always to be taken by itself as a trustworthy criterion of quality, and more refined processes of analysis are now needed. In a recent Bulletin of the Imperial Institute he again emphasises this point. He states that, "at present the caoutchouc is usually determined by difference from the results of the direct determination of the other constituents. All the errors of the analysis are therefore concentrated in the stated percentage of caoutchouc, whilst, in the absence of an accurate direct determination of the caoutchouc, the homogeneity of this constituent in different samples of crude rubber and in rubbers of different origin has to be assumed. The physical characters of rubber are still more roughly determined by the manual tests of brokers, and precise methods of determining strength and resiliency are much needed."

It is, however, the opinion of many that though the chemical composition of rubber may exhibit considerable variation, the physical properties of raw rubber can often be correlated with them. The elastic caoutchouc in the various rubbers is of a very similar chemical structure, and the same may be said of some of the ingredients of raw rubber which have already been isolated.

The Properties of Rubber Constituents.

In the analyses here given it will have been noticed that the constituents previously recorded in the chapter on the composition of latex are still present in the raw product. In most cases, perhaps in all excepting the caoutchouc and proteins, the latex constituents are very similar in their properties to those in the dry rubber. Irrespective of these relationships between the same groups of constituents in latex and rubber, there are many points of interest, chemical and physical, to discuss in connection with each component of the finished raw product.

The Caoutchouc Hydrocarbon.

The caoutchouc globules present in the latex persist (according to Schidrowitz, who examined Hevea and Funtumia rubbers under the microscope in order to determine this point) in the crude rubber Specially prepared sections exhibited globules in appearance and size similar to those occurring in the latex. They were also seen in the solutions of the rubber prepared with benzene, and in the films left after evaporation of the latter. Fickendey cannot confirm this, and believes that the globules lose their identity during coagulation.

The chemical nature of the caoutchouc hydrocarbon is still largely a matter of discussion, though upon the physical side matters are a little clearer. It is a colloid, that is, a substance of very high molecular weight with accompanying physical characteristics. One of the tests of such a body is that, suspended as particles in the form of an emulsion, or as a solution, it will not pass through an animal membrane, as does a crystalline body in solution.

Resins in Rubber.

In addition to the resins already present in the latex, the quantity of resins in prepared rubber gradually increases owing to oxidation of the caoutchouc hydrocarbon, a change that leads to gradual loss by the rubber of its essential physical qualities. Fine hard Para is said to possess from 1 to 4 per cent of resins when obtained from mature trees.

Resins and Age of Plants.

The percentage of resin in rubber appears to vary according to the age of the trees, or the part of the plant, whence it is derived. Bamber analysed samples of rubber from Hevea trees in Ceylon which varied in age from 2 to 30 years. The following are the details :—

	Two years.	Four years.	Six years.	Seven years.
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%

According to Hooper, a more marked difference is observable in the resin from *Ficus elastica* (Rambong) rubber. He states that the percentage of resin varies from about 20 to 30 per cent. in rubber from young trees to less than 10 per cent. in that from older trees.

Weber has similarly shown that in the case of Castilloa rubber the percentage of resin decreases with increase in age. Rubber from eight-year-old trees gave 7·21 per cent. of resin, and that from three-year-old trees 35·02 per cent.

It will be noticed that Hevea rubber does not show the same great reduction in percentage of resin with an increase in age. In this respect Hevea seems to occupy a somewhat isolated position.

Resins and Part of Plants.

There is also a relationship between the percentage of resin n rubber and the age of the section of the tree whence the rubber is derived.

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 :—

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

This increase in percentage of resin as one passes from the old to the younger parts of the plant is very pronounced in Castilloa, and probably occurs, though to a less extent, in many other species.

Resins in Various Rubbers.

The following percentages of resins in various rubbers are given by Weber :—

	%
Para (*Hevea brasiliensis*)	1·3
Ceara (*Manihot Glaziovii*)	2·1
Colombie (*Castilloa elastica*)	3·8
Madagascar (*Landolphia ?*)	8·2
Assam (*Ficus elastica*)	11·3
Mangabeira (*Hancornia* sp.)	13·1
African balls	27·8

The resins are a highly complex class of bodies consisting, as a rule, of a mixture of various constituents ; different resins behave in different ways and their conditions as well as quantity are of importance. It is possible that some resins are not only not disadvantageous, but possibly of advantage up to a certain point. This certainly applies to the harder resins.

Removal of Resins from Rubber.

Though the various "Plantation" and "Wild" rubbers which arrive in Europe contain resin in quantities varying from 1 to about 40 per cent., they appear to be all subjected to a somewhat similar 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 also the stability of the finished article. Owing to the supposed detrimental effect of the resins after vulcanization, no efforts are spared to reduce them to the desired quantity in 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.

The Effects of Resins upon Vulcanization of Rubber.

The presence of resins in plantation rubber and in wild Para and other rubbers has an important bearing upon the reactions that take place during vulcanization. According to the India-Rubber Journal of August 13th, 1906, Dr. R. Ditmar made a careful comparison of several brands of rubber, and communicated the results of his observations to the "Gummi-Zeitung." The amount of resin contained in each sample having been first determined, 10 gram lots of the various brands were vulcanized with 10 per cent. of sulphur at 145 deg. C., under a pressure of 3-4 atmospheres, for one hour, and then tested for elasticity and tensile strength. It was found that fine hard Para, containing 1·44 per cent. of resin, was completely vulcanized and was very elastic. It was only surpassed in the latter respect by Mozambique balls and spindles, Massai balls, and Ceylon plantation rubber. The behaviour of the Mozambique ball was remarkable, for, although it was considerably richer in resins and was not fully vulcanized, it showed a greater elasticity and strength than the fine hard Para with only 1·44 per cent. of resin. The cause of this is probably to be sought more in the origin of the rubber than in the resin it contained. The same properties were also observed in Adeli balls, Lewa rubber, and Soudan twists, although they did not contain such a high percentage of resin as the Mozambique balls. It is therefore concluded from these experiments that, if the amount of resin does not exceed 7 per cent., it does not have an injurious effect upon vulcanization, but when over this amount it tends to prevent complete vulcanization of the rubber. At the same time the origin of the rubber is also of great importance in this respect. More accurate information on this subject, however, would be obtained by vulcanizing Para rubber, for instance, with increasing amounts of resin extracted from one quality of rubber. Accordingly, experiments were eventually carried out in the following way: fine hard Para containing 3·28 per cent. of resin was well washed and dried, mixed in five-gram lots with 10 per cent. of sulphur, and worked up with increasing quantities of Congo resin, extracted from finest black Upper Congo rubber with acetone. Ten such samples were vulcanized for 45 minutes at 145° C., under a pressure of 4-5 atmospheres, then dried, and subjected to physical tests. With the proportion of added resin rising from 3·30 per cent., the breaking strain fell from 9 kilos to 3, whilst the extensibility of the rubber rose from 3·9 to 5·7. The first five samples (3·15 per cent. added resin) were well vulcanized, the remainder were vulcanized throughout, but became gradually softer as the proportion of resin increased.

The percentage of resins in plantation rubber and in fine hard Para is, however, usually much smaller than in many of the other rubbers here mentioned, and the injurious effect of excess of resins may, as far as rubber growers are concerned, be dismissed.

Value of Resins in Rubber.

It has been shown that the amount of resin in various samples of rubber varies considerably; even in different samples known under the same name the quantity may vary quite 50 per cent. As to the value of rubber freed from resin, opinions are somewhat at variance. The Rheinischer Gummiwerke—(cf. I.R.J., Feb. 1907)—claim to be able to place on the market a rubber which for all technical purposes may be considered free from resin. An examination of these resin-free rubbers has been made by Drs. Frank, Marckwald and Leibschütz with the object of determining whether the extraction of the resins from washed crude rubber influences the manufacturing process favourably or unfavourably. They report that the sheets of rubber obtained in the ordinary way from the extracted rubber are in every case less sticky and more uniform than those from non-extracted material. Further, the extracted rubber was described as being brighter in appearance and the smell characteristic of the several brands had invariably disappeared. Physical tests were also made both with the extracted and non-extracted rubbers. Various brands of upper Congo, Madagascar and Gambia rubbers were employed for these determinations, containing varying amounts of resin, ranging from 4 to 38 per cent., which after extraction were reduced from 2 to 9 per cent.

As a result of their experiments on the rubbers from which the greater part of the resins had been extracted, they concluded that: (1) The specific smell of the raw material is removed; (2) its stickiness also disappears completely by extraction of the resins, thus materially assisting mixing operations; (3) the solidity of vulcanized goods made from extracted rubbers of typical bad qualities is invariably greatly superior, being sometimes as much as 50 per cent. better than the non-extracted rubber, and (4) the extraction of resin facilitates uniform qualities being supplied.

The removal of resins from rubbers in this way is of more interest to those planters concerned with Para rubber in the wild state or with other American and African rubbers containing large proportions of resins. It is, however, a subject of interest to all rubber growers as, besides producing the advantages already mentioned, it would effect a reduction in cost of transport and be of importance to the manufacturer. Pure plantation rubber containing less than 4 per cent. of resin would, however, not require such treatment.

Desirable Quantities of Resin.

During the discussion upon a lecture by Schidrowitz (Society of Chemical Industry, May 16th, 1910) Colonel Birley said that the manufacturers required a minimum of resin, and that this should be as hard as possible. A little resin of the right type does no harm in rubber. Good, hard resin had no prejudicial effect *per se*, if there is not more than 6 to 8 per cent.

Other views upon these points were expressed at the Conference held in connection with the Rubber Exhibition of 1911. According to Potts, it is immaterial, speaking generally, to the manufacturer what the percentage of resin is within 1 or 2 per cent. Frank thought that the percentage of resin may or may not be significant according to the nature of the resin, provided it lies within the right limits for that particular rubber. There are hard and soft resins. The former are generally more objectionable. The chairman of the meeting said that the manufacturer does not care whether there is 3 or 6 per cent. of resin.

Crepe from Jelutong.

Probably one of the most recent commercial developments of importance in this direction is the conversion of sticky jelutong from Dyera trees into first-class crêpe, comparable in many respects with that from Hevea plantations. Developments upon similar lines have been recorded with highly-resinous products obtained from *Euphorbia Tirucalli* in Africa. It appears quite possible, if prices for raw rubber are maintained at a high level, that supplies may be appreciably augmented by the extraction of resins from products hitherto regarded as insignificant sources of rubber.

A Resin-Extracting Machine.

A very heavily-built mixing and masticating machine, equipped with a jacketted-trough which can be heated or cooled by steam or water, and also fitted with attachments so that the gums can be treated *in vacuo*, is made by Messrs. Werner, Pfleiderer and Perkins.

Freshly-washed jelutong is taken in its wet condition and put into this machine, which dries it thoroughly, rapidly, and automatically; when dry the resin solvent is introduced and well incorporated with the jelutong. When the resin is dissolved, the solution is sucked out through a pipe and the rubber left behind. The rubber, which still contains a quantity of spirit, can then be washed clean in the same machine. In addition the machine will extract the solvent from the resin solution as a secondary process.

Proteins.

The proteins, which either alone, or with other substances, lead to putrefaction, exist almost entirely in solution in the fresh latex. In the rubber they are reputed to be responsible for much tackiness, for the evolution of objectionable fumes during hot vulcanization, and also for certain cases of "blowing" in vulcanization. Their removal from latex as well as rubber has often been discussed and many experiments have been devised with this object in view.

Removal of Proteins.

Weber suggested that an expeditious method would be to centrifugalize the solutions, a method 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 proteins and (2) to cause the rubber to collect on the top of the mixture. The proper application of this re-agent to Castilloa latex is said to free the rubber from every trace of proteins. It has, however, been questioned whether, or not, the caoutchouc would coagulate or even coalesce, if all proteins were removed from the latex.

There is a slightly higher percentage of proteins and resins in Hevea rubber from young than in that from old plants. The poor physical properties of young plantation rubber may be ultimately associated with the proportion of these constituents.

Torrey (Indiarubber Exhibition Lectures, 1908) suggests a method of getting rid of a large proportion of the proteins. After thorough cutting-up, wash with cold water, following with, say, a 48 hours' soaking in a caustic soda solution of perhaps 2 per cent. strength. He points out that, during vulcanization, sulphuretted hydrogen is evolved by the action of the sulphur upon the proteins. It is certain that many of the obstinate cases of blowing or porosity in rubber goods may be traced to this cause. Furthermore, when these proteins are exposed to the ordinary vulcanizing temperatures in contact with basic substances, such as occur among the ordinary compounding materials, decomposition is almost certain, and will be accompanied by evolution of ammonia, and perhaps other gases.

Thorough washing and drying of the rubber is generally all that is necessary to prevent the decomposition of the protein. The protein in fine hard Para is said to be more or less immune to the action of putrefactive bacteria on account of the presence of cresol.

Distribution of the Proteins.

Spence has shewn that protein is the substance which Weber regarded as an oxygen-addition compound of rubber, and that the so-called insoluble constituent is in every case the protein of the latex. The jelly-like residue left when rubber has been dissolved in such solvents as chloroform, toluol, etc., was not examined by Weber for nitrogen ; had this been done it would have led to the identification of protein. Spence states that the conception of a protein film around each caoutchouc globule, as outlined by Weber, is no longer necessary to account for the peculiar structure and stability of the caoutchouc globule. He found that by digesting the latex of *Hevea brasiliensis* with trypsin, more than half of the protein in latex can be afterwards removed without coagulation taking place. Its distribution depends largely on the method of coagulation employed, a fact which may explain the difference in tensile strength between fine hard Para and plantation rubber. Parkin urges that what militates against this view is that in mastication and vulcanization such structure must most likely disappear.

The following researches upon the distribution of protein in fine hard Para were made by Spence (Quarterly Journal, Institute Commercial Research, Liverpool University, 1907). At first, samples were repeatedly digested in chloroform over long periods for the extraction of the caoutchouc hydrocarbon, as far as that was possible. Some of the jelly-like residue, which dries in bulk to a hard, tough, almost friable brown mass, was spread upon a microscopic slide, and was compressed into a thin film. This film was allowed to dry, when it was examined under a low power of the microscope. "Fibrous-looking threads running in all directions, as if the material had contracted on itself, leaving clear spaces covered with thin films of what appeared to be caoutchouc, were readily discernible." One may remark that any gelatinous or colloidal substance, when dried, is perhaps likely to show this appearance. Spence turned next to the examination of sections of raw rubber, in which, by a certain method, a deposit of metallic silver brought into view a fibrous or thread-like structure running through the mass. He considered that here was the protein.

What we desire to know from such a research is the exact and minute relationship between the individual caoutchouc globules and the protein, and it cannot be said that Spence's methods were efficient from this point of view. He suggests that when the raw rubber is digested in chloroform, the latter passes through the protein and is absorbed by the caoutchouc hydrocarbon, which becomes enormously increased in bulk, but cannot escape, even as a solution, through the protein. The protein walls of the cavities must, therefore, become greatly stretched; and it is by their eventual rupture that the caoutchouc solution escapes. It is unfortunate that Spence bases his decision upon the examination of such a distended and ruptured protein meshwork.

NOTES ON PROTEINS BY SPENCE.

To the above account of proteins in crude rubber I desire to add a series of notes which Dr. Spence has been good enough to compile for me:—

"The nitrogen of rubber is not entirely of protein origin as has been usually held, and we must distinguish between protein-nitrogen and the nitrogenous bodies of the acetone-extract which are of well defined alkaloidal character and are readily isolated by suitable means from Para rubber or its acetone-extract. The distribution of the nitrogen in some samples of Para rubber is shewn in the following table:—

No. of Sample.	Nitrogen in Acetone-Extracted Para Rubber.	Nitrogen in Acetone Extract.
1	0.44%	0.297%
2	0.367%	0.50%
3	0.356%	0.41%

"The protein or 'insoluble' nitrogen of rubber has, until recently, received but scant attention. Recently, however, its importance has become more recognized. In the case of Para and of some other rubbers, I have shown that this insoluble protein exists in the rubber as a fibrous network-like structure which can be made evident by a suitable method of staining. Protein is present in greater or less amount in all latices and invariably becomes bound up in the rubber clot when the latex is coagulated, unless special methods are adopted whereby the protein is eliminated before the final coagulation takes place. It is exceedingly difficult, however, if not well nigh impossible, to remove the entire nitrogen from rubber in this way, and numerous experiments conducted with the object of removing the entire nitrogen from the latex have been only partially successful. Indeed, there can be no doubt that the protein of the latex, colloidal in character as it is, is one of the most important elements in determining the stability of a latex on the one hand, and the ease with which it can be coagulated by certain coagulants on the other. The influence of this 'protective' colloid (*Schutzkolloide*) in problems of coagulation is too well known to require mention here, but to those who have the practical problem of latex coagulation before them each day, no more fruitful field of investigation could be found than that of the influence of various protective colloids on the stability of latex emulsions.

"That it is well-nigh impossible to remove the entire protein from the latex is probably due to the fact that it is adsorbed, at least partially, by the latex emulsion. That these globules are surrounded by a film of protein in the sense as Weber at one time suggested, we have as yet no satisfactory proof, nor does the existence of such a protein sheath around each globule appear to be necessary to explain the existing facts.

"The proteins of rubber appear to belong to the class of the glyco-proteins rather than to the simple proteins. The nitrogen contained in these proteins is very much less than that in the simple proteins by reason of the large carbohydrate complex attached to the former. This complex can be split off and plays a not unimportant rôle in the latex as well as in the rubber derived from it. But we have no reason to believe that the protein of the various rubbers is all alike. On the contrary, differences in the nature of the protein in different rubbers probably accounts to some extent for differences in the ease with which the various latices are coagulated.

"That the insoluble constituent of rubber is of protein character, and is not a carbohydrate as Weber suggested, I have endeavoured in various publications to show. The reactions of the insoluble constituent, the action of the enzyme trypsin on the same, and the peculiar staining properties of the substance, all stand to confirm this belief.

"The retarding influence of the insoluble constituent on the process of solution of raw rubber in solvents is recognized. I have endeavoured to explain its influence in this connection by a theory based on its peculiar distribution in the form of a network of microscopic fibres running throughout the mass, this network being pervious to solvents but impervious to the colloidal rubber solution. If this network is destroyed by working the rubber on the mill, the complete solution of the rubber is hastened. Whether this simple mechanical theory will serve to explain all the phenomena observed in the preparation of a rubber solution or not is still doubtful. The fact, however, that the complete destruction of the protein fibre in raw rubber by mechanical means greatly facilitates the preparation of a homogenous solution of the same goes far to show that the apparent retarding influence of the protein fibre on the rate of solution is of a mechanical rather than of a chemical or a physical nature.

"From the analytical standpoint, the protein impurities in rubber are of even more importance than the resins themselves, for these are readily extracted and determined, whereas the quantitative separation of rubber from protein or of protein from rubber is a much more troublesome task. It is interesting, however, to note that the importance of the protein fibre in this connection is to-day recognised by those most active in advancing methods for the chemical analysis of rubber. The separation of the protein from a rubber solution by filtration or by centrifugalization is barely possible. On the other hand, I have found that these nitrogenous elements of rubber can be almost entirely eliminated by saponification with alcoholic alkali under suitable conditions."

I have quoted the above from Dr. Spence in detail in order that no misconception may arise as to that scientist's views on this important constituent of rubber.

Ash.

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

Spence, as a result of his analyses (I.R.J., Sept., 1907), of Funtumia rubber, concludes that the ash in a sample of washed rubber is remarkably constant in quantity, and supports Weber's suggestion that the ash contents might be employed, when exhaustive investigation of the quantitative composition of the ash of the various brands has been made, as a chemical method of distinguishing washed rubber from different sources. The constancy of the mineral constituents in washed rubber is a point of considerable importance.

Potassium in Washed Rubber.

Spence in his concluding paragraph states "that the percentage of potassium salts to be found in a sample of washed rubber from *Funtumia elastica* may be taken as an indication of the purity of the rubber and the efficiency of the washing process." Whether the same applies to washed Para rubber has not yet been stated by chemists.

Potassium, though it is the chief mineral constituent in the ash from the latex, disappears from the coagulated rubber in the process of washing. In a sample of *Funtumia elastica* latex it was present in the form of soluble salts of inorganic and organic acids and composed about 75 per cent. of the ash of the latex on incineration.

Action of Chemical Agents on Rubber.

The effects of various chemical agents upon crude and manufactured rubbers have been observed. In the latter these are modified according to the nature of the compounding ingredients used, and of the process of vulcanization. An attempt is here made to isolate the facts relating to the effects of chemical agents on crude rubber alone.

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

Copper and its salts have very pronounced effects upon rubber, and rapidly bring about its decay. They accelerate the rate of oxidation of rubber.

The effect of chlorine, bromine, and iodine on 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 indiarubber. Strong sulphuric acid chars rubber on heating. Strong nitric acid attacks it vigorously, forming at first a yellow compound which is subsequently decomposed.

Rubber—crude or vulcanized—tends to become hard and brittle under the action of oxygen in the air. Thus, thin vulcanized goods may oxidise eventually to a plastic condition, and finally to a brittle product capable of being powdered, the addition of oxygen to the caoutchouc molecule resulting in the formation of resinous bodies of which Spiller's resin is the best known. This oxidation is encouraged by light, and by the presence of small quantities of copper or of its salts, and also of oils.

While rubber does not readily react with many common reagents, it does to a surprising degree with sulphur in its various forms, the process of combination being commonly spoken of as vulcanization. Pure sulphur does not combine with rubber at temperatures below 270° F., but sulphur mono-chloride readily reacts with it at ordinary temperatures, a fact that is taken advantage of in cold vulcanization.

Action of Oils on Rubber.

Rubber dissolves in mineral oils (benzene, toluene, petroleum spirit, etc.), in ether, chloroform, carbon tetra-chloride and disulphide, in essential oils (turpentine, terebene, etc.), and in certain fatty oils (neatsfoot oil, sperm tallow). Other fatty oils cause it to swell up. Though preparations of fatty oils are used in rubber-compounding in small quantities, all oils are injurious, and may reduce the rubber to a sticky mass if not in amount sufficient to dissolve it. An additional effect, about which there is some doubt, is the acceleration of oxidation.

The danger from lubricating-oil in the washing machines is avoided by lengthening the rollers or by other devices.

Action of Heat and Cold on Rubber.

Rubber becomes sticky when subjected to high temperatures, assuming also a soft and plastic condition. At from 170° to 180° C. it becomes more or less fluid. When heated to the melting-point only, it afterwards remains soft and adhesive on cooling, but hardens when spread out in thin layers. At 200° C. it is converted into a sticky mass that does not harden on cooling; Ditmar puts the melting-point for fine hard Para at 188° C. The melting-point, if rubber can be said to have one, is higher than this if the resin has been extracted. It is, therefore, obvious that all drying and coagulating processes adopted on plantations or elsewhere should be so devised as to ensure the temperature being efficiently regulated. A maximum temperature considerably below that just quoted should be guaranteed in any patent appliances.

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

When submitted to low temperatures, rubber loses its softness and distensibility, becoming hard and rigid before the freezing point of water is reached.

Action of Light on Rubber.

Experience and experiment have shown that rubber is injuriously affected by light, the rays most deleterious being the ultra-violet or actinic (chemical) rays. In order to determine more fully the effects of actinic light upon rubber, Henri (le Caoutchouc, 1910, p. 4371), submitted some sheets of crude and vulcanized rubber prepared in different ways to the action of a mercury vapour lamp. Kept about 8 inches away from the sheets, an exposure of 20 hours was sufficient to produce visible deterioration in the crude samples; the rubber darkened and became shiny, cracking at the surface when stretched. In the case of dark-brown cut-sheet, the action was only superficial; but it proceeded more deeply in the case of paler samples. Vulcanized rubber took a longer time to deteriorate—as long as from 48 to 72 hours. Experiments performed in the absence of oxygen showed that the latter was essential to the change, and therefore that the process was one of oxidation under the influence of the actinic rays.

Enough has been said to show the importance of keeping crude rubber away from the light, or at least of keeping it in rooms the light for which has been filtered through red-coloured glass.

Absorption of Water and Gases.

Though rubber is insoluble in water, it rapidly swells when immersed in it and absorbs a considerable amount of the liquid, the actual amount capable of being absorbed increasing with a decrease in the resin and oily substances. On this account rubber from young trees may perhaps be roughly detected by the water capacity of the sample of rubber, allowing for normal variations. When vulcanized the water absorption power is small.

Gases diffuse through rubber; they are also partly retained, the rubber having the power of absorbing and holding them.

General Properties of Rubber.

The specific heat of rubber, as determined by Terry and Gee, is 0·84—the same as that of turpentine. It is a slow conductor of heat and stands high as an electrical insulator.

Beadle and Stevens (Chemical News, Nov. 15th and 21st, 1907), give several determinations of the specific gravities of plantation rubbers examined by them. They show that the specific gravity of apparently similar biscuits, blocks, etc., may vary according to the method employed in the preparation of rubber, those having a large proportion of air bubbles or which have not been severely pressed being lighter than others. The values are: block, 0·96; biscuit, 0·919; and fine hard Para, 0·927. The specific gravity of fine hard Para after cleaning has been variously estimated. Faraday gave it as 0·925; Weber, from 0·915 to 0·931; Julian, 0·925; and Terry, 0·924. In Allen's "Commercial Organic Analysis" there is a statement to the effect that highly purified rubber has a specific gravity of 0·911 at 17° C., and the technically pure substance from 0·915 to 0·931.

Rubber is almost incompressible; that is, it retains its original volume under pressure.

The mechanical properties of rubber are incidentally considered in the part of this chapter dealing with the methods of testing, though some reference may here be specially made to the nature of "nerve."

The Nature of "Nerve."

The word "nerve" is used in reference to the usual physical and mechanical properties of raw rubber. Mastication or heating, resulting in the production of soft rubber, is said to destroy, for the time being, the "nerve" of rubber. This quality of crude rubber is credited by Schidrowitz to mechanical, physical, and chemical factors. The mechanical factors referred to are, in the case of fine hard Para, the film structure due to the method of coagulating in succession layers, and the fibrous network of protein. By the physical he means largely the consistency of the caoutchouc globules. The chemical factor is, of course, the state of polymerization of the rubber molecule. He has stated that there was no doubt in his mind that the great nerve of fine hard Para is due partly to the method of coagulation in concentric layers. The smoking and drying of one thin layer upon another in endless succession may, in his opinion, be compared to the manufacture of wire-wound artillery. It is well known that the strength of a gun built up by tightly winding wire round a core is much greater than that of a solid cast or forged mass. In a later deliverance he puts forward the opinion that the mechanical structure of the crude rubber—referring to the film structure and the protein network—is probably of little utility, as it is very largely broken down upon the washing and mixing mills. The physical nerve depends upon the colloidal state of the caoutchouc hydrocarbon. And this depends largely, if not entirely, upon the state of polymerisation; that is, it is a function of the chemical nerve. The chemical nerve is a very important factor and varies probably according to the species of the tree, the method of coagulation, etc. As Schidrowitz suggests, chemical nerve being to a great extent a question of the quality of the latex, and this in turn being partly dependent on the age of the tree, it is obvious that the quality or nerve of plantation rubber must improve as time goes on.

Tackiness in Rubber.

The majority of planters, even if they have only just commenced to tap their rubber trees, know what tackiness in plantation rubber means. In the mild form it presents itself in the drying-shed as a sticky appearance on the surface of rubber. In some cases it does not make its appearance until the rubber has been packed and despatched to Europe. Frequently, however, the rubber in the drying-house practically resolves itself into a syrupy liquid. In fact, tacky, or as it is sometimes called, heated rubber, is sold more as a by-product. Tackiness has been known for many years on plantations, and has also been known to manufacturers even in the vulcanized material. In these notes tackiness as it occurs on plantations is dealt with. It is a subject of more than ordinary importance to every producer in the tropics and to estate proprietors.

At the present time it is known that various agents may bring about this undesirable condition, and it is doubtful whether many experts can be found who will be bold enough to state that any one agent is solely responsible. From a study of the researches of various authorities it can be concluded that this condition is due to several causes acting sometimes alone, and on other occasions conjointly. The agents which hitherto have been associated with this sticky development of rubber may be grouped under the following heads: (1) bacterial; (2) sunlight; (3) heat; (4) chemical.

Already the effects upon crude rubber of some of these agents have been considered, but tackiness is a condition that deserves separate discussion, especially as we cannot always be certain of the specific cause or causes.

Bacteria and Tackiness.

When tackiness was first studied in Ceylon it was stated to be almost entirely due to the development of bacteria upon or in the rubber, and as a means of overcoming this it was suggested that all affected specimens should be immediately isolated, and that in order to avoid the frequent appearance of this disease, the whole of the factory and utensils should be periodically disinfected. As a result of these measures in some quarters it was stated that the disinfecting of the factory had resulted in a reduction of tacky rubber.

That some cases of tackiness are due largely, if not entirely, to the action of bacteria, producing putrefaction of the proteins in rubber, is admitted. The fermentation of the sugars and other carbohydrates possibly also plays a part. The first rubber from old trees or that from young trees seems very liable to undergo putrefactive changes. Now, such rubbers, or the original latices, usually possess a high percentage of proteins and carbohydrates, which render the conditions for the development of bacteria more favourable. Furthermore, analyses of tacky rubber show a high percentage of proteins.

The relation of the protein-content to tackiness is indicated in the analyses, made in Ceylon (Committee Agric. Exper., Peradeniya, 1905), of sound rubber and material in various degrees of tackiness :—

	Sound Rubber.	Tacky.	Tacky.	Very Tacky.
	%	%	%	%
Moisture	0·30	0·36	0·06	0·44
Ash	0·38	0·28	0·54	0·72
Resins	2·36	2·32	2·66	3·70
Proteins	3·50	3·85	3·50	4·90
Caoutchouc.. ..	93·46	93·19	93·24	90·24
	100·00	100·00	100·00	100·00

That bacteria play a part in tackiness is suggested by the fact that this form of the disease can spread from one piece of rubber to another by contact. Furthermore, fine hard Para and smoked rubber from plantations do not very frequently go tacky. The explanation of this probably lies in the presence of antiseptics in the smoked rubber. The preventive measures (if bacteria constitute one of the essential factors) to keep in view are, first, to keep the factory and all utensils well disinfected, to wash and squeeze thoroughly all freshly-coagulated rubber, to dry the rubber as rapidly as possible without exposure to high temperatures, and occasionally apply formalin to the latex or the surface of the prepared rubber.

Sunlight and Tackiness.

Though sunlight is a bactericide, it is acknowledged that tackiness sometimes develops more quickly under its influence. Samples of rubber when exposed to strong sunlight may become tacky in a few hours. Brindejonc submitted some samples of Landolphia rubber to the action of sunlight, diffused light, heat, sea-salt, and solutions of weak acids, such as might be produced by bacterial action. Of these agents direct sunlight had the most deleterious effect ; diffused light, unless particularly bright, had very little effect. While the effect of sunlight in this direction cannot but be admitted, it is only fair to say that in my office there are samples of rubber which have been directly exposed to sunlight since 1907. One is a specimen of Lanadron block rubber which was manufactured in 1906, and part of which was shown at the Ceylon Rubber Exhibition ; other samples are comprised of biscuits from Ceylon estates. Not a single specimen has yet shown any tacky developments. Yet the importance of this factor—sunlight—is being more recognised on plantations, and in order to exclude the actinic or chemical rays of light, the windows of many factories are being supplied with ruby or orange-coloured glass.

Heat and Tackiness.

Rubber, when exposed to high temperatures, becomes soft and sticky. This is well known to all planters who have used vacuum driers, and to rubber manufacturers generally. It is for this reason that the temperature of drying factories is usually maintained at a maximum of between 90 and 100° F. Generally speaking, however, tackiness is not frequently associated with heat alone. Heat appears to have a more softening effect, and if, while this condition of the rubber lasts, care is taken to prevent putrefactive changes, the rubber on cooling sets to the ordinary consistency. If, however, the rubber is heated in atmospheres rich in organic matter, tackiness may set in.

Chemical Causes of Tackiness.

Like sunlight, chemical agents are apparently direct causes of tackiness, acting directly on the caoutchouc molecule or inducing a chemical state in which the molecule tends to alter, that is, producing that condition which is the most favourable for the chemical changes. Bamber seems to stand alone in placing the responsibility upon the enzymes, but this is merely an hypothesis, and no proof is adduced. This view is combated by Spence, who has prepared samples of rubber from the latex of Funtumia that were entirely free from oxidising enzymes, and yet in course of time became tacky. Spence has demonstrated the effect in producing tackiness that is exercised by such a coagulant as sulphuric acid, which has a strong effect. Brindejonc used weak solutions of acids, such as might be produced by bacterial action. Rubber that had been soaked in acetic acid deteriorated fairly rapidly when heated in moist air. Curiously enough, this happened also in the case of an antiseptic like carbolic acid, a fact that would tend to show that bacteria are not essential, or at any rate, that their action is an indirect one. The change also took place in rubber steeped previously in salt solution.

