THE REALM OF RUBBER.

BEING

A RECORD OF EXISTING CONDITIONS IN THE RUBBER INDUSTRY

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(With 30 Illustrations, Map & Chart.)

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PREFACE.

There should be no need of an apology for writing on the many changes that have taken place recently in the rubber industry as very few books are up-to-date regarding them. Most of the information that exists on the subject of development is scattered about in the pages of scientific journals and rubber periodicals, also in the bulletins of the research departments of certain governments and planters' associations. Brought about by economic pressure, these innovations are causing a rapid regeneration of the industry, which no rubber planter or manufacturer can afford to ignore in his constant efforts towards economy and improvement.

Much of the ground covered in this work has not been traversed as yet by any other book. A few of the subjects dealt with here have not quite passed the experimental stage, and so these have been presented as tendencies in the industry rather than as established practices. Facts relating to them have been obtained from the most authoritative sources, to ensure the absolute accuracy of which, every possible care has been taken.

The rubber industry embraces such a wide range of technical subjects that no individual writer can possess a deep insight into all its different sections—economic, agricultural, botanic, mycological, chemical and technological. Hence only the first four sections have been treated as fully as possible, while merely the vital changes in the last two recorded, mostly in the language of the experts. Here also an attempt has been made to deal very thoroughly with the economic aspects of this industry which are of vital concern to it at present owing to the crisis that rubber is passing through.

Rubber planting is apparently the most scientific agricultural industry of the day, and it is prone to vicissitudes which only the very experienced in the field can vaguely adumbrate. Consequently to bring success to his efforts in these days of rapid progress the rubber planter has to be a man of extensive information and attainments. He must not only be a practical botanist, economist and agriculturist in his own sphere, but should possess a working knowledge of certain sections of mycology, chemistry and technology. On the other hand, the rubber manufacturer cannot afford to be unacquainted with the consequential developments on the plantation side. No other industry seems so varied in scope, so exacting in intelligence.

The photo-prints of Hevea diseases have been reproduced from the official publications of mycological departments in the U.S.A. and the Middle East. A concise description containing the treatment of these diseases has been included in the book for obvious reasons. In the days of low rubber prices, which we are passing through, no planter can afford to suffer any loss by the unhealthiness of his estate; and, in the future every precaution must be taken to grapple with this evil.

The author is greatly indebted to various people for providing him with literature and illustrations for this work. These persons are too numerous to be mentioned individually and he begs to thank them all for their courtesy and kindness. He is also indebted to three scientists for reading over some proofs of this edition, but, as they desire to remain anonymous, he takes this opportunity of thanking them for their assistance.

THE AUTHOR.

Calcutta, 15th October, 1928.

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CHAPTER I.

RUBBER EFFECTS ON ECONOMIC LIFE.

A PERIOD OF RAPID MOVEMENTS.

There is little doubt that in the tide of human affairs a new stage has been reached in the striking features of which may be traced the introduction of rubber culture along with some connected mechanical inventions. Ushering in a greater rapidity of transport and communication on land, sea and air, this age has revolutionized our ideas of space and time. Developments of this kind seem destined to have far-reaching effects on our material civilization, although they were imperceptible early in the present century. How the forces underlying this current have been operating for many years and in what manner they have already affected our lives constitute a romantic chapter in the world's economic history.

With the growth of the world's population, it is obvious that the consumption of most products must steadily increase. Still under a special feature of modern economic advancement, the use of rubber seems to have augmented with greater rapidity than the consumption of any other raw material. The U. S. A. Department of Commerce reports that "in 1900 just 4 tons of plantation rubber were produced in the Middle East," but now the production of this area roughly comes to about 580,000 tons a year. At the beginning of this century, there was indeed an extraction of wild rubber from certain parts of the world, but it did not exceed 54,000 tons in 1900, which was insignificant compared with the present outturn. When we begin to reflect that production must more or less keep pace with consumption, it becomes obvious that there has been a phenomenal rise in the use of rubber all over the world since the early years of this century.

This development has taken place chiefly by the expansion of the automobile industry and the world's desire for rapid locomotion over land much as it has been through the air. It is for this reason that the present period is sometimes described as 'the rubber age,' though it would perhaps be more appropriate to call it the age of speedy transport and communication, if we are to include in it the introduction of wireless telegraphy, long-distance telephony and television—to say nothing of the other characteristics of this rapidly moving and fast-living era. Communication is said to help international commerce and credit, but, until facilities for the transport of goods develop concurrently along with it, fast communication with slow conveyance cannot expand much the trade of nations. Though the conquest of the air is a vaunt of this century, aerial flight has so far assisted but little towards the progress of civilization. It astounded the world by a display of its destructive powers during the Great War, but has not yet been able to convey men with any degree of comfort through the air. While it captivates the human imagination with its potentialities, its latent utility still remains to be revealed.

Rubber has at least helped to expedite the carriage of men and goods where railways cannot be constructed. The expansion and quickening of such transport are indeed so much more important than the extension of communications that without the former little economic progress can actually be stimulated by modern innovations in the transmission of intelligence. And, rubber has helped, though to a small degree, the construction of aeroplanes and submarine cables. The utilization of rubber has consequently been of greater service to man than probably any of the inventions that claim to develop the transport and communications of the present century.

THE SCANTY RECORDS OF RUBBER.

Rubber is believed to have been found originally in tropical South America shortly after the discovery of that continent by Columbus. This belief is probably based on tradition, for no authentic records are known to exist about the first finding of rubber. Those who have written about it declare that early in the sixteenth century, the Spaniards saw the natives playing with a ball made of a dark substance from the evaporated juice of a wild tree, the attention of the foreigners being drawn to the ball apparently by its elasticity. "The earliest known mention of India rubber," relates Sir George Watt, "is the remark by Herrera in connection with Columbus's second voyage (nearly 500 years ago) of the inhabitants of Hayti playing a game with balls made from the gum of a tree. These balls, he remarks, though large, were lighter and bounded better than those of Castile."[1] About this time also rubber probably existed as a wild plant in the tropical East, else it would be difficult to explain why it is known as India rubber.

After its discovery, nothing more was heard of this product until about 1770 when an English chemist, Joseph Priestly, is said to have used it to 'rub' out pencil marks. Hence its name was derived. Obviously little use was found for rubber until the world advanced sufficiently in material civilization. In 1823 it was utilized by Macintosh, a Scotchman, as a waterproof cover for clothing, but his experiments at first were not satisfactory. Rubber when melted, becomes 'a sticky, worthless, semi-fluid.' So something had to be done to produce a chemical composition with it which would make rubber more serviceable. This was effected between 1844 and 1845 when Thomas Hancock, an Englishman, and Charles Goodyear, an American, patented the process of 'vulcanizing rubber' which is

[1] *Dictionary of Economic Products of India*, by Watt, London, 1890, Vol. IV, Article on India Rubber.

described as 'the chemical union of caoutchouc and sulphur which hardens the viscous portion of the former, thus producing soft and hard rubber.'

The vulcanization of rubber gave it the qualities it needed for successful waterproof clothing, shoes and boots, thus making it possible to prepare with it endless goods in the service of man. This treatment naturally resulted in the growing use of rubber for various small purposes during the latter half of the nineteenth century. Of the many services found for rubber in the seventies, its use in the cycle tyre was apparently the most extensive. It was also the most significant because with the advent of the bicycle the first step was taken in mechanical transport which gradually involved the biggest increase so far known in the consumption of this product. But although the bicycle began to be manufactured about the year 1870, the use of cycle tyres did not assume any large proportions until the safety bicycle was constructed and the pneumatic tyre was devised by Dunlop in 1888.

INVENTIONS DEVELOP THE USE OF RUBBER.

Material progress in the modern age has passed from one stage to another, not merely by the evolution of economic events but by a multitude of movements in which the march of science has been very prominent. Thus we find that the reign of rubber was ushered in by several inventions of which the most momentous was the devising of the 'internal combustion engine.' Had this particular type of motive power not been invented and if the regular cultivation of rubber were not undertaken some years prior to it, the modern desire for fast transportation could not have been nurtured although it was awakened by the advent of the bicycle. Economists say that human desires grow by their capacity for fulfilment. In this case the desire for rapid locomotion was fostered by the fortuitous concurrence of the two aforesaid factors. Again, originally rubber provided mostly for the luxuries of man, not for his essential requirements. But in an era of advancement, what are luxuries to-day become indispensable needs to-morrow. Hence rubber is fast becoming a product essential to the welfare of man.

In the eighties of the nineteenth century, Gottlieb Daimler, M. Levassor and De Dion Bouton were responsible for the evolution of the internal combustion engine. Daimler patented his device in 1885 and all three of them employed their engines to drive cars for road locomotion, more or less attaining practical success. But their commercial utility was not proved until the application of the pneumatic tyre to automobiles in the nineties of the last century. In the meanwhile the progress of metallurgy—by which a betterment in the composition of steel was sought by alloying it with rarer metals like vanadium, tungsten, chromium and nickel—contributed not a little towards this tendency. In truth we must admit that not merely to the development of rubber but to the small, light, high-speed, petrol engine and all the connected inventions, modern road transport and aerial flight owe their realization. Among these factors, rubber has thus far contributed but little towards aerial navigation, but its potential utility as an outer casing for ships and cables as well as for the pavement of roads is immense.

THE SPREAD OF AUTOMOBILISM.

In the opening years of this century, the automobile had attained commercial success by proving itself a faster and more convenient conveyance than any drawn by horses; and various types of it began to be built in France, Great Britain, Germany and the United States of America. Objections were, however, raised against the introduction of engine-driven vehicles on the public roads and restrictions on their use actually existed in certain countries. Moreover their initial cost was heavy. These circumstances retarded their general adoption. Gradually the opposition to their running in the towns died down and the connected restrictions were removed. Experience in the manufacture of these vehicles moreover lessened the expenses of their production, and, with the lowering in the prices of automobiles, their use began to spread.

About 1910 motor cars and trucks were adopted almost everywhere in the West and since then the expansion of automobilism has been almost phenomenal throughout the world. For instance, at the present time it is estimated that there is 1 automobile to every 6 persons in the United States, 1 to every 51 persons in Denmark, 1 to every 53 in France, 1 to every 55 in Great Britain, 1 to every 75 in Sweden, 1 to every 84 in Belgium and 1 to every 99 in Norway. Workmen in the United States actually drive to the factories in their own motor cars mainly because their country possesses the largest automobile industry and the American operative—helped to some degree by 'prohibition'—is deservingly passing through his days of abounding prosperity. The employment of these vehicles is still very limited in the East and would not bear comparison with their use in the West, but the prospects here are promising. In this country, for instance, the use of the motor-bus is extending rather rapidly because the multitude cannot afford the use of cars. But with the extension and metalling of country roads in the densely populated provinces the use of both the motor-bus and the motor-lorry will expand directly these improvements take place.

The initiation of rubber culture in plantations many years before the advent of the automobile was really providential for the success of rapid locomotion. Though it cannot be said that the automobile inspired the regular culture of rubber, the use of the safety cycle and the existence of cushion tyres apparently had some influence on the invention of the internal combustion engine and the progress of metallurgy. At any rate it is certain that after 1910 the concurrent rapid growth of rubber culture and automobile construction are by no means fortuitous. That automobiles have increased the welfare of man was questioned not long ago owing to the increase of street accidents since the advent of motor vehicles. It was urged that while they have augmented the comforts of the rich, these vehicles have subjected a few of the poorer classes to injury and death on the roads. This drawback must, however, be weighed against the convenience to the masses themselves by the use of the motor-bus and lorry as well as by the wider services they now derive in their rural life by a continuous transfer of live stock from the towns to the villages. Moreover, speedy transport saves time which is precious and it has made it possible for perishable goods (such as fish, meat, fruits, eggs, milk and vegetables) to be conveyed from cheap to dear markets.

RUBBER IN OTHER INDUSTRIES.

Speaking about the use of this product in the smaller industries, Sir Stanley Bois, Past President of the British Rubber Growers' Association, London, remarks: "The more important of these may be most conveniently considered under the headings of Health and Home, Power and Light and Communications. Without rubber many surgical operations would be impossible in the absence of the numerous appliances now everywhere available, to say nothing of the extent to which the comfort of the invalid is ministered to by the provision of hot-water bottles, rubber pillows, mattresses, etc. Then in the home we now see steadily increasing use of rubber floor covering, panelling, bathroom sponges and fittings, and so forth, whilst footwear for sports and as protection against damp and the weather for ordinary wear, supplements leather and in many directions displaces it. *** There is another direction, however, namely, the use of hard rubber as vulcanite and soft rubber for insulating purposes in electrical appliances of all descriptions, in respect of which it is impossible to exaggerate our indebtedness to rubber which has made possible so many modern miracles. Our electric lighting systems and the safety of the great power stations of the world are dependent on the use of rubber in some shape or form."[2]

[2] Paper read by Sir Stanley Bois on *Rubber in Economic and Social Progress* before the Royal Society of Arts, London, in November, 1926.

Regarding the use of rubber in the modern means of transport and communication, Sir Stanley Bois says: "Then again, rubber has largely contributed to knitting together the world in general and the British Empire in particular through the medium of telegraphy, telephony and wireless. Opinions differ as to the extent to which these developments would have been possible had rubber been non-existent, but I can think of no material which could well have taken its place, and it needs no amplifying on my part to bring home to us all the social effect of rapid and world-wide communication. *** Rubber is an integral part in the construction of the aeroplane, and the recent long flight made by Sir Alan Cobham from this country to Australia and back is an achievement which opens up great possibilities in the future, and will doubtless have effects upon the economic and social progress of the world which cannot yet be foreseen."[3]

THE CIVILIZING POWER OF TRANSPORT.

Rubber aided by several inventions helped the advent of automobilism in the West during the early years of this century. This sort of locomotion has been of such convenience to overland transport that it is destined to prove a many-sided economic stimulus to large countries possessing a network of roads. Often it is said that transportation is civilization. Speaking with greater precision, this phrase signifies that much human progress has been attained by utilizing different modes of conveyance mostly as a means of seeking more useful purposes. Thus transportation has been regarded as a great builder of civilization, and this is true in the sense in which man's advancement is now understood. Man cannot live and prosper by himself. The more he comes into touch with the outer world, the more are his chances of success. And it is obvious that without transport there could be no production, exchange and consumption of commodities, no personal knowledge among men with its resulting mutual trust

[3] Paper read by Sir Stanley Bois on *Rubber in Economic and Social Progress* before the Royal Society of Arts, London, in November, 1926.

which has evolved the system of credit, no co-operation among them and no social intercourse between communities.

There is much interdependence among men, the invisible links of which exist in the countless lines of transport and communication that have been laid throughout the globe. In short without transport and communion, no exchange of goods, ideas and services—which have advanced the material and social progress of mankind—could have taken place. In the past ages, transport helped the exploration of new lands which brought much enlightenment to the world. Was it not the discovery of Columbus, in search of a route to India, that stimulated thought and action to such a degree as to bring the world out of the darkness of the Middle Ages? Yet writers have sometimes urged that when society was self-contained, man had more happiness and contentment. If such were the case, his placid mentality was due rather to a slender struggle for existence than to his insularity and unenlightenment. With the growth of population, however, man finds himself immersed in an age of rivalry where he sees no fighting chance without the aid of extensive economic movements. The channels of all such activity must be an endless network of transport, news and intelligence services.

Until the end of the 19th century, the horizon of the peasantry in almost every country was very limited. Their personal knowledge of the outer world was mostly confined to what they observed within a few miles' journey on horseback from their village homes. To-day these villages are linked to towns and markets by regular automobile services which have altered the outlook on life and added to the material conveniences of even primitive peoples. In short our notions of time and space have been revolutionized, to say nothing of the intellectual movements of the day which have been quickened by improved means of transport and communication.

Further it appears that the human race must gradually spread itself out more evenly over the face of the earth and thus attenuate the competition of thickly-populated regions. Although the time has not yet come for emigration from large countries, the shifting of people from congested to uncongested districts is expedient in many countries. In fact almost everywhere men must seek fresh fields for wealth production, and as more lands are brought under the sway of economic activity, the need arises for increased transport and communication. Then since time is a valuable consideration in business, the movement of men and goods must be rapid, especially when commerce is conducted between far-distant places. Space in relation to time has to be reduced to the safe limit and great distances encompassed as fast as feasible.

Rubber Prospects and Automobilism.

Nevertheless it is true that in the past every new form of transport has met with popular opposition which was based on the insecurity connected with rapid locomotion. When the stage coach was introduced in Europe about 1670, it was regarded as a break-neck vehicle. Again, when the locomotive was brought into use in England about 1825, the people were apprehensive and anxious to limit its speed to 8 or 9 miles an hour. Similarly, when the automobile was introduced early in this century, restrictions were put on its use in towns and its speed was limited everywhere. Such were the misgivings of men with regard to several useful innovations—a feeling which it is quite easy to understand.

There is an element of risk in every form of transport—whether by sea, over land or through the air—which usually increases with its speed or some other attending circumstance. Yet the present-day wants of civilization demand that speedy transport for men and goods by the three foregoing methods should be developed. Endeavours must in consequence persist with the ultimate aim of making aviation as safe and cheap as automobilism. Each mode of transport —navigation, aviation and locomotion—will find its own particular sphere of utility in economic advancement and there is no fear of any of them falling into disuse by rivalry with one another. In spite of all that sceptics might think about commercial aviation, it is making steady headway in the West. There are already 36,000 miles of air routes in Europe, of which Germany operates 14,800, France 8,300 and the United Kingdom 1,090 miles.‡

Commercial aviation will doubtless be gradually introduced in the East and the present British scheme of working a 10,000 miles Empire Air Route between England and Australia should lead the way to it. But of all methods of transport, automobilism is destined to see the greatest development in the near future owing to its comparative cheapness. For instance, the extension and improvement of roads need a smaller capital outlay than what is required for the construction of railways. Moreover, no state or syndicate would care to undertake the risk of railroad enterprise so long as automobiles serve the immediate requirements of a locality. These circumstances along with others, that have been already enumerated, point to the certainty of an ever-increasing demand for rubber.

‡ In course of time aviation should be able to advance the study of meteorology and help in local weather control. Already scientists in the United States are reported to have succeeded in breaking up small rain-clouds by scattering on them electrified sand from aeroplanes. If aerial navigation ultimately leads to the partial control of weather conditions, man's claim to the conquest of the air will be vastly strengthened.

CHAPTER II.

THE GENESIS OF RUBBER CULTURE.

THE COLLECTION OF WILD RUBBER.

Between 1770 and 1845 the chief causes retarding the use of rubber seem to have been the crude methods employed in its manufacture, the uncertainty of its supply and the consequent high price of rubber goods. With improvements, however, in its system of manufacture, the preparation of rubber goods doubtless increased and along with this development, the supply of the raw material gradually augmented. About 1870 the advent of the bicycle appears to have created a further decided demand for rubber. Thus, although the collection of wild rubber must have been fitful and inadequate until that period, it appears that a continuous trade in the extraction of this product was established thereafter. And it was about this time that the idea of regular rubber cultivation dawned on the minds of far-seeing men like Sir Clements Markham and Sir Joseph Hooker which led to the India Office sending Mr. H. A. Wickham for seeds of the Para rubber tree to Brazil, as will appear presently.

Dr. W. R. Dunstan, some time President of the International Association of Tropical Agriculture, writes: "At first there were but three types of wild rubber found in the world's markets: India rubber, the product of the *Ficus elastica* from Assam, Burma and Java; gum elastic, the product of the *Hevea brasiliensis* from South America; and 'virgin gum' from the *Castilloa elastica* of Central America. ***In 1921 all grades from whatever source were termed India rubber."[1] *Funtumia elastica* is a well-known species

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[1] *Encyclopaedia Britannica*, 13th Edn., New York, 1925, Article on Rubber.

of the rubber tree indigenous in East and West Africa. For many years it was the chief source of wild rubber in the dark continent. *Ficus elastica* is a large spreading, slow-growing tree with aerial roots developing downwards from the branches. Ceara is a very hardy, quick-growing tree of the region bearing that name in Brazil and has been known to thrive in various parts of tropical Asia and Africa.

"*Hevea* is indigenous," describes Mr. W. P. Rutter, "to the regions of the R. Amazon and the tributary areas of Peru, Bolivia, Ecuador, Colombia and Venezuela. ****Hevea* is a large tree, of slow growth and long life. *** *Castilloa elastica* or *Ule* rubber tree produces heavy yields of inferior rubber and while found in Peru and elsewhere, south of the Equator, its principal range is in Central America and South Mexico. ****Manihot Glaziovii* grows in the tropical region south of the Amazon and furnishes Ceara. ** Its habitat is a high, stony and arid country. ***Tropical West Africa comes next to Brazil in the world's output of wild rubber, the valleys of the Niger and Congo rivers being the chief producing areas. *** Wild rubber in South America and Africa suffers from difficulties of labour and wasteful exploitation, whereas in the Far East, the natives are an admirable source of labour."[2] Here it may be added that Assam and the tropical East also produced a small quantity of wild rubber until about 1921.

The extraction of wild rubber from the aforesaid regions in South America and West Africa was a very perilous, wasteful and precarious enterprise for many years. The extractors had to cut their way through the forests with axe and spade, in fear of wild animals, contracting malaria and other fevers. They had to hurriedly tap isolated trees, by primitive and wasteful methods, and return with their collections over water or through the jungles which were often impassable. There being scarcely any means of transport, almost

[2] *Geography of Commerce* by Rutter, London, 1925, pp. 126 and 127.

every time a collection was made, an expedition had to be organized, which was a very expensive business. Finally the collections were largely adulterated and dissimilar in quality. An industry of this sort could never provide for the growing needs of rubber when the automobile arrived, especially in competition with the plantation product, and had to go under before it. The rubber market of the world has consequently shifted from Para to Singapore some years ago. In 1900 the output of the Middle East plantations was only 4 tons while the world's forests produced about 54,000 tons. In 1913 the output of the two sources was about equal. But in 1922 the outturn of the plantations was about 340,000 tons while that of wild rubber declined to 23,000 tons.

Early Steps in the Industry.

Government records in this country relate that as early as 1876, at the suggestion and expense of the India Office in London, an English forester, H. A. Wickham, brought seeds of the Hevea tree from Brazil to England where they were cultured successfully in the Kew Botanical Gardens near London and thence distributed to India and Ceylon. The Indian seeds were sent to Burma and the Ceylon seeds to British Malaya and probably thence to the Dutch East Indies. The actual birth of regular rubber planting dates from the seventies of the last century and originated by the efforts of Sir Joseph Hooker, at that time Director of the Royal Kew Gardens, of Sir Clements Markham, then a high official of the India Office, as well as of Collins, Cross and Wickham, the seed collectors.

Sir Clements Markham has recorded how, after visiting the forests in South America, he decided to obtain seeds for the regular cultivation of rubber in the East. The story of the first steps towards the inception of this industry had better be described in his own words. "My first step" he relates, "was to enquire into the best species for such introduction. With this object in view I entrusted the duty of making the necessary researches and investigations to Mr. J. Collins, then Curator of the Museum of the Pharmaceutical Society. He drew up an able and exhaustive report and submitted it to me in 1872. ***In Mr. Robert Cross I found the man with all the requisite qualifications. He left England in May, 1875, after I had succeeded with some difficulty in persuading the India Office to employ him on that difficult service. He collected 600 *Castilloa* plants, and also drew a quantity of the milk in order to bring home samples of the rubber. It was reported to be of excellent quality. In 1876 the *Castilloa* plants were sent to India."***

"In June, 1876, Mr. Cross again left England to collect the Para kind (*Hevea Brasiliensis*) on the banks of the Amazon. He succeeded in making a collection of 1,000 plants, established in four cases, and despatched them to England, where they were established at Kew. He then proceeded to the Ceara Province where there is a dry climate. The rubber plant of Ceara is *Manihot Glaziovi*. Mr. Cross obtained 42 plants and 700 seeds. Thus all the valuable caoutchouc trees of South America were obtained for cultivation in India. I considered it most safe to send them in the first instance to the Ceylon gardens at Peradeniya, whence their cultivation would be extended to India, where its importance was better appreciated by the authorities. The Ceara plants arrived in Ceylon in October 1876 and grew admirably at Peradeniya and Henratgode. The Hevea plants arrived in November and also throve well, very soon 500 plants being sent to Madras and Burma. The *Castilloa* plants grew best at Henratgode."[3]

WICKHAM'S INESTIMABLE SERVICE.

Mr. H. A. (now Sir Henry) Wickham was enterprising enough to make several excursions to the valleys of the Amazon and Orinoco between 1866 and 1876.

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[3] Bulletin of the Rubber Growers' Association, London, November, 1927.

Of the first half of this period, an account was published from his notes in 1872. This valuable work gave a description of the tapping of *Seringa* (*i.e.*, *Hevea*) as known to the *Seringaros* (rubber collectors) of the Alto-Amazonas. It also included an exact illustration by Wickham of the leaf, fruit and seed of the tree. With the help of this volume, Sir Joseph Hooker was able to describe the *Seringa* tree botanically and he is reported to have given it the name of *Hevea Brasiliensis.* Records show that while still on the Alto-Amazon, Wickham received a letter from Sir Joseph Hooker, enclosing a commission from Lord Salisbury (then Secretary of State for India), warranting him to collect seeds of this special tree and to convey them to the Kew Gardens. Wickham was not restricted in any way as to the ways and means he should adopt in this errand.