Fox, and in this he is confirmed by Schidrowitz, asserted that alkalies have in many cases a tendency to produce tackiness; the latter states that organic acids in strength tend to produce hard and brittle, not soft or tacky, rubber.

Imperfect Coagulation as a Cause.

An explanation of tackiness that does not come under any of the above headings has been put forward by Frank, but it is purely a hypothetical one. Adopting the idea that the caoutchouc hydrocarbon changes by polymerisation during coagulation into the substance with which we are familiar, he attributes the abnormality to the presence of imperfectly-polymerised portions that owe their existence to unsatisfactory coagulation, the coagulant and the latex not being intimately mixed, so that some parts of the latex do not receive proper treatment. Such other factors as heat, light, bacteria, enzymes, and mechanical treatment, are admitted as possibly accessory. While imperfect and unequal coagulation can readily be admitted as a factor, and for this and other reasons should be guarded against, we shall require, before Frank's explanation may be accepted, a proof that polymerisation of the caoutchouc occurs during coagulation.

Changes during Development of Tackiness.

The nature of the chemical alteration underlying tackiness is yet a matter of doubt. Spence will not admit that the change depends upon oxidation of the caoutchouc hydrocarbon, or to resin formation, which is the result of oxidation. And, of course, we can at once realize that resin formation is out of the question. There can be little doubt that the chemical change taking place is a process of depolymerisation, the caoutchouc hydrocarbon breaking down into substances of the same percentage chemical composition, but of less molecular weight. If viscosity in solution is a test of the molecular complexity of a rubber, it is significant that tacky rubbers have a low viscosity.

There is doubt as to how far the change is chemical and how far physical. Spence remarks that he is driven to the conclusion that tackiness is not directly caused by chemical changes in the rubber, and he would even go to the length of suggesting that it is largely the result of physical deterioration. One feels that Spence would have been nearer the mark had he suggested that this physical deterioration is the natural result of a chemical change.

Testing of Plantation Rubbers.

The desirability of the planter knowing the defects of his rubber is undoubted, but at present this knowledge is to a large extent denied him except in a very superficial form ; some system of testing the rubber upon the spot is, nevertheless, called for. If the testing of rubber is left to the buyer, it is most unlikely that he will let the seller or producer know why and when he considers certain samples depart from the normal. It is his duty to bid a price and be sure he gets good value for his money. How, then, is the planter to know the real quality of his rubber ? Obviously either he or his broker must determine this. Whenever possible, the application of simple and reliable tests, by the manager's scientific staff, to all rubber before it leaves the plantation should be made. It is perhaps not too much to hope that, seeing many directors have had the good sense and foresight to appoint scientific officers to deal with pests as they arise, and investigate chemical problems relating to the soil and preparation of rubber from latex, they will some day consider it a part of the scientific officers' duty to test, and grade accordingly, the various lots of rubber before they are shipped.

How this is to be performed is as yet not at all clear, but no doubt in the course of time a series of simple tests will be formulated and the necessary apparatus devised to meet the needs of the planter. One source of difficulty is the form—crêpe—in which so much rubber is now turned out, a form that is beyond submission to tensile tests ; even tests made on biscuit and sheet are not too reliable, as a uniform thickness and homogenity of material throughout a test-piece cannot be guaranteed. It must also be borne in mind that in the preparation of each kind of plantation rubber different physical forces have been brought into play which have an effect on the properties of the finished raw material.

The Force of Thumb.

Unfortunately, the testing of rubber by some brokers but fortunately not all—consists in smelling at it, and seeing if it will tear when stretched between two hands, or give way to a strong push of the finger or thumb. This is a most empirical system of testing, and yet it is the most that the majority of consignments are submitted to before being sent to the buyers. It is, indeed, a test by "force of thumb."

Consider, for a moment, what is done with tea—a product which is shipped in millions of pounds every year, from Ceylon, India, Java, and China. Every consignment of tea, even if it comes from an estate which has, by its mark, been favourably known for twenty years to brokers and buyers, and even though it may have been tested in the factory before leaving the plantation, or in Colombo or Batavia before being shipped, is carefully sampled and a pot of tea brewed from it. The "tea taster" knows the value of every degree of strength and flavour, and values the tea to a fraction of a halfpenny.

It is not suggested that brokers shall have every sample of rubber submitted to a detailed chemical analysis, or tested for its distensibility, durability, breaking strain, etc. ; all that is asked is that they devise some simple scheme whereby samples of even appearance shall be tested rapidly, accurately and cheaply. When one considers the variability of plantation lots which sell at practically the same price per lb. at the regular auctions he cannot help thinking that someone is the loser. It may not appear very necessary to adopt reliable tests to-day, while Hevea rubber sells at such high prices, but when the price realised is a question of pence only—and that is the difference between cost of production and profit—some radical change will have to be effected. If brokers and planters will only reflect on the history of tea, coffee, and other products, they will conclude that the present system, which is literally one of "force of thumb," is most inadequate.

A scientific system of testing is likely to make itself more necessary in future years, when, in order to satisfy manufacturers that there is the minimum variability, plantation rubbers will be more finely graded than they are to-day. The sooner it is realized that stretching between the hands can never give an indication of the comparative value of crêpe and sheet from the same country the better. Chemical analyses would, if plantation rubbers showed considerable loss on washing, be of some use, but under the circumstances they would not help sellers very much. Some simple physical device is wanted.

Possible Tests on the Plantation.

It has been said that tests on raw rubber are not so valuable as those on the vulcanized article ; while this may be true it does not warrant the setting-aside of all tests on the raw plantation material. Furthermore, it does not mean that tests on the vulcanized article must always be made outside the plantation. Tests on the raw and vulcanized article can be made on the plantation providing the staff has the necessary training and equipment. On the majority of estates, owing to the absence of scientific officers and apparatus, tests can only, at present, be applied to the rubber prior to vulcanization. The tests thus applicable are very few in number.

Viscosity appears to be a practical test requiring very little apparatus. Adhesion tests, similar to those applied in proofing, may also be tried. In this test the quality of rubber solution is determined by brushing it on a piece of cloth or strong paper and allowing it to dry. The dry sheet is folded and the two surfaces pressed together and made to adhere ; a test is then made to determine what weight or force is required to tear the adhering surfaces apart. Simple tensile tests may also be applied to rubber which has been pressed into a definite shape during cooling or drying, time being allowed for the recovery of the natural properties before the tests are applied.

Some authorities (Rubber Exhibition, 1911) have concluded that tests on raw rubber, whether adhesion tests or viscosity determinations, lead to conclusions which a e not in strict correlation with the vulcanization tests. The difficulties in carrying out the above tests lie mainly in the length of time required to make reliable solutions and the effect of mastication on crêpe and block forms.

Tests on the vulcanized material, which are eminently desirable, can be made in many ways, some of which are indicated in the following pages. The vulcanization test is said to be quite possible on the plantation (Conference, Rubber Exhibition, 1911). A small mixing mill, a calender, and a little vulcanizing press, would not cost much more than one assistant's annual salary. Esch has suggested that small pieces of crêpe could be placed in a bath of molten sulphur, heated for some time, and on cooling, be tested by a small apparatus similar to a spring balance.

Another simple test, likely to give immediate and beneficial results, is that of testing the rubber for the quantity of acid left behind after coagulation. The acid should, if possible, be entirely removed by washing. If some of the rubber from the washing machine is cut into small pieces and boiled for a few minutes in distilled water until the liquid is sufficiently concentrated, the application of litmus paper to the mixture will immediately indicate whether or not too much acid has been left in the rubber.

A great deal can also be done by the planter if typical samples out of each consignment are kept in the factory together with details of preparation and appearance when packed; a comparison of prices realized and samples despatched will soon enable the planter to determine the preparation most suitable to the buyers.

The Devising of Reliable Tests.

While the foregoing simple tests have been suggested for use by the planter, it must be admitted that the whole system of testing rubber scientifically—crude or manufactured—is now in the melting pot. This is the case not only because great improvements are being made in physical, chemical, and mechanical methods, but also because the whole subject is under the discussion of specially-constituted committees. There is a strong feeling that improvements in systems of analysis are necessary and that some standard system for all countries should be adopted so as to facilitate business transactions. At the Rubber Exhibition of 1908 an international committee, with sections for each country participating, was formed. A general conference of the members of the committee was held at the 1911 Exhibition, when sectional reports were given, and a scheme for discussion drawn up. Apparently partly as a result of the formation of the committee, the German and Dutch Governments have established organizations of a tentative character. But we are not yet in possession of an organized system of testing that has the confidence of planters, brokers, and manufacturers alike, and that can be adopted so as to render disputes next to impossible.

Chemical Analysis of Crude Rubber.

Though the methods of chemical analysis do not always show how a rubber is going to vulcanize and do not come within the purview of this work, some brief indication may be given of their nature. The moisture is determined by the difference in weight after drying. Resins are generally extracted with acetone and weighed. The ash is obtained by decomposing the rubber under heat. The proteins are calculated from the nitrogen content, multiplying the value of the latter by the factor 6·25, though this is open to objection, as all the nitrogenous bodies present are not proteins. A separate determination may be made of the matter insoluble in benzene or other solvent, and though this may contain proteins, there are other substances present. Caoutchouc is usually estimated by difference, a most unsatisfactory method. Some chemists prefer estimating the caoutchouc by determining the amount passing into solution, and see no advantage, except in special cases, in those direct methods of determining the caoutchouc such as by the nitrosite or tetrabromide.

Mechanical Tests.

Mechanical tests must, according to some chemists, be placed first in importance. If they indicate unsatisfactory quality, chemical tests may then be applied to ascertain why this is the case. Of recent years there have been great advances in the mechanical methods of testing; new principles have been adopted and new apparatus devised. Perhaps it is not too much to claim that the rise of the plantation industry helped to stimulate these advances, for the desire to obtain accurate estimates of the quality of plantation rubber and to compare it with that of fine hard Para has been very great and has kept the subject to the front.

Of course, not all the possible tests are necessary in every case. When being examined from the manufacturer's point of view, the nature of the tests vary according to the intended use of the rubber. And where rubber is being used mainly because of its non-permeability to air or water, or for, say, its electrical properties, very few tests are necessary, though those required are of a special character. Otherwise an extensive series of tests seems to be called for.

The variety of tests made upon the rubber have been summarized thus by Schidrowitz. The oldest and most favoured tensile tests are the determination of the breaking stress per unit of cross-sectional area and the elongation at break. But worth ascertaining also are the elongation under a constant load, and the effect of varying the load below the limit of breaking stress. And this is also true of the determination of the load that may be supported at a fixed elongation over a certain time period. Such tests as these lay bare rather the mechanical strength of the rubber, and for the determination of its resiliency a different series is made.

The simplest of these observations on resiliency are those made of the "permanent set," or "coefficient of resiliency," and the "sub-permanent set." The permanent increase in length, after the full retraction of the rubber following upon the withdrawal of the stress, is the "permanent set." Measured at definite intervals before the rubber has been allowed time to fully retract, it is the "sub-permanent set."

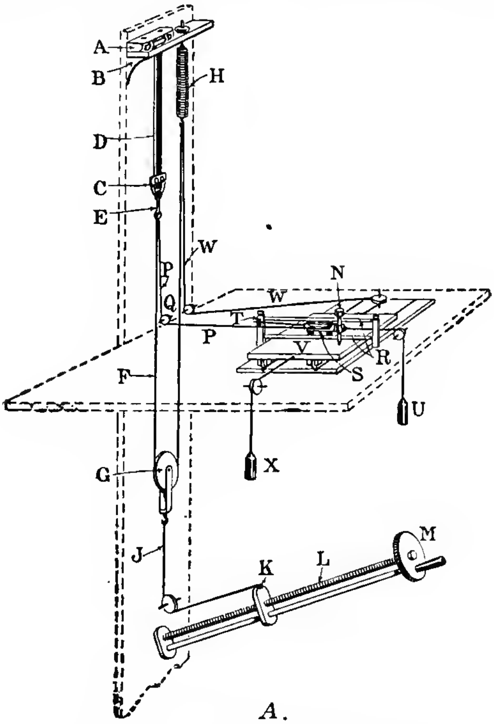
Additional insight into the qualities of the rubber is obtained by determining the minimum load producing a specific sub-permanent set, and the effect upon the sub-permanent set of varying the factors of load and time.

If the results of the tests are plotted out in the form of curves, their story may very easily be read, and out of this graphic method of recording has arisen a new form of determination of mechanical qualities. If the stress has been carried to a point short of the breaking strain, and the load is then gradually removed, it is found that the retraction curve does not coincide with the extension curve—a phenomenon known as "hysteresis"—the length of the rubber under the same load being different during extension and retraction. The double curve thus obtained is known as the "hysteresis loop," and much knowledge of the quality of the rubber may be gained by a study of the form of the double curve, of the area enclosed, and of the relationships of area to load and elongation. According to Schidrowitz, these are much more important factors in forming an estimate of the quality of rubber than the question of "set." A series of hysteresis loops, shewing the effects of a series of repeated elongations, is most instructive of all.

Beyond the tensile tests, there are few in the mechanical division which can be here described. Rubber for railway buffers and the like is submitted to so-called compression tests It has already been said that rubber is practically incompressible, but these are really tests of the capacity of the rubber to return to its original shape after distortion by compression. In abrasion tests the rubber undergoes continuous friction, as when placed against an emery wheel. Hardness may also be measured, and also porosity to air and water.

Schwartz's Hysteresis Machine.

This machine for determining hysteresis is designed to effect the extension of the rubber by a load which is increased at a given



A.

SCHWARTZ'S HYSTERESIS MACHINE.

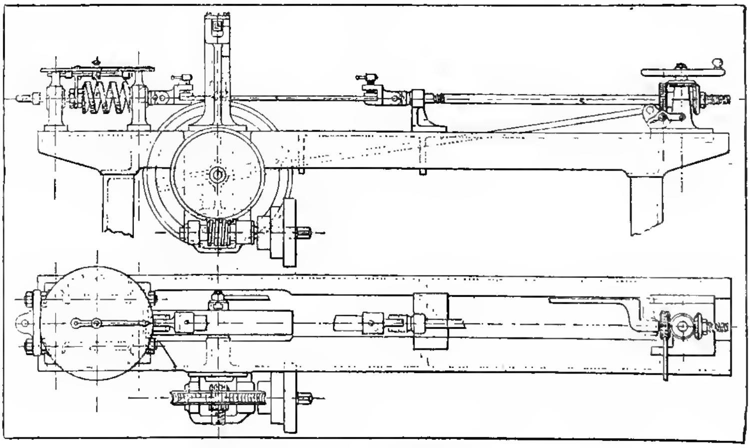
rate until either a given load or a given extension is reached. Then the load is lessened at the same rate and the rubber allowed to retract. An automatic recording device traces extension and retraction curves—the two together forming the hysteresis loop—upon a chart lying on a travelling table.

The stress is exercised from the wheel M, the axle of which is screw-threaded so that K travels up and down and thereby moves the floating pulley G. Any force exercised through this pulley is distributed so that both the strip of rubber D and a calibrated spring H are stretched. To the ends of each of these is attached a thread, one (P) attached to the clip at the end of the rubber, causing the movement backwards and forwards of the pencil N according to the extension of the rubber, the other (W), attached to the end of the spring, and therefore moving according to the load, moves the travelling table. These two movements result in the tracing of the hysteresis loop upon the chart. A series of, say, five hysteresis tests may be made rapidly.

A study of the loop diagram enables one to determine: (1) the degree of extension with load; (2) the work done in extension; (3) the work done by the rubber in retracting; (4) the work expended by the rubber itself; (5) the sub-permanent set.

Breuil's and Schopper's Testing Machines.

Breuil's dynamometer tests rubber in strip form and is provided with a variety of devices for determining the different qualities of rubber. It permits of making slow, rapid, or intermittent tensile tests; slow, rapid or intermittent compression



BREUIL'S DYNAMOMETER.

tests; repeated flexion (bending) tests; and tests of wear and resistance to perforation. An automatic device registers the results automatically in diagrammatic form.

In the Schopper apparatus a ring punched out of a sheet of the material is tested for elongation at break and breaking strain.

The ring is stretched between two rotating spools, so that every part of it is submitted in turn to the stress. The machine is worked by hydraulic power, a gravitation water supply giving

SCHOPPER'S TESTING MACHINE.

40 lb. pressure being sufficient. This machine also is provided with an automatic recording device, and may be worked at various speeds.

Viscosity Tests.

A new method of estimating the quality of rubber is the determination of the viscosity of a solution. It has always been recognised that low-grade highly-resinous rubbers tend to give thin solutions, and high-grade rubbers highly-viscous ones. Schidrowitz and Goldsborough advance the theory that the degree of viscosity approximates fairly closely to the nerve of the rubber. The theory is based upon the hypothesis that the nerve of a piece of rubber depends upon the molecular complexity of its contained caoutchouc, and that viscosity is a function of molecular complexity. Schidrowitz claims that with rubber from the same species of tree, viscosity measurements give a direct line as to strength and vulcanizing capacity. The method is obviously peculiarly adapted for testing rubbers before vulcanization.

An improved apparatus for making the determination has been devised by Frank (I.R.J., April, 1910). I am under the impression that this apparatus, while giving comparative commercial figures representing "fluidity" of commercial solutions, does not give results of the same order as viscosity tests made in a viscometer of the scientific type. The results only refer to the properties of solutions of a given concentration and not to the viscosity of the rubber as such.

In their work upon rubber (p. 100), Beadle and Stevens remark that mastication of rubber has an effect upon the readiness with which it dissolves and on the viscosity of solutions, so that biscuits and sheets are less easily soluble than crêpe. Thus viscosity tests, according to them, may be vitiated by the presence of the finely-divided (solid) protein matter which results from mastication or is present in the crude rubber. This objection cannot, presumably, apply to efficiently filtered solutions.

Physical Tests.

According to the purpose for which the rubber is intended to be used, various physical tests, *i.e.*, determinations of its behaviour under the action of physical agents—heat, etc.—may be made, but always upon vulcanized samples. The British Admiralty require that rubber—intended for valve-packings, etc.—shall be subjected to dry and moist heat tests. In the former the sample is kept in a hot-air oven for two hours at a temperature of 132° C., and deterioration is noted or mechanical tests made before and after the application of heat. In the latter it is heated in steam in a sealed glass tube or an autoclave for 3 or 4 hours at 160° C. If the rubber is intended for insulating purposes, appropriate tests are made. The usual "sun cracking" tests are also applied in certain cases.

Chemical Tests.

Sometimes it is necessary that the behaviour of rubber in acids, alkalies, oils, etc., should be noted. Such observations are made upon samples prepared in exactly the same manner and of the same composition as the manufactured article, for the compounding ingredients modify the behaviour of the rubber, either in an indirect way or by themselves being affected.

I have gone into some little detail on the subject of testing in the hope that many producers in the tropics will find information which will lead them to evolve or suggest tests of some use to themselves in future years. At a later date reference must be made to scientific apparatus described in other books and in the various journals devoted to rubber.

CHAPTER XXIX.

MANUFACTURE AND COMPOSITION OF RUBBER ARTICLES.

Rubber, as shipped from the plantations, differs very little from that received in the factory of the manufacturer. It may have lost from half to one per cent. in weight through the evaporation of water, or have become hard in winter months. On its arrival at London, Liverpool, Antwerp, or New York, it is stored in vaults at the wharves, where every care is taken to protect the rubber against exposure to sunlight and foul air. Only samples are removed from the wharves prior to the auctions at the salerooms.

Masticating and Mixing.

The first processes through which ordinary wild rubber is put are washing and drying ; with the plantation product these can sometimes be almost entirely dispensed with. The dry, clean rubber is then put through the masticating machines.

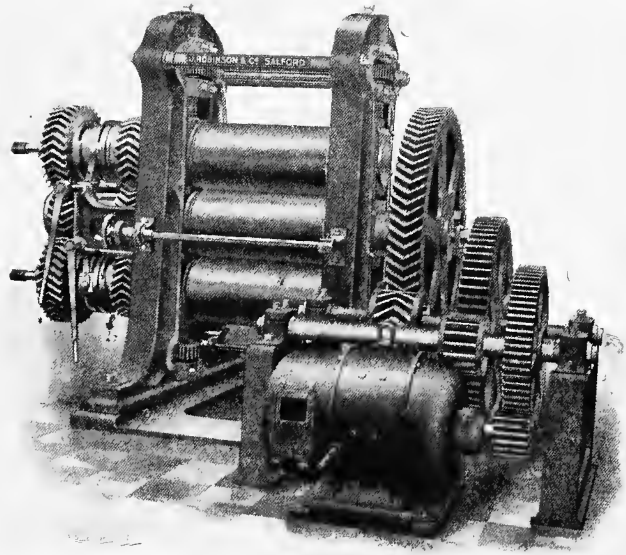
This is done in order to convert it into a soft, doughy mass, and is achieved by passing the dry rubber through a pair of smooth rollers heated by means of steam similar to those on a sheeting washing machine. In the course of half-an-hour the rubber is usually of the required consistency for the next process—mixing—to be put in operation.

In mixing, the various compounding ingredients, having been carefully weighed, are placed on the rubber, and by repeatedly passing through the rollers of the masticating machine are uniformly distributed and worked into it. The masticating and mixing processes can be carried out on the same machine, though it is usual to keep separate machines for each process.

Calendering.

What happens next depends upon the kind of goods to be manufactured. Generally the compounded rubber is passed through a calender, and is thereby turned out in the form of sheet, which is led to a revolving wooden roll on which it is layered or rolled between cloth. A calender consists essentially of superimposed smooth rollers, two or more in number, between which the rubber can be fed. The rollers are hollow for steam-heating.

If the rubber is not intended to be prepared in sheet form, the material from the mixing rollers may be pressed into moulds, or forced through a die, as when solid tyres and some forms of tubing are being made.



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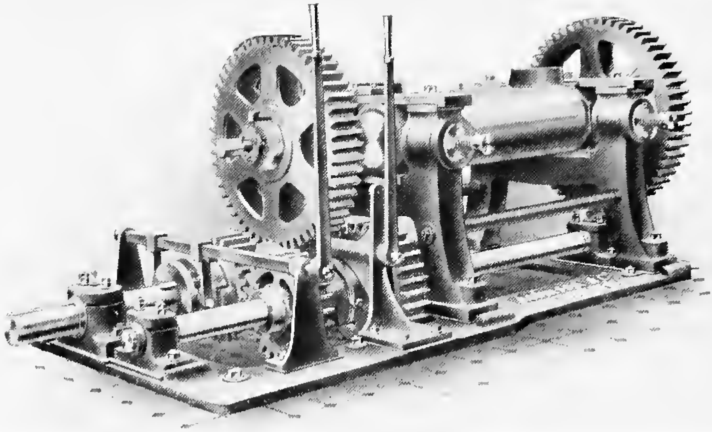
THREE-ROLL CALENDER WITH MOTOR.



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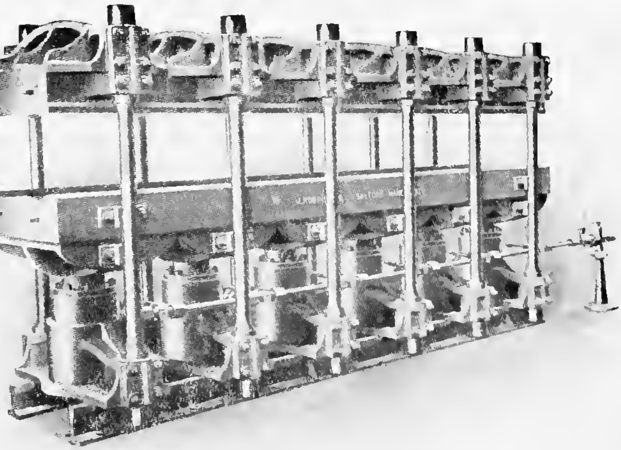
MIXING MILL.



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HYDRAULIC VULCANIZING PRESS.

If the article to be prepared is elastic thread the washed crude rubber is spread on cloth and vulcanized by the cold method.

Vulcanization.

Vulcanization is effected by mixing sulphur in one of its many forms with the masticated rubber and then heating the mixture, or by dipping the manufactured article in a liquid containing monochloride of sulphur and bisulphide of carbon. Usually only from 4 to 5 per cent. of sulphur is used in ordinary vulcanization, but in the production of ebonite or vulcanite as much as 20 to 40 per cent. of sulphur may be used. A more complete distribution of sulphur through the rubber may be possible if a solution containing sulphur be added to the latex before coagulation. Prismatic sulphur is readily soluble in carbon bisulphide, benzene, ether, &c.; solutions may be made with any of these and other reagents containing varying amounts of sulphur.

In vulcanization most of the sulphur becomes fixed by the rubber, but not the whole of it; there is always a certain quantity of sulphur in a free state in vulcanized articles. Ordinary sulphur, or various compounds of sulphur, may be used in this process.

The Heat and Cold Cures.

In the "heat cure" the rubber and sulphur are brought into intimate admixture by masticating and mixing, or the rubber is dissolved in naphtha to facilitate the mixing with sulphur. The temperature is then raised to over 100° C., when chemical union takes place between the components, and vulcanized rubber is formed. The whole of the sulphur does not combine with the rubber, but if the high temperature is maintained for a long period, more and more of the free sulphur enters into combination and produces a darker and tougher vulcanized product. Action does not begin between the two constituents until the temperature is equal to or above that of boiling water; in Europe a temperature varying from 125° to over 300° C. is commonly used in the process of vulcanization. If alkaline polysulphides are used, vulcanization can be effected at temperatures little above 100° C. The essential detail in the "heat cure" method is that the temperature of vulcanization must be above the melting-point of sulphur—114·5° C.

Though most of the rubber is vulcanized by the above process, the "cold cure," dependent upon the action of sulphur components in the cold, is often adopted. In the "cold cure," diluted sulphur monochloride is mixed with the rubber, with which it readily combines at ordinary temperatures, and produces a vulcanized product suitable for the manufacture of goods which would be damaged by high temperatures. Sulphur monochloride is a liquid at ordinary temperatures, and on account of its violent action with rubber is diluted by dissolving in carbon bisulphide before being used for vulcanizing. The sulphur chloride, with the help of the solvent, penetrates into the rubber.

Apparatus used in Vulcanization.

Vulcanization is usually effected in long cylindrical boilers or presses. The boilers or pans are heated by steam, which is well distributed in order to effect uniform heating. The goods are run into the cylinder or wheeled cages along light rails, the door is then bolted, and the process commenced.

Vulcanizing presses, which serve as heaters and moulds, may also be used. They consist of series of steam boxes, each provided with smooth even surfaces facing one another, and capable of being worked by hydraulic pressure.

Using Latex Directly.

Many attempts have been made to use latex direct, or after treatment with sulphur solution, in the preparation of rubber articles. Large quantities of latex have been sent to Europe from Africa, Brazil and the Indo-Malayan region, and though it appears to have arrived in a satisfactory state, but little advance has been made in this line of research. Hancock (I.R.J., Oct. 8th, 1906), so far back as 1825 patented a process for the manufacture of certain ropes by treating the surface of the fibres with latex which, on coagulation, formed a waterproof, elastic, and durable covering; at a later date he also invented a process of mixing the latex with a fibrous compound made by mixing hair, wool, cotton, etc., to which certain substances, such as whiting, ochre, brickdust, emery powder, were added according to requirements. As the result of his labours, Hancock finally decided not to make any further efforts in connection with the utilization of latex direct, mainly owing to the difficulties he experienced in obtaining it in sufficiently large quantities and in good condition. In his summing up he states that: "Although rubber in this state would be very useful, and many things could be done with it which are hardly practicable with the solutions, yet the loss of weight by evaporation being nearly two-thirds of the whole, the expense of vessels and the freight of so much worthless matter will probably prevent its ever being used extensively. Before the difficulty of dissolving ordinary rubber was overcome, it was thought that the liquid, if it could be obtained, would be invaluable; but now, all things considered, the dry material, for nearly all the purposes of manufacture, is the cheapest and most easily applied, although to persons unacquainted with practical details this may appear enigmatical."

Bamber subsequently, in a somewhat similar manner, made samples of rubber belting, flooring, mats, etc., by using sulphurized latex in conjunction with waste coir-dust and coconut fibre. When these are thoroughly mixed and combined with sulphur, and the mass is dried and vulcanized, a strong, hard, and pliable article is said to be obtained.

A method of rendering garments waterproof by the direct use of latex has been experimented with by Henri. The cloth is first placed in warm water, and is then dipped in the latex several times, when the fibre of the cloth becomes thoroughly penetrated. Vulcanization follows.

Colouring Latex.

The latex can also be coloured by organic dyes (T.A., Oct., 1906), such as methylene blue, etc., and any poisonous colouring matter be thoroughly mixed with the rubber instead of being put on the outside as is so often done in the manufacture of children's toys. It is interesting to note that though Hancock pointed this principle out in 1857, the method has not been taken up on commercial lines in any of the countries where rubber plants are cultivated. Among the more notable colouring substances used by rubber manufacturers are vermilion, lithopone, golden sulphide, red and brown oxides, zinc white and others, many of which contain combined sulphur.

Sulphurizing Latex.

The subject of the treatment of the latex with solutions which will precipitate large quantities of free sulphur in a fine state of division, is one which has been much ventilated. In one process (T.A., Oct., 1906), a solution of sulphur is added to the fresh latex and thoroughly stirred. On treatment with acid, sulphur is precipitated and the latex coagulated, the resultant rubber being minutely permeated with the finely-divided particles of sulphur. The complete mixing of sulphur with the latex while the latter is in a liquid condition is intended to do away with this process at a later stage in the manufacture of the rubber goods, and to thereby effect a saving in time and power.

Feasibility of the Direct Use of Latex.

It should, however, be pointed out that the processes through which raw rubber has to pass in the manufactories are not designed solely for the perfect mixing of sulphur with rubber, but for the removal of various impurities—economically impossible once the latex has been sulphurized—and the admixture of various compounding ingredients, known only to the trade. It is not likely that the manufacturers are going to instruct planters what compounding ingredients must be mixed with the latex prior to vulcanization.

If the direct treatment of the latex is to be of avail to European producers in the tropics, it appears to be necessary to first remove undesirable impurities and subsequently add not only the required sulphur but the balance of compounding ingredients commonly used. It is difficult to see how the admixture of sulphur alone to ordinary latex can at present be a very great saving of labour to manufacturers who deal with wild and plantation rubber. It still leaves the raw rubber of the wild forests to be dealt with on old lines, and prevents the removal of undesirable components from the latex so sulphurized.

Furthermore, the treatment of latex while in a liquid condition necessitates the introduction of various arrangements not at present in common practice. It is necessary in the first case to keep the latex in a liquid condition from the moment it leaves the tree to its arrival at some central factory, and to so treat the latex that it will not deteriorate during transit. Experience has taught most people that the whole of the latex cannot be collected as such, a large proportion invariably drying up as scrap especially with latex other than that from *Hevea brasiliensis.* It is also maintained that the addition of ammonia and formalin—especially the former—is not always accompanied with constant results, and the latex, owing to its very varied composition, is difficult to standardize.

Sulphurizing Freshly-Coagulated Rubber.

When the coagulation of the latex is complete, the rubber is in a very soft spongy state and can be easily torn into very small pieces, kneaded, and rolled or pressed into any desired shape. On some estates experiments have been made with the freshly-coagulated rubber while in this condition, mixtures of sulphur with other ingredients being added, and after thorough mixing, pressed into blocks or sheets and dried It is obvious that rubber so treated possesses the maximum amount of resinous, protein and other impurities, and if washed after the additional compounding ingredients have been mixed with it, a loss of the latter may be occasioned.

The mixing of foreign ingredients with rubber, if ever considered desirable, can, as far as ordinary estates are concerned, be best carried out when the rubber is in the freshly-coagulated spongy state. To adopt such a treatment, on the plantation, with the rubber after it has passed through the washing machine would not be attended with satisfactory results; the processes of masticating and mixing can be best performed by the manufacturer.

It has been claimed that the addition of these ingredients prevents the rubber from becoming soft or tacky, and that there is an improvement in the physical properties of the rubber. The tackiness or softening may, however, be obviated by careful work during drying and washing or the addition of suitable antiseptics to the latex. Except it is desired to conduct the manufacturing operations in the tropics, there appears to be very little in favour of adding a small percentage of certain vulcanizing and compounding ingredients to the freshly-coagulated rubber. The writer certainly does not know of any manufacturers who have asked for rubber in that condition.

Henri claimed to have devised a method by which the rubber in latex could be obtained in the form of a cream as thick as one wishes. One is able to mix with it in this state sulphur and other compounds, obtaining homogeneous mixtures thereby. Such a cream, as he pointed out, can easily be treated in manufacture. As Henri made his claim in 1907, and has been silent on this subject since, the method has apparently not been brought to a successful issue.

Compounding of Rubber: Ingredients Used.