Wickham's own narrative, which is now published, is a romantic record of initiative, resource and organizing faculty finally crowned with success by the hand of Fortune. "I carried on my work in Brazil," he relates, "and was beginning to despair when the European settlers were startled by the news that a fully equipped ocean liner had arrived in the river to inaugurate a new line between Liverpool and the Amazon. It occurred to me that with the arrival of this ship the thing was done, but later after she had proceeded to the upper reaches of the river, we heard that the vessel had been abandoned and left on the captain's hands after having been stripped by the skeleton crew. She had not a stick of cargo to take back to Liverpool. This was my chance. I had no cash. The seed was beginning to ripen in the trees. in the high forests. I knew the skipper must be in a fix, so I wrote to him boldly chartering the ship on behalf of the Government of India."

"Then getting an Indian canoe, I went up the broad river—rather ticklish work in so small a craft—and struck for the deep woods, where I knew were to be found the full-grown rubber trees. Working with

PLATE 2.
(To face p. 17).

A wild Hevea in the forests of the Upper Amazon being tapped by a *seringuero* with the *machadinho*.
(Photo lent by David Bridge & Co., Ld., Castleton.)

as many Indians as I could get together at short notice, I ranged the forests and we packed such heavy loads of seeds as we could march under. I got the village maidens to make openwork baskets or crates of split cane for carrying the seed." In order to get a clearance from the port of Para, Wickham and the skipper had to explain to a local officer that 'they were bringing home delicate botanical plants for His Majesty's gardens at Kew.' 'Wickham thus collected and delivered at Kew on 16th June, 1876 about 70,000 *Hevea* seeds the expenses for which were paid for by the Government of India.

" Sir Henry Wickham," comments Sir Leybourne Davidson, a pioneer of this industry, " never met either Collins or Cross, the Kew botanists, but believes that such plants and seeds as were collected by them of the Para (*Hevea*) were all obtained on the lower reaches of the Amazon, the Ceara from the Province of Ceara and the *Castilloa* from the Varigua Province of Panama. The Hevea seeds collected by himself personally with his Indians came from the wide plateaux dividing the Tapajos from the Madeira rivers, and were of the variety known as 'Casca preta' producing the 'up-river fine hard para.' ***Some of these, together with seeds collected by Messrs. Collins and Cross, were sent to Calcutta (against Wickham's advice). ***The bulk of the rubber seeds were sent to Peradeniya and Henratgode in Ceylon whence, later in the year 1876 and in 1877, seedlings in Wardian cases were distributed to Singapore and elsewhere."[4]

THE WORK OF PIONEERS.

Though seeds, seedlings and cuttings of the Hevea were distributed throughout the tropical East about the latter half of the seventies, it would appear that for nearly two decades only a straggling band of self-sacrificing men experimented with Para on small plots of land and its regular cultivation did not begin until about the closing years of the last century. Recalling that memorable period, the veteran planter, Sir Leybourne Davidson, writes: "I look back upon the time from 1880 to 1900, when the pioneers ploughed their lonely furrow and they were looked upon as 'rather a peculiar people' and I am delighted to think that we persevered in season and out of season, in pushing the industry."

Mr. Thomas North Christie, another pioneer planter, relates: "In 1880 there were several attempts made in Ceylon to cultivate India rubber in the Trincomallee district. Lands there were taken up by A. T. Karslake, A. H. Macartney, T. N. Christie and a few others, but it was the Ceara variety that was planted, and its unsuitability was soon proved and the lands were abandoned; then there was a long pause before the success of the Hevea was sufficiently pronounced to encourage the plantings that ultimately became so numerous and successful." A depression in Ceylon tea prices about 1900 finally served as the direct stimulus to the spread of rubber planting in this island, notably in Kalutara, Kelani valley and Dumbura valley.

Mr. Christie has recorded that the first rubber trees planted in Malaya was on a patch near the riverside at Kawala Kangsa and these were sown at a very early date by Mr., afterwards Sir Hugh, Low. Sir Leybourne thinks that this must have been about 1883. Mr. Christie moreover informs us that the first rubber company started in Malaya was the Selangor Rubber Company, registered in 1899 when it had only 200 acres of coffee and rubber. It commenced tapping in 1902 and paid its first dividend of 20 per cent. in 1905.

Thus after endless toil and contrivance, the rubber culture of the Middle East was established, and it is due originally to the initiative of the India Office, to the shipment of Wickham and subsequently for the most part to British enterprise. This fact is candidly admitted by an American writer although his countrymen complain bitterly of the British control of and supremacy in this product. "Thus from a few seeds collected in the Amazon Valley," remarks Professor Russel Smith, "have grown the vast rubber plantations in the Eastern tropics, with over 300 million trees and supplying over 95 per cent. of the world's needs from 3 million acres of land (1925)."[5]

RUBBER IN THE TWENTIETH CENTURY.

Rubber has passed to a large extent from the stage of a wild tree growing in the forest to that of a cultivated plant the yield of which is easily accessible to man. This adaptation has been wrought with the aid of scientific agriculture and some of the best species of its family can now be grown in almost every country within the equatorial rain belt which encircles the earth. But the scarcity of labour, virulence of disease and difficulty of transport will confine the culture to particular spots. The inducement to rubber cultivation is great because its processes are comparatively simple and the tree is less liable to damage and destruction from natural causes than tea, cotton, coffee and some other plants. And it has this advantage over many others that, though the initial outlay on it is considerable, its expenses drop very substantially when the plantation comes to maturity after a few years. Moreover, rubber has the prospects of a product, the consumption of which is augmenting at a very high rate while its production can grow only at a moderate pace. For these reasons it is the most promising of agricultural products at the present day. In countries, where the State is offering lands in perpetuity for rubber planting, this culture leads to the added benefit of conferring on the planter the rights of virtual land-ownership.

Sir Leybourne Davidson roughly estimates that "to-day the planted area of rubber in the world is 4,500,000 acres, worth about £450,000,000. ***In 1926 the world's production of rubber was 614,000 tons to which Ceylon and the Straits alone contributed

[5] *Industrial and Commercial Geography* by Smith, New York, 1925, p. 575.

353,000 tons. The world's consumption was 548,000 tons, of which America took 368,000 tons which at 2*s.* per lb. was worth £82,000,000. ***No industry has had a more romantic history than rubber, no industry has helped the British Empire more than the rubber industry has done during the last few years, especially in the matter of assisting Britain to liquidate her enormous debts to the American Government."[6]

[6] *Bulletin* last referred to.

CHAPTER III.

PARA RUBBER CULTIVATION.

HEVEA BRASILIENSIS.

There are endless species of the rubber plant, but the best so far discovered is the Hevea Brasiliensis and the product from it is known as Para which fetches the highest price in the world's rubber markets. "Hevea brasiliensis," writes Mr. Harold Brown, "is a large forest tree which occurs wild throughout the entire valley of the Amazon and its tributaries to the south of the main stream. It has been found to grow well in suitable situations throughout the tropics and is now being cultivated extensively in Ceylon, the Malay Peninsula, India, Sumatra, Java and other countries."[1] Hevea was first successfully acclimatized in Ceylon, where the most scientific methods were applied to it, the result being that the product of Ceylon fetches a higher price than that of wild Para. Thus the home of Hevea has shifted to a large extent from its original habitat in the immense valley of the Amazon and its tributaries to various places in the tropical East for certain reasons among which the paucity of its inhabitants seems to be the foremost. This valley contains about the largest forest in the world running over an area of something like 1 million square miles but its population is only about 1 to the square mile.

SOIL AND SITE SELECTION.

Hevea Brasiliensis thrives best on a moist, low-lying land of rich alluvial soil in a hot climate protected from high winds. But being a hardy plant, it grows

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[1] *Rubber, its Sources, Cultivation and Preparation* by Brown, London, 1914, p. 31.

well in any tropical country with a minimum temperature of about 75° and a rainfall varying from 75 to 150 inches in the year. In selecting a site for Hevea cultivation, the nature of the land should be of primary concern. If covered with dense vegetation, it is a sign of soil fertility which promises well for rubber culture. The clearing of a thick forest is, however, an expense which does not always repay itself from the available timber. Then its location with regard to the means of transport has to be considered. "Hevea brasiliensis as a rule," describes Dr. W. R. Dunstan, "flourishes to the greatest extent at low altitudes on rich soil capable of retaining moisture. The nature of the soil appears, however, to be of secondary importance, provided that it is able to hold moisture and that climatic conditions of high and even temperature with considerable rainfall and absence of wind are satisfied. Although the tree is sensitive to such conditions, it appears to possess a certain capacity of adaptation which should be borne in mind. Generally a low altitude is desirable, but good results have been obtained in Ceylon in sheltered positions at elevations of 3,000 feet and over, although at higher altitudes the growth of these trees appears to be slower."[2]

Speaking in greater detail on site selection for rubber, Dr. R. H. Lock observes as follows: "In short it may be asserted that Hevea can be grown to a profit on almost any soil in the latitude of Ceylon up to an elevation of 2,000 feet provided the rainfall exceeds 75 inches a year and provided a situation is chosen which is not exposed to strong winds, especially at the dry season of the year. On the other hand, the richer the soil and the lower the altitude, the better, provided that on swampy lands good drainage be provided. The best test of a soil—much better than the test of chemical analysis—is the character of the vegetation growing upon it. If the growth of forest over a given area is luxuriant, other conditions being favourable, then a

[2] *Encyclopaedia Britannica*, 11th Edit., New York, 1911, Vol. XXIII, Article on Rubber.

good growth of rubber is assured when the forest is cleared. And if it is intended to plant rubber where other agricultural products are already established, the fact of a good return from crops of any other kind may be taken as an earnest of good crops of rubber to come."[3]

Forest Lands Mostly Utilized.

The selection of a proper site is of fundamental value to a rubber estate. It is true that in Ceylon rubber trees have been planted through existing tea gardens, in Java among other products, and in Sumatra on old tobacco land, either for want of suitable virgin soil or other reasons. Similarly grass lands or sites on which rice and sugarcane were once sown, have been used for rubber in these islands. This shows incidentally that the nature of the soil—not of the site—is of secondary importance. Usually in such cases, however, the growth of the rubber is slower and its outturn poorer than on virgin soil or on land used exclusively for this product, unless the defect has been removed by some such means as manuring, etc. At any rate to avoid the handicap of a poor soil, by far the bulk of the rubber estates in the Malay Peninsula and in other countries have been planted on virgin lands obtained by the clearance of jungles. Moreover, the timber, firewood and other products from a forest are a source of income provided that, after retaining the portion required for buildings on the estate, the rest could be sold in the district.

Proximity to Labour and Transport.

A river, sea-port, railway station, canal or trunk road would help the transport and disposal of the surplus timber. In any case, the site for the estate would have to be selected near some such means of communication, otherwise nothing could be done there. In opening an estate, the availability of labour is another matter of vital concern. Of all places in the tropical Middle East, South India possesses the most plentiful

[3] *Rubber and Rubber Planting* by Lock, Cambridge Univ. Press, 1913, pp. 95-96.

supply and Tamil labour seems prepared to go anywhere at least in the Eastern tropics. It should be remembered though that the labour required to extirpate a jungle is immense, and it would perhaps be the wisest plan to do the work by contract. In fact the largest amount of labour is necessary when clearing a forest and opening out an estate during the first two years. Tapping also needs a fairly large staff of permanent employees after the fourth or fifth year, but their number would be much less than those employed in the initial operations. In the interval, however, between the opening of the estate and the tapping of the trees, the main work in the garden would be weeding, and so a small staff would suffice for this brief period of about 2 or 3 years.

LAND CLEARING, ROADS, DRAINAGE, ETC.

In clearing the site, all trees should be felled as closely as possible to the ground and their stumps uprooted, because rotting timber breeds fungi which is a serious menace to rubber trees especially when young. When mechanical root-extractors cannot be used, the stumps may be blown up with dynamite. Such procedure is essential as buried and rotting stumps cause *Fomes lignosus* (formerly known as *Fomes semitostus*) a dangerous fungus pest which attacks the roots of Hevea with fatal results. If the debris cannot be removed, they should be burnt down and the ashes spread over the soil as a fertilizer. Separate blocks and divisions in the estate of about 20 and 100 acres respectively, bounded by roads, drains or canals if necessary, should then be laid out and marked off. The numbering is necessary to organize the working of, and control the labour in, the entire plantation. Reference plans thereof should be kept by each member of the higher staff. Nursery beds should then be prepared, as nursery plants usually a year old are required to sow up a rubber estate.

"The first step in the formation of a rubber plantation," says Mr. Harold Brown, "is to clear the land by cutting down the existing trees, and then if the

PLATE 3.
(To face p. 24).

Hevea interplanted with Cacao in a plantation at Urucurituba, in the State of Amazonas, Brazil.
(By courtesy of the U. S. A. Department of Agriculture.)

timber cannot be disposed of, it is burnt when dry. It is desirable, if possible to remove the stumps of the trees from the soil, as, if these are allowed to remain, they decay and serve to harbour white ants and fungoid diseases which may subsequently attack the rubber trees. ** A number of mechanical appliances for facilitating the removal of stumps are now available. After the land has been cleared, suitable roads are made through the estate and any necessary drainage is done. The land is then divided into blocks and 'holed' for the reception of the rubber plants. ** Considerable discussion has taken place regarding the distances at which Hevea trees should be planted. *** In Ceylon distances of 15 ft. by 20 ft. (about 150 trees to the acre) or 20 ft. by 20 ft. (about 110 trees to the acre) are now generally adopted, whilst in Malaya the usual arrangement is 20 ft. by 20 ft. or 24 ft. by 12 ft. (about 110 and 150 trees to the acre respectively). ** Experiments conducted in Malaya and in Ceylon have shown that widely planted trees increase in girth much more rapidly than closely planted trees and that consequently the former will more quickly attain the necessary size for tapping."[4] The roots of this discussion will be presently disclosed.

SEED CULTURE.

Proper seed culture is of vital concern to the planter, as upon it will largely depend the constitution of his plants. At the outset the very best seeds from a thoroughly reliable source—such as the scientific department of a rubber growers' association, a government seed farm or direct from the flourishing trees of a good rubber estate—ought to be obtained. It is of the utmost consequence that seeds must be selected from the most vigorous and best yielding trees at least 10 years old in preference to such trees of younger growth. It is only after this age that the constitution of a rubber tree has been put to the searching test of time. But prior to obtaining seeds from such trees, seed beds should be prepared in the estate, because Hevea seeds soon lose their vitality and must be planted as early as possible

[4] *Rubber, Etc.* by Brown, pp. 109-110.

after the mother tree has shed them. When ripe the fruits of the rubber tree burst spontaneously and scatter the seeds around it. Described botanically, the seeds are about an inch long, flattened at one end and round at the other; in colour they are shiny brown, mottled with blotches of darker hue.

SOWING IN NURSERIES.

The richest soil in the estate, which is thoroughly drained, partly shaded and well-sheltered from the wind, is usually reserved for the seed and nursery beds. The soil should be well dug up and loosened to the depth of about a foot and laid out in beds of any convenient size, say, 8 ft. by 24 ft. A drain about a foot wide should be cut around each bed, so as to prevent water-logging in the nurseries. The beds may be manured with leaf-mould. Seeds should be planted at distances of about 8 in. apart from one another, deep enough to conceal them and then they should be just covered over with the fine soil. Many more seedlings should be raised than would be finally required, so as to allow for rejections. The seeds may be expected to germinate in 8 or 10 days, when they are often transplanted in the nursery beds about 2 ft. apart from one another. The nurseries should be fenced around so as to exclude animals which are fond of seedlings. The beds must also be shaded, especially from the scorching midday sun, by a light framework covered over with matting, and watered copiously on dry days. When the seedlings rise to a height of over a foot, the shade should be gradually removed so as to harden them.

After a few months, when the plants attain a height of 3 to 6 feet, they are most cautiously dug out from the nurseries with earth completely around the roots and immediately covered with leaves. The roots along with their leaf wrappings are then tied up into balls, very special care being taken not to damage or disturb the roots in any way. The plants are finally replanted in their permanent holes in the fields. The pits must be large enough to take in the roots easily, and, if the plants are over 6 months old, they may have to be 2 ft. to 3 ft. in depth and diameter. A layer of rich soil or manure might be put in the holes. After planting, the earth around the young plants should be loose so as to admit of air. The best season for sowing is the monsoon, but planting may be undertaken at any other time if the sowings can be watered when required.

VARIATIONS IN PRACTICE.

The procedure for seed-culture varies in different countries and seems largely a matter of local convenience or individual experience. But this is not the only part of rubber cultivation that is undergoing a change through experiments. The seed-bed is not regarded as essential by many planters to-day, and even the nursery-bed is sometimes dispensed with, though perhaps with some risk. To take a few instances. Seeds are occasionally germinated in baskets, and not infrequently sown direct in the nursery-beds—avoiding altogether the use of the seed-beds. Still another present-day plan is 'sowing to stake' in which the seeds are planted straight away in their permanent positions in the plantation. Plants thus widely diffused in an open field cannot be properly cared for and so this short-cut method does not seem wise. The only justification for it is that the roots of the young plants cannot possibly be damaged as might happen when they are replanted from the nursery-beds to their permanent positions.

Germinating in baskets or 'sowing to stake' means planting the seeds direct in nursery-beds or in permanent positions, without recourse to the selective process which is possible only in the prior stage. In these circumstances, it would seem imprudent to cut short or dispense with the use of beds and thus expose the plants to risks in the open field and still be deprived of the benefit of selected trees merely to save the labour of transplanting and avoid the possibility of the roots being disturbed.

Care should be taken to protect the nurseries against fungi and insect pests by digging them over with lime—and a little sulphate of copper if possible—and allowing them to lie fallow for some months before sowing on them a second time. This procedure should be adopted prior to every sowing in the nurseries.

"Hevea Brasiliensis," explains Mr. Harold Brown, "is usually propagated from seed, of which the trees produce large quantities after the fourth or fifth year. Seed intended for planting purposes should be preferably selected from vigorous trees 8 to 10 years old giving a large yield of rubber. *** When the plants are to be raised in nurseries, well-prepared beds of rich soil should be formed in a suitable position and arrangements made for providing the young plants with shade. This is usually accomplished by means of a light framework about 8 ft. high upon which a covering of leaves or matting can be spread. The seeds are sometimes germinated in a seed-bed and then transferred to the nursery-bed, or they are at once planted in the nursery-bed 6 to 9 in. apart and 1 in. below the surface. ***The subsequent procedure varies considerably. The seedlings are sometimes allowed to attain a height of about 2 ft. and are then carefully lifted from the beds and at once planted in the prepared holes. *** In other cases the plants are allowed to remain in the nurseries for some months until they are 5 to 6 ft. high. The upper portion of the stem is then cut off, the plants are lifted from the beds, the roots trimmed and the stumps thus obtained are carried in bundles to the plantation and placed in the holes."[5]

The Need of a Seed Farm.

"It is of the utmost importance," remarks Dr. R. H. Lock, "that seed for future planting should be taken from the best yielding trees. ***A few acres should be set apart definitely for seed bearing, as is done for example in the case of tea. All the trees in this area should be tapped in the same way for a definite period —say for 50 tappings—and a record should be kept of the yield of each individual tree. All except the best yielding trees should then be ruthlessly cut down and the stumps extracted in order to avoid the danger of root disease."[6]

[5] *Rubber, Etc.* by Brown, pp. 110-111.
[6] *Rubber, Etc.* by Lock, pp. 101-102.

PLANTING DISTANCE.

There is much controversy over this subject owing to the uncertainty of profit per acre which is based upon the productivity of trees under different methods of cultivation. Closely planted trees would be greater in number per acre than widely planted ones. For instance, 15 ft. by 15 ft. would give 193 trees, 16 ft. by 16 ft. would give 170 trees, 18 ft. by 18 ft. would give 134 trees and 20 ft. by 20 ft. would give 109 trees. But closely planted trees would be tall and widely planted trees short generally. Short and sturdy rubber trees are, however, preferable to tall and spindly ones owing chiefly to their wider girth or tapping surface, partly to their superiority in vigour and invariably to their greater latex-yielding capacity. If all trees in the estate had the same yielding power, a closely planted acre would return more profit than a widely planted one, despite the greater labour of tapping.

But there are other conditions which make the problem of planting-distance very complicated and almost impossible of a clear solution. In a closely planted acre, the expense of weeding is less than in a widely planted one. At the same time weeding is a limited process when catch-crops are sown. The question of profit per acre therefore becomes more complex the more diverse the planting conditions. Hence until the profit, under each set of conditions, has been more definitely ascertained, there will be much discussion on this subject. The planter has consequently to decide for himself the planting-distance, considering the objects he has in view and the mode of cultivation he will adopt. In any case, the trees should not be crowded, as their girth diameter ought to be encouraged.

GROWTH OF THE PLANT.

In suitable conditions of soil and climate, the Para tree if widely planted should grow about 8 ft. in height and 4 in. in girth annually during the first few years. In its original home in the valley of the Amazon, a mature tree usually attains a height of 60 ft.

and a trunk circumference of 6 ft. approximately, while in the tropical Middle East many Para trees reach these dimensions. "Under favourable conditions of climate and soil," remarks Mr. H. Brown, "Hevea Brasiliensis is a very quick-growing tree. In Malaya, where the conditions are exceptionally suitable, the rate of growth is more rapid than in any other country, and cases have been known there of trees attaining a height of 20 ft. and a girth of 8 in. in one year after being planted out. *** After the trees have become established, the only work required on the plantation for the first three or four years, unless catch-crops are to be grown, is to keep the weeds under control and to prevent them from interfering with the growth of the trees."[7] An American writer affirms that the Ceara tree attains a height of 10 ft. the first year, 30 ft. the second, and is ready to be tapped in 4 years, growing on dry, rocky soil useless even for food crops.

Disease-Resisting Belts.

Every estate may with prudence be divided into convenient sections by rows of trees to resist epidemics of disease that might break out, also to serve as wind and shade screens for the benefit of young plants. Mycologists believe that epidemics which attack Hevea do not affect other species of rubber. Owing to this and other reasons, the disease-resisting belts may consist of Ceara and *Ficus elastica* trees.

Weeding and Soil Protection.

Weeding is essential in every rubber estate to prevent the growth of small, useless vegetation which covers the soil, abstracts a part of its vitalizing properties, prevents the access of air to it and harbours rats and insects. This work is necessary not only to remove the obnoxious growths but to break up and overturn the soil so as to admit of air to it. Deep stirring of the earth, however, is not required in the dry season, as it may cause too great an evaporation of the inherent moisture. Even where catch-crops are sown, weeding

[7] *Rubber, Etc.* by Brown, p. 116.

must be religiously carried out. Clean weeding and wide planting help the rapid girth development of Hevea.

Undergrowth may, however, prove beneficial only when rubber is planted on sloping ground and the cover is able to prevent soil denudation, but in no other circumstance is it of any avail. Although on the face of it, it may appear unwise to leave the land between the young trees at one time exposed to the rays of the tropical sun and at another to the wash of the heavy monsoon, experience shows that if the weeds are to be prevented from choking up the young Hevea, the only practical course is to keep out the weeds altogether, because along with them some very obnoxious growths crop up occasionally, such as *Lallang,* a very coarse grass which grows to a great height and is extremely difficult to eradicate. "The experience of planters in general," explains Dr. W. R. Dunstan, "is in favour of the complete removal of weeds from a rubber plantation. This practice, which involves periodical weeding, adds considerably to the cost of maintaining plantations, and though justified so far by results, possesses several other disadvantages."[8]

"During the tropical rains," he continues, "the soil is liable to a greater or less extent to denudation which becomes very serious when the land slopes; and in any case, the soil is apt to become impoverished by the loss of its soluble constituents. These disadvantages are at their maximum when the rubber trees are quite young. At a later stage, the shade of the large trees compensates to a considerable extent for the absence of cover on the ground. Another disadvantage of uncovered soil in a plantation of young rubber trees is that the ground under the heat of a tropical sun rapidly loses its moisture. For this reason, proposals have been made to plant in the place of weeds low-growing leguminous plants, the growth of which will not only prevent impoverishment and loss of soil during the

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[8] *Encyclopaedia Britannica,* 11th Edit. Article on Rubber.

rains and conserve moisture in the heat, but will also have the effect of enriching the soil in nitrogenous constituents through the power leguminous plants possess of absorbing nitrogen from the air through nodules on their roots. Among the plants which are being tried for this purpose are various species of Crotolaria passion-flower and the well known sensitive plant of the East."[9]

CATCH-CROPS AND MIXED PLANTATIONS.

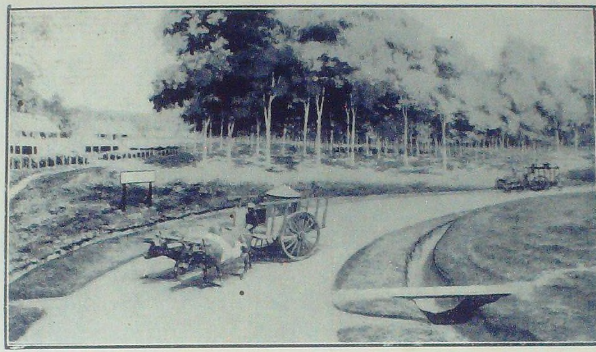
There is, of course, little scope for weeding when catch-crops are sown and some rubber estates grow such crops in their early years. In a paper read before the International Rubber Conference held in London in 1908, Mr. Kelway Bamber, Curator, Peradinya Botanic Gardens, Ceylon, said: "In some parts of the Federated Malay States and Java, the practice of growing catch-crops in rubber has been adopted, often with marked success both as regards reducing the cost of bringing the rubber into bearing and for the growth of the rubber itself. Cassaya has been most largely planted. **As a rule tapioca was manufactured. **Other catch-crops are coffee, especially C. robusta in Java, sugarcane, ground-nuts, indigo and citronella grass." Mr. A. M. G. Forbes, General Manager, Tenasserim Hevea Plantations, Ld. has grown tea, coffee, sugar, cotton and African oil-nut palm on his estate and found the last by far the most successful.

In some tea estates in Ceylon, rubber is being planted on new plots as an adjunct of tea so that, if need were, the new trees would enable the conversion of the declining tea garden into a rubber estate without a cessation of income. The same policy has been adopted in a few tea gardens in South India and Assam. "In many plantations," states Dr. W. R. Dunstan, "besides catch-crops (cassava, sesame, ground-nuts, etc.) other crops, such as tea, coffee, cocoa and tobacco, are grown with rubber. It is improbable, except in the early stages of the rubber tree, that this procedure will

[9] *Encyclopaedia Britannica*, 11th Edit. Article on Rubber.

PLATE 4.

(To face p. 33).



A Rubber Plantation in Malaya, showing young Hevea trees.

(Taken from a Diorama at the Imperial Institute, London).

succeed; the rubber will ultimately dominate the position to the detriment and ultimate extinction of the other crop whilst the growth of the rubber tree will be retarded. A partial exception may perhaps be made in the case of cocoa, when the two plants are placed not too closely in about equal numbers. In these circumstances, it appears that satisfactory results may be obtained from both crops, at any rate for a certain number of years."[10]

PRUNING.

Pruning is essential to cut out the growth of useless parts in the rubber tree, so as to concentrate its vigour to useful portions, especially the lower part of the trunk which is tapped for latex. Branches in this portion should be lopped off so as to leave a clear tapping surface. If the tree shows a tendency to branch too freely in other directions, trimming may be resorted to in those places.

MANURING.

If virgin soil has been selected for the estate, manuring should not be necessary at least for some years. But in other circumstances fertilizers may have to be applied to the soil. The cheapest manure is leaf-mould which may be prepared by burying the uprooted weeds and leaves which fall from the rubber trees and allowing them to decay in pits underground. The application of this manure, which contains potash and nitrogen, would enhance soil fertility when this is required.

TAPPING FOR LATEX.

With good growth, the Para tree may be tapped at the age of 4 or 5 years, that is, when its girth reaches 18 in. to 20 in. in circumference. Tapping is one of the most scientific processes in a rubber estate, its object being to obtain a fair quantity of latex with the least amount of bark removal. It should be carried out with great caution. The inner part of the trunk known as the cambium—which is the layer of vascular tissues between the wood and the bark—must not be cut with the knife or injured in any way, as wounds in the cambium may lead to serious tapping difficulties. Only about one-twentieth inch of the bark (cortex) should be removed at each operation which is usually conducted every other day for about 9 months in the year. Early morning is about the best time for tapping when the heaviest flow of latex seems to occur. At certain seasons the flow is also said to be enough in the evening and all night long, but these are not convenient times for tapping. In fact whenever the temperature is low and the moisture in the air abundant, the latex seems to flow readily. After the preliminary tappings, the flow of latex increases in the Hevea tree, which is known as 'wound response.'

Provided short periods of rest are allowed, tapping may usually be conducted every other day throughout the year. But the tree must not be overtaxed, and, at the first sign of exhaustion by a lessening of the latex, it should be allowed to rest for a time. "Severe tapping," remarks Dr. R. H. Lock, "has a reverse effect in every way. If the trees are tapped to excess, growth is checked and in particular the proper renewal of the bark is interfered with. The latex moreover becomes poor in quality and contains a smaller percentage of caoutchouc. Most serious of all is the effect upon the general health of the plant. The tree may be so weakened that it is unable to withstand the attacks of fungus diseases, which would not have been able to gain a footing if the tree had been preserved in a condition of perfect health. Canker and similar diseases seldom attack the trees unless the latter are either overtapped or very closely planted."[11] The trunk is tapped at the base—between 6 ft. and 1 ft. from the ground—where the maximum of latex is to be found. Above this height, the latex is poorer in quality and quantity.

"Cultivated Para trees," writes Mr. H. Brown, "are considered to be ready for tapping when they have

11 *Rubber, Etc.* by Lock, p. ...

attained a circumference of 18 to 20 in. at 3 ft. from the ground. In Malaya this girth is usually reached in about 4 years and in other countries in from 5 to 7 years, according to the climatic conditions and the nature of the soil. **Tapping is usually restricted to the basal portion of the trunk up to a height of about 6 ft. as it has been conclusively proved that the greatest yield of latex and rubber is obtained from this area. ***Experiments made by Ridley at the Botanic Gardens in Singapore showed that morning tappings furnished a larger yield of rubber than those made in the evening. ***The method of tapping Para trees which is most generally adopted at the present time on the plantations in Ceylon and Malaya is the 'half-herring-bone system,' the incisions being restricted to one quarter of the circumference of the tree at a time and re-opened every day or every second or third day. ***A quarter of the trunk treated in this manner will, therefore, suffice for a year's tapping. During the second year the opposite quarter is tapped and then the two remaining quarters in rotation. In the fifth year the renewed bark on the first section will be tapped and so on."[12]

"One of the most important subjects," writes Dr. W. R. Dunstan, "in connection with rubber plantations is the method to be adopted in tapping the trees for latex. The native methods in vogue in Brazil and Mexico are primitive and often injurious to the tree. At present it cannot be said that finality has been reached on the subject, of the best method, giving a good return of latex with a minimum of damage to the tree. A method at one time largely adopted was to make a series of V-shaped incisions on four sides of the tree to a height of about 6 ft. from the base—that is, within the reach of an ordinary man without the need of ladder or scaffolding; the latex obtained from the upper part of the tree is said to furnish less rubber and of poor quality. The latex is collected in cups placed at the apex of each V."[13] Tapping is conducted at present by 'excision' or removal of the bark rather than by 'incision' or cutting into it as in former days. A very thin shaving is pared away at each operation, so that the cut descends very gradually. To-day the tendency is towards the most conservative system of tapping possible and the methods now in vogue are the basal V, the half spiral and the half herring-bone.

In various parts of the tropics, the methods of tapping for wild rubber were either wasteful of the latex or injurious to the tree, but in the plantations the systems practised have as a rule been more economical. Of the latter, 'the V-method' is the oldest and it was probably borrowed from Brazil. It yields little latex while it needs several cups. It is altogether a very crude and laborious process and so it began to be superseded by 'the herring-bone system' in the early years of this century and has now fallen into disuse almost entirely. By the latter plan, the bark is removed in the shape of a herring-bone. A vertical channel is cut from a height of about 6 ft. down to about 1 ft. from the ground. Lateral ducts are then cut alternately on either side of the central channel from ¾ ft. to 1 ft. apart and at an angle of about 45 degrees. The ducts are connected to the main channel in the middle, at the foot of which a cup is placed for the collection of the latex.

The idea of 'the herring-bone system' was perhaps suggested by 'the V-method,' but it is a great improvement on the rude old plan which often hurt the cambium. 'The half-herring-bone system,' which has already been described in the words of Brown, is probably the most widely adopted process of tapping at the present day. In recent times, 'the spiral system' of tapping has also been introduced. By this plan a series of spiral grooves are cut all round the trunk so that virtually the entire area of it is tapped. This is however regarded by many planters as too

[13] *Encyclopaedia Britannica*, 11th Edit.

drastic an operation. In fact all these systems may still be considered as experimental, and new processes are being suggested occasionally, which will doubtless bring in further improvements.

Latex Coagulation.

After tapping the next process is the coagulation of the latex so as to produce rubber in the form and of the quality required by the manufacturer. "The plan usually adopted," relates Dr. W. R. Dunstan, "is to collect the latex in rectangular tanks or casks. It is then coagulated by the addition of an acid liquid, acetic acid or lime juice being generally employed and the mixture allowed to stand. The coagulated rubber separates as a mass of spongy caoutchouc. If the coagulation has been effected in shallow dishes, the rubber is obtained in a thin cake of similar shape known as a 'biscuit.' The rubber thus formed is washed and dried. The coagulated rubber separated from the watery fluid is cut up into small pieces and passed through the grooved rollers of the washing machine, from which it issues in sheets, long crinkled ribbons or 'crepe' which are then dried in hot air chambers or in a vacuum dryer, by which means the water is dissipated at a lower temperature."[14] The rubber comes out in plain sheets when the rollers are smooth.

From the trees the latex is sent in enamelled vessels to the curing house where it is strained through sieves to free it from its admixtures, such as bits of mud, bark, etc. Next, the clarified latex is allowed to stand in shallow enamelled pans. If left in that state, the latex should coagulate—that is, separate from its other fluids and appear as a spongy mass—in about 24 hours, but to hasten the process, a little lime juice or acetic acid is added to it. "This coagulated mass," describes Braham, "is then pressed with a metal roller; placed upon clean porous shelves to drain, and afterwards placed for some time in the

[14] *Encyclopaedia Britannica*, 11th Edit.

smoke of a wood fire. Finally the rubber, which is now in the shape of 'biscuits,' is placed upon shelves constructed of some light material which admits of the free circulation of air."[15] The air-drying of rubber in a moist climate is a slow process, to hasten which smoke-drying is often resorted to. Smoke saturation is, moreover, supposed to prevent rubber from getting mouldy. This method of curing is, however, expensive owing to the high price of fuel, and so vacuum drying is often resorted to. Other systems of coagulation and raw rubber preparation—somewhat different in method, but not in principle—have been experimented with in recent years and improvements in these processes are being brought about, as will appear presently.

Economic conditions at the present day compel the use of up-to-date machinery in preparing rubber for the manufacturer. The old system of hand preparation, though very thorough when carefully conducted, needs specially trained labour which is very expensive and needs time which cannot be spared when the raw product is in urgent demand. The different processes of preparation—coagulation, drying, smoking, pressing, etc.—must therefore be conducted by modern machinery especially in a big estate and the planter should keep himself informed of the latest patents in these directions. There are several good coagulating machines, vacuum dryers, creping devices, etc., and the planter should instal those most suitable for his purpose.*

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[15] *Rubber Planter's Note-Book* by Braham, London, 1911, p. 48.

*Improved rubber plantation machinery are being manufactured by various makers in the United Kingdom, Germany, the United States and elsewhere. Among them may be mentioned the names of David Bridge & Co., Ltd., Castleton, Manchester; Walker Sons & Co. Ltd., 36, Basinghall Street, London, E. C. 2; and Fr. Schwabenthan & Co., No. 55, Saarbruckerstrasse, Berlin.

CHAPTER IV.

PRODUCTION, TRADE AND RESTRICTION.

LABOUR IN RUBBER CULTURE.

Prof. Russel Smith rightly comes to the conclusion that cheap labour is the basis for the success of rubber cultivation in the Middle East. "Within a comparatively short distance of Singapore," he observes, "are enormous additional labour supplies that can upon demand be furnished by the millions of China, of Java, of India. **This kind of labour supply tropic America does not possess and the feverish talk of Brazil about entering upon the cultivation of rubber seems destined to poor success unless she imports Chinese labourers into her empty Amazon lands."[1] The population of the whole of Brazil is about 20 millions and of the immense forest in the valley of the Amazon and its tributaries about 1 to every square mile merely. This scarcity of inhabitants lies at the root of Para rubber production shifting almost entirely from its original habitat in spite of its proximity to the U.S.A.—the biggest sphere of rubber consumption in the world. But it is not the local labour of Malaya and the Dutch East Indies so much as the labour supply available there that has brought about the success of the Middle East.

Mr. J. B. Carruthers, Director of Agriculture, F.M.S., showed at the International Rubber Conference, held in London in 1908, that in 1907 the total number of coolies employed in the rubber estates of the Malay Peninsula (*i.e.* the Federated Malay States, Straits Settlements

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[1] *Industrial and Commercial Geography* by Smith, p. 584.

and Johore) was 74,911 labourers made up as follows: Tamils from South India 49,647; Chinese 12,848; Javanese 7,538 and Malays 4,838. India was, consequently, some years ago the chief recruiting ground for the labour force working in the Middle East plantations.

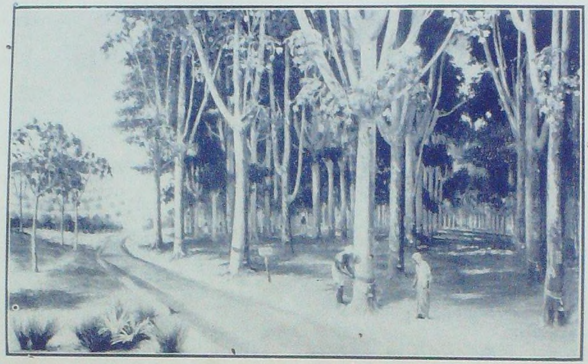
To-day the position of labour in Malaya indicates that extensive cooly recruiting still continues there from China, India and the Dutch East Indies. The undernoted table shows the arrival and departure of labourers into Malayan ports and therefrom during September 1927, according to the *Straits Settlements Government Gazette*:—

	Arrivals from—	Departures to—
CHINA PORTS:		
Chinese	25,940	19,163
INDIAN PORTS:		
Indians	11,132	3,688
D. E. I. PORTS:		
Chinese	5,215	7,240
Malays	5,039	6,656
Indians	362	174
MISCELLANEOUS PORTS:		
Chinese	2,084	1,845
Indians	169	286
TOTAL ARRIVALS	49,579	39,052
TOTAL DEPARTURES	39,052	
EXCESS OF ARRIVALS	10,527	

The extent of Indian labour seems more striking at present in Ceylon. Speaking at the annual meeting of the Planters' Association of Ceylon on 11th March, 1927, the Governor of the island, Sir Hugh Clifford, said: "In this country if we are to depend on local labour, we would never be able to keep estates going even for a few weeks. It is because you can offer inducements to the people of the Madras Presidency and have always been able to do so, that a steady flow of

PLATE 5.

(To face p. 40).



A Rubber Plantation in Malaya, showing mature Hevea trees being tapped by the present system of single circular half-cut.

(Taken from a Diorama at the Imperial Institute, London).

labour into this Colony has been kept up and that the great industry in Ceylon has been what it is."

Cost of Production.

The cost of Para rubber cultivation depends on circumstances which are not the same in every country. In most places land is acquired from the State by reclaiming forest or waste land, and in some places cultivable land is leased on rent or has to be purchased outright. In calculating the cost of production, interest on capital outlayed in land reclamation should not be charged if the produce on the land (timber, fuel, etc.) recoup the expenses of labour for reclaiming. Moreover, the gradual accruing of a land value, along with its final appreciation, should amply compensate for the initial expenses. But where rent or royalty is paid for the land, it should form the *first* item in the cost of production. Capital outlayed in buildings, plant and machinery is not entitled to interest if a depreciation is deducted from these assets before calculating profit. The *second* item would be the salaries of the staff including the wages of coolies, and the *third* the other legitimate expenses of production. Joint-stock concerns add the additional item of a salary for management and even of a managing agency commission in the cost of production and so they cannot show such good profits as private concerns managed by the owners.

Variations in the cost of production chiefly depend on the natural resources of the land (fertility or otherwise of the soil, means of transport, etc.), on the local facilities or difficulties for labour, and on the system of production (whether conducted on a large or small scale, with or without improvements). Naturally the cost of production varies to some degree according to locality and system of working, although the method of Para rubber cultivation is more or less similar in every country. In consequence all estimates of the cost of production are based upon particular sets of conditions which are not exactly the same in every country, much less in every rubber estate. Yet they cannot vary

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On this point Dr. W. R. Dunstan writes as follows: "An average of 150 trees to the acre (20 ft. by 15 ft.) and a yield of 1½ lb. of rubber per annum per tree at 2*s*. 6*d*. per lb. gives the result of £28 2*s* 6*d*. per acre. The cost of production may be assumed to be about 1*s*. per lb. to which has to be added the expense of transport. The cost of clearing forest land and planting with rubber in Ceylon is estimated at about Rs. 100 per acre in the first year and from Rs. 20 to Rs. 30 per acre in subsequent years until the sixth year when the plantation would begin to be productive."[2] From calculations on the cost of production, made in October 1925, by the *Rangoon Gazette* it would appear that the average 'all-in' cost (*i.e.,* including freight and London charges) for Malaya was 10.3*d*. per lb. while in Burma it was only 9*d*. per lb. with a considerable amount of young rubber.

There is a tendency at the present day to reduce the cost of production as low as possible so as to stimulate increased consumption. The *Malayan Tin and Rubber Journal* (31st October, 1927) quotes a rubber planter of Malaya who shows that his cost of production is about 4*d*. per lb. f.o.b. He is a small planter and has evidently managed to reach the rock-bottom limit. Such drastic economy is, however, unsafe and in any case is not called for as yet.

Seats of Plantation Rubber.

The principal countries producing plantation rubber, in the order of their importance, are Malaya (the Federated and Unfederated Malay States and the Straits Settlements), the Netherlands East Indies (Sumatra, Java, Borneo and Celebes), Ceylon, India

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[2] *Encyclopaedia Britannica*, 11th Edit. Art on Rubber.

and Burma, Sarawak, French Indo-China, British North Borneo, Siam, the Phillipines and Liberia. The chief places yielding wild rubber are Brazil, Bolivia, Peru, Mexico, Central America and certain districts in Africa. While statistics of most raw products are deficient or unreliable, especially in the backward countries, the figures relating to the production of crude rubber, as also to its consumption in certain localities are known to be very untrustworthy. The main reasons for this deplorable deficiency and inaccuracy of rubber statistics are the incomplete census of output as well as the fact that raw rubber is collected both in the dry and wet state containing no little impurities. In former years the want of statistics helped much speculation in the trade and wild fluctuation in price, but since 1922 the restriction of rubber exports from British territories has at least improved the statistical data for this product.

At present the equatorial regions of the Middle East form the centre of the world's rubber plantations, as the best species of this product thrive in a damp tropical climate and the industry needs a plentiful supply of cheap labour now found in these localities. The scarcity of low-paid plantation labourers seems to be the only obstacle to the extension of this industry into tropical America, for which strenuous efforts have recently been made by the United States Government. If the labour difficulty is somehow overcome there is almost a certainty of rubber cultivation spreading to the Middle West. Such an occurrence, however, would not threaten the existence of the present plantations, as there are other industrial limitations. Economic history indeed indicates that an agricultural industry does not shift from an established habitat except through over-powering competition after years of inherent decay.

PRODUCTION OF RUBBER.

Statistics relating to the acreage and yield of rubber plantations in all countries of the Middle East are not available, but the world's total production of raw rubber during the last 3 years has been roughly estimated by a noted Malayan Rubber Journal in tons as follows[3]:—

Countries		1924.	1925.	1926.
		tons.	tons.	tons.
Malaya (net plantation)	..	177,000	197,500	276,000
Dutch East Indies	..	154,000	197,000	201,000
Ceylon (N.P.)	..	37,000	46,000	57,000
Other countries	..	26,500	30,239	32,000
Brazil (mostly wild)	..	23,500	27,386	28,000
Other wild rubber	..	6,000	6,735	12,000
TOTAL	..	424,000	504,860	606,000

In addition to the above output, reclaimed rubber amounting to about 114,000 tons in 1925 and roughly 150,000 tons in 1926 were reproduced in the United States. "The growth of the world's production of rubber," relates Sir Stanley Bois, "is indeed amazing. From the 54,000 tons of wild rubber in 1900, it rose to a total of 85,000 tons in 1910, of which 10,000 tons was plantation rubber, and has expanded until the figures for 1925 show a restricted total of 505,000 tons, of which 475,000 tons were derived from the plantations of the Middle East."[4]

Production seems to be growing rather rapidly and the 1926 figures would probably be below the outturn of the current year. Anyway they appear to be the only recent world figures now available. Messrs. Symington and Sinclair, of London, reported recently that the Malay States Information Agency had received a cable from the F. M. S. Government stating that the official estimate of standard production for the current restriction year (November 1926 to October 1927) is put at 333,840 tons. "This," they explain, "is slightly higher than had been anticipated, the generally accepted estimate up to now having been about 330,000 tons. This figure is for the restriction area only and does not include the islands of Singapore and Penang for which

[3] *Vide Malayan Tin and Rubber Journal*, Ipoh, February and March, 1927.

[4] *Vide* Paper read before the Royal Society of Arts, already referred to.

an addition of about 6,000 tons must be made bringing the total standard for Malaya up to 340,000 tons"

DEFICIENT STATISTICS OF ACREAGE.

Based upon the best available figures of production and calculating an average yield of 300 lbs. per acre (*i.e.*, about 2,240 lbs. or 1 ton for every 7½ acres), we may presume the present world areas under plantation rubber to be as follows in round numbers: Malaya—2,550,000 acres; Dutch East Indies—1,610,000 acres; Ceylon—450,000 acres; Other Countries—256,000 acres. Here it is surmised that the above areas are actually yielding the product. The plantations would cover larger areas consequently. Statistics of rubber production in Ceylon, Burma and India also seem to have been defective in former years. Mr. C. W. E. Cotton, referring to them in 1924, observed as follows: "At the end of 1923 the area under rubber cultivation in Ceylon was 445,000 acres, in India it was 62,000 acres and in Burma about the same as in India, making a total of 569,000 acres in Ceylon, India and Burma. From the present areas, Ceylon is expected to produce some 68,000 tons and India and Burma about 13,000 tons by 1930."[5] Of the world's area under plantation rubber, about 64 per cent. seems to be under the British Government and 32 per cent. on Dutch territory. This is apparently the direct cause of the British supremacy of rubber (as it is of tea) and the reason why London is the centre of distribution for the bulk of these products to the world.

THE TRADE IN RUBBER.

Plantation rubber now forms about 95 per cent. and wild rubber some 5 per cent. of the world's total production. The cultivated product, milled and unmilled, is usually sent for foreign shipment to ports like Singapore, Penang, Colombo, Batavia and Saigon where almost all the output of the Middle East is collected. Speaking in April 1927 at the Institution of

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[5] *Hand-Book of Commercial Information for India* by Cotton, 1924, Calcutta.

the Rubber Industry in London, Mr. H. Eric Miller, who is well acquainted with the rubber trade, remarked that the markets of Singapore and Penang attract all the rubber of Malaya, some of the dry rubber of the Dutch East Indies, nearly the whole of the rubber produced in Sarawak and Siam, and part of the rubber produced in British North Borneo, French Indo-China and Burma. From these places raw rubber is exported mainly to London, Liverpool, Amsterdam and Antwerp whence re-exports take place largely to America and Europe. Rubber grown in Dutch territory more often goes direct to the absorbing countries.

There is a restriction on the export of rubber grown in British territory (excepting India and Burma) under the Stevenson Scheme.[6] Circumstances which culminated in this plan need to be explained. A great boom in rubber took place about 1910 when many companies began to be promoted in the world's rubber markets. During the next decade a great expansion of the industry took place, which led to over-production resulting in the price of the product dropping as low as *7d.* a lb. in 1921 and 1922, the years of severe rubber depression. This alarmed certain producers and exporters who scented disaster ahead of them and appealed to the British Government for intervention. The Government appointed a committee, presided over by the late Lord Stevenson, to investigate into the matter and suggest a remedy. Accordingly the committee formulated a plan of restricting exports from British territory, known finally as the Stevenson Scheme. By this plan, rubber can be released in British areas only upon coupons issued by the rubber controller and the Act connected therewith came into operation on 1st. November 1922. The Dutch East Indies were invited to join in the scheme but they stood apart. While the British restricted, the Dutch went

[6] The idea of restriction is said to have originated long before the Stevenson Act when the wanton destruction of wild rubber trees was taking place in Africa.

on undisturbed. Stocks of the commodity naturally continued to pile up in London until they reached the high level of about 80,000 tons in 1923.

Absorbtion and Consumption.

Statistics go to show that about 75 per cent. of the world's rubber production is absorbed by the United States and about 7 per cent. by the United Kingdom. Crude rubber indeed forms the most valuable item in the imports of the U.S.A. According to the U.S.A. Department of Commerce (Rubber Division) in 1926 the United States imported 926 million pounds or 413,393 tons of raw rubber valued at $505,800,000. Moreover the Department estimates that the rubber consumption of the U. S. A. was 366,000 tons in 1926, as against 387,629 tons in 1925. The Rubber Association of America show that at present 85.1 per cent. of their total absorbtion of crude rubber goes into automobile tyres and tubes, 4.6 per cent. into mechanical goods, 4.3 per cent. into boots and shoes, 0.9 per cent. into insulating compounds, 1.3 per cent. into soles and heels and 3.7 per cent into other goods. Since the U. S. A. possesses about 80 per cent. of the world's automobiles, her percentage distribution of absorbtion is somewhat different from that of the rest of the world. "I think we cannot be far wrong," states Mr. H. Eric Miller, "if we assume that roughly 80 per cent. of the world's absorbtion of crude rubber goes into automobile tyres and tubes. Improvements in the manufacture of tyres and in the surfacing of roads have thus far-reaching influence on the world's rubber position." Rubber planters could, therefore, ill afford to be ignorant of coming developments at least in the manufacture of tyres and tubes.