When crude rubber increases in price, there is a tendency towards the loading of rubber goods with higher percentages of compounding ingredients, as well as of substitutes and inferior rubber. It must, however, be made clear that compounding ingredients, used in reason, confer some benefit and are essential in most classes of goods. Further, to use high-class rubber would in very many cases be wasteful.

Thus it is sometimes economical to use compounding ingredients simply as fillers. They may also be used to colour the rubber. But more important purposes to which they may be applied are the making of rubber tougher, harder, or more resilient, the rendering of it more resistant to the action of oils, acids, and other chemicals, and the increasing of its heat-resisting and electrical-insulating capacity, or the decreasing of its permeability to water. One very convenient advantage with certain compounds is that they contain the sulphur necessary in vulcanization ; a further advantage is that some may accelerate vulcanization. For some or other of these purposes are used : magnesia, litharge, red sulphide of antimony, zinc oxide and sulphide and carbonate, plumbago, white lead, red oxide of iron, barytes, French chalk, whiting, lampblack, asbestos powder, infusorial earth, etc., etc. The value and even necessity of many compounding ingredients is not realized by every consumer of rubber.

Quantity of Rubber in Common Articles.

The important part which 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 :—

	Roller Covering. %	Steam Packing. %	Outer Cover of a Tyre. %	Tobacco Pouch. %	Garden Hose. %
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 vulcanization ..	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	—	—	—	2·50	2·20

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

Rubber in Tyres.

A considerable amount of analytical work has been done in Europe with the object of determining the composition of rubber tyres. Schidrowitz and Kaye (Journal Soc. of Chem. Ind., Feb. 28th, 1907) conducted an examination of tyre covers of representative makes, and the following are analyses of several brands which they investigated :—

Mark.	B.	D.	D.	E.	F.
Part of tyre.	Tread.	Tread.	Body.	Tread.	Tread.
	%	%	%	%	%
Rubber	69·10	53·07	83·76	65·00	30·82
Organic extract	5·80	3·13	4·54	7·90	9·50
Sulphur : Total	5·80	4·00	4·90	9·80	2·78
Mineral matter	19·30	39·80	6·80	17·30	56·80
Fatty substitutes	Nil.	Nil.	Nil.	Nil.	Nil.

They concluded that manufacturers are by no means agreed as to the quantity of rubber and mineral matter to be used. Certainly the analyses published show that the proportion of rubber is very variable in the covers examined.

Clayton Beadle and Stevens (Chemical News, August 2nd, 1907), subsequently gave an account of their investigations into the composition and value of tyre rubbers ; the following are results obtained with solid tyres :—

Sample	1.	2.	3.	4.
	%	%	%	%
Rubber (caoutchouc) by difference ..	42·3	43·3	43·0	47·7
Rubber substitutes (alcoholic potash extract)	10·2	8·9	9·1	11·7
Resins, &c. (acetone extract)	9·0	8·6	7·2	7·4
Mineral matter (ash)	38·5	39·2	40·7	33·2
Total sulphur (calculated on caoutchouc)	7·8	9·0	10·0	11·3

Vulcanite or Ebonite.

This material is produced by using a much larger proportion of sulphur in vulcanization than for ordinary goods, while the mixture is heated for a much longer time and (or) at a higher temperature. A plastic mass results that hardens to vulcanite on cooling. Yet this material has little interest from the plantation point of view, for inferior quality rubber can frequently be used in its preparation.

General Uses of Rubber.

The finished product forms an important factor in everyday life. In personal use it appears as rubber boots and shoes, goloshes, heels, tobacco pouches, pencil erasers, and umbrella and other rings. It takes its place in the household in the form of mats, bags, door stops, sponges, bottle and other stoppers, and garden hose. In the field of sport it is used in game and fishing-bags, tennis and golf-balls, football-bladders, children's playing-balls and even rubberized-leather cricket balls. In the workshops are rubber-valves, packing and belting, and in the office erasers and dating-stamps. To the chemist, doctor and electrician, rubber-tubing, storage-bottles, and gloves are indispensable. If one travels, one cannot help being impressed by the universal occurrence of rubber. The streets are cleaned with rubber strips fixed on wood. Every second person or passing cart is using water-proofed goods of some description or other. Vehicular traffic appears to be absolutely dependent upon rubber, and in this direction larger quantities are being consumed month by month. In the buffers of railway-carriages it saves the passengers many a jolt. Overhead, telegraph and telephone wires, balloons, and even aeroplanes cannot do without it. On the sea one finds it as the floor-tiling of the corridors and halls of steamers. Even below the surface of the sea it may be found surrounding telegraphic cables. The usefulness of rubber articles, the dependence of other industries upon rubber, and the world-wide distribution of rubber goods all testify to the importance of our product.

Raw Materials Required by Rubber Manufacturers.

In dealing with the manufacture of rubber goods, it has now been shown that raw rubber is not the only substance required. It must also be realized that the life of a sample of rubber is not limited to that of the article into which it is first made. It has already been shown that various compounding ingredients are used in large quantities. There are also numerous substitutes, mainly oxidised oils, and many so-called artificial rubbers required in ordinary manufacture. Over and above these there are enormous quantities of rubber waste which are annually reclaimed and reformed. Probably the least important, though none the less interesting, source of raw material is the "synthetic" product.

Synthetic Rubber.

Synthetic rubber may be defined as one built up by chemical means from various substances, and possessing all the chemical and physical properties of natural rubber. It is essentially formed of the same hydrocarbon or hydrocarbons that occur in natural rubbers. As a standard for natural rubber one may take that obtained from *Hevea brasiliensis*.

Now natural rubber consists chemically of very complicated compounds, the most important of which are distinguished by the terms caoutchouc, resins and proteins. Water and various mineral substances also generally occur in raw rubbers, but need not be specially considered here. It may not be well known to many, but it should, nevertheless, be borne in mind, that some of the foremost rubber chemists of the day frankly acknowledge their ignorance regarding the exact chemical constitution of some of the substances which normally occur in almost every sample of natural rubber.

The substances referred to in such empirical terms as "resins" and "proteins" are in themselves highly complex bodies, the components of which, though recognised and conveniently grouped together, are but little understood. The synthesis of caoutchouc, the essential and therefore the most important constituent of natural rubber, has received more attention from chemists than the average person ever dreams of, and yet it has never been made successfully on a commercial scale, except in small quantities.

History of Synthetic Rubber.

The first report of the synthesis of a rubber like substance was made in 1860 by Williams. Isoprene, after standing for some months, had become viscid, oxygen being absorbed. Upon distillation of the product, the oxygen was given up, and a white, spongy, elastic mass remained which gave the same odour as caoutchouc when burnt. In 1879, treating isoprene with strong acids, such as hydrochloric, Bouchardet obtained a tough, elastic solid that he and Tilden found to be apparently a true rubber. Wallach later reported the polymerisation of isoprene that had been exposed to light for a long time, from which a caoutchouc-like mass separated out upon the addition of alcohol. In 1892 Tilden found masses floating in isoprene that had been stored in bottles for several years; these masses possessed the physical and chemical properties of caoutchouc and united with sulphur to form a tough, elastic compound. The spontaneous polymerisation of isoprene after 9 months is also recorded by Weber and after 3½ years by Pickles, in both cases the caoutchouc being separated from the viscid mass by addition of alcohol. Last year, Harries was able to announce that by heating isoprene with glacial acetic acid in a closed tube he had synthesized rubber. According to him, this rubber is quite as tough and elastic as the natural product, but the process is very costly. Lebedeff's method is to heat isoprene at 150° C. in a closed vessel. Recently, substances allied to isoprene have been treated by similar methods with, it is reported, the same results.

Cost of Manufacturing Synthetic Rubber.

All of these are merely laboratory experiments, and all that can be fairly said is that we are promised rubber upon a commercial scale, with the bye-products of manufacture to lessen the cost of production. One great difficulty is to prepare isoprene cheaply enough. It can be obtained by, say, passing turpentine through a red-hot tube; but, according to Tilden, the maximum yield is 10 per cent. It would appear that the isoprene or other intermediate product used can be prepared more cheaply from other substances than turpentine, though at what cost one cannot say. Some degree of secrecy is being maintained by most of the interested parties with regard to the financial aspects of synthetic rubber production, and the actual proportions of the intermediate product—say isoprene—obtained from the raw material, together with the proportion of caoutchouc yielded by the intermediate product is not a matter of certainty. Thus it is difficult to discuss synthetic rubber from the financial side. The price of American turpentine is now (25th November, 1911), 3⅝d. per lb. On the basis of a ten per cent. yield of isoprene from turpentine, and, as claimed by two different interests exploiting synthetic rubber inventions a yield of 15 and 50 per cent. of ubber respectively from the isoprene, an estimate may be made of the cost of the raw materials, to which must be added factory and other charges.

But attention should be drawn to a report that a German firm of chemists is selling synthetic rubber to a manufacturing firm at 2s. 7d. per lb.

Misuse of Term "Synthetic Rubber."

It is now time to strongly object to the gross misuse of the term "synthetic rubber." Its application to any substance which is remarkable for its lightness in weight or great elasticity is not justifiable, and in my opinion should never be allowed. Boiled seaweeds or bones give light, elastic, gummy substances, but it would obviously be unfair to refer to these, even in the most popular sense, as synthetic rubbers. Peaty substances, if subjected to bacteriological treatment, may be partly transformed into gummy elastic products; but whether the latter should be named "synthetic rubber" must surely depend upon the results of a complete analysis of the products formed. High-grade and low-grade natural rubbers, when mixed with balata or gummy extracts, may show considerable improvement in physical properties and this may be especially true of resinous, low-grade rubbers; but no chemist would allow the improved product, so derived, to pass under the name "synthetic rubber." Nevertheless, the term is being very loosely used in reference to substances which are merely gummy fermentations, or vulcanized or oxidized oils, or to materials which have as their basis a varying proportion of natural rubber.

Rubber Substitutes.

Rubber substitutes are already largely employed in the manufacture of certain rubber articles, and large factories have long been established for their preparation. Vulcanized oils, the preparation of which is rendered possible on account of the action of sulphur and sulphur chloride on various oils and fats, are largely used as rubber substitutes. In the manufacture of these substitutes, processes somewhat similar to those used in ordinary vulcanization are carried out; hence the reason why they are described as vulcanized oils. Linseed, rape, poppy seed, cotton seed, castor, and numerous other oils are used in this way, as well as substances having a gummy and resinous texture. There has never been any attempt at secrecy in connection with the use of these substitutes, as most people know that rubber would be of very little use if it were not mixed and compounded with such substances.

Terry, in dealing with rubber substitutes, states that the efforts inventors have made to discover or prepare a substitute for rubber have been very noticeable, but up to the present time no real substitute has been discovered. In his opinion, the substitutes which have so far been used have no status beyond that of cheapening ingredients, and only such a substance, which on admixture with rubber cheapens it without at the same time reducing its quality, can be claimed as a desirable substitute. He makes a pertinent remark to the effect that the great bulk of the rubber substitute inventions have benefited no one except those who are professionally concerned with patents, and that the present prospects of wealth for the discoverer of a rubber substitute are largely illusionary. It is, however, pointed out that in the manufacture of rubber articles where elasticity is not really required, *e.g.*, waterproof goods, doormats, etc., certain substances may be legitimately used which will not impair the efficiency of the manufactured article.

Artificial Rubbers.

Artificial rubbers as well as rubber substitutes are often met with. They are substances usually derived from some organic source, and generally possess one or more of the physical characteristics of natural rubber. The chemical constituents in artificial rubbers or rubber substitutes need not, however, be even remotely related, chemically, with those in the natural article; in this particular lies one of the great differences between them and real synthetic rubber.

One might with advantage distinguish between artificial rubbers and rubber substitutes; the former being roughly defined as substances containing, essentially, a quantity of natural rubber together with other substances and as allied to natural low-grade rubbers, and the latter as materials derived from sources other than crude rubbers.

Composition of an Artificial Rubber.

The desire to place on the market a comparatively cheap composite mixture having physical properties similar to raw rubber is strongly marked. From time to time samples for report and analysis are received; when they possess characters of value to rubber manufacturers they usually contain, as an essential component, a proportion of rubber, reclaimed or otherwise. In the "Gummi-Zeitung" an account is given of material submitted as "an artificial rubber prepared from vegetable fibres" to Marckwald and Frank. The following details are given regarding the composition of this substance:—

	%	%
Moisture, volatile at 100 deg. C.		12·86
Acetone extract		61·50
Which consisted of—		
Saponifiable constituents	9·44	
Unsaponifiable constituents	49·88	
Sulphur	2·18	
Mineral constituents		7·16
Sulphur combined with rubber		3·00
Rubber substance		15·48
		100·00

In such a sample it is obvious that 100 parts of rubber are combined with about 19 parts of sulphur. The mineral constituents are said to have consisted largely of alumina, together with iron oxide and small quantities of chalk; magnesium carbonate was also present. Chemical tests further revealed the presence of starchy and resinous compounds. In conclusion, it is stated that the "artificial rubber" under investigation may be regarded as having been derived from an inferior reclaimed rubber containing sulphur and mineral substances, and cannot lay claim to being an artificial rubber in the true sense of the term.

Improved Low-Grade Rubbers.

There is on the market a preparation, made by a secret process, which is said to possess excellent qualities. It is made essentially from guayule rubber and certain gummy substances, and a large factory has been established for its manufacture. The manufacture of this substance—which may be described as an artificial or modified rubber—has been going on for some time, and already large quantities of the improved product are being turned out. It is obvious, however, that in the preparation of this class of rubber, materials very expensive in themselves have to be used, guayule rubber alone standing at 2s. 7d. per lb. (Feb., 1912.) Furthermore, the necessary ingredients are obtained from plants which grow very slowly, and the method of extraction is such as to involve the destruction of the plants whence they are derived. It is, therefore, obvious that the natural sources of supply may be partially exhausted before many years are over. But what puzzles the writer is that this new substance, which from all accounts appears to be nothing more than an improved low-grade rubber, should have been referred to as "synthetic rubber."

Reclaimed and Reformed Rubber.

At the present time there is a ready market for discarded rubber goods, the rubber being reclaimed, that is, devulcanized as far as possible, and then worked up again, but rarely into articles requiring the highest class of rubber. Such reclaimed rubber has also found a use in replacing in some cases oil substitutes. While an inexpensive method of making synthetic rubber is a matter of remote possibility, and one which the plantation owner may almost ignore, the question of reclaimed rubber is more insistent, the probability being that in course of time this substance will become more perfect in quality, and will render less necessary the use of the first-grade product. The popular reclaiming methods all seem to have a prejudicial effect upon the caoutchouc hydrocarbon.

The general principles followed are very varied. The first obvious step is the breaking-up of the rubber by grinding it to a powder between rollers, where that is possible; or, say, as in one method, by cutting it up with knives arranged in series. Beyond this there are great differences in procedure, and there are many patents covering this part of the process. The devulcanization may be performed by steaming the rubber or by heating it in hot-air stoves with resin-oil, petroleum, etc., preceded by treatment with blasts of air to remove any fragments of fibre. Otherwise alkalies or acids—which also destroy the fibres, and destroy or dissolve out contained oils or rubber substitute—are used as devulcanizers. Nowadays, alkalies are generally used. Finally, the rubber is washed, dried, and rolled into sheets. Some processes involve dissolving out the rubber by means of such solvents as petroleum, and then precipitating it by means of alcohol.

Reformed differs from reclaimed rubber in that no attempt is made to devulcanize. The fragmented rubber, in the form of powder or flakes, to which oil may be added, is directly moulded by heat and pressure into the finished article. Satisfactory results are obtained, the homogeneous mass, on cooling, being indistinguishable in appearance from an article moulded from first-hand rubbers.

Disuse of Rubber.

In some countries the authorities have 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 sometimes so peculiar 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 the usual insulation. Nevertheless, cheap substitutes are being used in cable work in many parts of the world.

Burgess states that land cable carrying telephone wires, which at one time were insulated with rubber, are now largely insulated with dry paper, and that heavy cables for electric light supply are demanding for use in their manufacture less and less rubber every year, its place being taken by papier-maché and cellulose pulp. He attributes this to the high price of raw rubber, and is of the opinion that there will be a great extension of the electrical application of rubber when the price of raw rubber is reduced.

In recent years, while prices for rubber goods have been abnormally high, there have been still other instances of the gradual disuse of rubber. The more extensive use of cork, instead of rubber, in door mats, and the substitution of metal springs for rubber buffers are two popular examples. On the other hand great advances have been recorded in the number of purposes for which rubber can be used, and a considerable demand has been established in other directions in which our product has long been in use. The disuse of rubber will not be of any consequence so long as the demand in old applications continues to grow at such rapid rates.

CHAPTER XXX.

THE SEEDS: PROPERTIES, USES AND DISTRIBUTION.

It is well known that trees of *Hevea brasiliensis* in the East flower and fruit after their fourth or fifth years. In other countries plants raised from cuttings have been known to produce fruits within three years. Each fruit usually contains three seeds; 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 capable of being produced from a five-year-old tree and its offspring, assuming that each tree after attaining its fifth year produces 500 seeds annually, and that all germinate :—

Year.		Total Seeds at end of each year.	Year.		Total Seeds at end of each year.
1st	..	500	11th	..	130,255,500
2nd	..	1,000	13th	..	1,259,006,500
3rd	..	1,500	15th	..	4,388,757,500
4th	..	2,000	17th	..	323,019,508,500
6th	..	253,000	18th	..	952,522,759,000
8th	..	1,504,000	19th	..	2,208,151,259,500
10th	..	3,755,000	20th	..	4,402,530,010,000

At the present time there are about 220,000 acres of Hevea rubber trees in Ceylon, 400,000 acres in Malaya, and very large areas in other parts of the world. It is obvious from a glance at the above table that, before long, very large quantities of seeds will be available.

Decorticated Seeds: Estimated Annual Crop.

Basing the calculations upon the assumptions that 800,000 acres of Hevea now planted will come to the bearing stage, that 100 is the average number of trees per acre, and that each mature tree produces only 400 seeds, then 32,000,000,000 seeds will be the annual crop. If we accept the Peradeniya estimate that the kernels after six weeks' natural drying weigh 700,000 to the ton, then there will be nearly 47,000 tons of decorticated seed for which a market should be found. Of course, the Peradeniya estimate was based upon the weighing of a comparatively small number of seeds.

Weight of Seeds.

Determinations of the weight of seeds have been made at Peradeniya (Circ. R.B.G., Ceylon, Vol. IV., No. 11). A sample of seed in course of shipment had been taken at Colombo and the weight of 1,000 of the seeds found to be 7·2 lb. The weight of 1,000 seeds collected at Henaratgoda and despatched to Peradeniya and weighed the same day was 8·5 lb.

But more detailed determinations were made with seeds from tapped or untapped trees, and the amount of drying that took place during certain intervals was measured. Fresh seeds from 20-year-old untapped trees weighed 9·1 lb. per thousand; from 30-year-old trees, lightly tapped the second and third year before, they weighed 7·8 lb. The latter group of trees was the same from which the late J. B. Carruthers got the seeds five years earlier—when the trees were then untapped—that weighed 9·1 lb. per thousand: an exact correspondence.

After six weeks' drying in open dishes, the seeds from untapped trees lost 17·6 per cent. in weight, and those from the tapped trees 20·1 per cent; a detailed experiment showed that the loss of weight took place almost entirely from the kernel. The seeds from tapped trees were smaller and individually heavier than those from the untapped.

When fresh, the shells of the seeds from untapped trees were 35·2 per cent. of the total weight, and the kernels 64·8 per cent. After six weeks' drying, the weights were 45·3 per cent. and 54·7 per cent. respectively. In the case of seeds from tapped trees the shells weighed 42·2 per cent. of the total, and the kernels 57·8 per cent., after six weeks' drying. The authors draw attention to the further loss of weight during transit to England, for the director of the Imperial Institute has stated that the kernels constitute about 50 per cent. by weight of the whole seeds weighed in England.

A planter states that 1,000 seeds from his 15-year-old trees now average 7 lb., and formerly seeds from the same trees weighed 10 lb., having diminished 1 lb. each year during tapping.

Value of Seeds for Export Purposes.

While rubber trees are yielding such large quantities of produce, high prices are ruling, and forests are being extensively cleared for planting, it is almost unnatural to expect planters to trouble themselves with the subject of the future uses, value, and disposal of rubber seed supplies. It is, nevertheless, quite patent that when an estate has reached its fifth year, it will be almost independent of outside sources for seeds. Since there is no limit to the area to be planted in rubber, there must, providing the trees continue to flourish, ultimately be a glut in the seed market. Considering the uses to which the various parts of plants are put in America, the manner in which every part of a plant can be used as the basis for the manufacture of some important by-product, it should not be difficult to enhance the value of the surplus rubber seeds by facilitating their use in various industries.

On the value of seeds, at present, for export purposes little can be said of an encouraging nature. The determinations referred to above show that taking the weight of 1,000 seeds as

8 lb., the loss of weight on drying at 20 per cent., and the weight of the kernel as 50 per cent. of the whole seed, then

1 ton = 280,000 fresh seeds.
= 350,000 dried seeds.
= 700,000 kernels.

It is pointed out that this estimate is too favourable on each point, but accepting it, and assuming that the kernels sell for £10 per ton, then the gross return per 1,000 seeds is 21·5 rupee cents. Out of this must be met the cost of collecting, decorticating, and the freight, insurance and general charges.

Form in which to Export the Seeds.

According to Dunstan it is useless to export unshelled seeds. The shells add to the cost of freight, and have to be removed eventually. There is no perfectly satisfactory shelling machine for these nuts on the market, but trials at the Imperial Institute show that "Miller's Nutcracking Machine" gives fairly satisfactory results. With this machine the broken shells have to be picked out by hand, but this can be done by children. The kernels should be dried thoroughly in the sun, or by artificial heat, as rapidly as possible, and shipped in bags. The difficulties of shelling will be speedily overcome if there is a demand for the kernels.

Estimated Profit from Export of Seeds.

As already pointed out, the estimation of the possible profit by collecting and exporting the seeds is difficult. But in order to obtain some guidance upon the point, the following calculations, based upon those made by Mr. Palmer of the Brieh Estate, are given. It is assumed that the kernels weigh in London 50 per cent. of the whole seed and that 700,000 weigh a ton :—

Cost of picking 700,000 seeds at 4 cents. per 1,000	$ 7·0
Decorticating 2 tons	14·0
Gunnies for packing	2·4
Packing, weighing, carting	4·0
Railway freight, at 20 c. per picul	3·4
Shipping charges, insurance, etc.	8·0
Freight from Port Swettenham	18·0
	$56·8

If the decorticated seeds realise £10 a ton in London, this allows of a profit of £3 5s. per ton. Assuming that there are 100 trees to the acre and that a tree will yield 400 seeds, then 1,000 acres will yield 40,000,000 seeds. These seeds ought to weigh about 57 tons, and the profit upon an estate of 1,000 planted acres will only be £185 ; against this, certain charges must be made.

This estimate is a conservative one, for it is quite possible that more than £10 per ton, perhaps double this figure, can be realized in London ; and geographical position may lessen in some cases the transport charges. But taken as a whole it is not very promising. Possibly, after all, crushing the seed on the spot by necessarily crude methods, and using the poonac as manure, may reward the planter best.

The Oil in Hevea Seeds.

As far back as the year 1872 Collins stated that the oil was said to be of use in the preparation of varnishes. And scientific investigations have shown that it is suitable as a substitute for linseed oil and similar drying oils. Technical trials by manufacturers have confirmed this view.

In January, 1911, the Director of the Imperial Institute drew attention to the fact that enquiries from manufacturers desirous of obtaining supplies of Hevea seed kernels or oil had been received there.

The oil was valued in 1903 at £20 per ton, and the cake at £5 to £6 per ton. From £10 to £12 per ton was the estimated value of the decorticated seeds. Since the year 1903, the prices of oil seeds and oils have very much advanced. For example, linseed oil, worth, on the average, not much more than £20 a ton in 1903, has been more than £40 a ton on the average during 1911.

The report made by the Imperial Institute (Bull. Imp. Inst., 1903), upon the oil is as follows :—

"The kernels constitute about 50 per cent. by weight of the whole seeds and yield 42·3 per cent. of oil. The husk and kernel together yield 20 per cent. 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."

An experiment was made in 1911 at Peradeniya in expressing the oil from dried kernels in a "chekku mill." The percentage of oil obtained was 17·75. The residue was an oily poonac that would not bind.

Hevea Seed Meal and Cake.

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

Chemical Analysis.

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

The ash was found to contain 30·3 per cent. of phosphoric acid present in the form of phosphates, which is equivalent to 1·07 per cent. 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 composition of some commercial feeding cakes.''

	Calculated Composition of Hevea Seed Cake.	Linseed Cake. New Process.	Linseed Cake. Old Process.	Cotton Seed Cake. New process.
	%	%	%	%
Moisture	13·36	9·4	10·8	11·1
Ash	5·19	5·4	5·0	6·1
Proteins	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 Hevea rubber seed meal may form a good cattle food, and that it contains very little indigestible matter.

" So far it has been impossible to obtain sufficiently large supplies of the cake to permit of feeding trials being made. Moreover, the cake has been found to yield small quantities of prussic acid. This is, of course, also true of linseed cake, but the fact makes it very important that feeding trials should be made at the earliest opportunity. In Ceylon it is certain that the cake would be valuable as a manure.''

Experiments with Hevea Oil and Cake.

Some seeds were sent by Mr. Kirk, of Malabar, to Messrs. Peirce, Leslie and Co., for oil extraction and determination of the manurial value of the poonac. The experiments were not altogether successful as the machinery available was not very efficient. The results indicate, at least, that the poonac is likely to prove a valuable fertiliser. There were operated upon 1,133 lb. of seeds, from which were obtained 361 lb. of kernels (or 32 per cent. of the whole) and 772 lb. of husk (or 68 per cent.). When crushed, the kernels yielded 38 lb. of oil (or 10·5 per cent.) and 260 lb. of poonac, a loss of 63 lb. Such a disappointing yield of oil was due to the oil left in the poonac, the latter still contained 33 per cent. of it. Thus the kernels originally contained 34 per cent. of oil.

In the first column of the annexed table is shown the analysis of this poonac ; in the second a calculated analysis when free of oil ; in the third an analysis of dried castor poonac :—

	%	%	%
Moisture	6·40	9·55	—
(*a*) Organic matter ..	55·12	82·27	91·59
Oil	33·00	—	—
Ash	5·48	8·18	8·50
	100·00	100·00	100·00
(*a*) Containing nitrogen	3·49	5·29	5·74

The ash contained 15·12 per cent. of phosphoric acid and 12·93 per cent. of potassium ; calculating the percentages in the oil-free poonac they are 1·23 and 1·06 respectively, the percentages in castor poonac being 1·8 and 1·2. The percentage of nitrogen in oil-free Hevea poonac is as favourable as that shown in the castor poonac analysis, in which the moisture is not included.

Transport of Seeds to Oversea Plantations.

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 unless great care is taken in collecting and packing operations.

The two most important factors are that the packing material should not be one that will allow moulds or bacteria to develop, and that it should be dry enough to prevent the seeds germinating and yet moist enough to prevent their being killed by drying. Other factors are mentioned in the notes below.

There is some advantage usually in sending packages of seeds by parcel-post instead of by ordinary freight. As the passage is shortened and the percentage of germinating seeds increased, it will generally be found that while the total cost per despatched seed is higher, the cost per germinated seed is lower.

Success in germination also depends, to some extent, upon the shortness of the time elapsing between the falling from the trees and the packing.

The Method of Packing at Trinidad.

The late J. H. Hart, of Trinidad, assured me that he always kept Hevea seeds damp and never dried them, and that he objected to the use of charcoal in packing as he believed the latter abstracted the moisture from the seeds. Mr. Hart informed me that coconut dust was best when "tobacco damp," and seeds packed with this material, in small tins of ½ lb. or so, kept sound, germinated freely, and did well when disentangled. One may presume that the seeds sent under these conditions had only a short journey to go.

The Method of Packing at Singapore.

The Director, Botanic Gardens, Singapore, has sent quantities of Hevea seed as far as Jamaica, Kew, Mexico, etc., with satisfactory results. The seeds were sent to Jamaica in biscuit tins, packed in slightly damped incinerator earth, with the upper part filled with sawdust to reduce the weight. The other seeds were sent in biscuit tins filled with damp, finely-powdered charcoal.

"In packing a certain amount of care is required (Str. Bull., 1906) in damping the charcoal so as to get it equally moistened all through and not either over wet or over dry. This is best done by damping it thoroughly and then drying it in the sun, consistently stirring and turning it over till it is uniformly slightly damped. The incinerator earth, which had been exposed to the elements, was damp when received, and only wanted partial drying to fit it for packing. Its weight is against its use, but both it and the powdered charcoal have the great advantage of preventing attacks of mould or bacteria likely to cause decomposition. Other experiments with powdered coir fibre and coirdust, sawdust, and variously prepared soils have been tried, but the results do not seem to have ever been as successful.''

On the occasion of my visit to Singapore in 1908 (My Tour in Eastern Rubber Lands) I noted what was the usual practice of the authorities there. Good results have always been got by packing in burnt rice husks. The old husks are obtained from the padi mills and burnt; the residue consists largely of finely-divided charcoal, very light in weight. Before the seeds are packed in it, the dust is sprinkled with water. One kerosene tin holds about 600 seeds; the tins are sealed in the ordinary way. After a journey of over four months, 60 per cent. of the seeds germinated. Mr. Ridley is strongly against using coconut dust and sawdust.

The Method of Packing at Peradeniya.

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 *Hevea brasiliensis*:—

''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 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″ by 16″ by 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 the 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 per cent. 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."

History of Certain Consignments.

It was reported by the late J. K. Nock, Hakgala, Ceylon, that on August 25th, 1908, some 1,500 seeds, packed in powdered charcoal and coir dust (mixed in equal parts and slightly damped) in ordinary biscuit tins, were despatched to India. "The consignee could not be traced, and the seeds were returned on November 4th, or 72 days after despatch. They were at once sown in an open bed, and no less than 496 plants were raised, the last seed germinating on December 20th, or 144 days after gathering. This number would have been exceeded had not porcupines visited the bed and routed out the seeds a week or two after germination had commenced. Out of 1,000 seeds forwarded to the Botanic Station, Seychelles, 750 plants were raised."

In the same year 10 packages (total 2,059 seeds) were sent from Ceylon to St. Lucia in charcoal dust, and occupied two months in transit. Success was obtained with 948 seeds, or about 46 per cent. It was asserted that the best results were got from seeds in tins the charcoal of which was dry on arrival.

From 500 seeds supplied by a Ceylon seedsman to the Gold Coast Botanical Department in November, 1900, 200 plants were raised. The seeds were packed in tins with charcoal, and were two months in transit.

Of various consignments totalling 172,957 seeds despatched between 1907 and 1910 from the Singapore Botanic Gardens to the Georgetown Botanic Gardens, British Guiana, 134,419 germinated, or 77·7 per cent. The journey occupies about 60 days. It has apparently been demonstrated that the best method of forwarding is by parcel-post in biscuit tins holding about 600 seeds and packed in weathered, charred rice husks. One lot of 50,600 seeds sent in this way cost on arrival about 1·2 cents. each. A comparison was made by Professor Harrison of two lots of seeds, one from the Singapore Gardens, the other from a Malayan estate. Both lots were packed in charred rice dust, but the latter were in hermetically-sealed tins, and were so closely packed that they almost touched, there being 823 in a tin, whereas of the former there were only 600. The latter consignment had partly fermented on the journey and only 19 per 1,000 germinated, while 702 per 1,000 germinated in the former case. Harrison ascribed the success of the Singapore consignment to the seeds being able to get sufficient oxygen for retaining their vitality.

Possible Superiority of Autumn Crops of Seeds.

The season at which Hevea seeds ripen may have something to do with their germinating capacity after a long voyage. The following table shows the fate of seeds sent from the Singapore

Botanic Gardens to the Georgetown Botanic Gardens, British Guiana, from which it will be seen that the autumn crop was superior :—

	No. of Seeds sent.		Germinated. Number.	Percentage.
1907-8	10,800	Spring Crop	6,955	64·40
do.	52,000	Autumn Crop	42,100	80·00
1908-9	50,000	Autumn Crop	43,150	86·30
1909-10	30,131	Autumn Crop	21,609	70·00
1910-11	29,676	Spring Crop	20,465	68·90
do.	303	Intermediate Crop	139	46·00

A greater difference has been experienced in Surinam with seeds from the same source. Of the seeds arriving in September, October, and November, from 50 to 80 per cent. were good, while only 15 per cent. of those coming in February, March, and April germinated.