In recent years American manufacturers have started an economy campaign by using reclaimed rubber. The U. S. A. Department of Commerce affirm that this product is usually utilized in the preparation of miscellaneous rubber goods and seldom in the manufacture of tyres and tubes. The reliability of this statement seems apparent from the fact that the Akron magnates (the tyre and tube makers of the U. S. A.) are still hostile to the rubber restriction scheme since they are unable to substitute to any marked extent the original crude rubber by the reclaimed product. The aforesaid Department estimate that in 1926 the proportion of crude to reclaimed rubber consumed in the U. S. A. was as follows:—

	Crude Tons.	Reclaimed. Tons.
In Tyres and Tubes ..	307,440	60,865
In Other Goods ..	58,560	103,635
Total=	366,000	164,500

PRICE MOVEMENTS.

According to the *India Rubber Journal,* of London (5th March, 1927 *et seq.*), the annual average prices of the best crude rubber per lb. in the London market from 1904 to 1926 were as follows:—

Year	Per lb.	Year	Per lb.
1904 ..	4*s.* 8½*d.*	1916 ..	2*s.* 9½*d.*
1905 ..	6*s.* 5½*d.*	1917 ..	2*s.* 8¾*d.*
1906 ..	5*s.* 9¼*d.*	1918 ..	2*s.* 3*d.*
1907 ..	5*s.* 2*d.*	1919 ..	2*s.* 1½*d.*
1908 ..	4*s.* 1¼*d.*	1920 ..	1*s.* 11*d.*
1909 ..	7*s.* 0¼*d.*	1921 ..	10*d.*
1910 ..	8*s.* 9¼*d.*	1922 ..	10*d.*
1911 ..	5*s.* 5¾*d.*	1923 ..	1*s.* 3*d.*
1912 ..	4*s.* 10*d.*	1924 ..	1*s.* 2¼*d.*
1913 ..	3*s.*	1925 ..	2*s.* 11¾*d.*
1914 ..	2*s.* 3*d.*	1926 ..	1*s.* 10¾*d.*
1915 ..	2*s.* 6*d.*	1927 ..	

This rubber in 1927 fluctuated between 1*s.* 4¾*d.* and 1*s.* 8¼*d.* The highest price ever reached in London by 'fine hard Para' was 12*s.* 10¼*d.* per lb. in 1910, and the lowest price by 'standard ribbed smoked' was 7*d.* per lb. in 1921. The annexed chart shows the average

PLATE 6.

(To face p. 49).

Young Hevea trees in the Experiment Station at Buitenzorg, Java.

(Photo taken by Dr. Tromp de Haas).

prices of 1st grade plantation rubber from 1904 to 1926. Sir Stanley Bois explains that the decline in rubber demand and its consequent low prices in 1921 and after were due largely to the effect of the longer wearing properties of the 'cord tyre' which was steadily displacing the short-lived 'fabric tyre,' while the increased demand in 1925 may be largely attributed to the introduction of the 'balloon tyre' which needs a greater quantity of rubber owing to its larger sectional area. Changes in the construction of tyres and the use of reclaimed rubber or any rubber substitute are naturally of great concern to the producers of this product.

The Stevenson Scheme.

Much controversy has raged in the Middle East, the United States and the United Kingdom on this subject. At the outset the scheme did not limit production legally, though it did so logically at times, but the Act only restricted the export of rubber when its price was low. At present the working of the scheme is more stringent. Sir Josiah Stamp explains that its object is to stabilize price and production, also that in principle it is different from monopolistic exaction. Its opponents however indicate that the cause of the panic which resulted in the Stevenson Act, was a temporary drop in American consumption, resulting in the accumulation of stocks in London, but that there was no regular over-production. They show that the U. S. A. consumed 230,000 tons in 1919, 220,000 tons in 1920 and 180,000 tons in 1921—a sudden decline from 1919 to 1921; also, that she consumed 239,000 tons in 1922, 304,000 tons in 1923, 335,000 tons in 1924 and 386,000 tons in 1925—a steady rise from 1922 to 1925. From these figures they argue that at first it was the sudden drop in American consumption which was responsible for the fall in the price of rubber and then the recovery of demand in America—not the scheme of restriction—which justified the price improvement from 1923 to 1925. Such clear facts would indeed make their argument seem incontestible.

Moreover, its opponents urge that restriction has handed over an increasing share of rubber production to Dutch planters to the detriment of British growers. They show that while in 1921 British production was 72 per cent. of the world's total, in 1926 it was only 61 per cent. and that in comparison Dutch production has gone up from 25 per cent. in 1921 to 34.6 per cent. in 1926. Finally they deplore that the scheme (mainly owing to its mismanagement) has failed to stabilize the price of the commodity to any visible degree and sound business men have been deprived of the trade pointers which enabled them in the past to predict the course of the rubber market.

On the other side, the supporters of this scheme assert that without it the price of rubber would fluctuate even more wildly than at present, and that price fluctuations depend fundamentally on variations in demand and supply, production costs, etc.—not on the inefficiency of management which can hardly be improved while world statistics remain so deficient. It is true that restriction can only regulate supply to demand as closely as indicated by price movements or by periodic forecasts of consumption in the manufacturing countries. In other words, it can only roughly adjust the exports from the restricted areas to such anticipations, and scarcely more could have been expected from it by the Stevenson Committee except price stabilization. Restrictionists also urge that 'the scheme has doubled the price of rubber to producers, as compared with the pre-restriction period' and thus saved the industry from languishing. This is scarcely borne out by the figures prior to 1921. Anyway, they do not deny its shortcomings but nevertheless maintain that while production remains in excess of consumption, restriction should continue—an argument which is forcible only when the excess is so great that it reduces the price to the cost of production.[7]

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[7] This in itself is a variable quantity, but is often referred to as 'the pivotal price.'

In 1922 the main object of this scheme was to raise the price of rubber and thus uplift the planting industry from depression. Since then the growing demand for rubber, assisted to a small degree by restriction, has helped the upward price tendency. But probably restriction has also helped to introduce reclaimed rubber. Reclaimed rubber comes into use when the price of crude rubber goes up to 2*s.* or so, and its use falls off with a decline in the price of the natural product, when the substitute ceases to be economic. Thus it is acting as a regulator of prices and lessens the need for restriction.

In any case we must not forget that price depends more on effective demand than on restricted supply, also that restriction must fail largely in effect unless (1) all rubber planters come under its sway, (2) consumption forecasts for every quarter year can be made more accurately which is almost impractical, and (3) developments like the use of reclaimed rubber can be counteracted. Otherwise the measure cannot prove very effective. At the same time, as compared with its little benefit to producers, restriction perpetuates an injustice to consumers whose interests cannot be always ignored. Even a good many British manufacturers are against restriction, and to-day the opinion in Malaya among some of the big planters is that restriction has done its work and should be abandoned as early as possible. In these circumstances the inevitable conclusion is that the Stevenson Scheme needs some relaxation, at least experimentally, when the price of rubber rises above 2*s.* a pound. It is needless to add that if the price rises to 3*s.*, restriction should be entirely withdrawn, as otherwise crude rubber consumption would be visibly diminished."[8]

[8] *The Statesman*, of Calcutta, which usually gets to the bed-rock of the puzzling economic problems of the East, has recently made some very helpful suggestions on the efficient working of 'the restriction scheme.'

CHAPTER V.

NEW METHODS IN PLANTATIONS.

A PERIOD OF REVIVAL.

There is little doubt that rubber planting is passing through a period of re-birth (which may in future be known as its 'stage of renaissance') as the result of economic conditions which have acted upon it in recent years. The boom period of 1909-10 was virtually the culminating point of the luxury stage of rubber. Thenceforth it was destined to become a product of necessity. Apparently, however, the boom had largely a stimulating but partly a demoralizing effect on rubber planting in the Middle East. Owing to high rubber prices, extensive areas were brought under this product in hot haste, which resulted in its careless cultivation. Planters now relate how many of the existing plantations were ruinously tapped to meet the demands of peak prices, how many new estates were sown with unselected seeds and how their young plants were insufficiently protected against disease.

When the speedily extended areas came into bearing, the rubber crops, though greatly increased in quantity, were raised partly from deteriorated plantations. These circumstances were probably to some degree responsible for the slump in the trade in 1921-22. During the previous decade, the methods of rubber planting, tapping and treatment made little or no improvement. But in recent years it has come to be realized that scientific methods must be largely employed so as to impart greater vitality to the trees, also that economy must be effected in every possible direction so as to reduce the cost of production. To-day it is further apparent, owing to the partial failure of the Stevenson Scheme, the introduction of reclaimed rubber and the persistent efforts of chemists to devise some rubber substitute, that the days of high prices for raw rubber cannot be expected to continue much longer. The poignant lesson of industrial history is now being borne in upon planters that the progress of an industry is ultimately based upon a progressive increase in the consumption of its products, which in turn must largely depend upon a continued increase in production at lower prices. These circumstances are ushering in better methods of rubber cultivation and preparation.

THE MIXED PROGENY OF PRESENT PLANTATIONS.

In planting up new estates, the proper selection of seeds has become a vital necessity. The present large 'population' of Hevea trees in the Middle East is composed of millions of descendants from seedlings which were introduced here about half a century ago. It is consequently a mongrel population produced by promiscuous inbreeding from ancestors which were themselves probably far from being the offspring of the healthiest and best-yielding specimens of Brazil. It is recorded that the seeds which Wickham procured represented about 17 varieties of Hevea obtained from the *Ciringals* of the Rio Tapajos. Of his 70,000 seeds, only 2,700 germinated at Kew and about 1,900 seedlings were received at Heneratgoda, Ceylon, during August 1876. In 1877 Ceylon is reported to have sent 22 plants to Singapore propagated from cuttings, and in 1881 these bore seeds which are believed to be the sources of plantations in Malaya, Borneo, and later on in Sumatra. Also it is said that in 1876 seedlings were received in India direct from Kew and these were in due course sown in Lower Burma. It is probable that the plantations in Southern India were raised both from the Burma and Ceylon stocks.[1]

[1] Records of the earliest sowings are not quite consistent. Herbert Wright explains that originally some plants were propagated from cuttings, but when the trees bore seeds, this system of propagation became unnecessary.

Out of such a degenerate progeny, it would be impossible to get seeds which have retained all the virtues of the native Hevea, although they would doubtless possess the qualities of an acclimatized breed. While seed selection from such a population must of necessity be continued for the present, it is essential to get selected seeds from Brazil so as to rear up a purer stock, which it should not be difficult to acclimatize. Owing to the similarity of climate between Brazil and Ceylon, acclimatization was only natural to the progenitors of the present stock. Complete adaptation to the new environment then took place gradually throughout the tropical Middle East where the physical features are more or less similar to those of the tropical Middle West. The same process could be repeated again at least for portions of new estates in the near future. There is little doubt that many of the old estates, including those hurriedly sown about 17 years ago, are languishing—the sure signs of which are their declining outturn and heavy casualties. Should the price of rubber go down to 1*sh*. a lb. their position would become very precarious. Most of these estates need replanting on modern principles.

THE REVIVAL OF DECLINING ESTATES.

Scientific research and technical skill in rubber culture were lacking until recent years and these estates are declining partly from age but largely through unskilful methods of cultivation. While their soils have lost the virginal character, manures are seldom used in them and little care is bestowed in some other directions. Their deterioration is due to a complex of causes among which may be named soil exhaustion, over-tapping, slow bark renewal, diseases sometimes neglected and often wrongly treated, resulting in a loss of vitality to the trees. Failures of this kind are, however, excusable in a new industry when planting experience is limited. "On many of the older areas," describes a noted rubber-journal, "and indeed on many young areas, the tapping panels are a mass of old wound calluses. Too high demands were made in previous years for production, too little care and a lack of the requisite knowledge of tapping that can be easily achieved, led to the present lack of tappable bark. Tapping systems have in many cases not been economical. ***Root disease can generally be traced to carelessness in the initial clearing of the land or the removal of a catch-crop. **Probably the greatest damage to the old areas has been done by the *Phypthora Faberi,* which includes stripey and fleck canker. ***The result of these diseases has probably been to destroy more tappable bark than any disease in the East. In the old days 100 per cent. tar was regarded as a panacea for all rubber diseases."

" Here again on many areas," continues this journal, "trees have had vitality and bark so damaged that to ensure future production drastic steps must be soon taken, as in many cases panels will be untappable in the near future. ***The foregoing causes have, in many cases, combined to ruin a very fair percentage of the old areas, together with the difficulty of finding tappable bark and the fact of poor and decreasing yield. It must be borne in mind that many of the older companies are restricted for reserve land, and that land that is both suitable and not too inaccessible for transport is becoming scarce. ***Further, seeing the numerous young clearings and considerable areas opened in the last few years, all of which have profited by the experiences of the older estates, and which have with proper treatment very large potential productiveness (which will naturally mean cheaper cost of production), it becomes increasingly plain that if the directors of older companies are to give a good account of their stewardship, Spartan remedies must be applied, and we may take it as certain that in the near future a great percentage of the old areas must be replanted."[2]

New Plan of Planting Distance.

In replanting estates with selected seed, one of the preliminary points to be decided is the most profitable distance of planting. This is still a very controversial question, as the scientific results of different distances

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[2] *The India-Rubber Journal*, London, 3rd September, 1927.

have not yet been properly studied, though some rough observations have been made by experts on this subject, which have been discussed in a previous chapter. Seedlings should be closely sown so as to have a wide scope, out of an extensive number, to select from eventually. For permanent sowing, however, the bulk of opinion so far has been in favour of distant planting, so as to allow ample room for lateral and root expansion, also because each tree, getting more sustenance from the soil, could develop a robust and hardy constitution. At the same time, close planting makes it rather inconvenient either to cultivate the soil without damaging the root system or to isolate the trees in case of root and leaf diseases. Despite these objections, some of the visiting officers at the present day advocate close planting at the outset, from 200 to 400 trees to the acre, and thinning out during the period of five years to a permanent stand of 100 to 120 trees per acre, no attention being paid to the regularity of position.

The argument is that the field of original selection would be far wider by this procedure. Planters may thereby be led to think that the new scheme is based upon the policy that rubber estates should be regarded more as latex factories than as disease-resisting establishments. And they would not be far wrong, as this is actually how it might be on economic grounds at least for the present. In the United States Rubber Plantations in Sumatra, "tests were made," says a noted rubber-journal, "with planting at different densities, ranging from 196 to 416 trees to the acre with selected seeds, as compared with the original system of 120 trees to the acre. After thinning to a uniform 100 trees per acre at six years old the yield per tree is about 10 per cent. greater in the more densely planted areas. This is in spite of the suppressive effect on growth due to the dense planting and is attributed to the proper selection exercised. Up to now there appears little difference between the various densities of planting from 196 to 416 trees. The tendency seems to be for the highest yields per tree to be given by the plots

A Section of the Nikakotua Estate, Matale, Ceylon, where both para trees and tea bushes are in bearing.
(Photo by Ivor Etherington.)

planted 350 trees per acre. The provisional conclusion is drawn that between 200 and 300 trees per acre are advisable when planting with selected seed or seed from buddings."[3]

THE CHIEF LINES OF PROGRESS.

Future progress in rubber culture is inclined to go along the lines of seed-selection and bud-grafting. Indeed among the advanced planters in the Middle East it is an accepted policy to-day that all new clearings should be sown if possible with selected pure seed or with the best available impure seed as well as with budded plants. Pure selected seed probably holds the key to the success of the future, but it is at present impossible to procure in large quantities, though rubber growers' associations could solve the difficulty at no distant date were they to find some original workers like Wickham. Impure selected seed could, of course, be obtained abundantly. "The comparatively unknown quantity," explains the aforesaid journal, "is budded rubber, and, although it is all but certain that the first generation will remain true to type, reversion in the future and atavistic traits may develop in succeeding generations. It is also not yet certain as to the percentage of buddings that will be able to continue to perpetuate the hereditary features after the first generation. ***It is however, certain that no estate can afford to neglect propagation by budding. Budding wood can be had in increasing amount by the propagation of multiplication nurseries."[4]

BUD-GRAFTING IN HORTICULTURE.

Bud-grafting is resorted to widely in horticulture, being a very familiar process even among illiterate gardeners. Its adoption in rubber culture is, however, quite an innovation and needs the scientific researches of the plant physiologist. Bud-grafting, as described by Mr. H. F. Macmillan, "consists of taking an eye or bud attached to a portion of the bark and inserting it

[3] *The India-Rubber World*, New York, September, 1927.
[4] *The India-Rubber Journal*, London, 3rd September, 1927.

in the stem or branch of another plant.* A condition necessary to success is that the sap be in active circulation, so that the bark may detach itself readily when gently lifted from the wood. ***The *modus operandi* is as follows: Select a shoot well furnished with plump dormant buds from the plant desired to be increased; cut off the leaves at half the length of the leaf stalks. ****In the bark of the young shoot in which the bud is to be inserted, make an incision in the form of a 'T.' Raise the bark carefully, push the bud gently into the opening, bind it securely to exclude air, leaving only the point of the bud exposed. **The bud-wood (*i.e.*, the shoot from which the bud is taken) should be not less than 2 years old."[5] Grafting is the operation of making one plant, or a part of it, grow upon another, and budding is only a special kind of grafting.

Precision in fitting the bud-bark with the incision in the bark of the stock is an important factor of success. When the union of stock and scion has taken place (which should happen in 2 or 3 weeks) the bandages may be removed. The plant on which grafting is done is termed the 'stock' while the part inserted into the stock is called the 'scion.' By scion is usually understood a twig consisting of one or more buds rather than detached buds. The essential principle of grafting is to bring the cambium layer (growing tissue between the bark and wood) of the stock and scion in close contact with each other and to keep them there until they grow together. Bud-grafting may be briefly explained graphically as follows: An incision resembling the letter 'T' is made through the bark of the stock, as shown in Fig. 1. The bark is then slightly lifted at the top of the cut and a little piece of bark containing the bud (often termed 'the shield'), as shown in Fig. 2, is inserted and pressed down so that it is held exactly in position. The bud is then tied firmly in place, as shown in Fig. 3, with raffia and some soft yarn. The

*An 'eye' is known in Botany as the embryo bud of a new shoot located at the base of a leaf.

[5] *Tropical Gardening and Planting* by Macmillan, Colombo, 1914, pp. 66 and 67.

stock is often prepared for the operation by being stripped off the twigs and leaves around the area to be

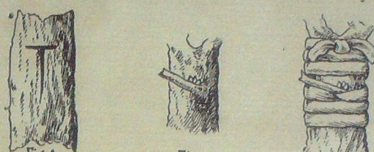

Fig. 1. Fig. 2. Fig. 3.

budded. Apparently this is done to concentrate its growing power as far as possible to the portion where it is most required until the grafting is complete.

CHAPTER VI.

RECENT DEVELOPMENTS IN CULTIVATION.

BUD-GRAFTING AND SEED-SELECTION.

Early in this decade certain economic causes led to experiments in bud-grafting and seed-selection by planters in the Middle East with a view to increase the productivity of *Hevea Brasiliensis*. That selective breeding results in an improvement of stock both in the animal and vegetable kingdoms has been proved long ago by scientists. Hence nobody could doubt the prospects that at least the better conducted of these attempts possess of attaining ultimate success. But as rubber trees take time to mature it will obviously be many years before such endeavours will lead to the regular increased outturn of plantations. Experiments so far conducted seem to indicate that the yielding capacity of the Hevea can be improved by the propagation of the most productive strains either vegetatively by means of bud-grafting or selectively through the medium of seed-selection and cross-breeding.

Bud-grafting was described a few years ago by Mr. Sidney Morgan, Senior Scientific Officer to the Rubber Growers' Association in Malaya, as follows: "Trees known to be uniformly good yielders are kept under observation and the seeds gathered carefully. These seeds are germinated in a special nursery, and the best grown seedlings are selected for further operations. At a certain stage a bud is taken from a high-yielding parent tree and grafted upon the stem of the seedling. When this has 'struck,' the original head of the seedling is removed. This ensures that one has in the seedling both the stem and future branch system of the same strain as the parent high-yielding tree. It is possible to go a step further, and by certain processes induce a new root system to grow above the existing roots which are then removed. One is then able to guarantee that the roots, stem and branches will be of the original high-yielding strain."[1] The difficulty is that such experiments need time to produce fruitful results. Anyway, bud-grafting seems a more thorough scheme of transmitting parent characteristics than the system entirely dependent upon successive breedings from selected seed.

At the International Rubber Conference held at Paris early in 1927, Sir W. R. Dunstan, who presided, said that the first two papers dealt with the highly important question of obtaining increased productivity on plantations by means of seed-selection and bud-grafting. The papers had been written by Mr. R. A. Taylor, Physiological Botanist to the Ceylon Rubber Research Scheme and Mr. J. Grantham, Director of Research to the U.S.A. Rubber Plantations at Kisaran, Sumatra, but pioneer work in these directions had been done by the Dutch in the Netherlands East Indies.

MR. TAYLOR'S PLAN OF WORK.

Mr. Taylor's paper gave an account of the plan of work which had been decided upon by the Ceylon Committee in bud-grafting on experimental plantations in Ceylon. Budding or bud-grafting was the method which had been adopted of propagating vegetatively from trees known to be high-yielders, such trees being termed as mother trees. Careful records of yields were taken for at least one year. It had been observed that not every high-yielding tree transmitted this quality to its budded offspring. The Research Scheme was making a careful study of both mother trees and stocks, and during the testing operations it was intended to make as many different combinations of stock and scion as possible.

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[1] *The Preparation of Plantation Rubber* by Morgan, London, 1922, pp. 5-7.

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The paper explained the method of breeding improved strains. It stated that budding could not be expected to produce trees with individually higher yields than the mother tree and it was necessary to have recourse to breeding if higher yielders were to be produced. Also the author observed that the only method of distinguishing high yielders from ordinary yielders appeared to be the taking of yield records, and every single seedling produced would, therefore, have to be grown to tappable size before any selection could be made, and unless in the meantime some morphological or physiological character was discovered whereby it should become possible to identify low and high yielders, the time which must elapse before a pure strain could be obtained would be considerable. A point mentioned in Mr. Taylor's paper was the selection of the best trees according to the number of rows of latex cells in the cortex, but he believed that this system had for some time been discarded, at any rate in Java and Sumatra, as not giving reliable results.

MR. GRANTHAM'S EXPERIMENTS.

In an exhaustive paper on this subject Mr. Grantham gave a survey of the methods which had been adopted in his plantations in Sumatra and Malaya to obtain new areas of high-yielding capacity. The author introduced a table giving the classification of yield over a nine-year period on a fairly uniform area of 12½ acres of rubber planted in 1911, the yield of every tree being collected each day and the dry yield being weighed half-monthly. The objects were to ascertain whether good yielders remained good yielders (a question which could be answered in the affirmative for a great majority) and to ascertain the distribution of yield in a normal 'population.' The table showed that the yield of the two highest classes was over three times the average yield. The author added that this experiment had formed the basis of much of the scientific work done, and calculations from it had formed the basis of larger scale work.

Full particulars of many other investigations were given, and the writer expressed the opinion that the following systems were worthy of consideration for large scale planting of new areas, set down in order of merit:

(1) Buddings of proved clones inter-planted with seed from buddings;[2]

(2) Buddings of proved clones only;

(3) Seedlings from seed of buddings planted densely enough to allow elimination of all poor yielders;

(4) Seedlings from seed of selected high yielders of the ordinary plantation planted in a similar manner.

It was not possible to see the end of the competition between buddings and seedlings, and it was quite probable that both would continue to be used for many years to come. Progress with a perennial tree crop must necessarily be slow, but it was under way and the rubber plantations of the future would, the author believed, show results of scientific development comparable with those achieved in older agricultural industries.

MR. BINGLEY'S OBSERVATIONS.

Mr. Noel Bingley, who has obviously had some experience in this line of work, also spoke on the same subject at this Conference. He said that he would like to mention some interesting features of bud-grafting results which he thought were worthy of attention.

(*a*) The yield per tapping of a budded Hevea, whether tapped at 20 inches from the ground or at two or three times that height, was the same. On his visit to the research farms he saw instances of trees with two cuts at 40 and 80 inches from the ground respectively where the yield was the same, instead of there being the normal excess of 100 per cent. in favour of the lower cut on a non-budded tree.

[2] Apparently the word 'clone' is used to signify buddings, the results of vegetative propagation, as a distinction from seeds the offspring of sexual reproduction.

For this reason it was advantageous to start the tapping on a bud-grafted tree much higher than in the case of a seedling, from the bark conservation point of view as well as from that of yield. A further reason was that it had been proved that tapping too close to the juncture of graft with stock caused abnormalities in growth of the lower part of the stem.

(*b*) All the bud-grafted trees from a given clone would inherit any abnormality peculiar to the mother tree—corky bark, knobby stem, inclination to lean over, etc.—generally in more pronounced form than was the case with the mother tree. He saw experimental areas planted with bud-grafts where the surface of all the trees was so covered with abnormal growths, and other areas where all the trees were leaning at such an acute angle, that tapping was practically impossible.

(*c*) Some clones carried no seed.

(*d*) Buds from selected high yielders would not 'take' on stocks from any tree but their own mother tree.

(*e*) Experiments extending over many years had shown that, of the buds from any hundred selected *elite* mother trees, approximately only one-third had better qualities than the parent tree or the same qualities. One-third of the number was doubtful and one-third useless for propagation purposes. This result was confirmed by experiments carried out by the scientific officers of the A.V.R.O.S. in Sumatra, and consequently he was inclined to believe that, in giving 8 as the approximate percentage of high yielders that transmitted their qualities to their offspring, Mr. Taylor was considerably below the mark. However the most vital point, to his own mind, in the whole question was that until one had approved clones at one's disposal it was most inadvisable to attempt budding on more than an experimental scale, otherwise one ran the risk of establishing large areas in which approximately two-thirds of the trees would be bad or doubtful yielders.

For those who were anxious to institute this method of propagation, without the delay of ascertaining by a

PLATE 8.

(To face p. 65).

Old Hevea trees in the Culloden Estate, Kalutara, Ceylon, some of which have given 25 lbs. of rubber in a year.

(Photo by C. H. Kerr.)

slow and patient process of experiment which were really the reliable trees on their own estates to use for propagation, the only safe course was to purchase first-class budding material from other sources.

The Chairman in conclusion remarked that the work in Ceylon had only just begun and Mr. Taylor's paper was necessarily not much more than an account of what it was proposed to do there. Mr. Grantham's paper was, he thought, one of the most valuable of all the papers laid before the Conference, as it gave a very full account of what was actually being done. As Mr. Bingley had said, many years must pass before the correct practice of bud-grafting could be part and parcel of ordinary plantation procedure, and any work along these lines must for the present be regarded as experimental.

THINNING OUT ESTATES IS IMPRACTICABLE.

Since individual trees vary greatly in outturn, in an average plantation it is probable that, roughly speaking, only 25 per cent of the trees yield about 50 per cent. of its crop. The process of thinning out an estate on the basis of yield would help to a large extent to bring about a final stand of high-yielding trees, but in practice it is difficult to plant a sufficient number of trees per acre to allow 75 per cent. to be finally eliminated. In course of time it occurred to the pioneers of these attempts that the establishment of detached seed-farms would promise far better results. Here it will be remembered that this scheme was originally suggested by Dr. R. H. Lock. Seed farms and experimental gardens in consequence came into existence and were planted up with bud-grafts from several good-yielding trees of known parentage. Then by the controlled pollination of these it was sought to secure strains giving a much higher average yield per tree than was obtained from trees grown out of unproved and unselected seed. It is probable, therefore, that at some future period, seed from the selected strains will be reliable for the propagation of high-yielding trees.

TAPPING EXPERIMENTS ON BUD-GRAFTED TREES.

Research work in other directions is being conducted in the United States Rubber Plantations. The tapping of buddings follow methods of conservation and allow ample rest to the trees for productive recuperation and bark renewal. "Buddings tapped with a double cut on one half the circumference," reports a leading rubber journal, "alternate fortnightly tapping gave an increase of 11 per cent. in yields over the alternate monthly tapping system. Another experiment with two cuts as against one cut gave only a slight increase in favour of two cuts. A point that is brought out strongly is the danger of relying on results obtained from too small an area. For example, results from experiments on a few trees are not likely to be duplicated when several hundred or several thousand trees are involved. From the experience of this company at least, it is concluded that the half cut alternate month tapping system with six years' renewal period has proved more satisfactory thus far than all others. No advantage is derived in giving a longer renewal period than six years. In fact a five-year renewal in young rubber is recommended and a six-year renewal in older rubber with alternate monthly tapping remains the standard system."[3]

YIELDS FROM BUDDINGS AND SELECTED SEEDLINGS.

Buddings have not yet passed the test of tapping on renewed bark, but there is no need to have misgivings on this score from present appearances, though it is most probable that some system of tapping, particularly suited to the new conditions, will have to be evolved. The yields from buddings as well as from selected seedlings are the results of other experiments. "The first year's tapping" continues the aforesaid report, "on one area gave a yield of 287 pounds per acre for the buddings against 181 pounds per acre for selected seedlings. The second year's tapping will, it is estimated, show a yield of over 500 lbs. per acre

[3] *The India-Rubber World*, New York, September, 1927.

for the buddings. Such an amount per acre is now obtained only on the best areas in fully matured 10-year old trees, and is considered very exceptional. This again speaks very well for buddings."

"Two small areas planted in 1920 with buddings gave yields of 388 (a very slow-growing section) and 669 pounds per acre respectively for 1926, as against 487 and 474 pounds per acre over two considerably larger areas of selected seed, and 487 pounds per acre for another area of selected seed, planted at different densities. While these yields from selected seed are lower than those from buddings, they are much better than the yields from unselected seed in the first year of tapping. The conclusion is drawn that, from data now available, it seems probable that the yield from selected seed planted at least 200 to the acre and thinned out by test tapping is about equal to the yield of mixed buddings of unproved origin. The research department has tried to obtain seed by artificial pollination. While some success attended these efforts, the percentage success has been too low to prove of interest."[4]

REPLANTING OLD AREAS.

The area sown on these American plantations in Sumatra consist of 82,583 acres, of which about 52,000 acres are in bearing. The oldest budded areas therein are about 8 years of age. "The question of replanting older areas," reports the aforesaid journal, "with buddings and selected seed is receiving much attention from the management. Preliminary experiments indicate that enhanced yields will be the reward for replanting. However, the question is there of determining how soon the loss of production from these already producing areas could be made up in the years of re-development. But it does seem that with the splendid results from budding and with the proper fertilizing program it will be possible to adopt a policy of gradual replanting of all the older less productive

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Tapping Experiments on Bud-Grafted Trees.

Research work in other directions is being conducted in the United States Rubber Plantations. The tapping of buddings follow methods of conservation and allow ample rest to the trees for productive recuperation and bark renewal. "Buddings tapped with a double cut on one half the circumference," reports a leading rubber journal, "alternate fortnightly tapping gave an increase of 11 per cent. in yields over the alternate monthly tapping system. Another experiment with two cuts as against one cut gave only a slight increase in favour of two cuts. A point that is brought out strongly is the danger of relying on results obtained from too small an area. For example, results from experiments on a few trees are not likely to be duplicated when several hundred or several thousand trees are involved. From the experience of this company at least, it is concluded that the half cut alternate month tapping system with six years' renewal period has proved more satisfactory thus far than all others. No advantage is derived in giving a longer renewal period than six years. In fact a five-year renewal in young rubber is recommended and a six-year renewal in older rubber with alternate monthly tapping remains the standard system."[3]

Yields from Buddings and Selected Seedlings.

Buddings have not yet passed the test of tapping on renewed bark, but there is no need to have misgivings on this score from present appearances, though it is most probable that some system of tapping, particularly suited to the new conditions, will have to be evolved. The yields from buddings as well as from selected seedlings are the results of other experiments. "The first year's tapping" continues the aforesaid report, "on one area gave a yield of 287 pounds per acre for the buddings against 181 pounds per acre for selected seedlings. The second year's tapping will, it is estimated, show a yield of over 500 lbs. per acre

[3] *The India-Rubber World*, New York, September, 1927.

for the buddings. Such an amount per acre is now obtained only on the best areas in fully matured 10-year old trees, and is considered very exceptional. This again speaks very well for buddings."

"Two small areas planted in 1920 with buddings gave yields of 388 (a very slow-growing section) and 669 pounds per acre respectively for 1926, as against 487 and 474 pounds per acre over two considerably larger areas of selected seed, and 487 pounds per acre for another area of selected seed, planted at different densities. While these yields from selected seed are lower than those from buddings, they are much better than the yields from unselected seed in the first year of tapping. The conclusion is drawn that, from data now available, it seems probable that the yield from selected seed planted at least 200 to the acre and thinned out by test tapping is about equal to the yield of mixed buddings of unproved origin. The research department has tried to obtain seed by artificial pollination. While some success attended these efforts, the percentage success has been too low to prove of interest."[4]

Replanting Old Areas.

The area sown on these American plantations in Sumatra consist of 82,583 acres, of which about 52,000 acres are in bearing. The oldest budded areas therein are about 8 years of age. "The question of replanting older areas," reports the aforesaid journal, "with buddings and selected seed is receiving much attention from the management. Preliminary experiments indicate that enhanced yields will be the reward for replanting. However, the question is there of determining how soon the loss of production from these already producing areas could be made up in the years of re-development. But it does seem that with the splendid results from budding and with the proper fertilizing program it will be possible to adopt a policy of gradual replanting of all the older less productive

[4] *The India-Rubber World*, New York, September, 1927.

areas. Where root disease has destroyed a large percentage of trees there ought to be but little hesitancy to replant with proven high-yielding stock."[5]

The Selection of Trees for Propagation.

In selecting a tree as a propagator, its high yield should be the first consideration, but its disease history could not be ignored. Though from its high yield a sound constitution may be presumed, a tree that has suffered from disease in the past is likely to suffer again unless precautions are taken. The state of its bark and its power of bark renewal may also be regarded. A microscopic examination of the bark will show the rows of latex cells or vessels, and the theory has been urged that generally the higher the number of these rows, the greater is the yield of latex. On these points both Mr. R. A. Taylor and Mr. T. H. Holland (Manager, Experiment Station, Peradeniya, Ceylon) have offered some valuable advice. "It is always possible," they suggest, "that even the best yielding trees on the estate are not outstanding yielders worthy of selection as mother trees and therefore an approximate calculation of the yield of dry rubber must be made in the case of the best trees. ***Although trees cannot be graded exactly by the counting of latex rows in the bark, this operation provides a valuable check on the yields recorded. As a general rule, trees with large numbers of rows are better yielders than trees with few, and also it is not advisable to propagate trees with too thin bark, as tapping cannot be carried out beyond a certain depth."[6]

Some Other Endeavours.

Major H. Gough, who seems to have had at least six years' experience of bud-grafting in Malaya, is optimistic on this subject. In spite of many disappointments in his endeavours, he thinks that in a few years he will be able to show an yield of 1,200 to

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[5] *The India-Rubber World*, New York, September, 1927.
[6] *The India-Rubber Journal*, London, 16th April, 1927.

1,500 lbs. per acre in place of the 250 to 350 lbs. per acre on the average present day plantation. "Even in Malaya" he writes, "I believe that before the end of 1928 there will be 20,000 to 30,000 acres planted from multiplications of buds from trees which I have already proved to have the power of transmitting their very high yields. The Malaya American Plantations also are bud-grafting large estates in Kedah with proved material."[7] Dr. J. Schweizer, of the Besoeki Experimental Station in the Dutch East Indies, had in 1926 some 200 mother trees from which he is reported to have made 50,000 graftings which are growing under observation. This is probably a source from which planters could get good budding material.

The Bud-Grafting of Rubber.

An excellent discourse on 'bud-grafting' by Mr. F. Summers, Head of the Botanical Division, Rubber Research Institute of Malaya, appears in the *Bulletin* issued in October 1927 by the Rubber Growers' Association of London. It was read at a recent Conference of the Incorporated Society of Planters in Malaya and runs as follows:—

"If we are to arrive at a correct definition of the present position of bud-grafting, two things are essential at the outset. First of all we must be perfectly clear as to what is meant by bud-grafting; for a great deal of misunderstanding has arisen, and a large number of misconceived ideas have been created as a result of regarding the method as an end in itself and not as a means towards an end. The impression still largely prevails that bud-grafting from a high-yielding tree is bound to give extraordinary results on a plantation scale without any further precaution than a preliminary measurement of the yield of the mother tree over two or three years.

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[7] *Practical Bud-Grafting and Seed Selection of Hevea Brasiliensis* by Gough, Kelly and Walsh, Ld., Singapore, 1926, price $4. [This is a very handy booklet for planters as there is at present no book on this subject and very few Research Stations to which he could turn for information, according to *The Planter*, Kuala Lumpur, F.M.S., of January 1927.]

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"The truth of the matter is that bud-grafting is merely a simple method of plant manipulation which has been applied to woody trees, in temperate horticulture, for an unknown number of centuries. There is, however, with Hevea this radical difference. In horticulture generally, the method is usually employed to improve the flowering or fruiting qualities of the scion, whereas in Hevea the object is the improvement of the yield of latex the production of which is generally held to be due to the activity of the vegetative portions of the plant, that is to say, the non-reproductive portions. On this account we must be careful in drawing analogies from the budding of fruit trees in temperate climates.

JAVA INVESTIGATIONS.

"While at this point I might remind you that investigations in Java and Sumatra have established the very interesting fact that the trees produced by budding are often strikingly early and vigorous as regards flower and seed production. On this account alone the method must be considered an important feature of modern plantation technique. In the second place, we must have some well-understood standard by which we can measure any progress due to the method and assess its value in normal plantation practice. Such a standard is by no means easy to agree upon. At the present moment it appears the height of folly merely to claim for a method that it will lead to increased yields. Nevertheless, the sole claim made up to date by the most enthusiastic advocate of bud-grafting is that it is the best method for providing the planter with a uniform stand of high-yielding trees. Naturally, certain precautions are advised, but we will not go into those at the moment. Unless there is a prospect, therefore, of a greatly increased demand for rubber by the time new areas, now being planted up, will come into full bearing, it does seem as though there were some justification, on economic grounds alone, for the attitude of conservatively-minded planters who refuse to regard bud-grafting seriously.

"At the other end of the scale are those enthusiasts who see in bud-grafting a cure for all the ills which the rubber plantation suffers from and it is unlikely that the same standard of measurement will be accepted by both these schools of thought. There are, however, one or two facts which will assist the man with an open mind who wishes to form his own conclusions from the evidence available uninfluenced by the leaders of either school of thought.

"First of all we are all agreed that the modern scientifically managed plantation, with its unceasing struggle against such adverse factors as soil exhaustion, soil erosion, leaf, root and bark diseases; with its experimentally developed tapping system; with its constant aim at a high-grade product from the factory; and with its correctly managed staff and labour force is highly superior to the ordinary go-as-you-please small holding. Secondly, I suppose we shall agree that these modern methods of estate management have been adopted because they are commercially sound and profitable. Thirdly, the aims of modern commercial horticultural practice are consistently directed towards the establishment of a plantation of uniformly high and good quality cropping trees as the surest method of increasing the difference between selling price and cost of production. Side by side goes a decrease of unskilled and an increase of skilled labour corresponding to the increased individual attention claimed by the trees.

"No amount of labour expended upon the individual trees of an old fruit orchard will give a return commensurate with the time and money expended. A vigorous thinning out of the semi-derelicts must be practised together with their replacement by known and proved high or good quality yielders. I cannot too strongly emphasize the difference which would be made if all the trees on a plantation were uniformly high-yielders so that the yield from a given area could be more or less closely forecasted. Trees could be tapped or rested much more systematically than at present.

Imagine for example the convenience of knowing that 50 per cent. of your acreage, tapped on alternate days, would give approximately 50 per cent. of the total yield. Yet, judging from the results of recent research, this is no impracticable ideal.

A Fundamental Omission.

"This brings me to what I consider has been a fundamental and serious omission in all discussions round the subject of bud-grafting. It has been tacitly assumed that the method has its usefulness only in the planting up of newly cleared areas. To my knowledge it has not been considered as an aid to the reconditioning of areas of old rubber. The economics of this important subject has not been worked out as yet and in doing so the possibility of replacing worn-out trees by established high yielders is certainly not one to be lost sight of. It is often held that the agricultural research worker ought not to be concerned with the economic implications of his work. In an industrial research institute however one is not entitled to pursue a research which a short preliminary investigation would show to have no sign of improving the economic position of the industry. The fact that the Rubber Research Institute is contemplating work on bud-grafting indicates that the progress made up to date in this and other countries warrants further investigation of the method.

"I assume that no person who is keenly interested in the rubber-planting industry is prepared either to extol or condemn any method, which seems to have potentialities for good, until he has made a critical examination of the evidence to be obtained from experimental work carried out on a plantation scale. This is the attitude which I myself take up and I am certain it is the same with most members of my audience.

Bud-Grafting Methods.

"In an endeavour to gain an indication of what has been accomplished by bud-grafting methods, I have

PLATE).
(To face p. 72).

A Rubber Estate at Sikong, North Borneo, showing Hevea trees being tapped by the V system.
(Photo lent by the North Borneo Trading Co., Ld.)

recently inspected experiments and plantings, not only in Malaya, but also in Ceylon and Sumatra. It is with very great pleasure that at this point I can acknowledge the great kindness and cordial assistance which I have received throughout. Of one thing I am convinced, namely, that those persons who are trying out the method, whether research workers or planters, are genuinely inspired with a desire to improve existing methods of plantation practice and that their efforts have met with a considerable degree of success. The simplest thing at the outset seemed to be to take the objections to budded trees, which have been formulated during the last few years and examine their significance in the light of the available evidence. These are I assume, very well known to all present.

" In the first place it has been stated that the junction between stock and scion is always likely to be a place of weakness, so that bud-grafted areas will always be liable to abnormal wind damage through breakages at the union. From experience with budded and grafted fruit trees this is a result that would scarcely be expected, provided the operation was successfully carried out; rather the reverse. In the case of Hevea the union, so far as my experience goes, is very intimate and complete. One would expect this to be the case for the degree of compatibility between stock and scion must, from the nature of things, be very high. A longitudinal section through a bud-graft of Hevea, three or four years old, shows no sign of weakness or incompleteness of union, while sections through younger bud-grafts show that the bud takes in quite a normal manner, and that subsequent development of the scion progresses in precisely the same fashion as in an apple-graft. This also applies to the healing process which results in the 'snag' being thrown off.

" Further, I have seen bud-grafted areas which have been exposed to sudden storms and have examined damaged bud-grafted trees three to five years old. In no case have I seen a union give way, while in two cases the damage to the trees was so great, showing that the strain must have been enormous, that the union could not have failed to give way had it been in any way weaker than the remaining length of the trunk. I might sum up by saying that personal observation leads me to conclude that there is no reason to suppose that the union is a place of weakness.

"A second objection is lodged against the unsightliness of bud-grafted trees. In reality, so far as I can make out, this only means that they are unlike the trees which we have grown up with and grown accustomed to. A similar objection might be made to every fruit tree in Great Britain, for there the signs of grafting—especially of top and double working—can be detected in trees of a considerable age. The 'elephant foot' of a bud-grafted Hevea tree does not interfere with the establishment of a good tapping surface, nor does the cylindrical shape of the trunk. Moreover the swelling below the union becomes less pronounced as the tree grows older. In some cases it becomes almost unnoticeable at an early age. Moreover no attempt has yet been made to ascertain whether the swelling cannot be eliminated or reduced by some modification of the method.

"From an examination of the results of tapping bud-grafts, it appears as though it would be advantageous to begin tapping at a considerably higher level than in a seedling tree. Thus, even by tapping alternate days on a half-spiral cut and allowing for a bark renewal of at least six and a half years, it would not be necessary to approach the union near which it has been proved that the yields fall off considerably.

"Thirdly, it has been stated that bud-grafts are likely to be less resistant or more susceptible to disease. I have seen no evidence for this and the general effect of grafting fruit trees is the reverse. In a few cases it has been shown that physiological diseases, for example, the mosaic disease of hops, can be transmitted from the stock to the scion—if the latter is susceptible. In California the English walnut is susceptible to root-rot; it is therefore never grown on its own roots but is grafted on to a

Black walnut stock which is resistant to root-rot. In such cases the precaution is always obvious; neither infected stocks nor susceptible scions need be utilised, for there are few planters who cannot recognise doubtful planting material. Susceptible stocks or buds of Hevea would therefore quickly become known if they existed and it would be a simple matter to avoid their use.

LONGEVITY.

"A fourth objection that has been advanced is that of a possible adverse effect of bud-grafting on the longevity of the resulting tree. It is held that this will have a span of life shorter than the allotted one for Hevea by the age of the mother tree from which the bud was taken. I can see no reason for this. The only analogy from fruit-growing I am acquainted with is the shortening of life of dwarf bush and standard apples which is usually consequent on years of hard pruning and heavy cropping. In very many cases grafting has the effect of actually lengthening life. Reasoning from analogy is of course justifiable here.[8]

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[8] Mr. Summers is not too optimistic when he says that the process of bud-grafting in very many cases has the effect of lengthening the life of plants, if we remember the results of gland-grafting on animals by Dr. Serge Voronoff. This remarkable scientist writes: "The technique of gland-grafting has been applied by myself and my pupils on several hundred animals in France, Algeria, Tunisia, Morocco, the French Sudan, Italy, and Cyrenaica. The graft is applied both to old animals and to very young ones. In the first case one obtains a rejuvenation marked by regained force and energy. The old ram (Nos. 3, 4 and 5 . . . . .) grafted in 1918, lived to the age of about twenty years, six years longer than its normal span of life, and procreated five offspring that are excellent specimens. The old bull 'Jacky' (Nos. 6 and 7) grafted two years ago, when he had become quite useless, is to date the father of a numerous family......Quite different is the problem of creating a new breed of sheep with superior qualities."

The above elucidation appears in the *Illustrated London News* (21st January, 1928) which states that Dr. Serge Voronoff's method of grafting farm animals with new glands, to increase their vigour and fertility or their wool-bearing capacity, has recently attracted fresh public interest from statements of British delegates on an international mission of agricultural experts who attended a recent demonstration at Tadmit, in Algeria. The British representatives were Dr. F. A. E. Crew, Director of the Animal Breeding Research Department of Edinburgh University; Dr. F. H. A. Marshall, Reader in Agricultural Physiology at Cambridge University; and Mr. W. C. Miller, of the Edinburgh Veterinary College. It is but proper that a subject of great potentiality, such as 'gland-grafting,' should become a matter of interest to all advanced countries and claim the attention of an international meeting.

OTHER OBJECTIONS.

"Other objections to the habit of growth or ridging of the bark and trunk only apply to a few clones and are by no means characteristic of bud-grafts as a whole. In fact I can see no characteristic disadvantage of bud-grafts and the disadvantages that are apparent at present will no doubt be eliminated in time.

" Assuming then that all is right with the method itself, let us examine the position from the point of view of the plantation and see what benefit can be safely expected from the application of the method there. It is somewhat easier to indicate what cannot be guaranteed. For example, however good a mother tree may be, it can never be sufficient to rely on the yield records for a few years to give the necessary confidence for planting up a large area of bud-grafts directly from it. The quality of a tree as a mother tree can only be determined accurately by the tapping of its buddings so that the first planting of a clone can only be regarded as a tapping trial. Even then the tapping should be carried on at least into the eighth year before a true indication can be gained of the yielding capacity of the trees. Conclusions have sometimes been drawn from the tapping results for a few months but it is never safe. A good yielder will remain a good one but a bud-graft which gives a low yield in its fourth or fifth year may improve out of all knowledge during the next two years. (*Mr. Summers here referred to a paper by Mr. Grantham, then explained certain charts on the board.*)

"These tapping trials will continue to be necessary until we have some method of identifying the high yielder at a much earlier stage. There is pressing need for research work on this point although I cannot say that definite results are bound to accrue. I have always been of opinion that an intensive study of the systematic characters of Hevea varieties and forms, combined with an investigation of their latex characters, would be the first line of attack and it was of the greatest interest recently to read in the Press that Hauser had laid the foundation of such work by investigating the hereditary character of latex particles. It is to be hoped that Hauser's work will stimulate activity in research along the above lines in every rubber research institution.*

COMMON MISTAKES.

" While these difficulties of testing clones are present, it is somewhat surprising to find that, in many plantation trials of bud-grafting, the commonest mistakes, to be made are, first, losing all trace of the mother tree from which the bud-wood came, and secondly, trying out simultaneously too many clones. The amount of measuring, book-keeping, supervision and training of personnel involved in trying out four to six clones is, in my opinion, as much as the ordinary Estate staff can undertake if the results are to have the necessary reliability. Pedigree bud-wood is likely to be of considerable value in the future—material of uncertain ancestry is worse than useless, it is, positively dangerous where a perennial crop is concerned.

" As you know the tendency in other rubber-producing countries is to rely on a central, controlled Experiment Station for the supply of proved bud-wood. The success of this procedure is reflected by the large quantities requisitioned by and supplied to estates. Individual estates are relieved of the responsibility and labour of trying out clones for themselves and can rely on the high quality of the material supplied.

" It has been shown beyond doubt that better yields can be obtained from well-proved clones than from trees grown from what is commonly known as selected plantation seed. (In parenthesis I may remark that this seed is never selected in the genetical sense of the word so that the resulting trees must vary in quality to a very great extent.) I do not consider, however, that the best

*Dr. Ernst A. Hauser is a leading authority on colloid chemistry in Germany. His researches on the physico-chemical properties of latex are of special value to the rubber industry.

method of tapping bud-grafted trees has yet been developed. As I mentioned earlier it has been shown beyond question that the yield falls when the cut approaches the union so that the obvious thing is to begin tapping at such a height that the most suitable period for bark renewal can be secured without the necessity for the panel to reach the region near the union. What this height should be remains to be worked out and of course the problem will be complicated by the difficulty of tapping above a height of four feet. The best period for bark renewal also remains to be worked out.

Reciprocal Action.

"One phase of the bud-grafting problem which urgently calls for investigation is the reciprocal action on one another of the stock and scion. I am apparently begging the question here for such action has not yet been indubitably demonstrated.

"Hauser rightly calls this question the dark spot of the vegetative selection of Hevea, for although he has not yet remarked any obvious effect of the stock on the yield of the scion, we must have the following questions settled as early as practicable. Has the stock any effect on the production of the bud-graft? Is the union such a disturbance of continuity that the yield must be adversely affected or has the stock the usual property of so increasing the vigour of the scion that the yield of the latter is correspondingly increased? There are ample grounds for suspecting some kind of influence for it has been recognised that the yield from a bud-graft may at times be surprisingly different from expectation. Again in a population of bud-grafts the yield generally shows a high degree of uniformity, but now and again considerable variation is encountered. Such variations are almost certainly not due to heredity and are probably due to some simple cause; but as the buddings are generally on unselected stocks there is always in the background a possible unknown source of variation.