The explanation of this difference given by Ridley is this : "It is possible that this is due to the drier weather about the time of ripening of the autumn crop. The spring crop comes on early in the year, just after or during the rains. The seeds are only thrown from the capsule during sunshine, and it frequently happens that when they are actually ripe, the days are dull and wet, and the seeds are retained in the capsule till the first fine day. In this case they have, it appears, a tendency to commence germination in the capsule, and even if the radicle is not protruded, the earlier preliminary stages may take place without any external symptons. Such seeds, when travelling, doubtless receive a check in growth which causes their death."

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 there may be a saving in the long run. If good seeds are sown, they will germinate in about ten or twelve days, and the percentage of failures 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 two 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 sides 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 may mean a year gained in planting.

Ridley maintains that Wardian cases are expensive and unsatisfactory, and considers that the method adopted in Singapore of packing in slightly-damped charcoal or burnt rice-dust gives better results.

Forwarding of Stumps Oversea.

Success with stumps shipped oversea seems to depend upon the care taken to maintain a sufficient degree of humidity within the packing or Wardian cases. If the journey occupies more than a week it is advisable that some one should accompany the consignment to perform a daily sprinkling with water.

Perhaps the most successful result obtained with stumps after a long journey is the following : out of 100,000 stumps sent from Ceylon to Samoa, at least 98 per cent. grew. The seedlings were taken out of the nursery beds when less than 20 inches high. Their crowns were cut off, and a stem of 12 inches left. The tap-roots were cut down to 4 inches. They were packed in petroleum tanks in a mixture of sand, mould, coconut fibres, etc., with a layer of moistened loam at the base. The mixture was maintained on the journey, which took six weeks, and some days elapsed before all were put into the ground.

But not all consignments are so successful. One learns that only 4,000 trees were got from 80,000 stumps sent from Ceylon to Surinam. Probably these were not attended to during transit. Properly treated on the voyage, stumps are superior to seeds ; there is also an advantage in the time saved in propagation. But whether or not the extra expense is justified is a matter for individual consideration.

How successful stumps may be on oversea voyages when properly cared for is shown by the results obtained by Mr. Stuart R. Cope, who has his consignments regularly watered on the voyage. I am informed that in the case of a consignment of 50,000 sent from Ceylon to Cameroon, the actual delivery, "live and in good condition," was 43,726.

Straightening Curled Roots.

When stumps or seedlings arrive from a distant country the roots are often considerably twisted and cannot therefore be placed in nursery soil except the curled roots are cut away. In such cases it is advisable to lay the plants out on planks, cover with soil and sprinkle water, and allow them to remain in that state for a few days in order that the roots may have a chance to straighten themselves as much as possible.

CHAPTER XXXI.

DISEASES AND PESTS OF HEVEA TREES.

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 consideration 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 plant occurs in large numbers and over extensive areas that anything like an epidemic is noticeable.

Specific Hosts for Fungi and Insects.

Perhaps the occurrence in large numbers of the host plant 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 Hevea to the exclusion of other kinds of rubber is a dangerous system" has probably much to recommend it. On some large estates the Hevea trees are being grouped, and each group is separated from its neighbour by a belt of other trees. Such a belt would prevent, to a certain extent, the spread of pests and diseases, and ne might be able to more easily combat insect or fungus pests, as soon as they made their appearance on the enclosed rubber tress.

It has been conclusively proved that many parasites on cultivated plants have specific or generic hosts; they usually confine themselves to a single species or groups of allied plants. Certain fungi which now thrive on cacao pods do not attack tea plants in the same district; one which attacks rubber plants will probably not damage cinchona; each pest thrives best and often only on a particular product. The pests appear to become established and effect the greatest damage wherever a very large acreage is occupied by only one cultivated product ; wherever the insects or fungi are carried, a fresh source of the same food is at hand, and in consequence of this, the parasites, though blown about for many miles, are rarely deposited in areas where a food supply is not available. Though this is the case it must not be lost sight of that many fungi have wide powers of adaptability and may select new hosts when least expected to do so.

Protective Belts of Trees.

A fungus which thrives on coffee leaves and kills them would probably die of starvation if placed on a tea plantation where only tea leaves were available. It may be generally stated that a large acreage uninterrupted with other species affords one of the best means of propagating parasitic species ! It is essential that, in order to check the spread of insect and fungus pests, the protective belts of trees, virgin or planted, shall be composed of species unlike—botanically—those to be protected. For instance, in some parts of Java, the cacao and rubber trees are arranged in separate patches, so that the rows of rubber trees form distinct belts between parallel groups of cacao trees. One plan which has been suggested is to plant five or more lines of cacao, the lines to be 10 to 15 feet apart ; interplant these with Dadap shade trees, if necessary, then plant three or six lines of rubber, the lines to be 10 to 20 feet apart.

A belt of jungle not possessing these cultivated trees will arrest parasitic insects and fungi, but may not feed them ; if these parasitic organisms are kept from their host plants they are apt to die or degenerate, the belts thus serving as traps.

Forest Belts and Harbouring Disease.

But some reservation must be made to the statement that jungle belts always protect cultivated trees against diseases. It may be fully accepted that the spores of "pink disease" and "dieback" are car ied at monsoon time from the jungle, which serves as a nursery for the disease, a factor that necessitates constant watchfulness. As other diseases may also be harboured by certain jungle trees, one begins to feel somewhat dubious about the principle of jungle belts. I cannot help believing that many of the organisms attacking cultivated plants in the tropics have always been in those areas, and are able to accommodate themselves to the new food supplies presented in vast areas of the same species under cultivation.

Forest Belts in Malaya.

The idea that all parasites come from the jungle, and that forest belts may therefore harbour pests, is one which is frequently brought forward ; it is admitted that the origin of parasites in the tropics is sometimes very problematical. Everyone, however, with tropical experience is convinced that small properties are generally freer from pests than large ones, and that barriers in the form of belts of unlike species generally assist one in keeping diseases at the minimum. The retention of barriers of virgin forest has been brought into force in the F.M.S. by the Government Botanist. There one very large tract of forest has been retained in a certain district. Prominent agriculturists have expressed their approval of this system.

Advantages of Mixed Products.

Mr. Green, Government Entomologist, Ceylon, has stated the case as follows:—"The history of every cultivation has shown that with increase of area and lapse of time, new pests arise, attracted by the altered conditions and an abundant supply of food. Our Ceylon system of exclusive cultivation of single products, though convenient for economic purposes, lends itself to the rapid spread of pests and calls for special measures to meet this liability. Plants in their natural state—where numerous orders, genera and species are intimately mingled together—are not nearly so subject to the ravages of disease. Apart from the physiological benefits of commensalism—now becoming more generally recognised—the more or less complete isolation of individual species that occurs under natural conditions is itself a check to the extension of disease.

"These facts lead up to the consideration of what I look upon as by far the most important part of my subject, that of isolation. I have been impressed with a sense of the immense difficulties that lie in the way of combating any serious insect pests where no efficient means of isolating any particular area for purposes of remedial treatment are present. What are the conditions that prevailed during the reign of coffee and that are now equally or even more pronounced during the age of tea? We find vast continuous tracts of land planted with a single product, unbroken by either natural or artificial boundaries, and affording no hindrance to the free distribution of any infectious disease. Under such conditions how can we hope to effectively deal with our insect enemies? Vigorous measures may be employed and a pest may be temporarily exterminated on a limited area, but the disinfected parts are immediately liable to fresh invasions from all sides. Given an isolated field we can deal with a pest with some confidence that our labour will not be nullified.

"The remedy lies in the formation of protective belts or boundaries of either jungle or cultivated trees. Such belts should be at least 30 feet in depth and composed of close-growing trees with a good cover of foliage. As in most trees the lower parts are bare of foliage, a separate undergrowth will be necessary to ensure an effective screen. It is also important to understand that the trees and shrubs composing the belts should be of kinds differing as widely as possible from the plants that are to be protected by their means. Insects, though seldom dependent upon a single species of plant for their nourishment, generally confine their attention to distinct groups of nearly related species and genera. If the protective screens are composed of trees belonging to a distinct natural order, there is much less chance of the inter-communication of pests."

Block Planting.

It is not necessary to apologise for such a lengthy extract from the remarks made by Mr. E. E. Green, as the subject deserves more consideration than it has yet received from Eastern officials and planters. In order to meet the views herein expressed several African and American rubber planting companies, dealing with the cultivation of several species in the same territory, have caused the trees to be planted in blocks so that the continuous area under each species is limited and the trees are surrounded by unlike species. This block system of planting can easily be carried out when the estates are first taken over.

When touring through Ceylon in April, 1908, the writer observed that many strips or patches of native compounds, planted with species other than those yielding rubber, were retained; these serve to isolate the large rubber estates in the same district from one another, and their preservation should, if possible, be encouraged.

Diseases of Rubber Plants.

Much has been written on the subject of plant diseases in the tropics, and Government have from past experience seen the necessity to appoint officers to investigate the life histories of fungi, insects and various pests as soon as they appear. Every cultivated plant in the tropics is subject to the attacks of injurious insects and fungi, and we are now in possession of up-to-date information which enables planters to suppress most parasitic diseases upon their appearance. The first appearance of a disease in the tropics is usually promptly notified by the authorities, every publicity is given to even the harmless forms, and planters are now fully alive to the importance of carrying out well-advised plant sanitation operations. It is satisfactory to know that effective remedial measures can be applied against most of the diseases known to affect cultivated rubber plants.

It is, however, well to realize that trees of *Hevea brasiliensis*, 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 many diseases or pests mentioned in this chapter most of them are not of a very serious nature, but they are nevertheless worthy of full consideration. Only the more important are dealt with in these notes.

General Principles in Plant Sanitation.

There are certain general principles to be adopted in attacking diseases on cultivated trees. Briefly they can be enumerated as follows :—

Diseases and pests should be promptly dealt with.

A permanent sanitary gang of experienced coolies should be set apart for disease work, and augmented whenever necessary, even if this involves reduction of working coolies on other important divisions of the estate work.

Efficient spraying machines should be kept at hand and always in working order. As Carruthers pointed out, the cost of even the most expensive steam-power spraying apparatus, one capable of reaching the tops of trees 80 feet or more in height, bears an infinitesimal proportion to the value of the trees on even a small estate.

A stock of chemicals for spraying should always be at hand, and acquaintance should be made with the methods of using the most efficient remedies.

The treatment of the soil after the removal of a tree having diseased roots is not in practice too clearly understood. Liming can only have an indirect effect, as by neutralizing soil the extreme acidity of which has been responsible for the encouragement of the disease. The use of one of the proprietary soil fungicides may be recommended, though one cannot at present endorse the claim that they effect a cure *in situ* of the diseased tree itself.

All Fomes areas should be at once isolated by means of trenches.

All diseased tissues, whether in the orm of fruits which have fallen from the trees, cankered bark which has been excised by coolies, branches, prunings, or roots, should be collected and burnt, either on the spot or in some central place.

The Removal of Stumps and Logs.

The question of removing stumps and logs always receives, for financial reasons especially, careful consideration. It does not appear as a rule to be essential in Ceylon, but in Malaya it is generally necessary as a preventative of root disease and of white ants. It is a question which the proprietors of each estate must decide for themselves, keeping in view the experience of estates in their districts. A very convenient, and in fact the best, time for removal of tree stumps and logs is before planting out ; though the objection has been made to this that delay in planting results, estate operations may follow a course with regard to the seasons that render this objection futile. At any rate, the greater expense of removal after planting must be considered as against the earlier maturity of the trees. Where, upon the older planted estates, the wood was left to decay, great improvement has since been made in many cases by clearing it away. The cost per acre has appeared enormous, but it has amounted to much less than the total cost of supplying and maintaining, which would otherwise have been incurred. Yet it has been said that the great expense some imes involved in clearing all logs and uprooting stumps is not warranted, since their removal does not appreciably decrease the loss of trees through attacks of root disease and white ants.

It should not be forgotten that weeding is better and more cheaply done on estates where all timber has been removed prior to or immediately after planting.

Some Precautions in Pruning.

When dead or diseased twigs and branches are cut away, care should be taken that they are removed flush with the branches or trunk, so that the bark may grow over the wound. Otherwise, as foresters have found out by experience, the bark being unable to cover the exposed area, the latter is very liable to attack by insects and fungi. All wounds left after pruning diseased branches should, if possible, be protected. Coal-tar is more efficient than wood-tar, but no more should be applied than is essential, in view of its possible poisoning effects. In America white-lead paint is sometimes favoured for this purpose, but information is not to hand of its applicability in the tropics, though there is no reason for doubting it. Care should be taken to prevent the coating materials being used on diseased areas, as, if the latter are simply covered with tar, the destruction will ultimately be greater. Where "cankered" bark is being treated, the operator should excise every particle of diseased tissue before allowing the area to be covered with tar or any other substance; in fact, it is usually safer to allow such areas to heal without being covered with any protective substances.

Spraying Apparatus.

Up to the present no extensive use has been found on rubber plantations for powerful spraying machines; those used so far apparently having been sprayers fitted with hand-pumps. For fluids or washes containing insoluble constituents, an up-to-date apparatus is necessary in which efficient stirring is brought about. In some forms of apparatus, as in the Strawsonizer, the stream issuing from the nozzle is broken up further by an air-blast impinging upon it.

Iron vessels should not be used when copper compounds are being sprayed. Copper sprayers should be discarded when ammoniacal spraying mixtures are used.

The sprayers now in use consist of (1) hand syringes, (2) knapsack sprayers for carrying on the coolies' backs, and (3) sprayers requiring considerable power. Some of these can be used in conjunction with the spraying of weeds.

Merryweather's have supplied various types of portable sprayers to estates. The simplest type, and one which can be recommended for work on a small scale, consists of a barrel constructed of oak, with a capacity of 36 gallons. A hand-pump for generating pressure is supplied. The apparatus is mounted on wheels and can be moved about and worked by one man.

In other sprayers, pumps are driven by oil or petrol engines. In one type the apparatus is provided with a horizontal oil engine, a pump of the "Valient" type, and 4 to 6 spraying jets. In another form, a vertical petrol engine is used to drive the pump, which is suitable for six spraying jets and for working up to a pressure of 200 lb. per square inch. This is recommended where pumping has to be carried on continuously for a considerable period. It will be obvious that these spraying machines can be used for spraying to a great height and over a large area.

Hand sprayers and syringes are sometimes the only kinds which can be used, as when the estates are steep and young and badly provided with roads. Numerous firms supply these in various types.

Fungicides.

All fungicides should be considered as poisons, though some are so only in a small degree. Care should be taken to guard against any corrosive effects upon the skin. All chemicals should be purchased from reliable dealers at prices that will command relative purity and freedom from constituents harmful to the trees.

Copper Sulphate.—The cheaper kinds contain iron sulphate, which is in strength sometimes sufficient to cause damage. Material with a purity of 98 per cent. should be used. This salt enters with lime into the composition of Bordeaux mixture; it has also been employed as a soil-dressing for root disease.

"Solubic Brand" sulphate of copper (prepared by Messrs. Strawson), is guaranteed not less than 99% pure, and also has the advantage of being in fine granular form which is instantly soluble in cold water. It is superior to ground or powdered sulphate of copper as it is more quickly soluble, and does not "cake." It is suited for use on rubber plantations for destroying weeds as well as a fungicide, owing to its solubility, guaranteed purity, and fine form.

Bordeaux mixture.—The constituents of this mixture are: copper sulphate (98 per cent.), 6 lb.; freshly-burnt lime, 4 lb.; water, 45 gallons. The following directions for making up the mixture are given by Strawson. In a wooden vessel dissolve the sulphate in half of the water. Slake the lime to a uniform mass, and add to it the rest of the water. Pour the lime mixture into the copper solution, stirring well. Upon settling, the liquid should not be tinged with blue. The mixture may be bought in powder form, already prepared, water being added for use. Constant agitation is necessary during spraying. The most useful application of this mixture is as a preventative of pink disease, when it is used as a wash; it can be applied with a brush. There is considerable difficulty in preparing the material so that it is uniform and neutral. Moreover, without a special dehydrating plant, it is impossible to concentrate the material.

Strawsonite (the original ready-made Bordeaux mixture) is highly concentrated—that is to say, a ton of Strawsonite actually contains the same amount of metallic copper as a ton of sulphate of copper itself. Thus 1 ton of sulphate of copper plus ½ ton of lime makes approximately only 1 ton of Strawsonite, the loss in weight being caused by driving off moisture. It is guaranteed to contain 24 to 25 per cent. of metallic copper, which is, of course, the same percentage of copper as in pure sulphate of copper itself. The advantage to the planter in using Strawsonite is (1) the material is uniform, (2) the trouble and risk of mixing is avoided—merely cold water has to be added, (3) there is economy in freight, as the lime is already included in the compound.

When buying ready-made Bordeaux mixtures planters should always ask for the strength in copper—some mixtures contain only about 5 to 10 per cent. of copper.

Lime-sulphur wash.—This mixture, with somewhat similar uses to Bordeaux mixture, especially as a preventative, has not received much notice in the East. Take freshly-burnt lime, 7 lb.; flower of sulphur, 3½ lb.; common salt, 3 lb.; water to make 10 gallons. Boil half the lime with the whole of the sulphur for an hour in 3 gallons of the water. Slake the rest of the lime, making up with 3 gallons of water, and add the salt. Pour the latter mixture into the first and add the rest of the water. This is an insecticide (for scale insects, etc.), as well as a fungicide. Its use is likely to extend, but at present one cannot recommend definite strengths for use. The above formula is that for a winter-wash in the temperate zone; probably on rubber plantations about 100 per cent. more water will prove a sufficient strength if the wash is used for other purposes than for painting the bark.

Carbolineum plantarium.—This extract of wood-tar has been recommended as a dressing in root diseases. But it must be noted that the general opinion is that coal-tar is more efficient than wood-tar, and this may apply as well to the extracts.

Soil fungicides.—A number of proprietary articles are on the market for soil treatment in root disease, among which may be mentioned, "Fungal," "Clubicide," etc. Lime and copper sulphate are also used for forking into the soil, in connection with root diseases.

Insecticides

The constituents of insecticides act in three ways: (1) as stomachic poisons for caterpillars, beetles, and other leaf and wood-eating insects; (2) as corrosives, for plant-sucking bugs, as the aphides; and (3) as asphyxiators, for white ants, and also for aphides. The stomachic poisons are sprayed on to the trees, dug into the soil, or bait poisoned with them is put down. The corrosives are sprayed. Asphyxiators are sometimes sprayed in the form of oil emulsions; occasionally they are dug into the soil as powders, which give rise to fumes, or the fumes may be directly applied.

Arsenate of lead.—This is a compound made up as follows: acetate of lead (98 per cent.), $2\frac{3}{4}$ oz.; arsenate of soda (98 per cent.), 1 oz; water, 10 gallons. The chemicals are placed in the water together and dissolved. If thought desirable, a pound of treacle may be added to ensure adhesion to the foliage. Arsenate of lead has been preferred to Paris Green, as it sticks better, and is said to be less dangerous to the foliage. It is a valuable poison for leaf-eating insects.

Arsenate of lead can be prepared on the plantation by the grower, but the chemicals are highly poisonous and are dangerous to handle. Moreover, home-made preparations frequently contain a high percentage of arsenious acid, which scorches the foliage.

Arsenate of Lead (*Strawson Swift*).—This is the original arsenate of lead which was first discovered in America. It is said not to scorch the foliage, and is so intensely adhesive that it will remain upon the foliage for many weeks, and is not even washed off by ordinary rains. It is in a fine state of sub-division, and does not clog the spraying machine.

Paris Green.—This is arsenate of copper and is a powerful poison. Being insoluble in water, the mixture must be well stirred during application. A standard preparation is Blundell's Paris Green, which is supplied as a powder or a paste. Take 1 oz. of either and mix in 10 gallons of water. A fine spray is necessary.

Petroleum emulsion.—This is the most useful remedy for plant-sucking bugs, which, of course, cannot be attacked by poisons sprayed upon their food material. The constituents of a typical formula are: petroleum, 2 gallons; water, 1 gallon; soft soap, $\frac{1}{2}$ lb. Add the soap to the water and bring to the boil, dissolving thoroughly. Into the solution, when boiling hot, stir the petroleum. Immediately well churn the whole to emulsify; then allow to cool, when a jelly should form. Use 1 part of this to 10 parts of water. Spraying should take place only in the evening, and in as dry weather as possible.

Sulphur.—This is sometimes useful for blights on nursery plants. "Flower of Sulphur" can be distributed as a fine powder by means of a hand-blower or in a bag made of coarse cloth.

Soil Insecticides.—A proprietary article for forking into the soil is "Vaporite," a preparation of naphthalin and tank-waste from alkali manufacture that liberates a poisonous gas in the soil. The manure "Kainit" has been recommended for the treatment of tender-skinned beetle grubs. Quicklime has a similar action.

Burrs, Twists and Fasciations.

Unusual growths, which cannot be associated with any disease, often appear on healthy Hevea trees. On the trunk two types of burrs (Circ. R.B.G., Vol. IV., and Straits Bull., June, 1911), may occur within the tapping area. One type is due to abnormal thickening or upraising of wood below the tapping lines or below spots through which the teeth of prickers have passed.

In such cases the cambium is injured and an excessive quantity of woody tissue produced. The second type consists of woody nodules in the cortex, each with its own cambium or growing tissue; these are at first isolated in the bark, but later become connected with the wood. The nodules betray their existence by raising the surface of the bark. Eventually they develop each into a larger burr, or a number may fuse together.

Tapping over burrs cannot be recommended. It is better to allow these to work themselves out, especially if they are in the form of small nodules.

Cases of twisted stems in seedlings are frequent; the cause is usually the position of the seeds in planting. The best position is perhaps the horizontal one with the flattened end upwards. When planted vertically with the more pointed (micropylar) end uppermost, a high percentage of abnormal seedlings develop.

Sometimes the trees are irregular in outline in consequence of having been exposed to wind, the surface facing the wind frequently being flattened; such trees when twisted are not as easy to tap as those with normal stems.

Fasciated stems have also been recorded; they are rare, and do not appear to be due to parasitic fungi or insects.

SEED PESTS.

There are no records of diseases of seeds due to fungi, nor are there any showing that seeds may carry the germs of diseases that may attack living plants. It is noteworthy that the Governor of Cochin-China, to protect against all possible danger of this kind, has ordered that all introduced Hevea seeds be immersed for half-an-hour in a solution of 0·1 per cent. corrosive sublimate or 1 per cent. sulphate of copper. He has interdicted the introduction of the plants.

Craw found that a consignment of seeds sent to Hawaii from Ceylon were infected by mites. The seeds were treated successfully with carbon bisulphide.

NURSERY PLANTS AND STUMPS.

Fungi.—A thread blight—*Pestalozzia palmarum*—the cause also of grey blight of tea and of leaf disease in the coconut, has been found on the green stems and leaves of nursery seedlings. The fungus forms irregular, white areas spreading generally from the tip of the leaf, or it forms similar areas at the base of the stem, when it kills the seedling. All the plants attacked should be removed, and the soil disinfected with, say, carbolic acid one part to 160 of water.

A leaf disease has appeared among seedlings in Surinam which produces irregular brown areas, with yellowish-green zones outside, upon the upper surfaces of the leaves. The disease has not so far been amenable to treatment, but it is not a serious one.

The fungus responsible for the final stage of dieback—*Botryodiplodia theobromae*—mentioned in the section of this chapter dealing with stem diseases—may attack stumps. The infection appears to arise from the soil in which the trees are planted. Liming, after pulling out the diseased plants, may be tried, though it is not in all cases efficient.

In the Straits, the leaves of seedlings have been attacked by a fungus (Straits Bull., July, 1905), regarding which Massie reported: "The pale blotches on the leaves are caused by some species of Cercospora, but the absence of fruit prevents specific identification." Ridley stated that this fungus was common all over the Malay Peninsula, but that except in the case of seedlings not much harm is done. It has been suggested that this fungus may be a species of Helminthosporium.

Leaves of Hevea seedlings *have* been attacked by a species of Helminthosporium. The leaves (T.A., June, 1905), were studded with circular, white, semi-transparent spots, each surrounded by a brown cushion from which arose the threads of the fungus This disease is one which leads to partial defoliation and checks the growth of the young plants. In all such cases the diseased leaves should be pulled off and burnt, and the rest of the plants sprayed with Bordeaux mixture.

Insect Pests.—"Mites" in rubber nurseries have been reported from the Straits. Arden (Straits Bull., June, 1905), stated 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 compared it to "Red Spider," and believed that the disease was mainly limited to plants growing under unfavourable conditions.

Bernard (Bull. Dept. Agric., Indes Neerlandaises, No. 6) records the attacks of mites on the leaves of nursery plants in Java. He recommends destroying the leaves, or as an alternative the use of insecticides.

Green has the following notes (T A., Feb., 1906), regarding pests which are associated with stems of young plants :—

"The cut ends of young Hevea stumps are frequently tunnelled by various small species of bees and wasps. But these insects are not responsible for the dying back. The pith of any dead stem would be utilized in a similar manner. When a young Hevea plant is stumped, it usually dies back to the node, and it is in such dried ends that the tiny wasps construct their nests. They cannot be regarded as pests, but more properly as friends, for most of them provision their nests with Aphides taken from some other plants."

The deserted tunnels of these wasps and bees are sometimes tenanted by a species of thrips, but the latter is quite harmless.

The grub of the large cockchafer—*Lepidiota pinguis*—appears to be troublesome on young Hevea plants; Green reports over 3,000 plants being killed in a single clearing. In some cases the tap-root has been eaten through. If "Kainit" or "Vaporite" are forked in within the areas affected, the grubs can be destroyed.

As the effects of their attack upon the plants appear only after the damage is irremediable, preventative measures against further attacks alone are possible.

Green (T.A , Feb., 1906), makes the following remarks about a beetle pest :—

"Specimens of a small Longicorn beetle, said to be responsible for the death of young Hevea trees, have been received from Southern India. The insect proved to be *Pterolophia annulata*, a species that occurs in Ceylon also. I have no records of injury done by this insect to Hevea in this country, but I have bred out a specimen from the diseased bark of a Ceara rubber tree. My correspondent from India reports that the beetles girdle the stems, the upper parts of the trees dying back down to the injured area. This girdling habit is common to many species of Longicorn beetles The object of the manœuvre is believed to be to check the sap and induce the degree of decay best suited to the nourishment of the grubs of the beetle, the eggs having first been inserted in the back above the point of injury. If this pest should become common, it might cause serious damage on rubber plantations. In case of any occurrence of the pest the stems of all the trees should be carefully searched. The adult beetles will probably be found clinging to the bark of the trees, when they can be easily captured and destroyed."

Specimens of another Longicorn beetle—*Moechotypa verrucicollis*—said to have killed young rubber stumps, have been reported upon by Green (Circ. R.B.G., Ceylon, No. 12, vol. IV.). The bark of the injured plants had been nibbled off, and the bare wood exposed. The probability is that the attacked plants were first diseased, as the beetles cannot deal with latex-yielding living tissues. Examination of the roots proved that they had previously been attacked by the parasitic fungus, *Botryodiplodia elastica*. Hand picking is suggested.

A few cases of damage to young plants by cut-worms—larvæ of *Agrotis segretis*—have been recorded. Injury can be prevented by adding "Vaporite" before putting in the seed.

Dragon-flies have in error been blamed for causing injury, but as they are insectivorous they should be regarded rather as beneficial.

The "black bug"—*Lecanium nigrum*—where it occurs thickly on young plants, checks their growth, but, according to one authority (Journ. Econ. Biol., May, 1911), does little or no harm to well-established plants. It affects leaves of young stems. Where destruction by hand is too laborious a method to adopt, one of the standard soapy insecticides may be applied. Other species of scale-bug seem to be of no serious importance

According to Green (Circ. R.B.G., No. 12, vol. IV.), the leaves of Hevea seedlings are reported to have been punctured by certain plant-sucking bugs, *Leptocorisa acuta* and *Callicratides rama*. The former is known as the "Rice-sapper." The bugs can puncture soft parts of the stem, causing the terminal shoot to wilt and droop. Damage from this cause can be prevented by lightly sweeping a butterfly net over the growing seedlings and destroying the insects by hand.

Crickets have been described by Ridley (Straits Bull., March, 1906), as biting off the tips of rubber seedlings, and Waterhouse of the British Museum has identified some of these pests as *Brachytrypes achatina* and *Gymmogryllus elegans*.

The mole-cricket has been blamed for eating off the young shoots of stumps. The planter complaining has tried liming, tarring, and even bird-liming without avail, and he has been told that all that can be done is to pull up the stumps and supply others of greater height. I have known of large acreages destroyed by this pest.

Spotted locusts have been reported to occasionally damage young dadap and rubber plants in Ceylon and the Straits, but they usually ignore Hevea trees.

Wingless locusts reported from various districts in Ceylon are said to destroy the seedlings, the bark being gnarled and completely eaten off in parts. Poisoned baits have been found effective in such cases (T.A., Nov., 1905), one of the best being "arsenic-salt-horsedung" mixture, made by compounding one part of Paris green or white arsenic with two parts of salt and forty parts fresh horsedung. It is recommended that this should be broadcasted among the affected plants or wherever the locusts may be noticed.

Several smaller species of grasshopper sometimes defoliate the young nursery plants. The same poisonous mixture should be used.

A species of white ant—*Termes carbonarius*—previously thought to be harmless, has been found stripping newly-planted stumps (Straits Bull., Aug., 1911), by eating the bark, over which it constructs galleries. The nests are in large mounds often six feet high. Treatment of their nests is by the fumigation method described later for use against *Termes gestroi*.

Leaf Diseases and Pests.

There are already several insects and fungi which live on the leaves of Hevea trees, but none of them are very harmful. To a very limited extent the annual fall of leaf that takes place on rubber trees after they have passed their third year is an advantage when dealing with leaf pests, as the foliage can be easily and regularly collected and burned. 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 Hevea trees are in possession of their foliage for about 50 weeks each year, and to assume that the leaves, owing to the deciduous character of the tree, are not likely to contract a permanent disease is by no means sound. Further, the trees do not pass through their leafless period all at the same time, so that there are at all times some trees in leaf to perpetuate disease.

Fungi.—A thread-blight (Straits Bull., April, 1911), attacks the leaves and younger twigs of trees in Malaya. Bancroft found white strands which may mat the leaves together in dense masses. As the disease progresses, the leaves fall, and the younger twigs wither. Infection is by contact, say by a fallen leaf infested with the disease being blown against a healthy leaf or a branch, or by the touching of branches of adjacent trees. All the fallen leaves and twigs under affected trees should be gathered into heaps and burnt. The trees should be pruned, the prunings being also burnt. Spraying with lime-sulphur wash will probably help to keep the disease in check.

Insects.—A species of weevil, allied to if not identical with *Astacus lateralis* (Wray, Perak Museum Notes, 1897), was reported in the Straits to eat Hevea leaves. Pratt received from Malayan estates some specimens of a weevil—*Eumeces squamosus*—that injures the young trees by eating the leaves and younger shoots. Two species of weevil eating the leaves have been recorded from Java. For these, hand-picking is the only remedy.

A new species of scale-bug upon the leaves, belonging to the genus Mytilaspis, has been recorded (T.A., Dec., 1905), but it is unlikely to cause any serious trouble.

According to Green, there is no single species of caterpillar that has a preference for the foliage of Hevea. But every caterpillar found actually feeding upon the plant must be treated as a potential enemy and destroyed.

Specimens of the "pigmy rose beetle"—*Cingala tenella*—were submitted to Green with leaves showing numerous small irregular perforations. The insects were dead on arrival, and were firmly glued to the leaves by coagulated latex.

Fruit Disease.

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 disease. The disease is the same —*Phytophthora Faberi*—as that responsible for the canker of cacao fruits, and, therefore, affects the cultivation of both Hevea and cacao trees. This disease can be considered when dealing with the same disease on the stems.

The most effective way of fighting the fruit disease is to collect all dried fruits which are on the trees 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.

Canker of the stem and of the fruits of Hevea (Circ. R.G.B., No. 13, Vol. V.), is caused by the same fungus—*Phytophthora Faberi*—that is responsible for cacao canker and fruit disease. On young trees the affected bark may appear darker ; in some cases the bark exudes a reddish or purplish liquid. In many cases the disease has been discovered only when the tree has ceased to yield latex. A black layer is found beneath the outer brown bark, and below it again the laticiferous tissue is discoloured, at first being greyish with a black border, later claret-coloured brown or yellow on green pods, and black on dark-red pods. If the diseased pods are left on the tree, the fungus travels down the stalks into the branches. The disease is usually discovered by the cessation of the latex flow. Sometimes all the cuts, sometimes one or two only, yield no latex when tapped. In some cases the tapping has struck a patch of canker where the bark is clearly diseased ; but in other cases the tapped bark appears quite healthy, though rather dry and slightly yellowish. In other cases the disease occurs at the base of the stem, and all the cuts are dry. On plantations of Hevea only, canker has not caused very much damage, but on mixed Hevea and cacao plantations it may be more serious.