"It is even quite possible that eventually we may have to select and propagate our stocks as carefully as our bud-wood. Research work in England has shown of recent years that in the case of apple and plum stocks this is vital to success, although again I ought to recall the danger of reasoning too closely from analogies. I have also noticed one or two possible cases of bud mutations or spots; where the sudden variation of a bud has produced a form quite distinct from that of the mother and capable of being multiplied and retaining its new form. A constant watch should be kept for these which might perchance prove to be of value.

" In conclusion it is frequently asserted that bud-grafting is but a temporary measure which will become superfluous as soon as surplus of seed are available from high-yielding pure lines. I think the up-to-date planter will always find it necessary to have the method at his command for a variety of purposes and most certainly until he is confident that the seed he is producing is pure and not contaminated by cross-fertilisation from neighbouring low-yielding trees. Moreover it must be remembered that selection and breeding work on a perennial tree of unknown character like Hevea must be a long and laborious proceeding. The view to be taken is a long one, and, while awaiting results, no one can afford to stand still. The best means to hand at the present time must be used, that is, careful and cautious application of the bud-grafting method.

" My discourse on the present position of bud-grafting has, I am afraid, been somewhat lengthy and diffuse. It might have been summed up in the following sentences. Bud-grafting is a horticultural operation which has been applied with an encouraging measure of success to the vegetative propagation of Hevea. The maximum benefit to the rubber-growing industry cannot, however, be obtained without much further research directed towards the improvement of the method itself and the testing of the budded progeny. Much of this work can only be carried out efficiently at a central experiment station in the form of extensive trials under plantation conditions. The large undertakings which have achieved such a striking measure of success by employing the method owe their success to keeping these principles in the foreground."

While bud-grafting has not yet passed out of the experimental stage as regards its final operations, such as the tapping of budded trees and the testing of their latex, the above thoughtful discourse of Mr. Summers ought to convince the most sceptical planter that it has already shown results which are decidedly encouraging else the rubber research institutes of the Dutch East Indies, Malaya and Ceylon would not persist for years in their efforts. In consequence, if the scientific principles which Mr. Summers enunciates are borne in mind, properly conducted work on bud-grafting ought to meet with greater success in course of time.

PLATE 10.

(To face p. 81).

Budded Hevea trees in the United States Rubber Plantations at Sumatra, with silt pits for soil conservation.

(Reproduced from the "India Rubber World.")

CHAPTER VII.

INTENSIVE RUBBER CULTURE.

THE ECONOMIC PRESSURE.

Although the demand for rubber has grown rapidly in recent times, the market tends to indicate that an increasing consumption must be accompanied by a gradual lowering of the price level. It also appears that, if an increasing supply is restricted arbitrarily, the growing demand has a tendency to be switched off to some rubber substitute. In other words, the natural product cannot be used by an ever-widening circle of consumers unless it comes well within their reach. At least such is the position at present, probably owing to a decline in the purchasing power of the world after the great War. This is the economic pressure which is being felt in almost every industry and rubber growers can find no escape from it. In truth it is the consciousness of growing competition, within and outside its own sphere, that has brought about a desire in the industry to improve the productivity of estates by the adoption of scientific methods. Those who are unable to foresee the future are likely to suffer in the impending struggle.

Scientific methods must, however, be utilized to meet certain definite economic requirements. "A rubber plantation," explains a noted rubber journal, "represents an intensive culture where every tree has an economic value. Each tree's characteristics as to rubber yields must be known, much as the records kept by a dairyman of the yields of his herd. Each tree must be taken care of individually if attacked by disease. Its possibilities as a source of buds or seeds for the artificial propagation of its kind must be known. In short, the estate can no longer be regarded as a collective unit of so many trees giving a total yield of so many pounds of rubber a year; it is an orchard of individual trees where everything which science has discovered must be taken advantage of to improve the breed, the yield and the quality of rubber."[1] Sound reasoning indicates, therefore, that the methods necessary for the improvement of rubber estates should be directed towards (*a*) *an increase of outturn,* (*b*) *a lessening of disease,* and (*c*) *a betterment of quality.* The reasons for such a policy are not far to seek.

A Review of Modern Research.

Research workers explain that the yield of rubber is something which depends directly upon properties inherent in the tree itself, such as its morphology, physiology, etc. Indirectly the yield may be influenced by soil, climate and other factors in the environment, but little can be done to improve the yield beyond the tree's specific capacity. Hence to raise the outturn, it is necessary to select and breed trees which have a high capacity as an inherent characteristic.

Disease resistance is also an innate faculty of certain trees, though protection against ailments is often possible with timely care by the aid of mycology entomology, etc. Reports from Sumatra go to show already that buddings from different mother trees indicate variable disease resistance. Such is the case with most living things. As instances, we know that even members of the same family display disease liability differently, that Holstein cows are less susceptible to tuberculosis than Jerseys, that some varieties of the same species among fruit trees are immune to certain diseases while others are easy victims to them. Because this immunity to disease is inborn rather than acquired, those strains which display the resisting faculty are selected and propagated. So far in the selection of rubber trees for propagation this characteristic has been

[1] *India-Rubber World,* New York, October 1927.

regarded but perhaps not so much as the more important one of higher yields.

Regarding variation in the quality of rubber, the problem has not been investigated so far in connection with artificial propagation. Still it is well-known that the latex of every tree in the same plantation is not the same in rubber content, colour, etc. This fact is supposed to be largely responsible for the 'variability' that is complained of by technologists who in consequence think that a standardization of quality is desirable. But since these differences are reduced by the practice of bulking all latex, the problem of minimizing variation in quality is of minor concern comparatively and has been left alone for the present to await future investigation.

On the principles above referred to, there are several systems by which the stock of plantation rubber may be improved. These have been described as (1) *seed-selection,* (2) *the choice of seedling,* (3) *vegetative propagation by bud-grafts,* (4) *artificial pollination, and* (5) *the empirical method of planting a large number of trees and selecting therefrom on test results.* All these systems are being experimented upon with varying results. In a leading world industry, progress can come rapidly if the experience of all workers is freely circulated.

Apparently the earliest experiments on seed-selection and bud-grafting, as applied to the Hevea, were begun about the year 1915 by Mr. W. M. van Helten, scientist of the Cultuurtuin (Botanical Station) at Buitenzorg, Java, and Mr. G. F. Bodde, Manager of the Pasir Waringin Estate, Java, in consultation with Dr. P. J. S. Cramer. It is reported that early in the last decade *the wide variation in the yield of rubber trees* was observed and the idea then emanated of developing a better stock of the Hevea by selection and reproduction. Van Helten's work stimulated interest and the United States Rubber Plantations, Inc. of Sumatra (known by the symbol H.A.P.M. standing for the Holland-American Plantation Maatschappi), followed in his footsteps with selection work in 1917. A report of the subsequent work of the H.A.P.M. on bud-grafting has recently been published, which may be reproduced here.

THE STORY OF BUDDING.

"The superiority of the stock that was to be selected and multiplied had to be established. This part of the program was very important. It was attacked in two ways. First, they had to determine beyond doubt that a tree which was yielding more than its neighbours, did this year after year because of its inherent nature. If it did, then that property could be expected to be reproduced in its offspring. Also they had to establish the converse, that a poor yielder always remained as such. To make this determination, the yield of every tree on a uniform area of 12½ acres was collected every day, and records of the dry rubber from each tree were made twice a month. These records, begun in March, 1917, have been continued to the present time. The results of nine years' records are grouped in Table I.

Table I.

Class.	No. of Trees.	Average Actual Yield per Tree in Lbs. per Year.
1	1	21.7
1	3	18.0
1	7	15.8
2	22	13.1
2	52	10.8
3	127	8.6
3	313	6.1
4	351	3.7
4	42	2.1

Total trees=918. Average yield of all trees =5.9 lbs. annually.

"From this table we note that the yield of the best class is over three times the average yield. The distribution of the different classes is significant. On this particular area, about 90 per cent. of the trees gave a yield of about 5 lbs. per year, as against the 10 per cent. giving an average yield of about 16 lbs.

"This experiment formed the groundwork of subsequent research. The next step was to survey the whole plantation for the purpose of confirming these preliminary results and then for the selection of the superior trees. To facilitate the work it was decided to measure the yield once a month for each tree. Certain symbols were devised to correspond with various amounts. For example, one dot would mean 5 cubic inches of latex; two dots, 10 cubic inches and so on. The tapper on the first of each month would pour the latex from the cup into a glass graduate marked with the symbols and record on the tree above the tapping surface the appropriate symbol. This method was first proved accurate enough by statistical calculation. In this fashion about 4,500,000 trees on 37,000 acres were tested, marked and classified for four consecutive years.

"After the first year's marking, they selected the highest yielders and indicated them by a special symbol. To make a refinement on the method, all the high yielders were subsequently measured with a special large-sized glass graduate and the yield recorded. The results of the survey over 37,000 acres after four years' recording, are grouped in Table II.

Table II.

Class	No. of Trees.	Per Cent. of Total No. of Trees.	Average Yield in lbs. Dry Rubber for 1921.
1	1,292	0.03	14
2	31,478	0.70	10
3	198,411	4.50	7

The average yield for 1921 for all trees was ± 3 lbs. per year.

"From these superior classes they next chose 250 of the very best for permanent record. These trees were tapped daily, the dry rubber was weighed and recorded separately. It was found that the premier tree gave during 1924 a yield of 55 lbs., and 52 lbs. the next year. Seventeen of these trees in 1924 and 21 in 1925 gave a yield in excess of 30 lbs. Since all these trees were scattered in the ordinary plantations and were not favored by isolation to make their maximum development, the ordinary yields of 30 to 54 lbs. are the more remarkable. Perhaps it would be expecting too much to be able to reproduce an extensive area of such extraordinarily high yielders. And yet, why not?

THE BUD GRAFTS.

"The basic selection having been performed, the very best trees having been singled out, the next thing to do was to bud-graft by using buds from these superior trees. The first buddings on H.A.P.M. were made in August, 1918. Buds obtained from mother trees were grafted on to seedlings in nursery beds. In November, 1918 ten acres were planted up with these buddings. These same buddings were the first to be brought into tapping. Sixty of the best developed were tapped on May 2, 1922. A few days later tapping operations were also commenced on buddings at Pasir Waringin Estate in Java. Following the success of these first buddings, larger scale plantings exclusively with buddings were made in 1920 and 1921. Buddings alternated with selected seed were extensively planted in 1921 and 1922. In these buddings, only material from Class I mother trees, recorded on the basic selection program of 1918, were used.

"Considering the uncertainties of the yielding power of buddings, and the influence which the root system of the stocks might exercise on the physiology of the budding, it took courage and faith to plant extensively with buddings. The alternate budding and selected-seed plantings are a reminder of the existing doubt. If the buddings failed, the selected seed could be relied upon to yield as good a return as by the old method.

BUDDINGS ARE TAPPED.

" In speaking of buddings, we will have to use the word clone. A clone means the offspring of a single mother tree by vegetative reproduction as opposed to seeds which are by sexual reproduction. It was expected that the inherent characteristics of the mother tree would be reproduced in its offspring by the budding operation. A clone shows the family trait. The yield trait of the clone seems to be constant, as will be noted in Table III.

Table III.

	Average Yield in lbs. per Tree per Year.			
	4th.-5th. Year.	5th.-6th. Year.	6th.-7th. Year.	7th.-8th. Year.
Clone				
A Good ..	5.7	7.4	9.6	8.6
B Good ..	4.7	8.5	11.0	11.4
C Good ..	3.9	6.7	11.2	10.6
D Fair ..	2.2	3.8	6.5	7.8
E Fair ..	3.2	5.7	7.6	7.4
F Poor ..	1.2	2.2	3.1	3.6
G Poor ..	1.2	2.1	3.3	4.2

" From the above we conclude a constancy in yield power is to be expected from each clone. However, we also are forced to note that a basic selection of clones is necessary. From 1921, the H.A.P.M. staff set out its seed nurseries with wider spacing than usual, bud grafted the seedlings, then forced the budding to develop, and when the buddings were about three years old they were test tapped. All subsequent budding material that was to be used for multiplication of the best yielders came from those clones in the nurseries which recorded the highest yields. Test tapping is the only means known at present to predict the quality of a clone with respect to yield.

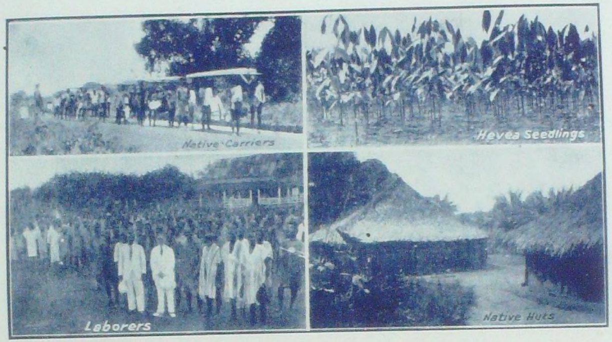
"Buds obtained from the one-year-old shoots of the clones selected in the nursery by test tapping were found satisfactory for use as planting material or for multiplication of such clones in the nurseries. And thus was established a method to get an unlimited supply of planting material of the best known yielding capacity—pedigreed stock, in other words. Since 1923, H.A.P.M. has used about six selected clones for planting new areas. As a measure of safety, these six clones have been mixed in any given area. As a further caution, the policy is followed of interplanting buddings with seedlings grown from seeds derived from superior clones.

Is it Safe to Plant Buddings Alone?

" Experience with buddings is too recent to justify broad conclusions and a fixed policy. Tapping of buddings has extended over four years only. Nothing is known so far as to bark renewal. Clones will require careful observation over a long period. It has not been all smooth sailing. It has been found that certain clones displayed particular weakness against disease; other clones showed a distorted renewal tapping surface with protuberances similar to brown bast effects; other clones failed to show a gradual normal increase in yield, even declining in yield in some instances. These illustrations suffice to prove that caution must be exercised in selecting the clones which will determine the final character of the trees on the plantation. Sufficient progress, however, has been made with buddings to warrant the belief that they offer a very satisfactory means of improving the character of rubber trees at present found on all plantations in the Middle East. The method outlined above is a practical one that may be made use of on present estates. There are estates perhaps in British Malaya which could produce clones superior to those reported from the United States Rubber Plantations. It may be possible to produce extraordinary yields from

PLATE 11.

(To face p. 88).



Typical Scenes from the Firestone Rubber Plantations in Liberia, Africa.

(Reproduced from the "India Rubber World.")

clones derived from exceptional trees in the high plateau region of the Upper Amazon.

"Proved clones are at present restricted to only a few estates. Even where they do exist they must be multiplied many times for large scale opening. To start from the beginning takes time. Allowing two years for basic selection of mother trees, five or six years for development of clones and test tapping, and two years for multiplying the proved clones on a sufficiently large scale means at least ten years. A couple of years could be saved by not test tapping in the nurseries, leaving the rejection to thinning operations in the field.

"There are advocates of seedlings as a better bet. They claim that a seedling having its own root system will be better than a budding. They insist it is better to establish buddings in isolated areas. Then when these buddings develop, the seed derived from them as a result of self or cross-pollination from the same clone will reproduce all the characteristics of the mother tree. These contentions are quite plausible. There is room for both methods and doubtless both systems will be used to mutual advantage. One thing is certain—the old haphazard method of planting is no longer justifiable."[2]

INVESTIGATIONS INTO HEVEA LATEX.

Dr. E. A. Hauser, the eminent scientist who is investigating the physico-chemical properties of various latices, is reported to have made an interesting discovery. "In his experiments with Hevea latex," reports a leading rubber journal, "he found that among the particles contained in a small quantity there was one globule of peculiar shape. This globule in one tree differed from the globule in another tree, but when a tree was grown from seed of another tree, examination of the latex would show that the distinguishing particle of the offspring was identical with that in the latex from the parent tree, consequently from the known

[2] *India-Rubber World*, New York, October, 1927.

qualities of the parent it would be possible to tell those of the offspring at a very early age. He has discovered what seems to be a law, but a good deal of work has still to be done in this direction. Besides this a number of experiments have been conducted to discover the production of latex within the tree, a problem of great importance as affecting tapping systems and the life and growth of the tree."[3] These experiments have still to be completed. While it would be unreasonable to expect on slender grounds the discovery of a natural law connected with the inheriting propensity or otherwise of latex particles, Dr. Hauser hopes that results, which will greatly benefit rubber producers, will be attained eventually by his experiments.

Hauser's work leads the way to a valuable line of research. Hitherto attention has been chiefly confined to the productive capacity of mother trees. To obtain the necessary bud-wood, such trees are selected as consistently give high yields under all circumstances. Then after propagation, the budded trees, at about the age of five years, are tested to ascertain if they have inherited the high-yielding capacity of the mother trees. All this work is undertaken with the object of selecting material having the best yield in quantity irrespective of quality.

But in the vegetative propagation of Hevea by means of bud-grafts, attention must also be directed to the *quality of the latex* from these selected trees, the reasons for which are obvious. Some trees yield latex with a higher rubber content than that of others, also the dry rubber obtained from the latex, when tested, may be found to be weaker or to have a slower rate of cure.

Such variation in quality offers no difficulty on present day plantations where the differences are neutralized by the great diversity of the trees and the extensive mingling of the latex. But in future estates,

[3] *India-Rubber World*, October, 1927.

consisting of bud-grafts from a few mother trees, a serious problem might arise in this connection. Should the product of one or more of the mother trees show any abnormality as to rate of cure, slope, tensile strength, etc., it is quite possible that the bud-grafts will repeat these weaknesses, with the result that the entire plantation may yield rubber with abnormal properties.

To test the quality of latex from budded trees, Dr. O. de Vries and Mr. W. Spoon conducted some experiments at the Rubber Research Station of Buitenzorg, Java. They tapped six mother trees and some of their bud-grafts from 1924 to 1926. The mothers were from 17 to 43 years old and the offspring from 6 to 7 years of age. "When the latex of the six trees was examined," states the report, "it was found that in the case of three trees the proportions of serum constituents and rubber content were not favourable, while in the case of two trees, including one of the preceding three, the dry rubber showed low viscosity, low tensile strength and high slope; that is, these trees yielded a poor grade of rubber."[4]

"Bud-grafts from these trees," continues the report, "were planted during 1918-1919. Tapping tests in connection with this investigation were begun when the trees were only six years old, but at that time the influence of the age of the trees was too prominent in the results to be of much value. However, the following year these tests were resumed and it was then found that the abnormalities observed in the latex of three mother trees, as described above, were apparently not inherited by the offspring. On the other hand, the slow rate of cure of one of the mother trees was repeated in the bud-grafts, as well as the weakness of the vulcanized rubber in one instance and the low viscosity and plasticity in two cases."[5] The number of bud-grafts on which these tests were made is not given, but obviously it was not considerable, and so, the tests can by no means be regarded as conclusive. In any case, they

[4] *India-Rubber World*, New York, November, 1927.
[5] *Ibid.*

show that bud-grafts may inherit one or other abnormality from their mother trees, and, owing to this possibility, there is need for much investigation on the quality of latex from budded trees.

Hevea Latex and Raw Rubber.

There is room here for the argument that even though tests have been made of latices from different trees for many years, no proper remedy has been found for 'variability.' This is quite true, but the reason for the failure is that no proper research has yet been made in this direction, as there was no pressing need for it owing to the rough practice of bulking all latex. However we cannot afford to get on in the old way much longer, and this problem must be tackled on the cultural side both from the quantitative and qualitative points of view. Periodic tests of latex and raw rubber from existing estates must continue to be made with a view to devising some means for the betterment of quality. The following is the abstract of a report of the London Committee of the Ceylon Rubber Research Scheme on the results of investigations carried out at the Imperial Institute, London:

It was considered in Ceylon that it would be of interest to determine the extent of variability in rubber prepared commercially on different estates, as it was thought that the information obtained would be useful in planning future investigations. A set of estate rubbers, consisting of twelve samples of smoked sheet, seventeen of air-dried crepe and ten of machine-dried crepe (*i.e.*, dried in hot air), was therefore collected from twenty-four estates and forwarded to the London Committee for examination. The question of the tests to be applied to these samples was considered by the technical sub-committee in London and it was decided to examine the whole series for variability in the following respects, each of which is of importance in considering the suitability of rubber for manufacturing purposes: (1) Plasticity. (2) Time of vulcanisation and tensile strength of a rubber-sulphur mixing. (3)

Mechanical properties when vulcanised in a mixing containing zinc oxide and diphenylguanidine, the latter being an accelerator of vulcanization.

"These investigations," states the report, "show that as regards plasticity the most uniform type of these estate rubbers from Ceylon is machine-dried blanket crepe, which is a product peculiar to the colony. Smoked sheet is fairly soft on the whole, but is variable. Air-dried crepe is frequently tougher than the other forms. It appears, therefore, that the temperature of drying is of importance in connection with the plasticity of the rubber as received by the manufacturer, and that in the case of sheet rubber, drying in smoke serves the useful purpose of making the rubber more easily worked in the factory.

"It is presumed from the correlation between the results of plasticity and vulcanizing tests, that rubber from coagulum which has been allowed to mature is tougher than that from coagulum which has been machined and dried quickly. If this is the case, the extent to which the coagulum has matured appears to be an important cause of such variability as occurs not only in respect of vulcanizing properties, but also in respect of plastic properties. The vulcanizing properties of the samples, in a rubber-sulphur mixing, are fairly uniform and similar in this respect to rubber from Java, but only the machine-dried crepe satisfies the high standard of uniformity desired by some manufacturers.

"The results obtained in a mixing containing zinc oxide and an organic accelerator of vulcanization indicate that variations in vulcanizing and mechanical properties in this mixing are of no importance.

"A consideration of the results recorded in this report suggests that further investigations would be desirable to determine (1) the cause of the variable plasticity of smoked sheet, (2) the effect of hot-air drying on the plasticity and uniformity of crepe, (3) the effect of different periods of maturing the coagulum on the plasticity of crepe and sheet, (4) the degree of uniformity which it is possible to obtain in plasticity and vulcanizing properties when rubber is prepared under the most carefully standardized conditions, and (5) the effect of different proportions of various compounding ingredients on uniformity."

THE SPREAD OF SCIENTIFIC METHODS.

Intensive rubber culture first began in the Dutch East Indies, then spread to the Malay Peninsula and has now come to Ceylon, though it is still conducted in these regions on a small scale experimentally. The Director of Agriculture, Ceylon, in his administration report for 1926, writes cheerily that the Rubber Research Scheme continues to receive increasing support. **The acreage of members represents about 62 per cent. of the total rubber acreage in the Colony. Considerable attention has been drawn during the year to the importance of bud-grafting rubber as a means of selection. This has been demonstrated in the Dutch East Indies and the visit of Messrs. C. E. A. Dias and H. W. Roy Bertrand to see what had been accomplished tended to centre the attention of Ceylon rubber planters on this question. The present position has been placed as clearly as possible before the industry and proposals have been formulated by the Board of Agriculture for a forward policy. These proposals appear to have received the support of those connected with the industry and there is no doubt that if Ceylon is to maintain its industry in a position to meet with competition in the future, steps must be taken to provide the necessary funds for the establishment of special Experiment Stations for testing out mother trees and of seed gardens for the supply of selected seed. A large number of estates are now taking yield records preparatory to starting budding. ***Plans were also made to have bark examination of all trees in the possession of the Department of Agriculture, and certain of its highest yielding trees were lopped to provide budwood for budding purposes; 415 feet of budwood of Heneratgoda No. 2 tree were sold during the year.

CHAPTER VIII.

PROGRESS IN RUBBER PREPARATION

IMPROVEMENTS IN TECHNOLOGY.

Rapid developments are taking place in the rubber industry, not only on the agricultural but the chemical and manufacturing sections, some of which call for investigation from planters because their adoption by manufacturers would necessitate some changes in the factories of plantations. A transition of this kind usually takes time to materialize. But, when the price of the raw material has a downward tendency, as in recent times despite slight fluctuations, progress in the economic methods of rubber preparation is likely to keep pace more or less with the decline in price.

Early in this decáde the stabilization of price and the standardization of quality were among the urgent problems connected with raw rubber. Price stability was sought by the Stevenson Scheme with results which have shown at least some little improvement. Quality standardization is also a problem to which much attention has been given for a long time. In consequence the methods of crude rubber preparation have been improved so as to avoid variation in particular standards and to effect economy in the cost of production. "The influence of numerous factors," observe two noted technologists, "such as that of the tree, conditions of soil, methods and periods of tapping, dilution of latex and the details of the coagulation, washing, drying and smoking processes have been thoroughly investigated, not only in regard to their effect upon the rate of cure and tensile characteristics, but also on such properties as plasticity and ageing."