It is remarked that "excision of diseased tissues is the recognised treatment for stem canker. All the discoloured tissue should be cut out and burnt. The difficulty here is the discovery of the canker before it has progressed so far that a large area has to be excised. The tapping coolies should be shown what cankered bark is like, and they should be instructed to stop tapping, and report any trees which cease to yield latex, even if the flow ceases only on one cut.

"If the wounds caused by excision of cankered bark are small, cow dung and clay is the best covering that can be used to promote the healing process. But where they are large, so that the bark cannot be expected to grow over them, the exposed wood must be protected. If it is left unprotected, it is soon riddled by boring beetles which rapidly bring about the destruction of the tree." Petch suggests that the exposed wood be tarred, except for a strip of an inch all round, and that this strip be treated with cow dung and clay as before. On badly-affected estates it may be advisable to spray all the stems with Bordeaux mixture in dry weather ; this treatment would kill the spores and thus assist in controlling the spread of the disease.

Pink disease.—In Java, Ceylon, South India, Malaya and in the West Indies, "pink disease," the "djamoer oepas" of Java, due to *Corticum javanicum*, occurs. In addition to Hevea it attacks tea, coffee, cacao, coca, cinchona, dadaps, crotalaria, etc. The spores are carried by the wind, evidently to some large extent from the jungle, and find favourable conditions for their development upon wet bark. In South India, the south-west monsoon period is the time when the disease begins to develop ; its growth is suspended in the dry season. Close-planting encourages it. It generally begins at the fork of a tree, or where several branches arise close together, these being situations where rain-water collects. At first a superficial pink incrustation is formed, and as it spreads over the surface there is also an extension into the bark, which it kills. This splits along lines at right-angles to one another, and begins to peel from the wood. Older patches lose their pink colour, becoming yellow and even white. According to Anstead, treatment by cutting out the diseased bark and painting the wound with Bordeaux mixture or tar is a failure. Affected branches should be cut off at least 18 inches below the point of attack. Where the trunk is affected, unless 3 feet of tappable stem can be left, it is best to cut the tree down to the ground and get a sucker from below to replace it. The knives and chisels, and also the coolies' hands, should be washed in permanganate of potash when proceeding from tree to tree.

Gudgeon used Bordeaux mixture on Palapilly estate, South India, to kill the alighting spores. Gum was added to make it stick on the trees. The mixture was applied to all wounds and points of attachment of branches to the main stem, the application being made before the beginning of the south-west monsoon. He reported (Planters' Chronicle, May, 1911), that:

"It has cost me about 150 rupees to do 500 acres, 200 acres of which were 2½-year-old trees and cost very little. This includes labour, pan, copper sulphate and brushes. The amount a coolie will do is difficult to say, as it entirely depends on the age and size of the trees; I also pruned the trees carefully as I went along, which is not included in the above cost. At least 90 per cent. of the trees were done in the older clearings; only those that had branches shooting out very high up were missed."

Dieback.—The essential fungus—*Botryodiplodia theobromæ*—causing "dieback" of the Hevea rubber tree and cacao (Dept. of Agric. F.M.S. Bull., No. 9, and Circ. R.B.G., Ceylon, No. 23, Vol. IV.), is distributed throughout almost the whole tropical zone, though as a disease of the rubber tree it is reported only from Ceylon, South India, and the Federated Malay States. Many other plants—tea, coffee, coconuts, camphor, tapioca, Albizzia, etc., upon which it is found, are mostly infected only upon parts already dead. The fungus attacks the branches of Hevea at a point some distance from the apex. Death of the terminal portion follows owing to interruption of the food supplies, and the disease spreads downwards, in some cases even to the roots. Growth is very rapid, and many cases are mentioned where a tree has died in a month or six weeks after the death of the uppermost branches, while there has been a case where a 2½-year-old tree was killed down to 4 inches from the ground in twelve days. Both wood and bark are discoloured, becoming grey. The cambium forms a black or dark brown film which subsequently dries. The fungus spreads mostly through the wood, and hyphæ extend for a distance of 4 or 5 inches beyond the discoloured part of the wood. Where the growth of the fungus is slow, and the infection has been upon an older part, a cankered appearance arises. In Malayan experiments to infect Hevea plants with the spores, it was found that infection was not possible upon an uninjured surface, nor at a shallow wound or carefully tapped surface, but it resulted in every case where wounds were deep enough to expose the wood.

Though the fungus *Glœosporium alborubrum*, said in Ceylon to prepare the branches for the attack of "dieback," has not been observed in Malaya, its characteristics must be noted. It appears on the branches away from the tip, and they become dark brown, later grey, a discolouration that extends towards the tip and towards the main stem. Fructifications develop that cause very minute swellings of the epidermis, which burst at the top to liberate the pink or white spores, the minute holes remaining giving the surface a rough appearance.

The most familiar fructifications of the essential "dieback" fungus—*Botryodiplodia*—are situated in the bark, and are small black spores about one hundredth of an inch in diameter, a size within the range of visibility. These spores frequently occur close together, and united into a continuous mass, which happens especially when they develop in cracks in the bark; in such cases they may form a projecting, swollen cushion. When extruded, the spores cover the surface of the bark with a fine black powder. This fungus has been variously named *Diplodia rapax, Lasiodiplodia theobromæ, Botryodiplodia elasticæ*, etc., but recent work by Bancroft in determining a certain form of its fructification other than the above—there are three forms in all—suggest that the name in the future must be given as *Thyridaria tarda.* In addition to thorough sanitation and good cultivation as general measures, pruning of the diseased parts is, of course, necessary. The cut should be sloping; it should be tarred and all excised parts burnt. A useful precautionary measure is to cut off all dead green shoots.

It should be noted that Ridley denies that the above fungus attacks living tisues.

A canker-like disease—due to a species of Fusicladium, and yielding to similar methods of treatment—is recorded from Java by Bernard.

WHITE ANTS.

Insects.—The termite or so-called "white ant"—*Termes gestroi*—which enters the root and may also excavate the stem, is a most troublesome pest, especially in the Federated Malay States. At one time stress was laid upon the association between white ants and root fungus, the ants following the latter; but Pratt states that there can be no doubt whatever that in the case of at least 90 per cent. of the trees attacked, the white ant is solely responsible.

The members of a colony consist of a queen, fertile males, soldiers and workers. The queen establishes the nest, and rears her first brood of workers and soldiers until they are capable of undertaking the duties of the colony. After this she becomes merely an egg-laying machine—the queen of another species of termite lays at the rate of 60 eggs per minute or more than 80,000 per day—and the workers, probably with the assistance in part of the soldiers, attend to her needs, care for the young, continue the building of the nest, and excavate the burrows through the soil. These burrows lie from six inches to three or even four feet below the surface, according to the character of the soil and the depth of the soil-water. They may be of great lengths, and have been traced to a distance of 300 feet from the nest. New nests may be started along the burrows Nests may actually be found in hollow Hevea trunks.

The sources of danger are decaying jungle stumps and logs. These serve not only for harbouring the pests, but also for supplying food in the form of finely-divided particles of wood, and probably also of the moulds present. Entry to the Hevea trees may be by way of the lateral roots, though occasionally the burrow goes straight to the tap root. The destruction of the roots and the hollowing of the stem may not be evident for some time The ravages of this pest often leads to unsightly excavations and to removal of soil from the main roots near the stem.

Upon comparatively new estates, where dead wood in various forms may be found in abundance, the insects thus readily find conditions that lead to their rapid increase in numbers. At the same time they are using up the available wood, which is also disappearing by process of decay. As a result of the disappearance of the food supply there is a much greater tendency for the rubber trees to be attacked, and the hollow stems of these contain nests in great numbers, which serve as new centres of distribution. The importance of dealing promptly with the pest is clear.

White Ants and Rubber Exudations.

A fanciful and erroneous idea has, in India, obtained a footing that *Termes Gestroi* "attacks the tree for the purpose of obtaining rubber from it, for, on applying pressure to the bodies of the termites, it was found that the majority of them were full of fresh latex. They apparently collect and store the rubber, masses of rubber being found as a rule in the nests, which are usually situated at the crown of the root. From one of these nests situated at the base of a three-foot girth tree as much as 2 lb. of rubber was collected." It has, however, been pointed out by Ridley and Green that the insect exudes from its mouth a milky substance, like latex in appearance, for protective purposes ; it has also been suggested that the latex may have exuded from some injury or from part of a diseased tree and trickled down to the ants' nest.

Insecticides for White Ants.

Before proceeding to describe the general methods of dealing with white ants, a word is necessary as to the substances used in killing them.

The ordinary soil insecticides in powder form are almost useless. Though carbon bisulphide liberates fumes that are very destructive to the ants, its cost is generally prohibitive. The most efficient remedy appears to be the fumes got by heating white arsenic with sulphur in the proportions of 85 per cent. and 15 per cent. respectively. A machine for generating and for driving the fumes into the burrows consists of a charcoal furnace in connection with a bellows or air-pump. Some of the sulphur and arsenic mixture is placed upon the fire after it is brought to a glow, and the lid fastened down A tube, with a nozzle for inserting in the burrows, leads from the furnace.

General Treatment for White Ants

In treating the root disease Fomes, the drastic remedy of entirely removing the whole of the logs and stumps from the estate, expensive though that be, is sometimes adopted ; it is fortunate that such measures are generally protective against white ants. And while it may not appear necessary to proceed to do this where white ants alone are present, except within the circumscribed areas affected, removal of the whole of the dead wood upon an estate, as far as that is possible, is a step that can be recommended, and especially its removal or destruction before planting operations are begun.

Pratt (F.M.S. Dept of Agric., Bull. No. 3), has made some recommendations that, with some modification, may be given in brief. It will be seen that total removal of the dead wood on an estate is not mentioned.

Having located the source of contamination in a log or stump, cut a trench around it, 3 feet away, say, 4 feet deep. Leave this open for a few days ; the ants will construct over it covered ways leading from the burrows by which it is possible to locate the latter. After these are known, proceed with the treatment, dealing first with the log or stump. Stop up the ends with clay if necessary, and bore a hole into which the fumes may be pumped. Inject the fumes for six minutes. Crevices allowing fumes to escape must be plugged, as also the hole after pumping. If the log is long enough, make other holes 25 feet apart and treat as before. Then treat the burrows between the trench and the tree, from the base of which fumes should escape if there are mud encasements on the bark. Should no fumes escape when pumping into the runs, then find the ends of the burrows at the tree and pump there. The burning of the log or stump must not be forgotten. Should it be impossible to locate the nest or the burrows, then destroy all the dead wood within the affected area, dig over the soil to a depth of at least 3 feet, adding an insecticide, and isolate the area by a trench four feet deep.

The trees themselves will require treatment. If they are hollow, bore a hole to the cavity and inject the fumes. In any case ensure that the runs are treated at their bases. Of course, some of the trees may be beyond hope, and must be burned.

Other Insects Attacking the Stem.

Green also records (T.A. August, 1906), a case of infestation of the stem of a Hevea tree "by the 'horned Termite,' *Termes inanis*. This species of termite takes advantage of any hollow in a tree for the construction of its nest." Though the termites occupied a large cavity in the bole of the stem, the tree continued to live. Scooping out as much as possible of the pest, and flooding the cavity with naphthalin dissolved in petrol proved successful.

Hevea brasiliensis has been attacked by a borer in Java, the report being to the effect that the insect proved fatal to a seven-year-old tree. The trunk had part of its wood exposed and pierced by numerous little holes. It is suggested that the borers were Scolytidæ. In Ceylon small Scolytidæ (a kind of beetle) have often been found in dead stems, but there was abundant evidence of the previous existence of a parasitic fungus.

Green states that he has repeatedly received specimens of *dead* branches and stems of *Hevea brasiliensis*, perforated by a Bostrichid beetle—*Xylopertha mutilata*—but he believes that in every case the beetle has effected its entrance after the death of the parts He also records the "shot-hole borer"—*Xyleborus fornicatus*—and the "brown borer"—*Arbela quadrinotata*. The former is found in cankered branches, while the latter strays from Albizzias and enters the Hevea tree at the angle of a branch or in the fork between two stems. The remedy suggested is to plug the hole with tow soaked in coal tar.

Pratt mentions that a borer occurs in Malaya, appearing invariably upon pollarded trees, rarely spreading to the unpollarded trees near, and then only at tapped surfaces. Most of the insects are caught in the latex and killed. He recommends that where lopping is performed, tar should at once be applied. Ridley has recorded a borer of the genus Platypus.

The caterpillars of a little moth—*Comoeritis pieria*—feed in Ceylon on the outer bark of the trees, but seldom cause a flow of latex. Their galleries, composed of fragments of bark and excreta fastened together with a silky web, can be easily brushed off by hand.

White slugs—*Mariaella dussumerii*—have been suspected by Green of feeding upon the renewing bark and developing buds, and also of 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." Where the numbers are small, hand-picking will be effective. Should the slugs be numerous, spread a broad belt of "Vaporite" around the tree. If this fails, place freshly-tarred cylinders of stout paper around the bases of the stems.

Considerable harm has been done in gnawing of stems by rats and porcupines. Maintaining an estate in a clean condition keeps them down in numbers by removing possible shelter. Green (T.A., August, 1910), suggests the lime and sulphur wash used against rabbits, the mixture being made by boiling together 3 lb. quicklime, 3 lb. flowers of sulphur, and 6 gallons of water, until the whole is reduced to 2 gallons.

Root Diseases.

Fungi.—The most serious root disease of Hevea, which also occurs on the first six inches of the trunk as well as on the roots, is *Fomes semitostus*. The disease (F.M.S. Dept. of Agric., Bull. No. 2, Gallagher), is not discovered, as a rule, until the tree is nearly dead ; as a matter of fact, often when the tree has been blown down after partial destruction of its root system. The first symptoms are changes in the leaves, which suddenly become brown, first around the edges and especially at the tips, and then entirely. These changes are often preceded by a curling of the leaf edges towards the under side. The leaves in time fall off, but generally before this happens the tree is blown down. Upon examining the roots, white or straw-coloured cords, each formed of a number of fungus threads, are found running irregularly over them, particularly over the lateral roots. There may also exist a white, cobweb-like felt, mostly upon the tap-root. An infected tap-root will be black in colour instead of the usual healthy white. Its cortex is soft and rotten, and the hard wood below is discoloured.

Characters of Fomes.

The fruiting part of the fungus—which produces the spores, that, carried by the wind or water, form new centres of infection—is not very common, and is found on decaying logs or dead trees, where they are exposed to the air. It has been described as follows (Straits Bulletin, May, 1904) : "the fruiting part of *Fomes semitostus* is a broad, flat, rounded plate often very irregular in form, usually reniform, 4 to 6 inches across, and of an orange-red colour beneath, paler above, where it is marked with rings and fine striae ; beneath can be seen with a lens the honeycomb-like structure of the hymeneal surface. The texture of the fungus is tough, and it possesses a strong mushroom-like scent."

Mitchell states that the fruit at maturity forms a semi-circular or kidney-shaped bracket attached to a dead stump or root. The upper surface is yellow-brown marked by a series of darker concentric lines. The under surface is orange or red-brown If cut vertically the upper half is white and the lower brown.

The original source of infection is frequently a diseased jungle stump or log, when this happens to be reached by a growing lateral root. Along this the disease extends, killing the root as it goes, eventually reaching the tap-root, and then passing to the other lateral roots. From an infected tree it may spread to healthy trees in the neighbourhood. The disease can spread also by independent growth through the ground, especially in low-lying, damp, heavy, and badly-drained soils (Bancroft, Agr. Rep. F.M.S., 1910). Mitchell has observed it on stumps of jungle trees to a depth of over three feet, though usually it occurs at 1 to 1½ feet below the surface.

PERCENTAGE OF DEATHS DUE TO FOMES.

There can be no doubt that Fomes is the most serious pest with which rubber planters have so far had to deal with. A very large number of trees are attacked almost every month and deaths are recorded frequently. On one estate where Fomes only appears to seriously affect trees over two to three years old, a monthly record of trees showing symptoms of the disease is being kept. The affected area is only 500 acres in extent, yet the number of trees killed in certain months were: April, 97; August, 118; September, 100; October, 54. A very high percentage of vacancies must therefore be expected on estates in Malaya. In Ceylon, Java, and Sumatra, where the soil is usually drier, there does not appear to be the same destruction due to Fomes.

CONDITIONS AFFECTING FOMES.

There are certain conditions which appear to encourage the spread of Fomes. This fungus commences as a saprophyte—one living on dead matter—and on the living roots of Hevea trees it becomes a true parasite. It is also possible, where the roots of Hevea trees have been partially destroyed by forking, trenching, attacks of white ants, etc., that the fungus may commence on the dead part of the root and spread to the living portion of the same structure. Hence the necessity to avoid undue destruction of rootlets of Hevea trees when carrying out manuring and tillage on the estate.

This capacity of the fungus to change from a saprophyte to a parasite is probably closely associated with the frequent prevalence of white ants and the fungus on the same spot. On the other hand, it is conceivable that white ants, by destroying dead material, may ultimately remove substances on which Fomes might have commenced to grow.

Mitchell, of Lanadron, states that it spreads very rapidly in loose, friable soils such as sand and loams.

REMEDIAL METHODS FOR FOMES.

The remedial measures recommended by Gallagher in the treatment of an infected area are: (1) remove all timber, roots, stumps, logs and bits of branches and burn them; (2) trench (changkol) over the soil a couple of times to a depth of two feet to expose fungal threads in it to the sun and thus kill them; (3) use lime every time the ground is turned over. All diseased trees within the area must be removed. When a diseased lateral root of an apparently healthy tree is met with, it must be cut off at a point six inches above the diseased part, and the specially treated area of the soil extended as far. Where root disease has been neglected, and is present in scattered areas over the estate, as a preliminary treatment a trench 2 feet deep and a changkol wide, should be dug round each area. The trench should not be less than 3 feet away from the certainly healthy trees. Supplies may be put in just after the last digging over, but it is better to wait for eight weeks.

Other Root Diseases.

The "brown root disease"—*Hymenochaete noxia*— is found in Ceylon, Malaya, Samoa, and New Guinea, and probably also in South India and Java (Circ., R.B.G., No. 6, Vol. V). It is not very dangerous, for it spreads very slowly, and only one tree is killed at each centre of infection unless a tree killed by the fungus is left standing for two or three years. As with other root diseases, the leaves of the tree wither and fall off, and the tree eventually dies. A thick, yellowish-brown felt, which later develops a black crust exteriorly, covers the roots, and to this covering are attached stones, sand, etc. The fruiting part is a thin, dark-brown crust adhering to the base of the stem. Nearly all the cases arise where cacao has been cut out, the stumps being liable to encourage the disease and pass it on to the Hevea when the roots of the latter come into contact with them. The remedy is to dig out and burn, with any neighbouring cacao stump, and afterwards lime the ground.

A third root disease—*Spaerostilbe repens*—has been found in Ceylon (Circular, R.B.G., No. 8, Vol. V.), but cases are few. The fungus forms red cords—which become black on decaying—between the wood and cortex, especially at the collar, where it may become a continuous sheet. One form of fruiting appears at the collar as a dense cluster of small, red stalks with white heads. The wood of the affected parts is deep blue when fresh, fading when it dries. The sources of infection are pieces of jak-wood. Dig up and burn the dead trees and any jak stumps, and collect and burn all pieces of wood which may encourage the fungus. Surround the infected area with a trench, and fork in lime.

Considerable damage has been done on the Gold Coast by a fungus—*Rosellinia* sp.—that attacked the roots and the collars of the stems (Report, Dir. of Agr., Gold Coast, 1909). The trees were removed and burnt, the areas trenched, and dug over with lime.

Insect Pests.—Specimens of a termite—*T. redemanni*—have been sent with the report that they were eating off the tap roots of young rubber plants. It is practically certain that the white ants have followed on fungal root disease, and they may be treated by the usual methods.

Grubs of the large cockchafer—*Lepidiota pinguis*—have been received by Green (T.A., Oct., 1905), from Yatiyantota, Ceylon, with the report that they are found about two inches below ground-level. It is stated that the pest 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 stumps die back. On touching the stump it breaks off. 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 adult beetle is of a 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."

Green also mentions the grub of another kind of large beetle (Circ., R.B.G., No. 12, Vol. IV.) that tunnels the tap-root and works into the stem.

CHAPTER XXXII.

COST OF PRODUCTION ON ESTATES.

The cost of producing Hevea rubber on estates in the East has, since the inception of the industry, been the subject of much discussion. Hitherto tapping has usually been carried out only on a relatively small number of trees often scattered through the estate. Where only from 10 to 50 per cent. of the trees on a given area are in a condition fit to be tapped, it is but reasonable to expect that the cost of collecting will be proportionately high. When, furthermore, the trees are being tapped for the first time the bark tissue wherein the latex accumulates is thin and soft, and a low yield of rubber per cooly employed can be expected. Guided by the results of a few years experience in the tropics, it was predicted that, when estates reached maturity, the production of rubber would be accomplished at from 1s. to 1s. 6d. per lb., the lower cost being characteristic of countries where labour is cheap and well trained, and the higher figure for areas where labour conditions are less favourable.

Variations in Systems of Costing.

The great range in the cost of production shown later in this chapter can be explained partly by the different methods adopted in compiling the accounts of the respective companies, but the outsider must, except some general agreement is arrived at, remain in ignorance of the actual items covered by the headings given. Where an estate possesses only a few scattered mature trees, and more than one product is cultivated on the same area, a reasonable excuse can be given for not detailing the items concerned. If, however, the whole area is in bearing and all estate and managerial items are chargeable against the rubber harvested, there is not the slightest excuse for keeping secret the cost per pound of rubber. Detailed information of this character should prove exceedingly valuable to directors in Europe, and managers abroad, when comparisons are made between the various items in monthly reports from different estates.

It is very difficult to form a correct idea of the average cost incurred in marking trees, tapping and collecting, curing, freight, packing-cases and packing, tapping-knives, etc., owing to the fact that each estate has its own system of accounts. Furthermore, on estates which are planted with tea and other products in addition to rubber, a varying proportion of the capital expenses are charged against the rubber, according to the system of accounts adopted.

Cost in Ceylon in 1908.

In the second quarter of 1908, I visited several rubber properties in Ceylon possessing a large number of Hevea rubber trees of different ages in bearing. On only one occasion was the superintendent unable to produce rubber at a profit—on paper—with rubber at 3s. per lb. In that particular case, all the trees were from four-and-a-half to five years old, and the youthfulness of the property, with the inexperience of the man in charge, were probably responsible for such a condition of affairs.

The cost of production varies considerably on estates in the same district, and especially when the plantations are of different ages. On one well-known Kalutara property, the rubber during 1907 was delivered f.o.b. Colombo at 80 cents (100 cents equal 16d.). On the same property it was estimated that in the future, with the whole of the estate in bearing, the cost would be reduced to 55 cents per lb. On another property, the cost of the rubber from young trees was 85 cents, and that from old trees 48·15 cents. The superintendent hoped to be able to bring down the cost, f.o.b. Colombo, to 50 or 60 cents per lb. On another property, the cost of production, including all charges in Colombo and London, was Rs. 1·10 from old trees, and Rs. 1·50 from young trees. The superintendent estimated that the cost in the future would be R. 1 per lb. when his cooly average was 35 cents per day. It is, therefore, quite obvious that even in the same district or country there is a considerable variation in the costs of production.

Influence of Labour on Tapping Costs.

The average daily cost of cooly labour has a great influence on the cost of production. There are many estates in Ceylon and Malaya where the daily average is 38 cents, but in the former country that is equivalent to 6d. and in the latter 10½d. Fraser (I.R.J., Aug. 22nd, 1910) stated that tapping was being done at from 10 to 18 dollar cents by Tamils and 22 to 25 cents by Chinese, but this, he thinks, will be greatly improved upon. A planter in the F.M.S felt certain that with crops of 500 lb. per acre, the f.o.b. cost of rubber might be brought down to 8d. or 9d. with Tamil tapping in F.M.S.; 1s. to 1s. 1d. with Chinese tapping in F.M.S.; 4½d. in Ceylon without manuring; 6d. in Ceylon with manuring.

Another point which influences cost is that some managers charge the actual cost of the labour employed in tapping against that item, instead of charging the average cooly cost over the whole estate. A case in point was where the tapping coolies were paid at the rate of 45 cents, when the cooly average over the property was 35 cents. On another property, where the average rate of cooly pay was the same, the cost per day for tapping coolies was below the average, viz., 30 cents, on account of only podians (boys) and women being employed for such work. Weeding and other work is just as essential as that more directly concerned with the collection and preparation of rubber, and it would appear to be fairer to charge the average cooly cost for the estate rather than the cost of individuals employed for the time being on this particular work.

Other Factors Affecting Cost.

It is obvious that the cost of production must also be largely determined by the ages of the trees and methods of tapping employed. The yield, and therefore cost, also varies according to the distance between the trees, the percentage of trees in the tapping round, the season, and the percentage of crop grades. The large variation in the cost of tapping knives alone will account for considerable differences between the costs of production on adjacent estates. Land, river, and sea transports, local agency charges, and many other factors are also responsible for the enormous variation in cost at the present time.

Daily Tasks in Collecting.

The weight of rubber brought in by each cooly per day has been given in the annual reports of various companies. On Lanadron estate the cooly outturn in 1908 (trees 5 to 9 years) was 3·67 lb. per day; in 1909 (trees 6 to 10 years) 3·18 lb.; in 1910 it was 2·63 lb. from trees 3 to 11 years. Ledbury estate obtained 2·14 lb. per cooly per day in 1909 (trees 7 to 10 years), and 2·97 lb. in 1910 (trees 3 to 11 years). On Sione estate 2·69 lb. per cooly were obtained in 1909 from trees 4 to 12 years old, and 1·97 lb. in the following year from trees 3 to 13 years old. The Singapore and Johore Rubber Company report a completed task of 2·32 lb. per cooly for 1910. Jementah estate report 1·21 lb. in the same year, the trees on this property being 4 to 6 years old.

On several estates an outturn of 5 lb. of rubber per day per cooly is obtained from ten-year-old trees, a fact which indicates that a considerable reduction in cost of collecting rubber will be possible when Hevea trees reach the age mentioned.

Proportionate Cost on Estate.

If the accounts of estates in full bearing are examined it will invariably be found that the main item of expense, on the estate, is that included under the heading of tapping and manufacture. This amounts generally to from 50 to 80 per cent. of the total cost of production, and includes costs of tapping, utensils, washing, drying, packing, transport, and shipping. Cost of cultivation, which includes roads and drains, weeding, supplying, pests, forking, and tools, is usually next in amount, and averages about 10 to 15 per cent. of the total cost. Buildings and repairs are usually from 5 to 7 per cent. General charges also vary, including salaries, insurance, local and visiting agency fees, rent, medical and contingencies, etc., and on estates in view account for from 10 to 16 per cent. of the total costs of production. To the above must be added London costs, which include offices directors' fees, and commissions.

STANDARDIZATION OF ACCOUNTS.

It would be advantageous if managers in the same district or country could adopt the same form of accounts, as it would enable them to compare the costs of the various items with similar charges on neighbouring properties. It would also be a boon to accountants and directors. An attempt has been made by H. K. Rutherford to supply the necessary form, the actual charges incurred upon a Malayan estate being added :—

	per lb.			
GENERAL—				
Salaries	4·73 dollar cents.			
Allowances	·40			
Visiting and Agent's fee	·22			
Quit Rent	·43			
Hospital charges	·80			
Fire insurance	·17			
Stationery and postages	·10			
Cattle	·10			
Recruiting	·75			
Contingencies	·57			
		8·27		
CULTIVATION—				
Weeding	4·53			
Roads, bridges and drains	1·30			
Supplying	·24			
Pests and diseases	·46			
Tools	·07			
		6·60		
UPKEEP OF BUILDINGS, ETC.—				
Bungalows	·15			
Lines	·29			
Factory and Stores	·17			
Cattle sheds	·06			
Machinery	·16			
		0·83		
RUBBER MANUFACTURE—				
Marking trees	·42			
Tapping and scrapping	14·04			
Curing, including fuel	1·54			
Utensils	·59			
Packages	1·18			
Transport, including rail	·58			
Forwarding charges	·08			
Duty	4·24	22·67		
		38·37	=	10·75 pence

Freight	·68 pence	
Warehouse charges	·33	
Sale expenses ..	·04	
Brokerage	·29	
Marine insurance ..	·23	
Discount and draft	1·73	
		3·30
		14·05 pence.

Principal Costs Itemised.

It has been shown that the principal cost on a mature estate is that included under the heading of "tapping and manufacture." The costs of each item in this charge vary according to estate conditions, and whether or not large numbers of trees are being regularly taken into the tapping round.

The following table is compiled from actual costs on different estates in the East :—

Items.	Cost in pence per lb. of Rubber harvested. 1	2	3	4	5
Marking trees	0·46	0·28	nil	nil	nil
Tapping and utensils	6·31	7·02	7·2	8·4	7·2
Washing and drying	2·72	3·4	1·3	0·6	1·1
Packing and packages	—	0·28	0·3	—	0·2
Transport	0·26	0·6	0·1	0·2	0·1
Shipping charges	2·46	1·15	—	—	1·9
Factory requisites	—	—	0·2	—	0·1
Insurance	0·42	0·23	—	—	—

The series numbered 1, 2, 4, and 5 relate to estates in Malaya and Sumatra, number 3 to Ceylon. Estates 1 and 2 are young, and several thousands of trees are being taken into the tapping round every month, the yield being about 3,000 lb. per month. Estate number 3 is a Ceylon property with the greater part in bearing, and yielding 5,000 lb. per month. Number 4 is a Sumatran estate, giving 2,000 lb. of rubber monthly from young trees. Number 5 is an estate in full bearing, and yielding over 20,000 lb. per month.

The Kuala Lumpur Rubber Company's report for 1910-11 states that the cost of collecting was 19·27 dollar cents per lb., as against 19·73 cents for the previous year ; and it also reports that curing costs were 4·19 cents per lb. as against 3·42 cents for 1909-10. It further states that the cost of production and marketing, for a crop of 676,648 lb. of dry rubber, was 20d. per lb., as against 19d. per lb. for the previous year.

Lanadron reports that the cost of marking trees, tapping and transport to the factory cost 16·69 cents per lb. for Lanadron, estate, and 32·30 cents for Jementah estate. Highlands and Lowlands quotes 15·87 cents per lb. for tapping on Highlands estate, and 12·11 cents on Batu Unjor. Ledbury costs for tapping and scrapping were 10·16 cents, and Pataling 9·49 cents per lb. Selangor gives 19 cents as the cost per lb. of tapping and curing, including the cost of tools and utensils. The cost of tapping and scrapping on Chersonese was 17¼d. per lb.

Costs f.o.b. Colombo, Madras and Belawan.

Though I am unable to state what items are included under the heading of "cost of production" in the reports of various companies, the following figures should prove of some value as showing the costs, in pence per lb. of rubber, free on board in Colombo, Madras, or Belawan :—

CEYLON. Estate.	Costs.
Eastern Produce	$13\frac{1}{4}$
Arapolakande	$9\frac{1}{4}$
Panawatte	$26\frac{1}{4}$
Rosehaugh	$12\frac{1}{2}$
Doranakande	$11\frac{7}{8}$
Yatiyantota	15
Sapumalkande	$21\frac{1}{2}$
Sittawa	$20\frac{1}{4}$
Moneragalla	$16\frac{1}{4}$
Grand Central	$15\frac{9}{10}$
Nagolle	$22\frac{3}{4}$
Lavant	14

SOUTH INDIA. Estate.	Costs.
Malayalam	$16\frac{2}{5}$
Rani Travancore	23
SUMATRA.	
Langkat Sumatra	$6\frac{3}{4}$
United Sumatra	12
Sumatra Para	$13\frac{1}{8}$
United Serdang	$19\frac{3}{4}$

It would be interesting to know what proportion of estate charges have been debited against the rubber from each of these estates. On Lavant 3d. per lb., included in the cost of 14d., was for weeding and manuring.

COSTS IN MALAYA.

There are many estates in Malaya whereon the costs of the various items are known. The variation in the costing system adopted is enormous, some giving the cost f.o.b., others c.i.f., and others with or without a proportion or the whole of salaries, bonuses, and London charges.

On a few estates the cost of collecting, together with all charges and London expenses, are given :—

ESTATE.	COST.	ITEMS INCLUDED IN COST.
Pataling	12d.	Directors' fees, London office expenses, bonuses, depreciation.
Selaba	22d.	Directors' fees, London office expenses.
Bikam	$34\frac{1}{8}$d.	Do. do.
Kuala Lumpur	20d.	Excluding London expenses.
Merton	31d.	London expenses.
Batu Tiga	$22\frac{1}{2}$d.	All London, and proportion local expenses
Castlefield	25d.	London expenses not included.
Kapar Para	14d.	C.i.f. London.
Sungei Kapar	$14\frac{3}{4}$d.	Total cost of marketing.
Kuala Selangor	$21\frac{9}{10}$d.	Part of London expenses.
Bukit Lintang	$19\frac{3}{4}$d.	Freight, duty, insurance, commission.
Inch Kenneth	$24\frac{1}{2}$d.	Do. do. do.
Carey United	$23\frac{1}{4}$d.	Total revenue expenditure, home and colonial.
Rembia	$15\frac{1}{2}$d.	Including establishment charges.

The above list indicates items charged in addition to the actual costs on the estates. The following figures show the proportions of the various items in two producing companies :—

Items included in cost.	Bukit Rajah.	Consolidated Malay.	Items included in cost.
F.o.b. including export tax ($1\frac{3}{4}$d.)	12d.	12·76d.	General charges and upkeep expenses.
Freight and selling charges.	4d.	2·13d.	Duty, transport, and shipping charges.
Directors' fees, London expenses, and management.	$1\frac{1}{2}$d.	5·00d.	London costs, ex-warehouse.
Totals	1s. $5\frac{1}{2}$d.	1s. 8d.	

It is quite conceivable from the above statistics that should the trees yield double their present daily outturn, the cost per lb. will be brought near to one shilling (including all charges) per pound of rubber in future years.

Costs f.o.b. Port Swettenham and Penang.

An instructive lesson may be gained from a study of the costs of the rubber delivered at Malayan ports. The following are the costs, in pence, f.o.b. Port Swettenham :—

Seaport, 32⅗d. ; Sungei Choh, 18⅛d. ; London Asiatic, 16d. ; Sandycroft, 14d. ; Golden Hope, 12¾d. ; Golconda, 12d. ; Anglo-Malay, 13d.

The costs f.o.b. Penang were 18d. for Allagar ; 14½d. for Cicely ; 12⅗d. for Jebong ; and 39·94d. for Chersonese.

The costs f.o.b. Teluk Anson were 19d. for Selaba, and 33⅘d. for Sungei Chumor.

Other companies have published the costs f.o.b. without mentioning the port of shipment. Bikam cost 28½d. ; Batak Rabit, 28¼d. ; Kurau, 26d. ; Straits Rubber, 22d. ; Rubana, 19d. ; Perak and Labu each 17·4d. ; Linggi, 15¼d. ; Kamuning, 15d. ; and Sendayan, 37·39d. per lb.

It must be understood that all costs mentioned in this chapter, except where it is otherwise noted, refer to the financial years 1910 or 1910-11 of the respective companies.

CHAPTER XXXIII.

ESTIMATED COSTS OF PLANTING.

The cost of clearing, draining, planting and up-keep of large acreages of Hevea necessarily varies according to the condition of the forests to be cleared, the nature of the land, and the rates of wages paid, &c.

In the last edition I was able, through the courtesy of various friends, to give estimates for the opening out of estates in various parts of the Middle-East. Owing to increases in labour costs and that of superintendence, the much heavier expenditure upon machinery and buildings now considered necessary, the aggregate cost of bringing an estate into bearing has reached figures that were once unexpected. This has demanded a revision of the estimates, and I am again indebted to some of my friends for the information they have supplied. In the case of the Ceylon estimates I have decided to leave them untouched, with the proviso that, the charges being now heavier, the total costs must be increased by 10 or 15 per cent.; the same remark applies to Java.

RUBBER PLANTING IN CEYLON.

ESTIMATE I.

ESTIMATE OF COST OF PURCHASING 100 ACRES OF LAND AND PLANTING WITH HEVEA—MATALE DISTRICT.

			Rs.
Cost of 100 acres of Land—			
Forest say at Rs. 60 per acre / Chena ,, 40 to Rs. 45	say Rs. 50 per acre		5,000
CLEARING—			
100 acres Forest at Rs. 20 per acre / 100 acres Chena at Rs. 15 to Rs. 17	say Rs. 17·50 per acre		1,750
NURSERIES AND SEEDS—40,000 seeds at Rs. 7 per 1,000		Rs.280 0	
30,000 Baskets, Rs. 4 per 1,000		120 0	
Making nurseries, including sheds for basket plants, sowing seed..		60 0	
Upkeep, watering for 3 months regularly ..		30 0	
Further occasional attendance for 6 months ..		20 0	
			510
ROADS AND DRAINS—at Rs. 6 per acre			600
LINING—say 15′ by 15′—about 200 trees per acre, including cost of pegs, at 75 cents per acre			75
HOLING—Holes 18″ by 12″: task 40 per man, say Rs. 1·80 per acre			180
PLANTING—20,000 Basket plants, including transport from nurseries, dipping in liquid manure, &c., 80 cents. per acre ..			80
SUPPLYING—Putting out 6,000 basket plants at 50 cents per 100 ..			30
SHADING—30,000 cadjans at Rs. 10 per 1,000 ..		Rs. 300	
Making up, fixing, and general attendance, say Rs. 1·50 per acre		150	
			450

		Rs.
LINES—1 set of temporary lines, 20 rooms, jungle post thatched roof, mud and wattle walls, at Rs. 20 per room		400
WEEDING—Forest land, first 3 months at Rs. 1·25, thereafter at 80 cents, say 10 months' weeding at Rs. 1·50 per acre ..		1,500
Chena Land: First 3 months at Rs. 2·50; Second 3 months ,, 1·75; Thereafter ,, 1·0		
FENCING.—Cost of wire and staples about Rs. 150 per mile, 3 wires at 1 foot apart; Posts: cutting holes, &c., and fixing, Rs. 30 per mile; Carpenters at Rs. 7 per mile } Rs. 187 per mile for 3 miles ..		561
TOOLS		100
CONTINGENCIES		100
SUPERINTENDENCE at Rs. 100 per month		1,200
COAST ADVANCES; 80 coolies, say Rs. 30 each		2,400
	Rs.	14,936
Add interest on Rs. 14,936 at 7%		1,045
	Rs.	15,981

		Rs.	
2nd Year ..	Superintendence	1,000	
	Weeding 100 acres at R. 1 ..	1,200	
	Nurseries, supplying cadjans, &c. ..	105	
	Roads and drains upkeep	50	
	Thatching lines Rs. 1·50 per 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 cents	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 cents	750	
	Supplying, &c.	100	
	Lines: 20 rooms—permanent stone pillars, mud and wattle walls, iron roof, Rs. 70 per room	1,400	
	Fencing	30	
	Contingencies	70	
			3,070
Interest at 7%		..	1,848
		Rs.	28,261

			Rs.	Rs.
5th Year ..	Superintendence	.. ..	900	
	Weeding	.. .. ..	750	
	Fencing	.. .. ..	50	
	Contingencies	.. ..	70	
	Roads, &c., 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 fifth year, as it is now generally admitted that tapping may commence, according to growth, between the end of fourth and sixth 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, &c., 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, &c.

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 two wires only, say at 1 foot 6 inches and 3 feet, backed by galvanized wire 3 feet by 3 inches 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 fourth year the weeding should be reduced in either forest or chena land clearings to an average of 75 cents 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, &c., though both would be required. Superntendent'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 revolutionize 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 these 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. 2,400 would probably be exceeded from and after the sixth year on tapping operations commencing.

E. GORDON REEVES.

Wiltshire,
Matale, October 10, 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 cents per day, in others 50 cents. 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 Rs. 12.50 to Rs. 20 ; roads and drains, according to lay of land, Rs. 7·50 to Rs. 12, and even Rs. 20 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.

The following estimate is made for an estate in the Central Province worked entirely by village labour. Lay of land, mostly on hillsides, with a fair number of rocks. Average cost of labour about 40 cents per day. I strongly advocate seed at stake in all new clearings.

ESTIMATE OF PURCHASING AND OPENING 300 ACRES OF LAND.

	Rs.
1.—Purchase of land, say 300 acres, at Rs. 50 per acre	15,000
2.—Felling, burning, clearing, rooting 300 acres, at Rs. 15 per acre ..	4,500
3.—Roads and drains, blasting and building, at Rs. 12 per acre ..	3,600
4.—Lining and pegs, 15 ft. by 15 ft., at Rs. 1·50 per acre	450
5.—Holing 2 ft. by 15 in. and filling, at Rs. 6·50 per acre	1,950
6.—Cost of seed at Rs. 6 per 1,000, 3 in a hole, at 5 cents per acre, and planting	1,500
7.—Nursery basket plants for supplies, 6,000 and upkeep	150
8.—Planting, Rs. 1·50 per acre	450
9.—Weeding, April to December, at Rs. 20 per acre	6,000
10.—Bungalow, Rs. 2,500 ; lines (20 rooms) Rs. 600	3,100
11.—Superintendent, Rs. 3,000 ; Conductor, Rs. 600	3,600
12.—Tools and contingencies	750
13.—Barbed-wire fence, 4 strands put 8 ft. apart, and erection of same, at 15 cents. per yard, or, in round figures, say, at Rs. 5 per acre (if 2-in. wire netting buried and put in ground—and 3 strands of barbed wire and erection, at Rs. 9 per acre.)	1,500
	42,550
2nd to 6th year:—	
Supervision, Rs. 3,600	18,000
Weeding, second year at Rs. 20 per year, Rs. 6,000 ,, third year at Rs. 15 per year, Rs. 4,500 ,, fourth to sixth year at Rs. 10 per year, Rs. 9,000	19,500
Upkeep of roads and drains at Rs. 1 per acre, 5 years at Rs. 5 ..	1,500
Upkeep of lines, bungalow, &c., 5 years	1,250
Supplying and attending young plants, 5 years at Rs. 200	1,000
Sundries and contingencies, 5 years at Rs. 250	1,250
	Rs. **85,050**

Total cost of 300 acres (Rupee at 1s. 4d.)—£**5,670** ; or £**18 18**s. per acre.

October 14, 1905. FRANCIS J. HOLLOWAY.

ESTIMATE III.

FIRST AND SECOND YEARS—PERADENIYA DISTRICT.

	First Year. Rs. c.	Second Year. Rs. c.
Superintendence	10 0	10 0
Felling	12 0	—
Lining, 18 feet by 18 feet	1 0	—
Pegging	1 0	—
Roads and drains	15 0	1 50
Fencing with barbed wire	14 0	—
Holing	6 0	—
Filling and planting	3 0	—
Plants	1 50	0 50
Weeding	10 0	9 0
Buildings	8 0	0 25
Tools	0 50	—
Contingencies	2 0	—
Supplying and fencing	—	2 0
Cost per acre	Rs. **84 0**	Rs. **23 25**

Estimate IV.

First to Sixth Year—Kalutara District.

The following estimate of the cost of opening up Hevea 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.

Year.	1st.	2nd.	3rd.	4th.	5th.	6th.
	Rs. c.	Rs. c.	Rs. c.	Rs. c.	Rs. c.	Rs. c.
Felling and clearing ..	8 0	—	—	—	—	—
Drains	12 0	—	—	—	—	—
Roads	4 0	2 0	1 50	1 50	1 0	1 0
Holing and filling ..	5 0	—	—	—	—	—
Lining and pegs ..	2 0	—	—	—	—	—
Weeding	18 0	16 0	12 0	12 0	12 0	12 0
Fencing	4 0	2 0	2 0	1 0	1 0	1 0
Plants	4 0	—	—	—	—	—
Planting	1 0	2 0	—	—	—	—
Tools	2 0	0 50	0 50	—	—	—
Superintendence ..	12 0	5 0	5 0	5 0	5 0	5 0
Survey, &c., and contingencies	1 0	0 50	0 50	1 0	1 0	1 0
Cost per acre Rs.	**73 0**	**28 0**	**21 50**	**20 50**	**20 0**	**20 0**

Total—Rs. **183**.

Estimate V.

First and Second Years—Ambalangoda District.

	First Year.	Second Year.
	Rs. c.	Rs. c.
Felling and clearing	10 0	—
Lining and pegging	2 0	—
Roads and drains	15 0	1 50
Fencing with barbed wire	5 0	—
Holing	9 0	—
Filling and planting	7 0	—
Plants	1 50	0 50
Weeding	12 0	12 0
Contingencies	2 0	1 0
Supplying and fencing	—	1 50
Cost per acre	Rs. **63 50**	Rs. **16 50**

Estimate VI.

First and Second Year—Ambalangoda District.

Principal Items in opening Swampy Land.

	First year.	Second Year.
	Rs. c.	Rs. c.
Felling and clearing	4 0	—
Lining and pegging	2 0	—
Roads and drains	30 0	10 0
Heaping soil	8 50	—
Fencing with wire	5 0	—
Filling and planting	7 0	—
Weeding	24 0	24 0
Contingencies	2 0	1 0
Supplying, &c.	—	1 50
Cost per acre	Rs. **82 50**	Rs. **36 50**

Estimate VII.

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

First Year.	Rs.	c.
Superintendence	10	0
Cost of watering and rearing plants, per 1,000	2	0
Felling and clearing	8	0
Lining, 20 ft. by 20 ft.	1	50
Holing and filling in, 2 ft. by 2 ft. by 2 ft.	9	0
Planting	1	0
Wear and tear of tools	2	50
Weeding, per month, Rs. 1·50	18	0
Drains	8	0
Roads	5	0
Supplying	0	50
Fencing with barbed wire	3	0
Cost per acre .. .. .. Rs.	**68**	**50**

Second Year.	Rs.	c.
Superintendence	5	0
Weeding, per acre per month, R. 1	12	0
Supplying	1	0
General upkeep—drains, roads, and contingencies	5	0
Rs.	**23**	**0**

No bungalow or lines estimated for in either first or second year. Cost of plants or watchman not taken into consideration, the cost of former being too fluctuating.

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 cost of felling, clearing, and weeding is very great.

Estimate of Costs in Southern India.

Estimate for Opening 500 Acres of Para Rubber with Five Years' Expenditure.

The conditions for which this estimate has been framed are those of the lowlands of S.W. India, which is the part most suitable for Hevea. Elevation at or near sea-level. Rainfall 80 inches and upwards.

The purchase of land is presumably from private owners. The British Government has very little land suitable for sale, and the Governments of Travancore and Cochin are difficult to deal with.

First Year.	Rs.
Purchase of land at Rs. 40 per acre, 500 acres	20,000
Filling and clearing at Rs. 15 per acre	7,500
Nurseries, 100,000 plants at Rs. 25 per 1,000	2,500
Roads and drains at Rs. 10 per acre	5,000
Lining and pegs, 18ft. by 18ft. (= 130 plants per acre), at Rs. 1 per acre	500

FIRST YEAR.	Rs.
Pitting, 2 ft. by 2ft. at Rs. 3 per acre	1,500
Filling pits and planting at Rs. 2 per acre	1,000
Supplying at R. 1 per acre	500
Shading at Rs. 4 per acre	2,000
Planting shade (dadap stumps), say	1,000
Weeding at Rs. 2 per acre per month—9 months	9,000
Fencing at Rs. 6 per acre	3,000
BUILDINGS, ETC. :—	
Coolie lines	1,500
Bungalow, out-buildings and furniture	4,000
Tools	1,000
MANAGEMENT :—	
Superintendent at Rs. 250 per month ; Writer at Rs. 50 per month ; Allowances at Rs. 25 per month	3,900
Visiting Agent at Rs. 100 per month	1,200
SUNDRIES :—	
Advances	1,000
Medicines, books, stationery	500
Taxes	500
General contingencies	500
	Rs. **67,600**

SECOND YEAR.	Rs.
Weeding at Rs. 2 per acre—12 weedings	12,000
Supplies	500
Digging at Rs. 7 per acre	3,500
Management, same as before	5,100
Upkeep roads and drains at Rs. 2 per acre	1,000
Tools, taxes and general contingencies as above	2,000
	Rs. **24,100**

THIRD YEAR.	Rs.
Weeding at Rs. 1-8 annas per acre—12 weedings	9,000
Supplies	250
Management as before	5,100
Upkeep roads and drains	500
Tools, taxes, and general contingencies as above	2,000
	Rs. **16,850**

FOURTH YEAR.	Rs.
Weeding at Rs. 1 per acre—12 weedings	6,000
Management	6,300
Upkeep roads and drains	500
Manure	3,000
Tools, taxes and general contingencies as above	2,000
	Rs. **17,800**

FIFTH YEAR.	Rs.
Weeding	4,000
Management	6,500
Roads and drains	1,000
Tools, taxes, and general contingencies as above	2,000
Factory and machinery .. .. .. £3,000 =	45,000
	Rs. **58,500**

SUMMARY.

1st year	Rs. 67,600
2nd year	24,100
3rd year	16,850
4th year	17,800
5th year	58,500
	Rs. **184,800** = Rs. **369** or **£25** per acre.

2nd October, 1911. E. G. WINDLE.

Mr. Windle has not allowed for interest (compound). Including this, at the rate of 6 per cent., the total amount for the five years is Rs. 222,968, which equals Rs. 446 or £29 15s. per acre.

RUBBER PLANTING IN MALAYA.

ESTIMATES FOR OPENING 1,000 ACRES, OR 250 ACRES IN EACH OF FOUR YEARS.

Year.	1st. $	2nd. $	3rd. $	4th. $	5th. $
Premium (1,100 acres)	3,300	—	—	—	—
Survey Fees	1,100	—	—	—	—
Rent	1,100	1,100	1,100	1,100	1,100
Felling, Clearing, and Burning	8,750	8,750	8,750	8,750	—
Removal of logs and roots ..	12,500	12,500	12,500	12,500	—
Lining, Holing, and Planting ..	1,375	1,375	1,375	1,375	—
Nurseries and Seeds	1,300	1,000	1,100	1,200	500
Weeding (first year for 3 months)	1,500	4,500	7,500	10,500	12,000
Supplying, Pests, etc.	—	1,250	2,250	2,250	1,750
Roads, Drains, Bridges, and Fences	3,500	2,500	2,000	1,500	500
Bungalow, Lines, Hospital, etc.	5,000	1,000	2,000	2,000	1,000
Upkeep of same	1,200	1,000	1,000	1,000	?
Tools, Live Stock, and Vehicles, and Factory	1,500	1,000	1,200	1,300	17,200
Medical Charges..	1,500	1,750	2,000	2,250	2,250
Superintendence, Allowances ..	5,500	6,000	8,500	9,500	12,000
Coolie Assessments and Recruiting Expenses	2,500	3,500	4,500	5,500	7,000
Water Supply	1,500	1,500	1,500	1,500	1,500
Assessments, Contingencies ..	2,000	1,500	1,200	1,200	1,300
	55,125	48,825	60,725	64,425	57,100

Total—**286,200** dollars.

In the above estimate for Malaya I have estimated for the removal of logs and uprooting of tree-stumps at a total cost of 50,000 dollars for 1,000 acres. I have also included the rent, premium and survey fees for 1,100 acres, out of which 1,000 acres can be planted. Furthermore, though a factory is included in the fifth year, no account is taken of revenue, which should, if the estate has been kept in order, have accrued in that year and the fourth year.

The total cost of 286 dollars (£35) per acre may be regarded as high, but if allowance is made for the extra cost of European supervision, erection of factory, labour and government assessments for hospital, drains and water supply, I do not think the amount estimated will leave a very big margin. Even this figure does not include London and local agency charges or interest on the money expended.

Costs of Planting in Borneo.

In view of the publicity given to rubber planting in Borneo, especially in the Northern British territory, an estimate of costs, compiled at my request by Mr. John Bruce, late Manager of Sekong Estate, Borneo, is here given. It will be observed that the costs up to the end of the fifth year on the East and West coasts are estimated respectively at 315 and 318 dollars per acre. On the East coast, Mr. Bruce estimates for planting 300, 400, and 300 acres respectively in the first, second, and third years, whereas on the West Coast he estimates for opening 800 and 200 acres in the first and second years respectively.

The East Coast is regarded as that area East of Marudu Bay. A launch is estimated for in that area and also the cost of keeping it in good order each year.

Mr. Bruce informs me that, as a general rule, the land on the East Coast is better, the jungle heavier, and the rainfall more prolonged than on the West Coast. He believes that five-year-old trees on the East Coast are six months ahead of those on the West Coast.

British North Borneo.

Cost of Purchase, Opening and Bringing into Bearing 1,000 Acres.

First Year.	East Coast.	West Coast.
Cost of 1,000 acres of land at B.N. Borneo Co. rates ..	17,142	42,850
Rentricing	75	200
Felling	2,400	4,000
Piling, Clearing, and Burning	7,500	7,200
Lining, Holing, and Planting	1,320	6,400
Supplying	75	200
Plants and Nurseries	1,900	1,100
Roads and Drains	2,100	5,600
Fencing	2,332	5,952
Tools, Implements, etc...	300	1,200
Bridges	1,200	500
Office, Stationery, Books, etc.	500	500
Buildings—		
Lines for 300 and 400 Coolies	1,500	2,750
Hospital for 60 Patients with outhouses, etc. ..	2,000	2,000
Dressers' and Clerks' quarters	—	500
Office, Store, and Shop	1,400	1,400
Manager's Bungalow and Furniture	3,500	4,500
Assistant's Bungalow and Furniture	1,400	3,400
Insurance on Buildings and Launch	627	218
Recruiting, Cost of importing 300 or 400 coolies, less amounts recoverable	13,200	18,000
Transport, Cost of Launch, Upkeep, Wages of Crew	7,750	3,000
Doctor and Hospital, Salary of Doctor, Dresser, Upkeep of 30 patients, including medicine, etc.	4,770	6,170
Weeding	9,000	9,000
Salaries—Manager, Assistant, Clerk	10,200	12,300
Agency Fees	1,457	1,457
Contingencies and Miscellaneous	2,000	1,500
	$95,648	$141,897

In these estimates 300 acres are opened up on the East and 800 acres on the West Coast. Weeding on the East Coast is taken at $250 per acre per month for 6 months; on the West Coast this is calculated as 400 acres for 3 and 400 acres for 6 months at $250 monthly, per acre.

SECOND YEAR.	East Coast. $	West Coast. $
Rentricing	100	50
Felling	3,200	1,000
Piling and Burning	10,000	1,800
Lining, Holing, and Planting	1,760	1,600
Supplying	175	130
Nurseries..	600	200
Roads and Drains	2,800	1,600
Fencing	2,976	1,480
Tools, Implements, etc...	120	300
Bridges	1,200	400
Office, Stationery, etc.	100	100
Buildings, Lines for 100 Coolies and Upkeep	600	880
Insurance	627	228
Recruiting 100 Coolies	4,400	4,500
Transport, Launch, Wages, Fuel, etc.	1,750	3,500
Doctor and Hospital, Salaries and keep of 40 Patients	5,500	6,170
Weeding	13,200	17,400
Salary of Manager, 1st Assistant, 2nd Assistant, Clerk	12,000	12,900
Agency Fees	1,457	1,457
Contingencies and Miscellaneous	1,000	1,000
	$63,565	$56,695

In the second year 400 acres are opened upon the East and 250 acres on the West Coast. Weeding is estimated for the East Coast at 300 acres for 12 months at $200 and 400 acres for six months at $250 per acre, monthly; on the West Coast 800 acres are worked at $150 and 200 at $250 per acre per month.

THIRD YEAR.	East Coast. $	West Coast. $
Rentricing	75	100
Felling	2,400	—
Piling and Burning	7,500	—
Lining, Holing, and Planting	1,320	—
Supplying	175	—
Nurseries	600	50
Roads and Drains	2,100	300
Fencing	2,232	150
Tools, Implements, etc.	100	100
Bridges	1,050	200
Office, Stationery, etc.	100	100
Buildings, Upkeep	300	300
Insurance	627	228
Recruiting	2,200	—
Transport, Launch, Repairs, etc.	4,365	4,000
Doctor and Hospital, Salaries and keep of 35 patients ..	2,770	4,801
Weeding	19,500	15,000
Carried forward ..	$47,414	$25,329

Third Year.	East Coast. $	West Coast. $
Brought forward ..	47,414	25,329
Salary, Manager, 1st Assistant, 2nd Assistant, Clerk ..	12,600	13,500
Agency Fees	1,457	1,457
Contingencies and Miscellaneous	1,200	1,000
Pests, Diseases and Pruning	400	1,000
	$ 63,071	42,286

On the East Coast 300 acres are planted in the third year. Weeding is estimated to cost, on the East Coast, 300 acres at 1/50, 400 at 2/-, and 300 at 2/50 dollars per acre, the last being for six months only; on the West Coast 1,000 acres are estimated to cost 1/25 dollars per acre, per month.

Fourth Year.	East Coast. $	West Coast. $
Supplying	100	100
Nurseries	150	—
Roads and Drains	500	300
Fence	200	200
Tools and Implements	100	100
Bridges, Upkeep	200	200
Stationery	100	100
Buildings, Upkeep	300	300
Insurance	627	228
Recruiting	4,400	1,200
Transport, Launch, Fuel, etc.	2,100	4,000
Doctor and Hospital, Salaries and keep of 20 patients ..	5,500	4,801
Weeding	18,000	12,000
Salary of Manager, 1st Assistant, 2nd Assistant, 3rd Assistant, and Clerk	14,700	14,100
Agency Fees	1,457	1,457
Contingencies and Miscellaneous	1,500	1,000
Pests, Diseases, Pruning	600	1,500
	$50,534	$41,586

On the East Coast weeding is estimated to cost for 300 acres, $1/00, 400 acres, $1/50, and 300 acres $2/00 per acre, monthly; on the West Coast 1,000 acres are estimated to cost $1/00 dollar per acre per month.

Fifth Year.	East Coast. $	West Coast. $
Roads and Drains	600	400
Fence	200	250
Tools and Implements	100	100
Bridges	300	200
Office and Stationery	100	100
Buildings	800	500
Insurance	627	228
Recruiting	2,200	1,000
Carried forward ..	$4,927	$2,778

FIFTH YEAR.	East Coast. $	West Coast. $
Brought forward ..	4,927	2,778
Transport, Launch, Repairs, etc.	2,000	4,000
Doctor and Hospital, Salary of Doctor and Dresser, and keep of 25 Patients	4,770	4,345
Weeding	12,000	6,000
Salary of Manager, 1st Assistant, 2nd Assistant, 3rd Assistant, and Clerk	15,600	14,400
Agency Fees	1,457	1,457
Contingencies and Miscellaneous	1,500	1,000
Pests, Diseases and Pruning	800	1,500
	$43,054	$35,480

On the East Coast weeding is estimated to cost for 300 acres, 50 cents, 400 acres, $1/00, and 300 acres, $1/50 per acre, monthly; on the West Coast 1,000 acres are estimated to cost 50 cents. per acre per month.

SIXTH YEAR.	East Coast. $	West Coast. $
Roads and Drains	600	400
Fence	200	600
Tools and Implements	100	100
Bridges	300	300
Office	100	100
Buildings. lines for 50 Coolies, upkeep, etc.	800	600
Insurance	627	228
Recruiting	4,400	1,000
Transport and Launch	2,200	4,000
Doctor and Hospital, Salaries and keep of 25 Patients ..	4,770	4,800
Weeding	7,800	3,000
Salaries of Manager, 1st Assistant, 2nd Assistant, 3rd Assistant, and Clerk	15,900	14,100
Agency Fees	1,457	1,457
Contingencies and Miscellaneous	1,000	1,200
Pests, Diseases and Pruning	700	2,000
	$40,954	$33,885

On the East Coast weeding is estimated to cost 50 cents. for 700 acres and $1/00 for 300 acres, per month; on the West Coast 1,000 acres are estimated to cost 25 cents. per acre, monthly.

SEVENTH YEAR.	East Coast. $	West Coast. $
Roads and Drains	800	400
Fence	100	200
Tools	100	100
Bridges	400	300
Office	100	100
Buildings	700	600
Insurance	627	228
Recruiting	200	500
Transport	1,500	3,500
Carried forward ..	$4,527	$5,928

Seventh Year.	East Coast.	West Coast.
	$	$
Brought forward ..	4,527	5,928
Doctor and Hospital, Salaries and Keep of 20 Patients	4,040	4,000
Weeding	6,000	3,000
Salaries of Manager, 1st Asst., 2nd Asst., 3rd Asst. and Clerk	16,200	14,100
Agency Fees	1,457	1,457
Contingencies and Miscellaneous ..	1,000	1,200
Pests, Diseases and Pruning	700	2,000
	$33,924	$31,685

Weeding is estimated to cost 50 and 25 cents. per acre per month on the East and West Coasts respectively.

Eighth Year.	East Coast.
	$
Roads and Drains	800
Fence	100
Tools	100
Bridges	400
Office	100
Buildings	700
Insurance	627
Recruiting	200
Transport	2,000
Doctor and Hospital, Salaries and Keep of 15 Patients	3,675
Weeding, 1,000 acres at 50 cents. ..	6,000
Superintendence	15,900
Agency Fees	1,457
Contingencies and Miscellaneous ..	1,000
Pests, Diseases and Pruning	600
	$33,659

Recapitulation.

	West Coast.	East Coast.
	$	$
First Year	141,897	95,648
Second „	56,695	63,565
Third „	42,286	63,071
Fourth „	41,586	50,534
Fifth „	35,480	43,054
Sixth „	33,885	40,954
Seventh „	31,685	33,924
Eighth „	—	33,659
	$383,514	$424,409
	at Exchange 2/4 = £44,743 or £44 15s. per acre.	at Exchange 2/4 = £49,514 or £49 10s. per acre.

Estimate for One Thousand Bouws Rubber in Java. By Mr. Noel Bingley.

The cost of opening and planting up land in Java with Hevea and bringing same into bearing varies so largely according to the character of the land, the locality, and, most of all, the labour conditions, that it is impossible to frame a standard estimate to suit the various conditions.

The following, however, may be taken as an approximate estimate of cost of bringing 1,000 bouws into bearing in a district which is fairly accessible by rail and road and where the labour conditions are such as to ensure good upkeep from the planting to the productive stage.

(One bouw equals 1¾ acres. One florin equals 1/8).

1st Year—			
General Expenditure :			
Salaries—			
Manager	Fl.500		
Assistant	150		
Visiting Agent	100		
Local Agents	100		
Native Clerk, etc.	50		
	900	x 12	Fl.10,800
Tools			400
Stable a/c.—Purchase 2 horses	Fl.500		
Upkeep	250		
			750
Contingencies			3,000
Native Festivities			500
Coolie Brokerage			500
New Lines			1,000
Manager's Bungalow			5,000
Assistants' Bungalow			2,500
Office and Stationery			300
Medical			250
Roads and Bridges			1,000
Rent and Taxes			3,000
Clearing 250 Bouws Rubber—			
Nurseries and Seed	Fl.10 per bouw		
Felling and Burning	40 ,,		
Draining	20 ,,		
Digging	20 ,,		
Roads and Bridges	5 ,,		
Lining	2·50 ,,		
Holing	5 ,,		
Planting	5 ,,		
Pests, etc.	2·50 ,,		
Fencing	5 ,,		
Weeding	10 ,,		
	Fl.125	x 250	31,250
			Fl.60,250

2nd Year—			
General Expenditure :			
Salaries—			
Manager	Fl.500		
1st Assistant	175		
2nd Assistant	125		
Visiting Agent	100		
Local Agents	100		
Native Clerks, etc.	50		
	Fl.1,050	x 12	Fl.12,600
Carried forward			Fl.12,600

Brought forward		Fl. 12,600
Tools		400
Stable—New Horse	Fl. 250	
Upkeep	350	
		600
Contingencies		3,000
Native Festivities		500
Coolies Brokerage		500
New Lines		1,000
Assistant's Bungalow		2,500
Upkeep Buildings		1,000
Office Stationery		300
Medical		250
Roads and Bridges		1,000
Rent and Taxes		3,000
		Fl. 26,650

New Clearing 250 Bouws—		
Nurseries and Seed	Fl. 10 per bouw	
Felling and Burning	40 ,,	
Draining	20 ,,	
Digging	20 ,,	
Roads and Bridges	5 ,,	
Lining	2·50 ,,	
Holing	5	
Planting	5 ,	
Pests, etc.	2·50 ,,	
Fencing	5 ,,	
Weeding	10 ,,	
	Fl. 125 x 250	31,250
Upkeep—250 Bouws at Fl. 40		10,000
		Fl. 67,900

3rd Year—

General Expenditure:

Salaries—		
Manager	Fl. 600	
1st Assistant	150	
2nd Assistant	150	
Visiting Agent	150	
Local Agents	150	
Clerk, etc.	50	
	Fl. 1,300 x 12	Fl. 15,600

Tools	400
Stable upkeep Fl. 500, and 1 New Horse Fl. 250	750
Contingencies	3,000
Native Festivities	500
Coolie Brokerage	500
New Lines	1,000
Upkeep Buildings	1,000
Office and Stationery	300
Medical	250
Roads and Bridges	1,000
Rent and Taxes	3,000
	Fl. 27,300
New Clearing 250 Bouws at Fl. 125	31,250
Carried forward	Fl. 58,550

	Brought forward ..		Fl.58,550
UPKEEP—250 Bouws at Fl.40	=	Fl.10,000	
250 ,, ,, 35	=	8,750	
			18,750
			Fl.77,300

4TH YEAR—

GENERAL EXPENDITURE :

SALARIES—		
Manager	Fl.650	
1st Assistant	225	
2nd ditto	175	
3rd ditto	150	
Visiting Agent	150	
Local Agents	150	
Clerk, etc.	50	
	Fl.1,550 x 12	Fl.18.600
Tools		400
Stable—Upkeep		700
		Fl.19,700

Contingencies	Fl.3,000
Native Festivities	500
Coolie Brokerage	500
New Lines	1,000
Assistants' Bungalow	2,500
Upkeep Buildings	1,000
Office and Stationery	300
Medical	250
Roads and Bridges	1,000
Rent and Taxes	3,000
	Fl.32,750

NEW CLEARING 250 bouws at Fl.125			31,250
UPKEEP—250 bouws at Fl.40	=	Fl.10,000	
250 ,, ,, 35	=	8,750	
250 ,, ,, 30	=	7,500	
			26,250
			Fl.90,250

5TH YEAR—

GENERAL EXPENDITURE :

SALARIES—Manager	Fl.700	
1st Assistant	225	
2nd ,, ...	175	
3rd ,, ...	150	
Visiting Agent	150	
Local Agents	150	
Clerk, etc.	50	
	Fl.1,600 x 12	Fl.19,200
Tools		400
Stable		700
Contingencies		3,000
Native Festivities		500
Coolie Brokerage		1,500
Carried forward ..		Fl.25 300

Brought forward		Fl.25,300
New Lines		2,000
Upkeep Buildings		1,000
Office Stationery		300
Medical		250
Roads and Bridges		1,000
Rent and Taxes		3,000
		Pl.32,850
UPKEEP—250 bouws x 40	= Fl.10,000	
250 ,, x 35	= 8,750	
250 ,, x 30	= 7,500	
250 ,, x 25	= 6,250	
		32,500
		Fl.65,350
6TH YEAR—		
GENERAL EXPENDITURE:		
Salaries		Fl.19,200
Sundries		13,650
UPKEEP—250 bouws x Fl.35	= Fl.8,750	
250 ,, x 30	= 7,500	
500 ,, x 25	= 12,500	
		28,750
Factory and Tapping Tools		35,000
		Fl.96,600
7TH YEAR—		
Salaries as before	Fl.19,200	
General Expenses ditto	13,650	
	32,850	
Less ¼ to Revenue a/c (250 bouws to Revenue a/c)	8,210	
		Fl.24,640
UPKEEP—250 bouws at Fl.30	= Fl.7,500	
500 ,, ,, 25	= 12,500	
		20,000
		Fl.44,640
8TH YEAR—		
Salaries as before	Fl.19,200	
General Expenditure ditto	13,650	
	32,850	
Less to Revenue a/c (500 bouws to Revenue a/c)	16,425	
		Fl.16,425
UPKEEP—500 bouws at 25		12,500
		Fl.28,925

INDEX.