"The problem to-day," they explain more lucidly, "is not that of discovering the causes of variability, but of devising some practical scheme of applying to different estates the methods which are known to lead to uniformity of properties in the final product. But let us suppose for the moment that the planter is in a position to overcome the problems of variability and asks the manufacturer what are the properties which he desires in his plantation rubber. Are we yet in a position to make up our minds on the subject of uniformity of requirements? There are, of course, certain desiderata, such as freedom from contamination with splinters, bark and grit, the absence of massing in the packed rubber and the avoidance of 'freezing,' about which there would be general agreement. On the other hand, there are other important properties of raw rubber upon which there does not seem to be any general consensus of opinion. *** The increase of fuel costs during recent years, however, has brought the questions of plant modernisation and better factory lay-out to the forefront, and the engineering practice of the industry is undoubtedly now undergoing a much-needed change for the better."[1]

Apart from these aims, the planter has sought to provide the manufacturer with the properties he desires to have in his raw material. Of the present standards of quality for plantation rubber, it is stated on high authority that manufacturers generally seem to award the first place to 'a tough, nervy, quick-curing product,' and that 'a more plastic rubber of medium curing speed would be more suitable for general use.' In the past, variability in particular grades was not the only shortcoming.* In addition to it certain processes were

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[1] Paper on *The Problems of Rubber Manufacture* read by Dr. S. S. Pickles and Mr. B. D. Porritt at the International Rubber Exhibition held at Paris in 1927.

*In former years, the raw product was standardized largely by tradition and partly by the skill of the compound man. Now, with the help of science, the industry answers to the changing scene by the use of better machines, chemical materials and mechanical methods. A few instances may be cited to show merely the chemical development. To prolong the life of rubber, agents known as 'anti-oxidants' are used. To hasten or modify the conditions surrounding vulcanization, chemical devices known as 'accelerators' are employed. In vulcanization itself, the use of sulphur can be dispensed with by the application of a catalyst or neutral agent known as 'trinitrol-benzol.'

unnecessarily prolonged and wasteful methods characterised almost the entire industry. There was prodigality in fuel consumption and culpable thoughtlessness in the waste of energy both manual and mechanical. These problems have not yet been properly solved. In recent years, however, investigations conducted with latex have led to some marked technical progress which is far more fundamental in character than the standardization of quality or the economical preparation of crude rubber. This progress foreshadows an extensive change in rubber technology during the next few years, as will presently appear.

THE CHANGING PRACTICE.

In the plantation factory, the present method of preparing raw rubber is undergoing some necessary change. In accord with the old practice, the latex is coagulated by means of acids and its rubber content (about a third of the latex) is obtained like white dough in the form known as 'coagulum.' This last is then removed from the vats and run into sheets through machines the hot rolls of which iron out its moisture. Finally the sheets are dried in air, smoke or vacuum, and then made ready for shipment. In recent years, however, a better technique has been initiated by the preparation of 'sprayed rubber.' After the latex is assembled in the factory, it is filtered, and then a preservative, negligible chemically, is added to it. The moisture is next removed from the latex in the 'spray' plant where the latex is finally transformed into sprayed rubber by the process described below. In some estates also the chemically preserved latex is being shipped direct to the manufacturers in steam-ship tanks because the use of such latex, especially in the manufacture of tyres, has been found to possess decided advantages over the use of sheet, crepe and other rubbers, apart from the economy in price and labour it effects.

There are many thousands of separate cords of cotton in a standard 8-ply cord tyre. Formerly the prevailing practice in the manufacturing industry was to build up tyres on moulds, cores or forms. Simply but of devising some practical scheme of applying to different estates the methods which are known to lead to uniformity of properties in the final product. But let us suppose for the moment that the planter is in a position to overcome the problems of variability and asks the manufacturer what are the properties which he desires in his plantation rubber. Are we yet in a position to make up our minds on the subject of uniformity of requirements? There are, of course, certain desiderata, such as freedom from contamination with splinters, bark and grit, the absence of massing in the packed rubber and the avoidance of 'freezing,' about which there would be general agreement. On the other hand, there are other important properties of raw rubber upon which there does not seem to be any general consensus of opinion. *** The increase of fuel costs during recent years, however, has brought the questions of plant modernisation and better factory layout to the forefront, and the engineering practice of the industry is undoubtedly now undergoing a much-needed change for the better."[1]

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There are many thousands of separate cords of cotton in a standard 8-ply cord tyre. Formerly the prevailing practice in the manufacturing industry was to build up tyres on moulds, cores or forms. Simply coatings of rubber were used between sheets of fabric and then cement, pressure and vulcanizing did the rest. But cotton did not 'like' the rubber and it became necessary to squeeze the rubber into the fabric. This was found possible because cotton 'likes' latex. Accordingly, in the magnificent plants where tyres are made, a better technique has been adopted. There you find cotton cords run off spools through a bath of latex which permeates the liquid into every microscopic cavity of the cord. The result is that there are no cross threads, as in fabric, to work, create friction and cause internal wear. The new system is naturally a great improvement in tyre manufacture.

SPRAYED RUBBER.

In addition to 'sheet' and 'crepe' rubbers, 'sprayed' rubber is beginning to find a market. The last-named grade is being prepared by a process in which the latex is sprayed on to a drum through hot air, so as to form a mist of fine droplets. It claims to possess a more even and regular layer than some of the other varieties as a point in its favour. A defect of this rubber, however, is said to be its hardness and the resistance it offers to milling.

Mr. Ernest Hopkinson is reported to have first conceived the idea of making sprayed rubber by atomizing latex nearly a decade ago. His 'atomizer' introduces the latex into a hot-air chamber in which a polished steel disc revolves at a very high speed. The latex falls on the disc and is atomized by its rotation. It is then whirled off into space by the tempest and the particles of rubber are dried instantly at a suitable temperature. The particles settle like snow on huge trays mounted on casters. When withdrawn the trays contain sprayed rubber of a pure and uniform quality. This rubber is preferred to 'sheet' or 'crepe' by many manufacturers owing to its greater suitability for various kinds of rubber goods.

PRESERVING LATEX WITH AMMONIA.

Dr. O. de Vries and Mr. N. Beumee-Nieuwland, of Buitenzorg, writing in the *Archief Rubbercultuur*

(1927, 17-18) explain a method of preserving latex with ammonia. An abstract of their description appears in the *Journal of the Society of Chemical Industry, London, 25th November,* 1927, as follows:—

"To maintain latex in good condition in open tanks for 24 hours on the plantation, the addition of 0.07 per cent. of anhydrous ammonia is sufficient. The decrease in alkalinity observed earlier in stored latex preserved with a sufficient proportion of ammonia is found to be due to loss by evaporation and not to any chemical or bacterial action. If the proportion of ammonia, however, is insufficient, the bacterial decomposition, which leads to coagulation, also leads to the formation of acids which cause a rapid decrease in the alkalinity. Spontaneous coagulation in ammoniated latex appears to be due to a decomposition of different type from that in non-preserved latex, the clotting in the former case occurring at a lower degree of acidity. The deposit which forms in freshly-ammoniated latex consists mainly of water, ammonium magnesium phosphate and rubber, with smaller proportions of other mineral matter, protein, dirt, etc.

"The alteration in the rate of vulcanisation of the rubber in preserved latex on storage is not accompanied by any corresponding change in the alkalinity or in the nitrogen content of the rubber; the viscosity and plasticity remain almost constant and show a decrease only in old ammoniated latex. Rubber from ammoniated latex shows normal behaviour with respect to a slight decrease in viscosity and plasticity on storage; the tensile strength and slope remain constant, whilst the rate of vulcanisation gradually decreases and approaches the value for the control from unpreserved latex. With increase in the age of the ammoniated latex up to six months, the rate of vulcanisation and viscosity of the rubber decrease whilst its plasticity is constant, and its condition remains good even after one-and-a-half years."

THE USE OF FUNGICIDES.

Since the introduction of sprayed rubber, there does not appear to be any other new process in crude rubber preparation, but in regard to certain rubbers, a slight improvement in their curing has taken place.* This consists in the use of some fungicide (disinfectant) to prevent the growth of mould, spot and rust which lessen their value in the market. Either a little of the fungicide is dissolved in the acid used for coagulation or after rolling the sheets are soaked in it for a while, but the nature of the fungicide must be such as to have no adverse effect on the vulcanizing properties of the rubber.

A great authority on rubber chemistry thinks that "the use of fungicides to prevent mould developing in plantation rubber, whether sheet or crepe, is to be encouraged, always provided that such fungicides have no appreciable influence on the vulcanizing properties of the rubber. Substances of this type are para-nitrophenol, di-nitro-ortho-cresol both of which are effective at very low concentration. Thus, the sheets may be soaked after rolling in a 0.1 per cent. solution. Alternatively, a little of the fungicide may be dissolved in the acid used for coagulation. The only defect attaching to the use of these substances is their pronounced yellow colour, which is noticeable even in very dilute solutions. This is, of course, not a real defect for the vast majority of purposes for which rubber is used. The colour introduced by the ordinary smoking process for sheets is much more intense and masks any slight coloration due to fungicide; but, in the case of crepe rubber, the colour is sufficient to be noticeable although not very pronounced."[2]

*The word 'curing' has been used here, as also in pp. 37 and 38, in the broad sense understood in some agricultural industries when the 'treatment' of raw materials before manufacture is implied. In rubber technology, however, the word 'cure' now merely means 'vulcanization,' though formerly the word was used to signify 'drying' or 'smoking' and the curing effect connected with it. See Wright's *Hevea Brasiliensis*, Colombo, 1906, pp. 108 and 119, also Woodroffe and Hamel Smith's *The Rubber Industry of the Amazon*, London, 1915, pp. 44 and 46.

[2] Paper on *New Methods and Modifications in Rubber Preparation* read by Dr. H. P. Stevens at the International Rubber Exhibition, Paris, 1927.

HIGH COST OF SMOKING RUBBER.

The smoked sheet variety is produced at a high expenditure—often one ton of firewood being required for every 185 lbs. of smoked sheet—although it is feared that there will be a dearth of wood, available at a reasonable cost, in the not-distant future. "There is a shortage of firewood for sheet-smoking," remarks Dr. H. P. Stevens, "in many districts in the Federated Malay States and Ceylon, and this shortage is growing and will become more acute in the future. Now, if sheet can be prevented from becoming mouldy by the use of a fungicide, air-dried sheet could be put on the market in quantity in place of the smoked sheet at present produced. It is, I think, now generally admitted that the smoking is not beneficial, although it may be harmless in respect to the vulcanising properties of the rubber. Certain manufacturers have even shown a preference for unsmoked sheet."[3] Probably there would still be the difficulty of preparing air-dried sheet without artificial heat of some kind in wet weather. Here it may be added that 'rust' is a thin brown film which forms on the surface of smoked sheet and cannot be detected until the sheet is scratched or stretched. Mycologists point out that mould, spot and rust are due directly to fungi and bacteria (*Penicillium, Aspergillus, Sterigmatocystis,* etc.) the growth of which is rendered possible by the moisture and impurities on the rubber.

MOULD PREVENTION.

Apparently methods so far employed to prevent mouldiness on crude rubber have not been attended with complete success, although the application of disinfectants both to the latex and the rubber after preparation has been tried repeatedly. Other practices adopted to lessen mouldiness have been (*a*) perfect drying before packing so as to insure the evaporation of all moisture in the usual indentations on sheet and crepe, (*b*) the use of bone-dry containers, and (*c*) storage in dry holds during overseas transport. But none of these

[3] Paper on *New Methods and Modifications in Rubber Preparation* read by Dr. H. P. Stevens at the International Rubber Exhibition, Paris, 1927.

precautions have been wholly effective. In all these expedients, the theory was emphasized (not without reason) that the chief cause promoting the growth of mould is the presence of moisture. For instance, it was observed that crepe at Para—which usually either does not mould at all, owing to its more thorough washing, or is attacked to a much less extent than sheet—was found to develop mould if rolled up when moist or if placed in a box of unseasoned boards.

Since the growth of mould can scarcely be prevented in a damp climate, it is imperative to discover an effective remedy for it. "Some recent research on this subject," states *Bulletin No.* 1380 (1926) *of the U.S.A. Department of Agriculture,* "has been made by Stevens. The addition of 1.8 grams of sodium silicofluoride to 3,000 cubic centimeters of latex and 3 grams to 3,000 cubic centimeters of latex was used to prevent mould on smoked sheets. Acetic acid in the proportion of 1 to 1,200 was used for coagulation. Stevens later verified his former results, finding that sodium silicofluoride in the proportion of 1.8 grams to 3,000 cubic centimeters of latex prevents all but the slighest traces of mould on sheet rubber during transport. Edwards experimented with the same chemical and verified Stevens's results. Soaking the sheets before smoking produced resistance to mould in a high degree." Since this report, the use of sodium silicofluoride and formic acid, at least as coagulants, seems to have proved quite serviceable.[4]

Mould on Raw Rubber.

Writing on this subject in the *Archief Rubbercultuur,* 11,1927, Dr. O. de Vries, of Buitenzorg, urges the following points:—"The prolonged and stimulated growth of mould on raw smoked sheet rubber, *e.g.,* for several years, causes an actual loss of rubber hydrocarbon. Even after two years when the loss amounts to 20 per cent., however, the rubber after cleaning and washing shows normal properties and

[4] See the *Bulletin of the R.G.A.,* September, 1925 and December, 1927.

composition, but continuous mould growth for five years, accompanied by a loss of over 30 per cent., causes depreciation in viscosity, slope and tensile strength, and a decrease in the rate of vulcanisation. The nitrogen content of various samples indicates that the nitrogenous constituents are not consumed by the mould."[5]

A Good Mould Preventive.

Referring to paranitrophenol, Dr. H. P. Stevens writes as follows: " This substance has been found very effective as a mould preventive and has no deleterious action on the rubber. Paranitrophenol prevents mould and rust forming on sheet rubber and spots in crepe rubber. The freshly rolled sheets can be (1) soaked in a solution of paranitrophenol in water or paranitrophenol may be (2) dissolved in the dilute acid used for coagulation. For crepe rubber the latter method is more suitable. Crude paranitrophenol consists of a dull yellow powder which is not very easily dissolved. There is usually a small amount of impurity which settles to the bottom of the vessel. Plenty of time must be given for dissolving the substance. The solution should be run or poured off from any sediment. Care must be taken that undissolved particles do not get into the latex as dark coloured specks will result. For this reason the soaking process is safer to use. The second process has the advantage that the whole of the rubber is uniformly treated and will be satisfactory if reasonable care is exercised to prevent undissolved particles getting into the latex.

"The formulae for treating rubber with paranitrophenol are as follows: (1) *The Soaking Process.* A 0.1 per cent. solution is prepared by dissolving approximately 3¼ ozs. in 20 gallons of water. This will suffice for soaking 100 sheets (150 lbs.) of rubber for 3 hours. With paranitrophenol at 1 dollar per lb. the cost of the preventive is .133 cent per lb. of rubber. (2) *Coagulating Process.* 1½ oz. of paranitrophenol

[5] *Journal of the Society of Chemical Industry*, London, 25th November, 1927.

and 5 ozs. of acetic acid are dissolved in 10 gallons of water and the mixture used to coagulate 30 gallons of latex standardised at 1¾ lbs. per gallon dry rubber content. With paranitrophenol at 1 dollar per lb. the cost of the preventive is .18 cent per lb. of rubber. Sodium sulphite and sodium bisulphite may be used as customary. Note.—*Paranitrophenol must not be dissolved in the water used for diluting the latex.*"[6]

DIRECT USE OF LATEX BY MANUFACTURERS.

The present method of marketing raw rubber, except in the case of very few estates which dispose of their produce in the form of latex, is in the shape of sheet, crepe and sprayed rubbers without any scientific measurement of actual rubber contents. But what the manufacturer requires is rubber in the purest form practicable irrespective of appearance, and the problem is to extract this from the latex in the cheapest manner possible. Since this desideratum can hardly be attained, under existing conditions the use of latex would be the most economical. Hence a marked tendency of the day is the direct use of this product for certain kinds of rubber manufacture, thus effecting an economy in the price of the raw material as well as a reduction in the cost of its manufacture. Progress with this idea is developing along two lines—the one mechanical and the other electrical. In the former the latex stabilized and preferably concentrated is mixed with suitable ingredients so that, after removal of the moisture, a solid product results which is capable of being vulcanized by one of the ordinary processes.

In recent years innumerable devices have been patented to introduce methods for the direct use of latex by manufacturers, and many of them are being experimented with in the concerned sections of the industry. Among these patents, only a few have so far attained commercial success resulting from definite merits appreciated by planters and manufacturers who required

[6] *The Bulletin* of the Rubber Growers' Association, London, December, 1927.

them. They are primarily designed to economise time and labour. Of these devices the most prominent may now be described.

THE VULTEX PROCESS.

A few years ago Dr. P. Schidrowitz devised a process for the direct vulcanization of uncoagulated latex, that is, to vulcanize latex under such conditions as to preclude any substantial coagulation. The patent specifies that "conditions inhibitive of coagulation are a non-acid mixing or the addition of basic re-agents or protective colloids such as soaps, alkali, lysal buminate or casein. The vulcanization may be carried out at high or low temperatures, and accelerators operating in a basic medium may be employed. The product is a spreadable, reversible, uncoagulated, vulcanized mass." The product has special advantages in the manufacture of certain types of rubber goods, particularly fabric sheetings and seamless articles, and the invention seems to open up a new avenue in rubber technology.[7] In 1927 he developed his original design with a view to vulcanize concentrated latex, preferably a paste containing at least 53 per cent. of caoutchouc.

VULCANISATION OF CONCENTRATED LATEX.

Writing on this subject in *Kautschuk*, 1927, 202-203, Dr. P. Schidrowitz explains: "In the preparation of concentrated latex in a vulcanised condition, the vulcanising agents may be introduced before the concentration operation or subsequently. The presence of an alkali and of a protective colloid is advantageous. By the use of suitable accelerators, vulcanisation may be effected below 100°, although vulcanisation at higher temperatures is possible. The products are of pasty consistency and can be re-diluted to form vulcanised latex or evaporated to yield vulcanised rubber of attractive mechanical quality."[8]

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[7] Plant in accord with this patent is being manufactured by Vultex, Ld., 24, Beresford Street, St. Helier, Jersey.

[8] *Journal of the Society of Chemical Industry*, London, 19th August, 1927.

THE REVERTEX PROCESS.

Dr. E. A. Hauser, writing in *Kautschuk* (1927, 2-16), explains the above new process of latex concentration. An abstract of his description appears in the *Journal of the Society of Chemical Industry, London, 4th March,* 1927, as follows:—

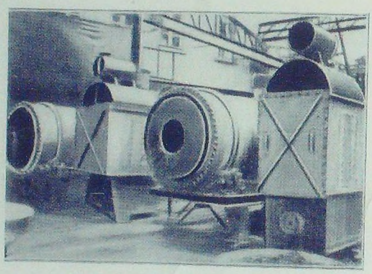
"Revertex is obtained by the concentration of latex by evaporation together with an alkaline protective colloid in an externally heated rotating drum, inside which a freely rotating roller ensures thorough mixing. The pasty product, which contains only 20-30 per cent. of water, can be re-diluted for any purpose needing latex, and in this form can be vulcanised like ordinary latex. Vulcanised liquid latex also can be concentrated by the revertex process, and homogeneous mixtures suitable for the manufacture of 'dipped' goods or unmasticated vulcanised sheet rubber can be obtained from it by incorporating fillers, preferably as colloidal suspensions. Compounding of revertex can conveniently be effected in a mechanical kneading machine into which the powders are introduced through a brush sieve, water also being introduced as necessary; the subsequent coagulation and drying may be effected on a pair of heated friction rolls, the final milling being completed on smooth rolls. If a content of carbon black is desired exceeding 20 per cent. (on the rubber) further quantities up to a total of 200 per cent. or more can be introduced during the drying operation. Revertex mixtures vulcanise more rapidly than ordinary rubber, and, as with most rubbers containing the whole of the serum solids, the vulcanised products 'age' well."

WORKING OF THE REVERTEX PROCESS.

A rather attractive method of latex concentration by the 'Revertex Process' has been devised by the Metallbank und Metallurgische Gesellschaft, Frankfort-on-Main, and the Krause Drying Plant, Ltd., London.

PLATE 12

(To face p. 107).



The Revertex Process.
New stationary models of machines used in the above process.

The method employed in the aforesaid patent is briefly described as follows by the patentees in *Commerce Reports*:[9]—The latex, which is collected in the early morning by coolies, is brought to the plantation factory, where it is first freed from any coagulants, and is then placed in large vessels with a preservative reagent of latex. It remains in these vessels until the apparatus for evaporation is available. Just before the latex is put into this special machine the protective colloids, which are made after secret formulas of the Krause Drying Plant (Ltd.), are added to it.

The evaporation machine consists in principle of a large rotating cylinder with double walls. Hot-water is entered constantly at one side of the machine into the intervening space formed between the two walls, and flows off at the other side. The water then passes through a hot-water heater, using oil as fuel, and is returned to the machine, thereby achieving a continuous flow of hot-water through the walls of the rotating cylinder. Within the inner wall of the hollow cylinder a small solid cylindrical roller rests, which is not attached in any way to the outer one. This is put into rotation through the movement of the hollow cylinder, and it forces a thin coating of the latex, which lies in the bottom of the hollow container, along the heated walls, thereby causing evaporation. After each rotation of the container it again dips into the latex bath solution. The inner roller insures a constant and thorough mixing. In order to dissipate the vapors which form, as well as to prevent the formation of a skin on the thin coatings carried along the walls, a current of cold air is forced through the apparatus by means of a fan.

This evaporation process is continued until the original latex adopts a paste-like consistency, which

[9] *Commerce Reports* of 26th September, 1927, issued by the U. S. A. Department of Commerce.

occurs when its water content has been reduced by from 20 to 30 per cent. The machinery is then stopped, and the material is drawn into vessels by means of a discharging piece attached to the lid of the machine. After it is cooled, the revertex, as it is now called, is fitted into simple Venesta cases coated with a thin paraffin layer, being then ready for shipment. It is claimed that the price of the apparatus employed in the revertex process is low in comparison with the cost of the machinery used in the production of crepe, smoked sheet or sprayed rubber. It is further stated that the expenses connected with its preparation are competitive with the costs of producing crude rubber in the common forms of sheet or crepe.

Dr. Hauser visited Malaya last autumn (1927) primarily in connection with the 'revertex process.' Latex treated by this method is being manufactured on a commercial scale at the Merlimau Estate, Malacca. Dr. Hauser went there to give the finishing touches to the process and to show that it was as simple and fool proof as possible.

LATEX UTILIZATION BY ELECTRICITY.

The direct use of latex in the manufacture of certain kinds of goods is sought with the aid of electricity by a process known as 'the electro-deposition of rubber.' This process is based upon the discovery that 'particles of rubber in a water suspension have a negative charge and under the influence of an electric current, travel to the positive pole or anode, there depositing as a coherent film of rubber.' The ability to make this deposit homogeneous served as the point of departure for a special technology of rubber. This discovery was made independently by Dr. Paul Klein, of Budapest, Hungary, and by S. E. Sheppard and L. W. Eberlin, of Rochester, New York. The success already attained has led to the formation of several companies in the United States, Hungary and the United Kingdom.

THE ELECTRO-DEPOSITION OF RUBBER.

The undernoted description of the 'Electro-Deposition of Rubber and the Anode Process' by Dr. H. P. Stevens appears in the *Bulletin* of the Rubber Growers' Association of London, August 1927.

"When very finely-divided substances are stirred in water, they remain suspended for a long time. Eventually they settle to the bottom of the vessel if they are heavier than water, like particles of clay; or rise to the surface if they are lighter, like the particles forming rubber latex. It is found that all particles suspended in water are electrically charged; that is, each particle carries a minute amount of electricity either positive or negative. Latex is a negative suspension, because the particles are negatively charged.

"If a current of electricity is passed through water having small particles in suspension, it is found that the particles are set in motion and travelling through the liquid are deposited on one of the electrodes, that is on the rods of metal, carbon or other material immersed in the liquid, and by which the electric current enters and leaves the liquid. If the charge on the particles is a positive one, the particles move to the negative electrode or cathode, if the charge is negative they pass to the positive or anode. As the particles of latex are naturally negatively charged they pass to the anode and hence the Anode Process.

"The phenomenon of particle movement is known as electrophoresis and must not be confused with electrolysis, the basis of the process used for electroplating. In the latter case the substance used, *e.g.*, silver cyanide, is split up in solution and the ions or parts of molecules, carry the electric current. What appears to happen is a breaking-down of a chemical molecule, *e.g.*, silver cyanide, the silver being deposited as such. These ions are very small indeed compared with the relatively large particles of which latex or the finest clay suspension consist. These latter can be detected or even examined with the microscope, or at least with the ultra-microscope, while molecules and ions are far beyond the reach of any magnifying apparatus. Indeed, this is obvious, for they are the ultimate particles (except for the electrons) of which all matter is built up.

"To revert to our suspensions—the process of electrophoresis has been used for various purposes, as for instance the purification of clays—the coarse particles settle out and the fine are deposited on the electrode. So fine are these particles that the clay is prescribed for dyspepsia and other complaints. It is not therefore strange to find that the awakening interest in rubber latex led to electrophoresis experiments, and it appears that Sheppard and Eberlin, in the U.S.A., and Dr. Paul Klein, in Hungary, worked simultaneously on the problem of adapting this principle to the manufacture of rubber goods.

"Rubber is a non-conductor of electricity and it might be imagined that once a film was deposited on the anode the current would cease to pass and no more rubber would be deposited. This in fact, can happen, but by adjusting the current voltage and density the film is so porous with interstices filled with water that the current continues to pass and the deposit may be increased in thickness almost indefinitely. A direct current of 30 to 50 volts is used and the current density may be varied considerably, but usually is of the order of 1-10th to 1-13th amp. per sq. in. By reversing the direction of the current the film deposited is again dispersed as latex particles in the liquid, which shows how loose is the aggregation of latex particles forming the film. In fact, this would appear to more resemble a latex cream than a solid lump of coagulum. It is not, however, sufficient to deposit a layer of latex particles; these require consolidation and removal of the moisture and the product is an unvulcanized rubber and therefore requires curing.