SPECIAL NOTICE TO THE RUBBER PLANTING WORLD.

PARA, CASTILLOA, CEARA, FUNTUMIA (TRUE), MANIHOT DICHOTOMA, PIAUHYENSIS, HEPTAPHYLLA NEW VARIETIES OF MANICOBA), MIMUSOPS GLOBOSA (BALATA), LANDOLPHIA KIRKI, Etc.

Seeds, Plants, and Stumps forwarded to all parts of the World.

TEA.—Manipuri Indigenous Dark Leaf approved Jats. 1911 crop sold to Mexico, South India, Java, etc. Orders being booked for 1912 crop and onwards.

TEA SEEDS FOR MEXICO.—London, 2nd September, 1910:—"On receipt of this letter please carefully prepare 10 maunds picked Seed Thea Viridis at £ —— per maund, 10 maunds Thea Assamica at £ —— per maund."

PARA SEEDS AND STUMPS.—Orders being booked for 1912 session and onwards, seeds already booked over five million for August-September shipment, stumps over two million for shipment April onwards in closed cases and in Wardian cases.

WARDIAN CASES OF PARA STUMPS.—On shipping 75,000 in August the following wire order has been received on the 7th September:—"Duplicate last order Wardian Stumps"; also 25,000 Para Seed by Parcel Post and 225,000 by freight has been forwarded to the same address.

FOR DUTCH GUIANA.—The Director of an Agricultural Department writes 11th August, 1910:—"The Agricultural Department has ordered in total 560,000 Para Seed."

"The India Rubber Journal" quotes from the "Tropenpflanzer," touching one of our Para stump shipments:—"The writer saw 100,000 of these stumps which had just been planted out, none were dead, and many were putting out new roots. The Ceylon consignors, J. P. William and Bros., Henaratgoda, guarantee a mortality not exceeding 25 per cent., and the Manager of the Upola Company estimated the loss on this batch at 2 per cent. only. This is decidedly the best method of transporting Heveas."

SAMPLE PARA STUMPS forwarded by sample post to intending purchasers in all countries, Post Free.

PARA STUMPS IN CLOSED CASES.

DEMERARA.—Secretary of an Agricultural Estates, Ltd., of British Guiana writes; New York U.S.A., 11th April, 1911:—"The enclosed copy of our letter of even date to your London Agents will show you that they have advised us by telegraph of the shipping arrangements in regard to the order for seventy thousand (70,000) stumps placed with you through our London representatives. We shall most likely require something like 200,000 seeds." The cost of Para stumps in closed cases is about half when compared with Wardian cases.

PHILIPPINE ISLANDS.—Manager of an extensive rubber plantations, in ordering 75,000 Para stumps, writes, dating Mindanao, 27th November, 1910:—"Your first consignment of Para seeds were a great success."

GOVERNMENT ORDER.—On receiving 25,000 Para seed by Parcel Post at Sierra Leone in October, a repeat order received on 14th November, 1911, runs as follows:—"With reference to your letter of 10th inst., please send at once 50,000 Para Rubber seed by Parcel Post to —— Sierra Leone, West Africa."

GLASGOW.—Secretaries of a Rubber Estates Co., Ltd., of Mexico, writes, 17th March, 1911:—"We have pleasure in informing you that our Directors are satisfied with the result obtained from the ten thousand Hevea seeds got from you last year, and they desire this year to plant another thirty thousand seed."

TRINIDAD.—A Planter writes, St. Joseph, February 3rd, 1911:—"I duly received the 50,000 Hevea Seed. I am about forming a Syndicate of the planters to order 250,000 Hevea Seed."

MANGO GRAFTS.—Over 75 varieties, including Creeping, twice-bearing, all the year round bearing. LITCHI GRAFTS.—12 varieties, including seedless. SAPODILLA GRAFT all the year round.

SEEDS AND PLANTS OF NUMEROUS COMMERCIAL PRODUCTS SUPPLIED, INCLUDING TEA, CELEBRATED CARAVONICA, MAMARA, BAING AND SPENCE COTTON, ARABIAN LIBERIAN HYBRID COFFEE, COFFEE ROBUSTA, COFFEE CONGENSIS VAR. CHALOTI PROVED TO BE ABSOLUTELY RESISTING HEMILEIA VESTRATRIX, SOYA BEAN, GREEN SAMAROW EXTREMELY EARLY AND PROLIFIC, GIANT YELLOW SANTA MARGARITA, OF ENORMOUS GROWTH, BEANS VERY LARGE, EXTREMELY PROLIFIC, COCOA, KOLA, SISAL, AND OTHER FIBRES, ETC.

For Green Manuring.—CROTOLARIA STRIATA, VIGNA, ALBIZZIA MOLUCCANA, PASSIFLORA FOETIDA, CASSIA MIMOSOIDES TEPHROSIA CANDIDA, I. PURPURIA, BEANS, ETC., SEEDS.

Six Descriptive Catalogues, with Circulars and Special offers post free to foreign countries. Separate Price List for Ceylon.

"SOUTH AFRICA," the great authority on South African affairs, says:—"An interesting Catalogue reaches us from the East. It is issued by WILLIAM BROTHERS, Tropical Seed Merchants, of Henaratgoda, Ceylon, and schedules all the useful and beautiful plants which will thrive in tropical and semi-tropical regions. We fancy Messrs. Williams should do good business, for now that the great Powers have grabbed all the waste places of the earth, they must turn to and prove that they were worth the grabbing. We recommend the great Powers and Concessionaries under them to go to William Bros.

Agents in London:—Messrs. P. W. WOOLLEY and Co., 90, Lower Thams Street.

Agents in Colombo, Ceylon:—Messrs. E. B. CREASY and Co.

No Sole Agents Anywhere.

J. P. WILLIAM & BROTHERS,

Tropical Seeds and Plants Merchants,
HENARATGODA, CEYLON

Telegraphic Address:—
WILLIAM, HENARATGODA, CEYLON.
Liber's, A.I. and A.B.C. Codes (4th and 5th Editions) used.
Also Private Codes.

Awarded Gold, Silver, Commemorative, and other Medals, Diplomas, Merits, and Certificates at various International Exhibitions, including St. Louis, 1904.

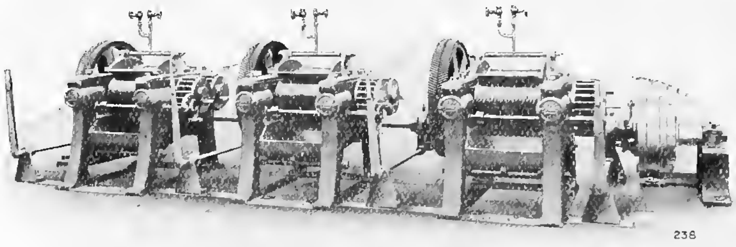
Awarded Bronze Medal with Diplomas for Para and Castilloa Rubbers at St. Louis Exhibition, 1904.

INDEX TO ADVERTISEMENTS.

Erratum :—Pulsometer Engineering Co., Ltd., for "Pumps" *read* "Drying Plant and Pumps."

RUBBER SHAW'S MACHINERY

Washing, Crepeing & Sheeting Machines.



BATTERY OR MACHINES WITH BACK SHAFT DRIVE.

DRIVING ARRANGEMENTS.

WE supply our Machines with either **Under Shaft** or **Back Shaft Drive,** but strongly recommend the latter, as the bearings are then quite clear of the dirt and water from the machines.

The line-shaft is driven from the Engine Crank Shaft by any of the following methods :—

(*a*) By Fast and Loose Pulleys with Belt-Shifting Gear.

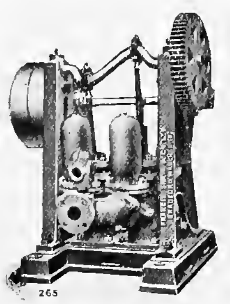
(*b*) By a Single Pulley mounted on a Hele-Shaw Friction-Clutch on the line shaft. (This is preferable to the fast and loose pulleys as no shifting of the belt is necessary).

(*c*) By Patent Double Helical Machine but Gearing direct from the Crank Shaft to the Line Shaft. In this case the wheel on the line shaft is mounted on a Hele-Shaw Friction-Clutch to throw the shaft into operation after the engine has been started under no load. This method is very useful where space is a consideration, as the engine can be placed close up to the machines.

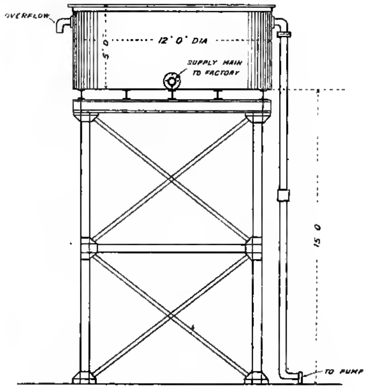
FRANCIS SHAW & CO., LTD.,

RUBBER SHAW'S MACHINERY

WATER SUPPLY.



BELT DRIVEN PUMP.



STEEL TANK AND TOWER.

We supply Pumps and Tanks of all sizes, but have standardized the following for Rubber Factories :—

PUMPS.

SIZE.	TO DELIVER
A	500 gallons per hour
B	1,000 ,, ,,
C	1,500 ,, ,,
D	2,000 ,, ,,

TANKS.

SIZE	CAPACITY
12′ dia. 4′ deep	2,500 gallons
15′ ,, 5′ ,,	5,000 ,,
20′ ,, 6′ ,,	11,000 ,,
24′ ,, 6′ ,,	16,000 ,,

The bottom of the tank is fixed at a height of 15 feet above the factory floor level, unless otherwise arranged. In some cases, where the larger tanks are necessary, they are arranged to form the roof of the Engine House or Store Room, thus dispensing with the steel tower.

PLANS AND ESTIMATES FOR COMPLETE FACTORIES FREE ON APPLICATION.

BRADFORD, MANCHESTER.

Please see pages 16, 26, 36, 37, 62, 63, and last page.

DON'T MISS OUR INTERESTING CORONATION SOUVENIR—80 PAGES FREE.

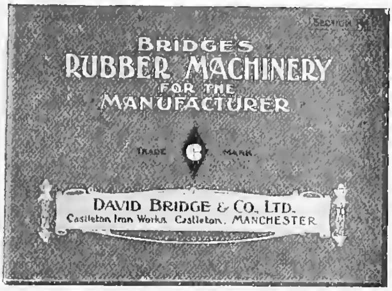
— N.B. —
This is undoubtedly the finest Catalogue yet published in connection with the preparation of Plantation and Crude Rubber.

— N.B. —
We would make it quite clear that even this Catalogue does not represent our Latest Designs of Rubber Preparation Machinery.

PLANTERS' CATALOGUE—200 Pages—Free on Application.

The above is a Photo of a Front Corner View of our Works; behind are our Foundries, Smithy, Pattern Shops, Joiners' Shops etc. [Covers 7,265 square yards].

— N.B. —
We make Complete Plants of Rubber Machinery for every section of the Rubber Trade.
Also Reclaiming Machinery.



— N.B. —
We make Gutta Percha and Balata Machinery in all its Branches. Also Cable Machinery.

MANUFACTURER'S CATALOGUE—130 Pages—Free on Application.

OUR CORONATION SOUVENIR GIVES A RESUMÉ OF VARIOUS RUBBERS.

AGENTS:

Ceylon & Southern India—Colombo Commercial Co., Ltd., London & Colombo.

Malay States—Kuala Lumpur Engineering Works—Secretaries: Paterson, Simons & Co., Ltd., London, Kuala Lumpur, Singapore, etc.

Dutch East Indies—Merrem and La Porte, Amsterdam, Batavia, Soerabaia, Medan, Bandjermasin, Padang,

Kelantan—Duff Development Co., Ltd., London and Kuala Lebir.

LONDON OFFICE:—35, Queen Victoria Street, E.C.

The DA COSTA Patent "Rapid"

LATEX COAGULATOR

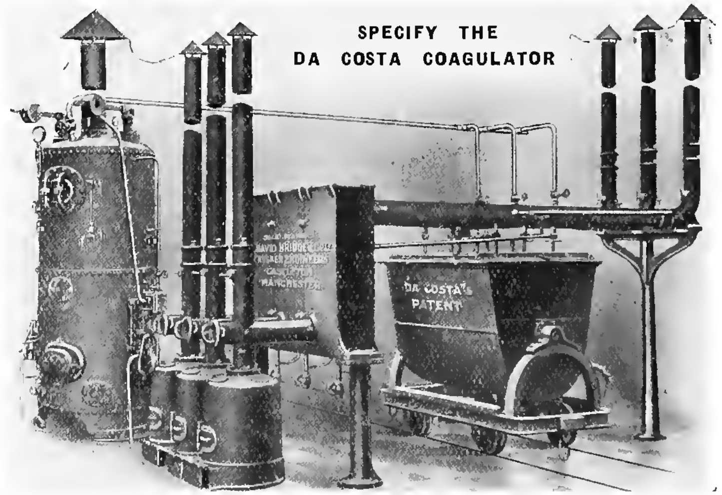
BY A SMOKING PROCESS.

—AWARDED GOLD MEDAL AND DIPLOMA AT RIO JANEIRO.—

Made in various sizes to Coagulate upwards of 5,000 gallons of Latex per hour.

PRICES FOR COMPLETE RUBBER MACHINERY INSTALLATIONS ON APPLICATION.

COMPETENT ENGINEERS SENT ANYWHERE TO ERECT & START UP COMPLETE PLANTS.



This is a photo. of an installation we sent to the FIRST RUBBER PLANTATION IN BRAZIL. The Brazilians know full well the Importance of coagulating their Latex by a smoking process.

N.B.—We have carried out extensive experiments on all kinds of latices both at our Works and on the plantations by the DA COSTA System, with the result that the Rubber is as near like Brazilian Fine Hard Para as possible, and it is pronounced by experts to be much stronger after vulcanization than that coagulated by Acetic Acid.

SEND FOR CATALOGUE—FREE.

SOLE MAKERS:—

DAVID BRIDGE & CO., LTD., RUBBER ENGINEERS,

LONDON OFFICE:—
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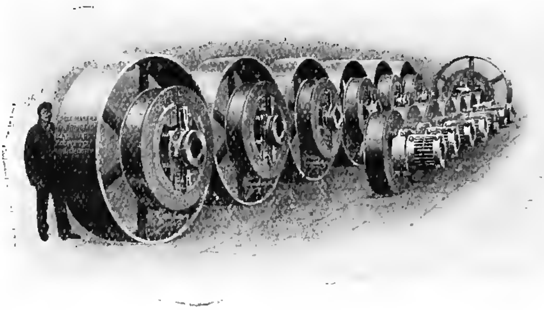
Norton Iron Works,
CASTLETON, Manchester.

HEYWOOD & BRIDGE'S PATENT

FRICTION CLUTCHES.

WE ARE THE PIONEERS IN THE APPLICATION OF CLUTCHES TO RUBBER MACHINERY FOR —BOTH PLANTERS AND MANUFACTURERS.—

We are continually receiving Repeat Orders from the leading Engineering and Manufacturing Firms throughout the World.

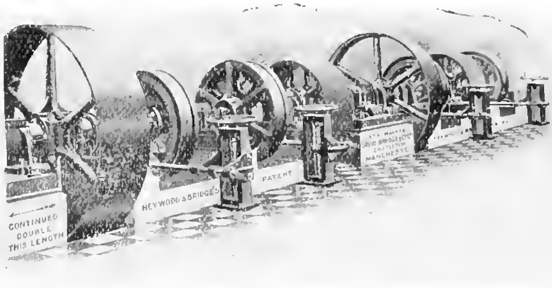


UNSOLICITED TESTIMONIAL.

"As you know, we have ordered with you a considerable number of clutches in the past, and we hope in the future to purchase many more, as we have been quite satisfied with the working of them."

ALL IN HALVES).
Battery of Clutches prepared for Belt Driving and Renold's Chain Driving. This single order represents over 2,000 h.h.p.

Smooth Running, Easy Adjustment.



Our Clutches are open and "Getatable."

This shows part of a complete installation (the other half being a duplicate of that shown) of our Heywood and Bridge's Improved Patent Friction Clutches for driving Stamp Batteries, Air Compressors, Pumps, etc., in connection with a large Gold Mine. The whole plant is driven by Gas Engines, and the Clutches are so arranged that any one Gas Engine, through our Friction Clutches, can be made to drive any particular unit — for instance, the Stamp Batteries can be driven by any of the four Engines The whole of the Clutches and Millwrights' work throughout have been supplied and erected by us on the site.

N.B.—We have been making our Friction Clutches for Users Engineers, Machinists, etc., for over 20 years, and during that period they have been applied to all **kinds of** drives which necessitated stopping and starting whilst running at **high and low speeds** when giving out light and heavy loads without any shock or jar taking place.

200 PAGE CATALOGUES FREE ON APPLICATION.

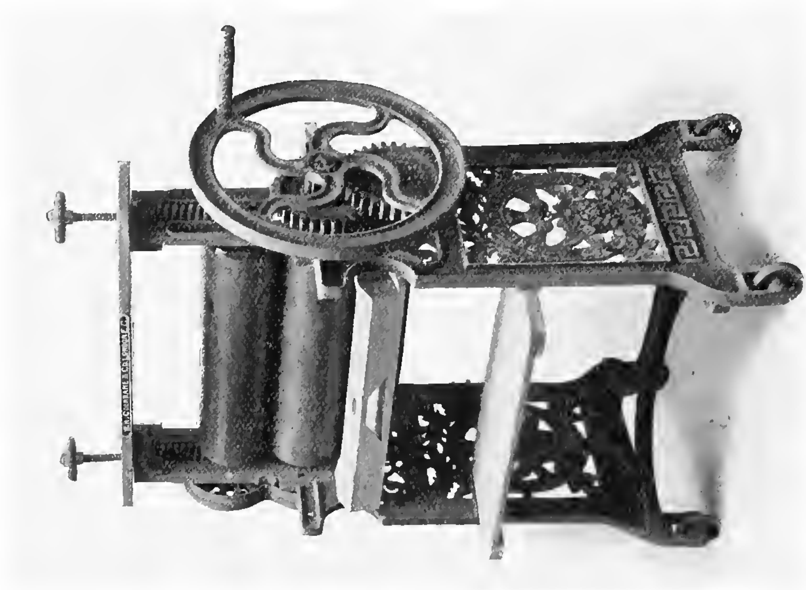
PATENTEES AND SOLE MAKERS:—

DAVID BRIDGE & CO., LTD., RUBBER ENGINEERS

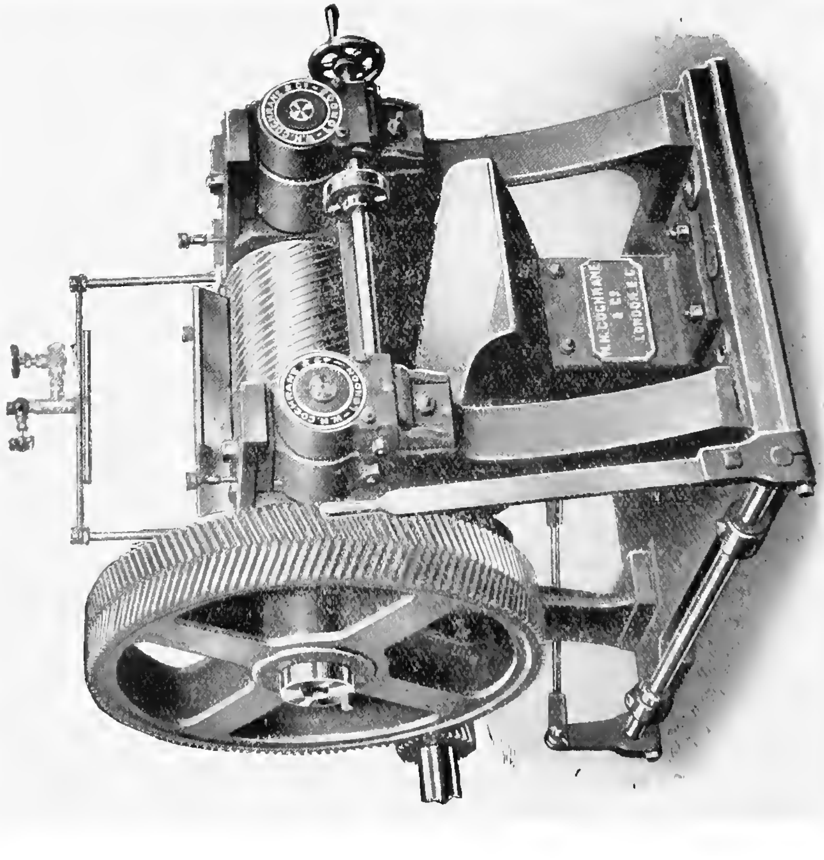
LONDON OFFICE ;— **Norton Iron Works,**

35, QUEEN VICTORIA ST., E.C. **CASTLETON, Manchester.**

W. H. COCHRANE & Co., Engineers, 110 CANNON STREET, E.C.

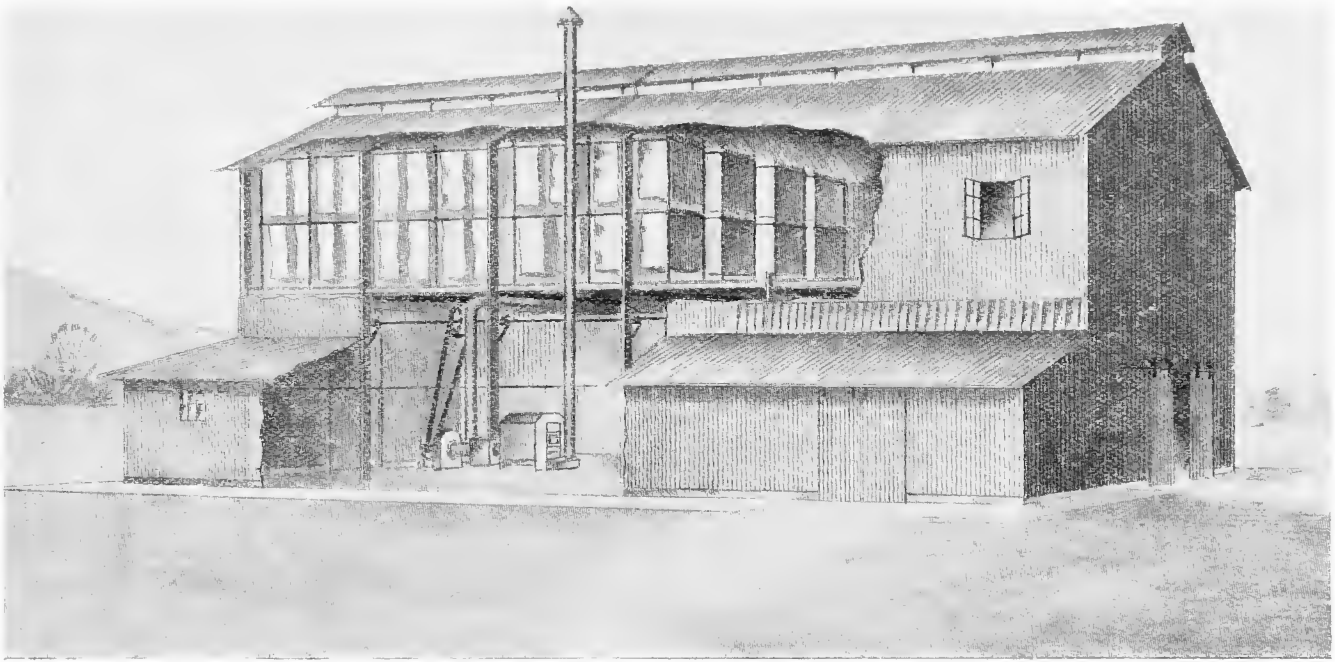


"F" Type Hand Machines.

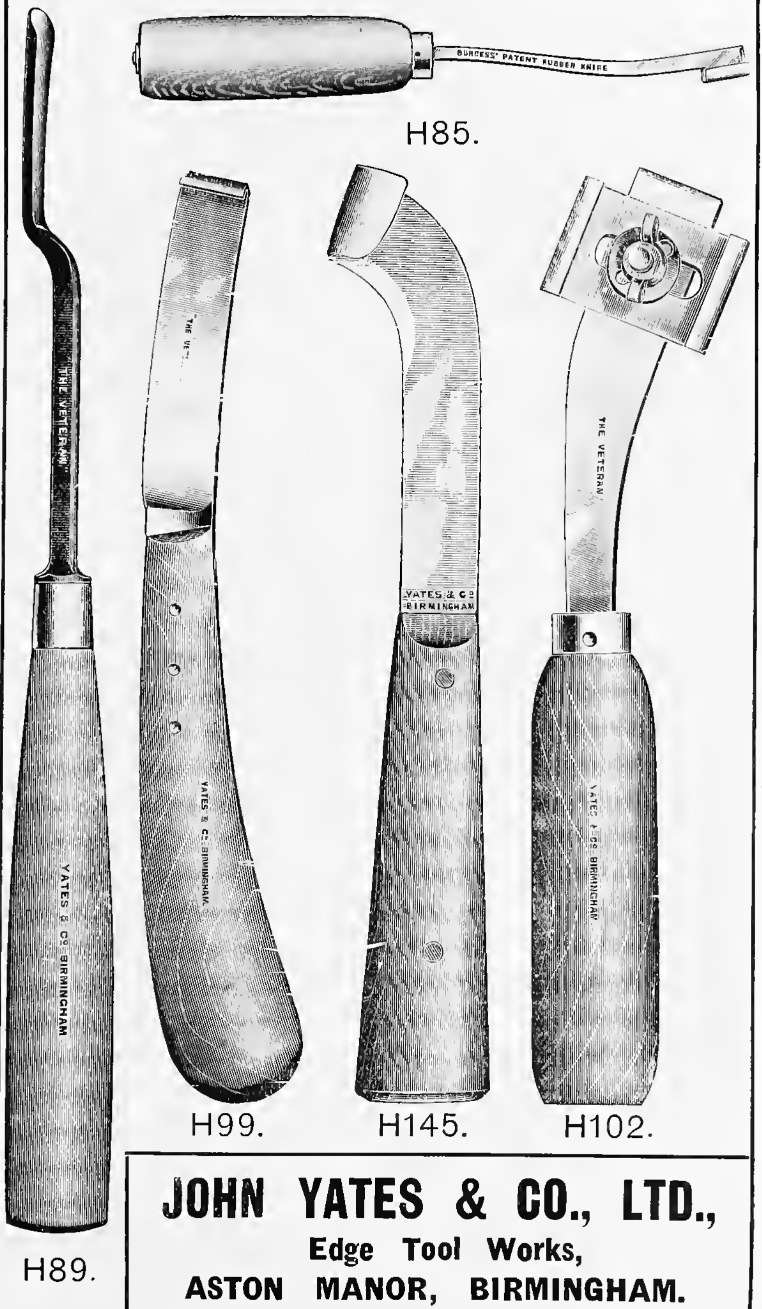


"P" Type Improved Machines.

Cochrane's Improved Mascerating, Crêpeing and Sheeting Machines.



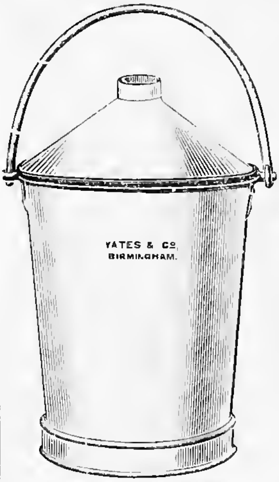
View of our "Z" Type Factory,
Showing the Drying and Smoking Plant, with Racks on the First Floor.


BURGESS' PATENT RUBBER KNIFE
H85.
THE VETERAN
YATES & Co. BIRMINGHAM
YATES & Co. BIRMINGHAM.
YATES & Co. BIRMINGHAM
THE VETERAN
YATES & Co. BIRMINGHAM
H99.
H145.
H102.
H89.

H81. Glass.

H83. Tin or Terne.

H84. Tin or Terne.



R158. Trans-porter.

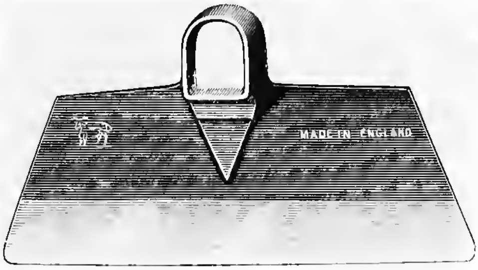
H78. With sieve and cover.

H79. Coagulating Tray. White Enamel.

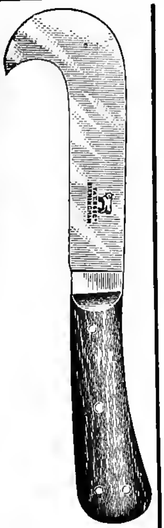
Latex Spout.

JOHN YATES & CO., Ltd., Edge Tool Works, Aston Manor, Birmingham.

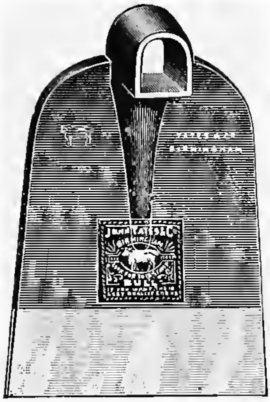
H132.



H126.

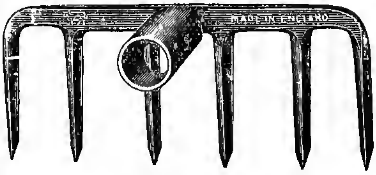


H25.

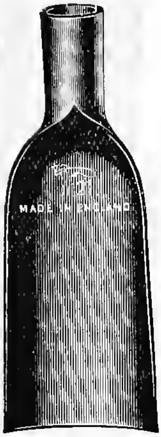


H5.

H130.



H127.

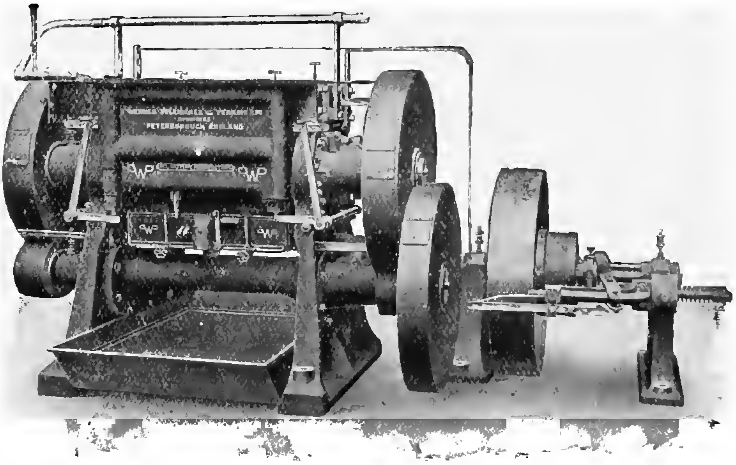


H134.

H131.

JOHN YATES & CO., Ltd., Edge Tool Works, Aston Manor, Birmingham.

THE PATENT
UNIVERSAL WASHER
(BRITISH MANUFACTURE).



PULLEY DRIVEN MACHINE.
(See also Opposite Page).

The following is a list of a few Firms who have adopted this Machine—

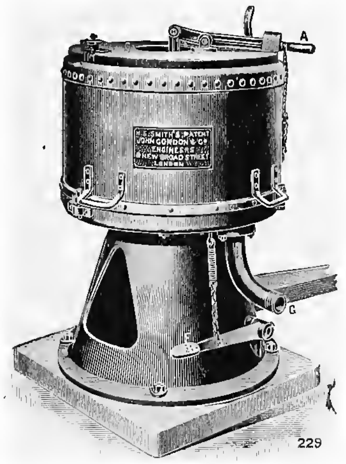
THE BORNEO COMPANY, LTD.
CONSOLIDATED MALAY ESTATES, LTD.
THE DAMANSARA RUBBER CO., LTD.
LANADRON RUBBER ESTATES, LTD.
(Lanadron and Jementah Estates).
LINGGI PLANTATIONS, LTD.
RAYIGAM ESTATES, LTD., CEYLON.
ROSEHAUGH TEA & RUBBER CO., LTD.
ST. GEORGE'S RUBBER ESTATES, LTD.

Werner, Pfleiderer & Perkins, Ltd.

ENGINEERS,

WESTWOOD WORKS, PETERBOROUGH, England.

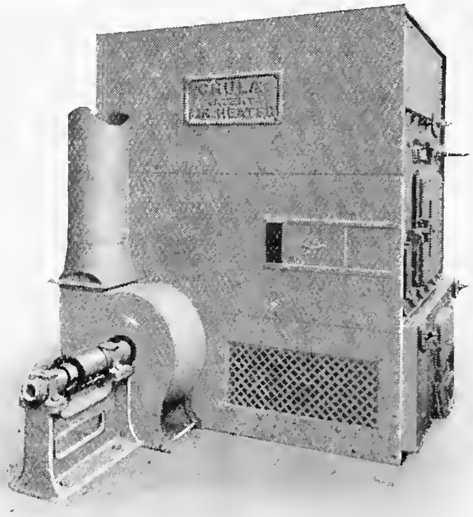
Telegraphic Address: ARKTOS, PETERBOROUGH.



For description see Page 338.

'CHULA' Patent RUBBER DRYING and SMOKING PLANT.

FOR PRODUCING EITHER PALE OR SMOKED RUBBER WITHOUT ALTERATION TO PLANT



¶ Dries large quantities of Rubber at a time, using a slow moving current of air or smoke at a temperature of 100° to 110° Fahr.

¶ With our method of sub-divided Drying Room a day's production of Rubber can be turned out ready for packing EVERY day.

¶ Can easily be applied to existing Factories where Drying Room is available.

¶ Cheap in first cost and in working.

¶ Further particulars and estimates for installation sent on receipt of plan of existing Factory.

¶ These plants are now working in Ceylon, South India, and F.M.S.

SOLE MANUFACTURERS:

Tyneside Foundry & Engineering Co.,

HEAD OFFICE AND WORKS:

ELSWICK, NEWCASTLE-ON-TYNE.

TELEGRAMS: "FOUNDRY, NEWCASTLE-ON-TYNE."
CODE: A B C, 5TH EDITION.

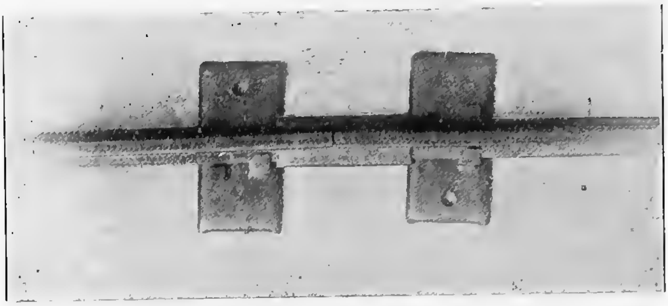
Please see pages 16, 26, 27, 36, 37, 63, and last page.

Please see pages 16, 26, 27, 36, 37, 62, and last page.

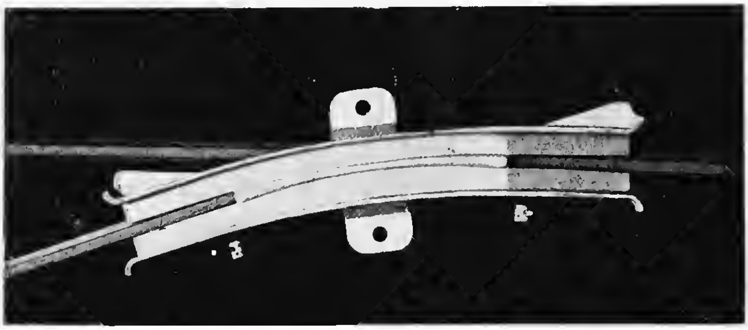
CAILLET'S MONO-RAIL For Rubber Estates.

The simplest of all transport systems to install and work.

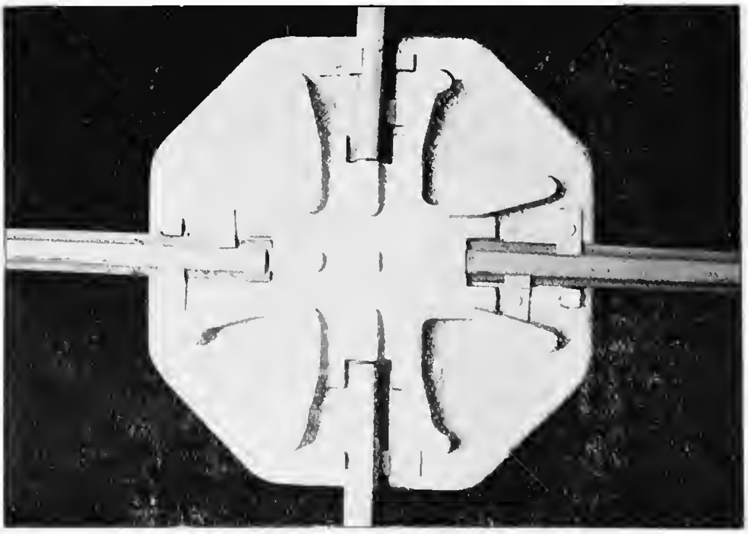
No allignment or ballasting of track necessary. Upkeep of roads practically nil.



Rail with Sole Plates and Fish Plates in position



Portable Ramp or Switch for temporary use on curves, etc.



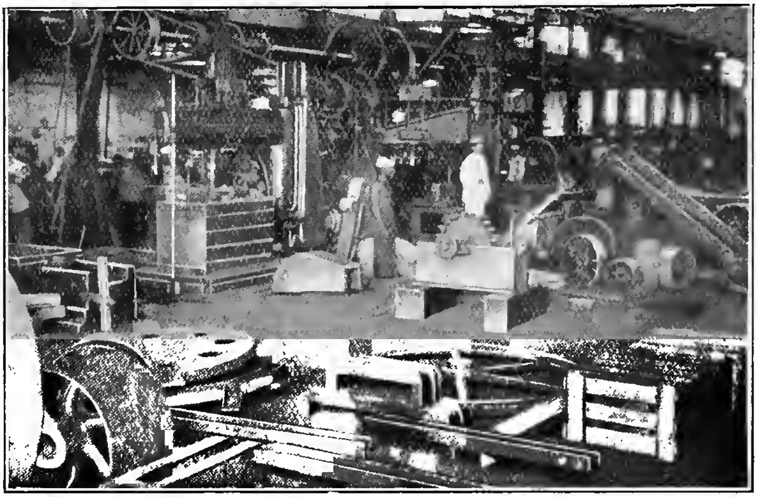
Crossing Plate for lines running at right angles.

CAR, TYPE 33, BEING USED ON A RUBBER PLANTATION IN MALAY PENINSULA.

MONORAIL, TYPE 47.

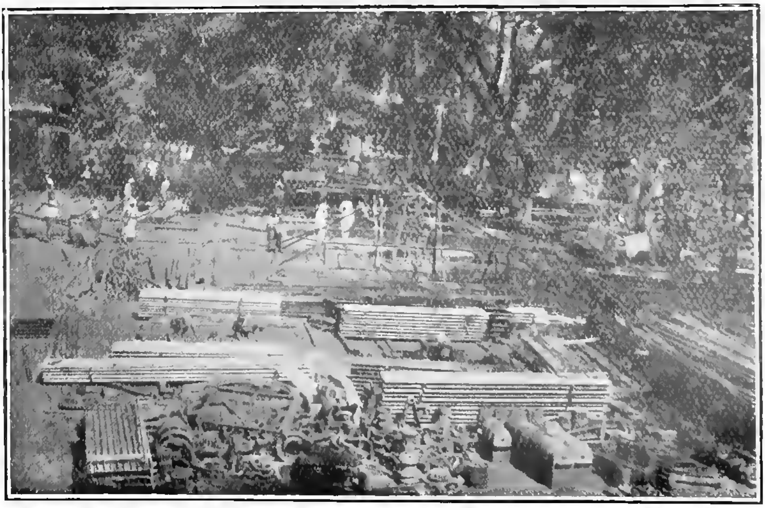
Colombo Commercial Co., Ltd.,

Engineers & Building Contractors. —— **COLOMBO.**



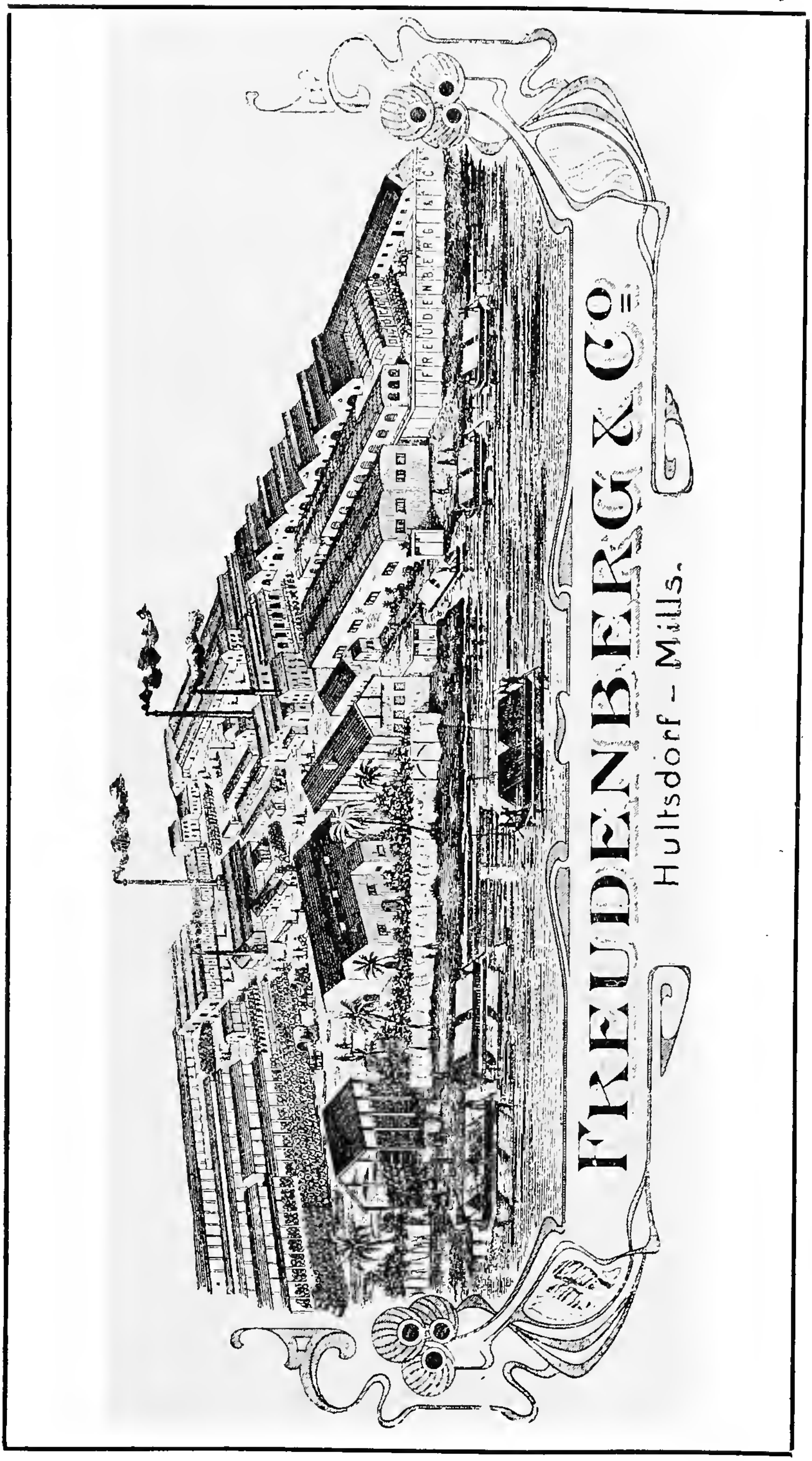
Manufacturers of :— WORKSHOP INTERIOR.

C.C.C. HOT AIR RUBBER DRYING APPARATUS.
PELTON WHEELS. AERIAL ROPEWAYS.
STEEL STRUCTURAL WORK FOR FACTORIES, COOLY LINES and for all types of ESTATE BUILDINGS.



Agents for :— STRUCTURAL STEEL YARD.

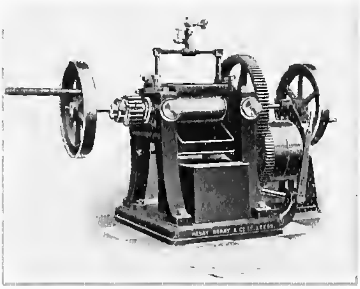
TANGYE'S SUCTION GAS PLANT.
DAVID BRIDGE & Co.'s RUBBER MACHINERY.

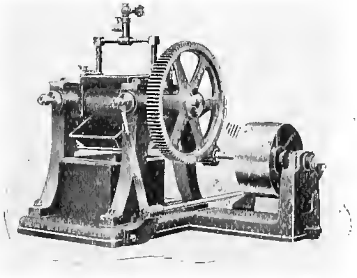

FREUDENBERG & Co.
Hultsdorf - Mills.
FREUDENBERG & Co.

HENRY BERRY & CO., LTD., LEEDS, ENGLAND.

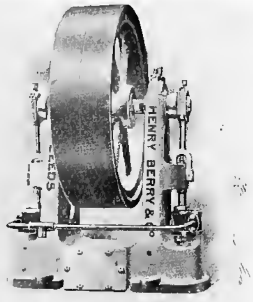
Specialities—RUBBER PLANTATION MACHINERY.
RUBBER FACTORY MACHINERY.
HYDRAULIC MACHINERY & TOOLS.

Estimates Given for Complete Plants and Single Machines.

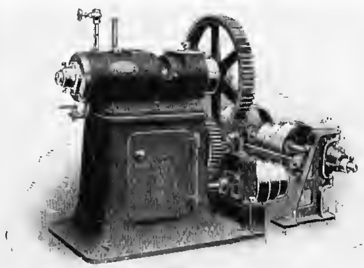




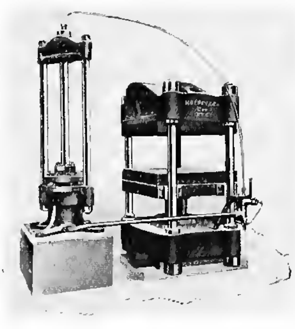
HAND AND POWER DRIVEN. BELT DRIVEN.
PLANTATION RUBBER WASHERS. — CRÊPERS. — MACERATORS. — SHEETERS.



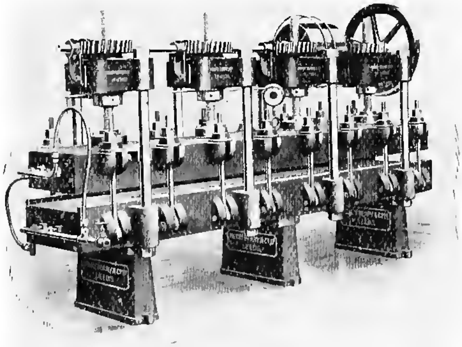
BELT DRIVEN HYDRAULIC PUMP.



PATENT RUBBER CORD TUBE AND TYRE FORCING MACHINE.



HYDRAULIC VULCANIZING PRESS AND INTENSIFIER.



SCREW TYPE BELT VULCANIZING PRESS.

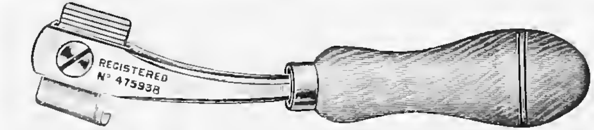
TRADE MARK.

R T S

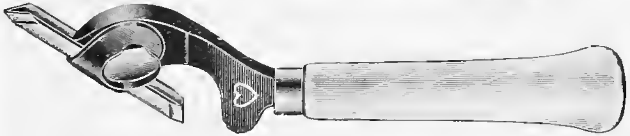
RUBBER TAPPERS

ESTABLISHED 1855 TRADE MARK

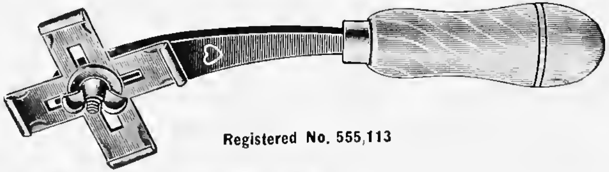
OF EVERY DESCRIPTION.



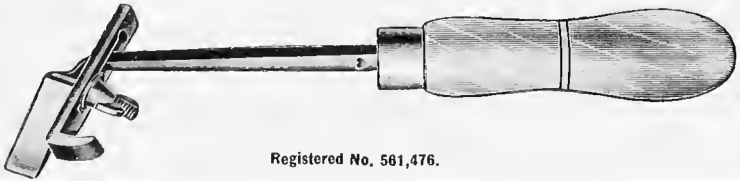
Registered No. 561,477.



Registered No. 561,475

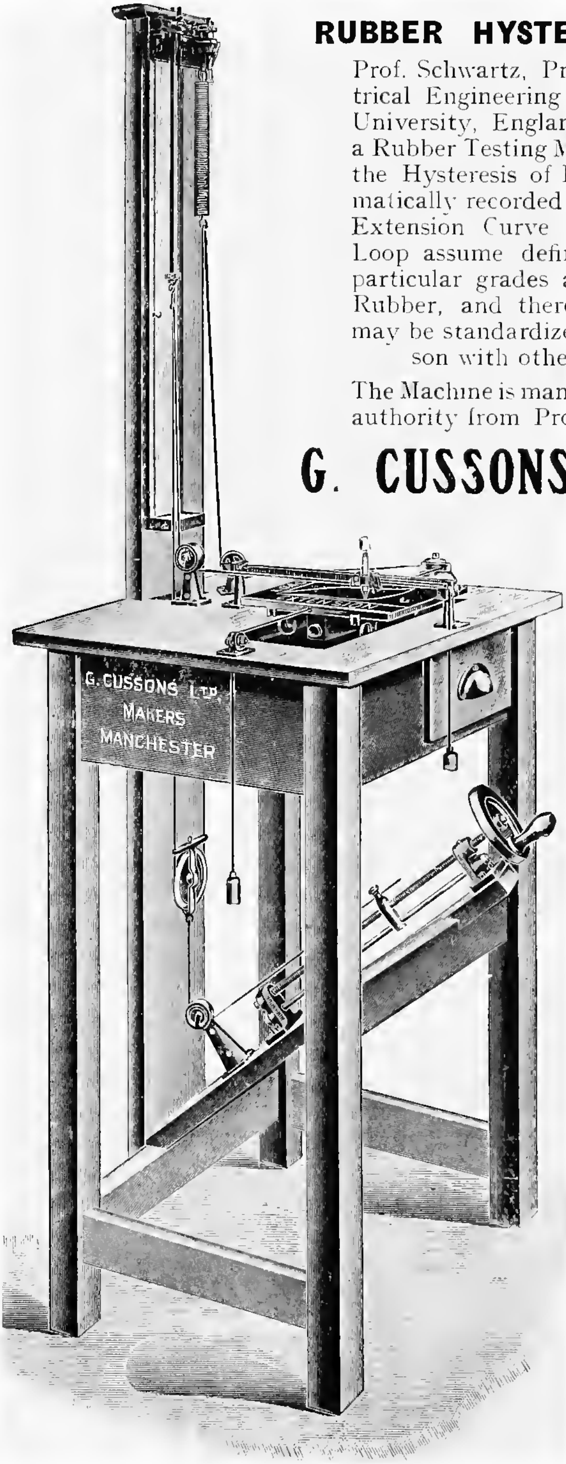


Registered No. 555,113



Registered No. 561,476.

WYNN, TIMMINS & CO., Limited, Century Works, BIRMINGHAM.



RUBBER HYSTERESIS TEST:

Prof. Schwartz, Professor of Electrical Engineering at the Victoria University, England, has invented a Rubber Testing Machine whereby the Hysteresis of Rubber is automatically recorded on paper. The Extension Curve and Hysteresis Loop assume definite shapes for particular grades and qualities of Rubber, and therefore specimens may be standardized for comparison with other samples.

The Machine is manufactured under authority from Prof. Schwartz by

G. CUSSONS, Ltd.,

The Technical Works,
MANCHESTER
AND
231, STRAND,
LONDON, W.C.

The make of the Machine is of the highest possible excellence. All Pulleys, Screws, and moving parts are specially designed, being rigid and highly sensitive. The Frame is of best mahogany, polished.

All requisite accessories are included with the Machine, viz., Brass Standard Cutting Apparatus, Special Cutting Knife, Guages, Clamps, Tools, etc.

Price complete £23.

See reference to this experiment on Page No. 453.

Size approx., 6ft. by 3ft. by 3ft.

Section of Para Rubber Tree showing process of bark renewal after pruning and treatment with Jodelite. Original cut 2½" wide reduced to 1" at time of photo. The wood is perfectly clean, healthy and free from parasitic growth of any kind, permitting of ready contact of new bark with it.

"JODELITE" Reg.,

The original British wood preservative and

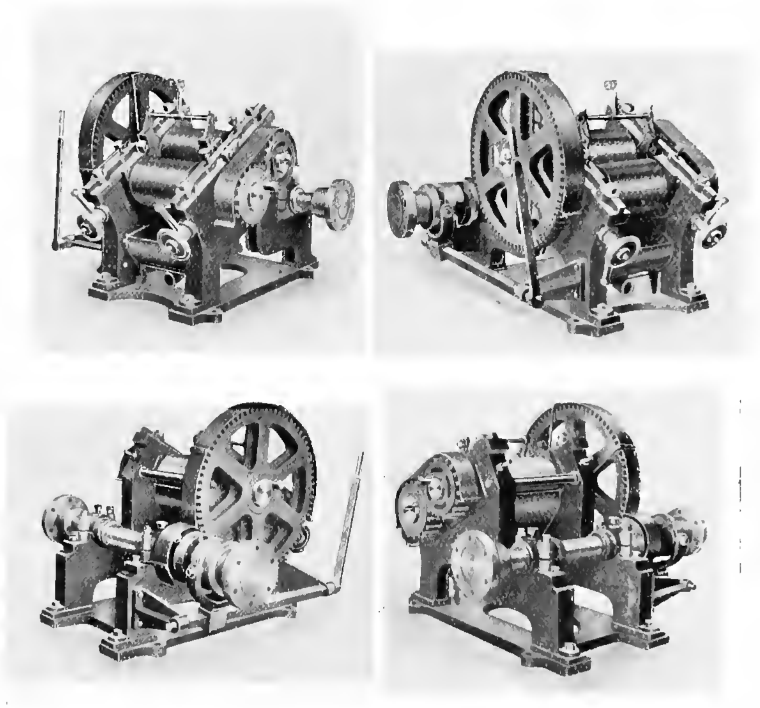
WHITE ANT DESTROYER

HAS BEEN USED FOR SOME YEARS PAST ON RUBBER PLANTATIONS & TREES WITH COMPLETE SUCCESS

Full Particulars, Samples, etc., Free on Application to the Sole Manufacturers:

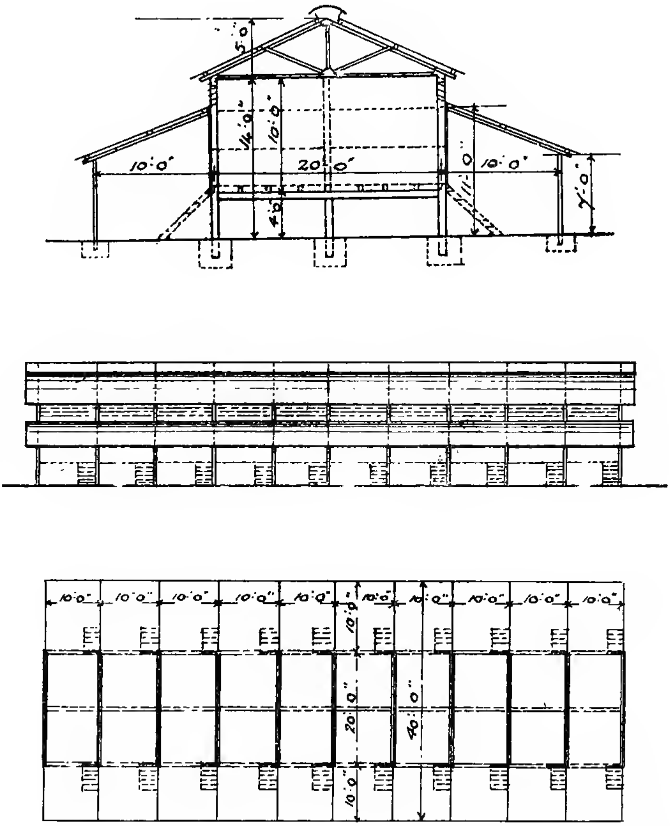
JOSEPH DEE & SONS, 5, CROSS STREET, MANCHESTER.

Tel Address: "Delight," M/c. (Contractors to H.M. Government). Code: A.B.C. 5th.



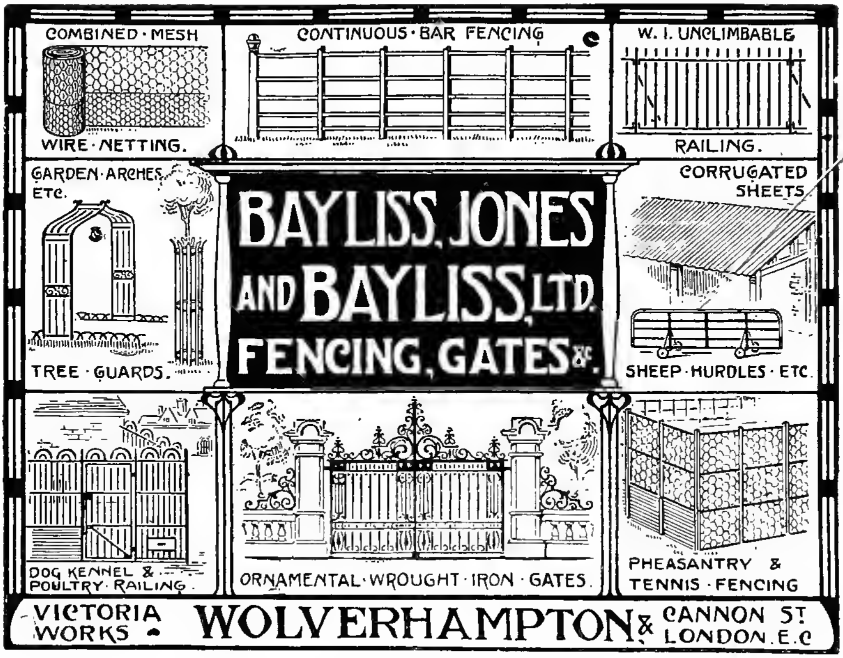
THE GLASGOW STEEL ROOFING Co., Ltd.

North Western Works, Possilpark, Glasgow.



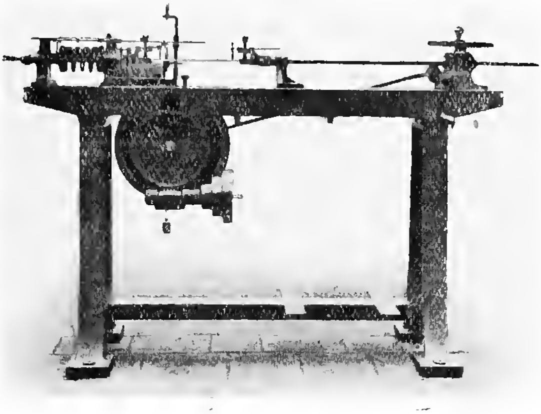
Approved Design Steel Framed Coolie House.

Cables: "ROOFING, GLASGOW."


COMBINED·MESH
WIRE·NETTING.
CONTINUOUS·BAR FENCING
W. I. UNCLIMBABLE
RAILING.
GARDEN·ARCHES ETC.
TREE·GUARDS.
BAYLISS, JONES AND BAYLISS, LTD.
FENCING, GATES &c.
CORRUGATED SHEETS
SHEEP·HURDLES·ETC.
DOG KENNEL & POULTRY·RAILING.
ORNAMENTAL·WROUGHT·IRON·GATES.
PHEASANTRY & TENNIS·FENCING
VICTORIA WORKS
WOLVERHAMPTON & CANNON ST LONDON. E.C.

DYNAMOMETER.

PATENT APPLIED FOR IN ALL COUNTRIES. **Trade Mark : P.B.**



HIGHEST PRECISION.

For testing supple and hard Rubber, Ebonite, Celluloid, Linoleun, Wax-cloth, Cables, Threads, Textile Fabrics, Belting, Plastic Materials, etc., etc.,

THE ONLY DYNAMOMETER IN THE WORLD.

FOR THE TESTING BY

TENSION (slow, sudden or alternate).
COMPRESSION (slow, sudden or alternate).
FLEXION (slow, sudden, or repeated bending).
WEAR AND TEAR (determination of the coefficient of friction).
PLASTICITY, etc., etc.

It can be used for testing at any temperature. It traces automatically diagrams. It can always be verified by the operator himself.

A. D. CILLARD,

Mechanical Engineer, Government Contractor, N.C.

49, RUE DES VINAIGRIERS, PARIS.

Branches.

MARSEILLES .. 29, Rue Pavilion
HAMBURG 21 .. 43, Osterbeckstrasse
NEW YORK .. 43-45, West 34th St.
JOHANNESBURG Palace Buildings
OBIDOS (Brésil).
MAJUNGA (Madagascar).

CORRESPONDENTS:

CONSTANTINOPLE. MADRID.
BRUXELLES. CEYLON.
SINGAPORE.

Awards.

BORDEAUX 1907	1 Gold Medal
NOGENT 1907	1 ,, ,,
PARIS EXP, SP. 1907	1 ,, ,,
TOULOUSE 1908	1 ,, ,,
FRANCO. BRIT. 1908 secretaire cl. 99	1 ,, ,,
MARSEILLE 1909	1 ,, ,,
BRUXELLES 1910	2 Grand Prix (Col.)
FRANCFORT 1910	Hors Concours
BRUXELLES 1910	2 Gold Medals
BUENOS-AYRES	1 ,, ,,
DOUAI 1910	1 Diplome d'Honneur
CLERMONT-FERR 1910	1 ,, ,,

GRAND PRIX : International Exhibition, Brussels, 1911.

Sole Agents for the United Kingdom—

W. MARTIN & CO., 93, Aldersgate Street, London, E.C.

Telegrams :—" WALKERS," Colombo, Ceylon.

WALKER SONS & CO., Ltd.,

COLOMBO IRONWORKS,
Colombo and Kandy, Ceylon.

WALKER SONS AND CO., Ltd., COLOMBO IRONWORKS,
ENGINEERING WORKS, BAY F, RUBBER MACHINERY.

WALKER SONS & CO., Ltd., COLOMBO & KANDY, CEYLON.

London Office—AUCKLAND HOUSE, 36, BASINGHALL STREET.

Please see pages 16, 26, 27, 36, 37, 62, 63.