"If the article is thick, the ordinary cold curing will not suffice, and means must be found to introduce sulphur and the other usual ingredients. As sulphur forms a negative suspension, it passes to the anode with the latex particles, and the mixed particles of rubber and sulphur are deposited. On the other hand certain fillers, particularly metallic oxides, tend to take a positive charge and may even cause coagulation of the latex through neutralization of charges. These difficulties are not insuperable—the particle charge may be protected, the suspension stabilized and even the charge on the particles altered in sign (+ to — charge, or the reverse), but it would lead too far to discuss these technical difficulties in detail. Another problem arises owing to the tendency of the electric current to electrolyze the aqueous liquid and dissipate part of its energy in the liberation of gases at the electrodes. This results in a porous product, to avoid which Dr. Klein has patented an ingenious modification of the process by which the anode is kept separate from the surface on which the rubber is deposited, the latter consisting of a porous non-conducting diaphragm surrounding the anode.

"The anode or the diaphragm may be made to move so that a continuous film of rubber is deposited, and there are obviously many possibilities of modifying the process to produce various results. The deposit of rubber takes the exact shape or form of the anode or porous surface on which it is deposited. The electrode must not be regarded as taking the place of the moulds at present used in rubber manufacture. They more resemble a mandrel on which rubber is wrapped in the manufacture of rubber tubes. Presumably the rubber compound deposited will be 'open cured.' This will be suitable for many articles, such as motor inner tubes, which do not need to possess a very well-defined, clean cut or patterned surface. It would also appear that great advantages would result by the substitution of vulcanized for raw latex. The articles produced would then require drying only and no subsequent vulcanization. Alternatively with raw latex accelerators can be deposited with the other ingredients and as there is no mechanical treatment necessary to incorporate them with the rubber, there is no danger of scorching, and very rapid vulcanizing products can be obtained.

"The process is not limited to the use of rubber latex. Artificial suspensions of rubber can be used, and of reclaimed rubber. This is claimed to have certain advantages, particularly where it is desired to 'plate' an article with rubber; that is, to produce a firmly adhering coating. At present this presents some difficulty, as generally the rubber deposit comes away readily from the anode. It is found best to give the article to be coated a preliminary zinc coat by galvanizing or electroplating in the ordinary manner.

"A point I have not seen referred to relates to the shrinkage of the rubber coat during drying. This must make it difficult to preserve the outer shape or form of the article and consequently the use of moulds for vulcanizing may still be necessary for the majority of rubber goods, even when the rubber is deposited electrically. The amount of current required is small, proportionately much less than that required for electroplating, and consequently the cost is not heavy in this regard. Another good point is the absence of any need for milling or mechanically treating the raw rubber which results in improved physical properties as contrasted with goods made by the ordinary process. This consideration applies, however, to any process in which goods are built up direct from latex, raw or vulcanized. It explains the better physical properties of articles made from vulcanized latex.

"Looked at broadly, the Anode Process provides a method for building up rubber goods direct from latex and the advantages as regards quality of the article produced are common to any process which yields the same results whether it be by evaporation or centrifuging or removal of moisture by sucking through porous diaphragms or merely by dipping forms in the latex or by any other practicable method of removing moisture from mixtures of latex with the vulcanizing ingredients mixed in so as to produce an article of a definite shape or form.

POSITION OF LATEX UTILIZATION.

So far the direct use of latex by manufacturers is not considerable as compared with the use of sheet, crepe and sprayed rubbers. During 1926 the raw rubber exported from the F.M.S. was 160,213 tons including 2,059,655 gallons equivalent to only 3,218 tons of latex (*Bulletin* of R.G.A., July 1927). But the export of latex is on the increase steadily at least from Malaya. From this country the export in 1923 was 73,757 gallons, in 1924 it was 714,617 gallons, in 1925 it was 2,315,439 gallons and in 1926 it was 2,087,845 gallons. These figures indicate that the export of rubber and latex from Malaya in 1926 was in the ratio of about 98 per cent. and 2 per cent. respectively—a circumstance which signifies that the use of latex in the rubber manufacture is still in the incipient stage.

There can be no question, however, that both the preparation of raw rubber in the plantation and the preliminary stages in the rubber goods factory are at present characterized by processes which are cumbrous or superfluous at least for certain kinds of goods. If in the manufacture of these articles, the direct use of latex (along mechanical and electrical lines) can be brought about in the near future, a wonderful progress will be attained in the entire industry. These processes will doubtless dispense with a certain amount of plant, power and labour both in the rubber plantation and in the rubber factory, but the change will probably begin with the manufacture of mostly 'pure gum articles.' In the near future it can hardly extend to all classes of rubber goods, unless some unexpected circumstances arise. Such changes in the industrial sphere are usually evolutionary—not revolutionary—because they depend not merely on the genius of the inventor but upon various economic conditions which cannot be altered all in a day. It is high time, however, for the planter to be prepared for the coming transition.

CHAPTER IX.

THE WORLD'S RUBBER SOURCES.

FEDERATED MALAY STATES.

The F. M. S. situated in the Malay Peninsula consist of the States of Perak, Selangor, Negri Sembilan and Pehang under the British Colonial Government. The area of these states is 27,506 sq. miles with a population of 1,324,890 in 1921. The chief towns are Kuala Lumpur, with a population of 80,356 and Ipoh with a population of 36,872. The F. M. S. at present form the largest rubber producing country in the world. In 1926 the total area in rubber estates (of 100 acres and over) was roughly 1,650,000 acres, of which about 1,250,000 acres were actually under rubber cultivation. These states have 1,073 miles of railways, 2,537 miles of metalled roads, 150 miles of unmetalled roads and 1,877 miles of bridle paths.

UNFEDERATED MALAY STATES.

These states, also in Malaya, are made up of Johore, Kedah, Perlis, Kelantan and Trenganu.

STRAITS SETTLEMENTS.

These settlements, also in the Malay Peninsula, consist of the provinces of Wellesley, Dindings, Malacca, Penang and Singapore. Their total area is 1,600 sq. miles and their population in 1925 was 994,266. The capital is Singapore with a population of 423,768. The area of rubber estates in these settlements in 1920 was 273,353 acres.

THE CLIMATE OF MALAYA.

According to the *Manual of Statistics* issued by the F. M. S. 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. * * * 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 the altitude may be taken roughly as a decrease of 3° for every 1,000 feet increase of altitude." The humidity ranges from 69 to 94 per cent. Of course, climatic conditions are very similar to the above in the whole of Malaya.

STANDARD PRODUCTION OF MALAYA.

In 1926 the standard rubber production of the Malayan restriction area was as follows:—

	Tons.
Federated Malay States	176,592
Johore	65,610
Kedah	27,126
Kelantan	7,220
Trenganu (roughly)	1,500
Straits Settlements	36,805
Total	314,853

DUTCH EAST INDIES.

These possessions, situated in the Indian Archipelago, consist of Sumatra with its adjacent islands, Java, South and East Borneo, Celebes and some smaller surrounding islands. The total area of the group is 34,785 sq. miles and its population 49,848,000 approximately. The chief ports and towns are Batavia, Semarang, Sourabaya, Padang, Palembang and Macassar. The climate is not quite the same throughout the islands owing to the high mountains (occasionally volcanic) which intersect them in various directions. A high degree of humidity is generally present in the atmosphere, but the variation in temperature is small, apart from differences caused by altitude. Usually the temperature declines by about ½° for every rise of 100 metres in elevation. Thus, besides a maximum temperature of 35°C. during the day in the plains, sometimes a minimum night temperature of a few degrees below freezing point occurs on the higher peaks. In Batavia the mean temperature during the day is 26°C. In that part of the archipelago situated on the south of the equator, the S-E. monsoon blows from April to October *i.e.*, the dry season) and the N.-W. monsoon blows from October to April (*i.e.*, the wet season), while north of the equator, the S.-W. monsoon blows from April to October and the N.-E. monsoon from October to April. The annual rainfall is above 3,000 millimetres in a great part of the high mountainous regions, there being about 250 rainy days in the year round about Buitenzorg.

STATISTICS OF PRODUCTION.

The International Association for Rubber and Other Cultivations in the Netherlands East Indies, in its thirteenth annual report, published some detailed figures regarding rubber cultivation in 1925. At the end of that year, the total area of European estates under rubber was as follows:—

	Planted Area. Acres.	Productive Area. Acres.
Java	446,000	318,778
Outer Territories ..	579,428	433,115
Totals=	1,025,428	751,893

The area planted to rubber in the Outer Territories is divided as below:—

	Planted Area. Acres.	Productive Area. Acres.
East Coast Sumatra	.. 423,867	331,485
Acheen and Dependencies	.. 42,887	31,223
Tapanoeli ..	.. 19,147	14,495
West Coast of Sumatra	.. 2,271	1,787
Bankoelin ..	.. 1,121	761
Lampong Districts ..	.. 24,581	18,271
Palembang ..	.. 5,716	1,971
Djambi ..	.. 538	173
Riouw and Dependencies	.. 31,458	19,497
West Borneo ..	.. 11,426	7,731
South East Borneo ..	.. 13,985	4,972
Menado ..	.. 899	548
Celebes and Dependencies	.. 1,359	143
Amboina ..	.. 146	69
Bali and Lombok ..	.. 27	—
	Totals=579,428	433,115

The production of plantation rubber, exclusive of native rubber, was 106,047 metric tons for the whole Netherlands East Indies, while exports including native rubber came to 233,978 metric tons. The following table shows comparative figures of production and exports during 1925, native rubber figures being included in the exports only. Quantities are in metric tons of 1,000 kilos:—

	Production. Tons.	Exports. Tons.
Java	.. 44,405	47,358
East Coast of Sumatra	.. 47,994	64,059
Acheen and Dependencies	.. 4,175	3,039
West Coast of Sumatra	.. 315	3,184
Tapanoeli ..	.. 2,668	6,012
Bankoelin ..	.. 24	583
Lampong Districts ..	.. 2,411	1,822
Palembang ..	.. 242	18,234
Djambi ..	.. 50	29,341
Riouw and Dependencies	.. 2,112	10,314
Banka	.. —	1,862
Biliton	.. —	106
West Borneo ..	.. 903	21,572
South East Borneo ..	.. 602	26,337
Menado ..	.. 126	146
	Totals=106,047	233,978

The tabulation shows clearly the enormous expansion that native rubber has undergone. Centres that in 1921 were of little or no importance as exporters of this type of rubber, in 1925 are listed with very considerable shipments, the most striking example being Palembang which in 1921 exported 83 tons of rubber, including native, while in 1925 the figure was 18,234 tons, chiefly native. Another instance is that of South East Borneo which in 1921 exported 760 tons but in 1925 came near the top of the list with 26,337 tons. The growth of the native industry is still more clearly shown in the table below which gives figures of native shipments exclusively:—

	1921 Tons.	1925 Tons.
Djambi	2,915	30,511
Riouw and Dependencies ..	600	7,863
Palembang	83	17,073
East Coast of Sumatra ..	—	16,648
West Coast of Sumatra ..	—	1,921
West Borneo	1,800	21,133
South East Borneo	600	26,299
Tapanoeli	—	3,528
Bankoelin	—	953
Banka and Biliton	—	2,303
Lampong Districts	—	193
	Totals=5,998	128,425

These figures represent wet rubber.

CEYLON.

Ceylon has an area of 25,332 sq. miles and a population of about 4,504,000 according to the census of 1921. Although not a large island, its climate varies according to elevation and position in regard to the sea. The altitude of the districts range from 33 ft. in Heneratgoda to 3,300 ft. in Yakdessa, and the annual rainfall from 75 inches in Badulla to 161 inches in Kelani, rising to about 200 inches in some parts. But the equatorial heat of the summer being modified by heavy rainfall, its average annual temperature is more equable throughout, and ranges from 73.4° in Badulla

(2,225 ft. elevation) to 80.7° in Colombo (40 ft. elevation). In the Colombo, Galle, Ratnapura, Kelani and Kalutara districts, the rains of the N.-E. and S.-W. monsoons are very heavy; in the Karunegala, Matele, Badulla and Passara districts, they are less violent. But in most of the districts, rain falls every month, varying from about 6 to 17 inches monthly.

Among the districts having large areas under rubber may be named Kelani, Kalutara and Kegalla. The following are extracts from the administration report of the Rubber Controller of Ceylon for 1926: "There was a noticeable increase in the number of rubber estates registered. In 1926 the number of registered estates was 4,536 (of over 10 acres each) the total area of which was 425,904 acres with a standard production of 64,245 tons (1926-27) or an average of 338 lbs. per acre. In the same year the number of registered estates was 33,355 (of under 10 acres each) the total area of which was 59,790 acres with a standard production of 9,594 tons (for 1926-27) or an average of 360 lbs. per acre. The total standard production for 1926-27 was 73,839 tons."

BRAZIL.

Brazil is one of the biggest countries in the world being at least twice as large as India. It consists for the greater part of selvas and savannahs (forests and grasslands) with endless species of flora and fauna. Being mostly in the equatorial rain-belt, it has generally a hot and moist climate which fosters rich vegetation. Some of its rainfall is due to the ascent of hot air over the equator (convection rains) and some to the south-east trade winds striking against the highlands (relief rains).

Among the products of the forests are rubber, cinchona, nuts, and various species of timber like rosewood, dyewood, etc. Of the produce in cultivated areas, coffee, cotton, sugar and tobacco are the most prominent. The population of Brazil is reported to be roughly 20 millions, as no proper census seems to have been taken. Its capital is Rio de Janeiro, but the ports in the rubber zone are Para and Manaos. Para is a sea-port which formerly exported all the rubber of Brazil. In recent years, however, the rise of Manaos—a beautiful city and inland port on the R. Amazon, in the heart of the forests, some 900 miles from the sea—has resulted in the loading of rubber steamers very largely at this harbour. Brazil is extremely poor in roads and railways.

Early in this century the world's production of wild rubber was about 50,000 gross tons yielding some 40,000 tons of dry rubber. Roughly speaking 68 per cent. of this supply was from the forests of Brazil, 25 per cent. from the wild trees and vines of tropical Africa, 5 per cent. from the *Ficus elastica* of the East and 2 per cent. from elsewhere. "The production in South America," relates Mr. H. Eric Miller, "depended largely on the equipment of regular expeditions which were sent up the Amazon and its principal tributaries, the rubber gatherers taking with them food supplies to last them for several months and returning in due course with their harvest of rubber. The waterways being the means of communication and transport, regular settlements were gradually established at convenient centres up the river and the rubber business radiated from these. The finance of such an industry involved the locking up of advances for a considerable time, and being a highly specialised trade, it was in the hands of a comparatively small number of European and American firms who were also responsible for the sale of the rubber to the manufacturers, who generally required credit."[1] In those days the price of 'fine Para' used to fluctuate between 3sh. and 4sh. per pound, yet the gatherers were miserably underpaid.

The conditions of the rubber industry in this country will be described in the next chapter.

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[1] "The Regulation of Rubber Supplies" by Miller in the *Bulletin* (R.G.A.), London, December, 1927.

CENTRAL AFRICA, LIBERIA, ETC.

Wild rubber was in former years obtained in Central Africa mostly from the dense, impenetrable forests of the Congo basin wherein lie the wildest jungles of the equator. Early in this century the collection of wild rubber in Equatorial Africa was less definitely organised than in Brazil, as much of the trade was conducted on a system of barter with the savage tribes. There was, moreover, a certain amount of oppressed labour employed for this purpose in the Belgian Congo and elsewhere. Often small sums of money were paid as advances to the collectors who had to risk their lives not infrequently to procure the crude rubber. It is well known that mortality among these gatherers was very heavy. But since the advent of plantation rubber, all the inhuman treatment of poor forest people in Brazil and the Congo Valley seems to have come to an end. The acquisition of wild rubber under such conditions will ever remain a slur on the material civilization of the opening years of this century.

Hevea Brasiliensis has been acclimatized in Siam, in Liberia (Western Africa) by the Firestone Syndicate and also in the Philippines (East of Indo-China) by American enterprise. About 25,000 acres have been sown so far in Liberia. Rubber is also found in West Africa (in Nigeria and the Gold Coast), in Central America and the West Indies, but the output of these regions is negligible.

FRENCH INDO-CHINA.

This is the eastern part of the Indo-China peninsula covering an area almost as large as Sumatra but more thinly populated. It has a climate similar to that of Burma and produces a small quantity of Para rubber. Its chief towns are Honoi and Saigong.

SARAWAK AND BRITISH N. BORNEO.

Both these states in the island of Borneo produce small quantities of Para rubber. Their climate is similar to that of the mainland, their chief towns being Sarawak and Jesselton.

INDIA AND BURMA.

The Para rubber zone in India and Burma lies roughly below 15° and 20° north latitude respectively. It covers an extensive area in South India and Lower Burma consisting of approximately 50,000 sq. miles or 32,000,000 acres including the hills. Para rubber needs a hot and moist climate with freedom from frost throughout the year and these conditions are generally fulfilled in the plains of these parts of the Indian Empire. Details of the districts in this zone, as indicated by Mr. R. L. Proudlock and the Director of Agriculture, Burma, are given in two subsequent chapters. Mr. Herbert Wright, in his classic book on Para rubber, rightly remarks: "The combination of rainfall, temperature and elevation required for the profitable cultivation of Para rubber eliminates many parts of the tropics for this species. In Ceylon, India and the Straits, the large tracts of land in the hilly districts cannot be included in the Para zone on account of low temperatures or unfavourable moisture conditions." Hevea Brasiliensis has, however, a certain amount of adaptability which is pointed out by this writer. "Already the cultivation," he observes, "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 the Straits, Ceylon and India."[1]

THE PHILIPPINE ISLANDS.

The Philippine Bureau of Agriculture has been taking steps to encourage rubber planting on the islands which are under the U. S. A. Government. Experiment stations have been established and agents sent to Malaya and the Dutch East Indies to report on rubber cultivation there. There are, however, only 16 small plantations, about 5 years old, at present in the Philippines, which yield only 200 tons of rubber per annum approximately.

[1] *Hevea Brasiliensis* by Wright, Colombo, 1906, p. 10.

THE WORLD'S RUBBER PRODUCTION.

The undernoted table, showing the exports of raw rubber (wild and plantation) in tons from all the producing countries, conveys some idea of the world's total production:—

Year.	British. Malaya. (*a*)	Ceylon.	Java.	Sumatra E. Coast.	Rest of N. E. Indies (*b*).	India.	Brit. N Borneo.	Sarawak.	French Indo-China.	Brazil.	Nett Total.
1925	316.825	45,683	48,709	62,524.	121,590	10,081	5,424	8,413	6,321	24,582	516,900
1926	391,328	58,799	51.269	..	125,800	9,878	6,079	9.382	7,421	24,452	618,100

(*a*) Gross exports from British Malaya include the re-exports of rubber imported from the Netherlands East Indies, British North Borneo, Sarawak, French Indo-China and other neighbouring countries.

The nett exports in 1925 from British Malaya was 210,000 tons, from N.-E. Indies 189,000 tons and from Ceylon 45,700 tons. The nett exports in 1926 from British Malaya was 286,000 tons, from N.-E. Indies 204,000 tons and from Ceylon 58,800 tons.

(*b*) This consists mostly of wet native rubber.

(*The above table is taken from the* Bulletin *of the Rubber Growers' Association, London, September and October* 1927.)

CHAPTER X.

WILD RUBBER IN BRAZIL

FLORA, FAUNA AND CLIMATE.

Brazil is the home not only of *Hevea Brasiliensis* but of other trees of the same species. The famous botanists, Martius and Muller d'Argrove, classify the *Heveas* in the 10 following species:—*H. brasiliensis, H. guayanensis, H. discolor, H. membranacea, H. panciflora, H. rigidifolia, H. notida, H. benthamiana, H. lutea* and *H. spruceana*.[1] Probably the homes of the *Heveas* have not been fully ascertained, but they are all reported to be large trees commonly growing to a height of 75 to 100 ft. and measuring 4 ft. 6 in. to 7 ft. 6 in. in circumference. Many of these laticiferous trees grow in the Amazon forests 'made dense by innumerable lianas and creepers, grasses which cut like razors, epiphytic and other exotic growths which hide in their mazes snakes, tarantulas, hornets, mosquitoes and ants and wild and dangerous animals, such as the panther and jaguar.' It is in jungles of this description that the *seringuero* makes his home. The proportion of *Heveas* to the surrounding trees of large growth in these forests is reported to be about 1 in 80, separated by distances of 30 feet to 300 feet. Usually the most abundant latex is obtained from the 3 first-named species, but the others, if found, are also tapped by the *seringuero*.

Wickham observed that the true forests of Hevea lie on the highlands of Brazil and those seen along the banks of the R. Amazon and its tributaries are usually

[1] To this list may be added *H. randiana, H. collina, H. confusa* and *H. patudosa* now found in the Botanical Gardens at Para, Brazil.

scattered and poor in growth. They do not convey a proper idea of the luxuriant conditions under which the Para tree flourishes in the valley. Ule in his book on rubber in the Amazon Valley describes as follows: "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," he continues, "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."

HEVEA IN THE FORESTS.

A tour conducted a few years ago through the Amazon Valley shows that the Hevea tree grows sparsely in the forests of Brazil but attains gigantic size and yields large quantities of latex.[2] It was found that those places showing the largest number of trees were invariably on high, well-drained land, usually red in colour. This is well illustrated on the trail leading from the Acre River adjoining the Seringal Itu (Villa Afarinha) to the centre at Palmares, a distance of about 15 miles. In the first ten miles there were only 30 Heveas within an estimated distance of 100 feet on

[2] *Vide* Crude Rubber Survey Report on Rubber Production in the Amazon Valley, issued by the U. S. A. Department of Commerce, 1926.

either side of the trail. The land here was rather level, with some of it low and covered with a growth of bamboo and wild bananas. For the next five miles it was hilly, well-drained land, and here there were 241 trees. In the first ten-mile stretch there was only one Hevea to eight acres, while in the last five miles there was an average of 2.4 trees to the acre. In the whole stretch of 15 miles, the average was one tree to 1.3 acres.

From the same report may be quoted a number of measurements which were made of representative trees in an *estrada* at Orion on the R. Abuna. They were on alluvial land close to the river bank, and had been so badly mutilated with the *machadinho* that many were dying from borers and disease. Measurements 3 feet from the ground gave an average girth of 6 feet. Measurements of trees on an *estrada* at Compinas about 25 miles from Sao Luiz, on the trail between the Abuna and Acre Rivers, gave an average girth of 6.85 feet. One tree measured 14 feet 4 inches in circumference; it was 71 feet to the first branch and 139 feet to the top. The largest clump of trees seen in the Acre territory was on the property of Colonel Honori Alves, on the trail between Itu and his home at Palmares. Within 150 yards of this clump were found two trees measuring 12 feet and 11 feet 10 inches, and near by were others measuring 14 feet 2 inches, 9 feet 2 inches, 12 feet 2 inches and 11 feet 5 inches in circumference. Colonel Alves stated that when he opened the *estrada* 30 years ago there was included a Hevea 23 feet 2 inches in girth. It yielded at the time 8 litres of latex per tapping, equivalent to about 7 lbs. of dry rubber. Many other trees were measured within the territory, all averaging about the same as those noted above. These measurements will give an accurate idea of the size of old Heveas now standing in their original home.

The tapping surface of trees that had been tapped for many years was a mass of burrs and protuberances. The bark was very thin. Most of the trees had been tapped up to 12 or 15 feet. Many trees had been ruined and destroyed by the system of tapping in use. It is probable that at least one-third of all the trees are now in a state of *descanso* or rest. When the *estradas* were first opened in the Acre territory, they were of about 120 trees on the average, and gave, it is said, an average yield of 12 kilos (26.5 lbs.) of rubber in a day of tapping. The *estradas* are now composed of 180 to 200 trees, and give seven to eight kilos (15.4 to 17.6 lbs.) per day of tapping. The present average for a *seringuero* is from 600 to 800 kilos in a season. In these days of plantation rubber, the *seringuero* spends most of his time in hunting, fishing and cultivating his field or garden and so has little time to devote to rubber collection.[3]

THE SCANTY PEOPLE OF BRAZIL.

The total population of Brazil is reported to be about 21½ millions including a rough estimate of something like half a million native Indians. In a vast country with scarcely any means of communication, the work of enumerating a thin population scattered amidst selvas and savannahs is no easy task. Hence no accurate census seems to have been possible there. Anyway, the majority of the people in that country consist of mixed descendants of the aboriginal Indians, the original invaders and the subsequent settlers. A few centuries ago, the European invaders of Brazil were Portuguese and Spaniards, but during the last century, partly at the invitation of Emperor Dom Pedro, other Europeans—such as Italians, Germans, Austrians, Russians and the French—settled in Brazil, mostly in the southern portions of the country. Also during the latter half of the last century, Japanese, Chinese and Negroids emigrated to Brazil. It has indeed been estimated that, during the last hundred years or so, about 4¼ million

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[3] In the forests of Brazil, the labourer who taps the wild hevea is known as the *seringuero*. He is usually in charge of an *estrada* which is a section of the forest containing from 100 to 150 trees generally. A *seringal* consists of several *estradas*. A *machadinho* is a small hatchet or tapping tool with a long handle so as to reach higher than a man's head. Incisions are made with this tool round the tree in parallel lines.

souls have settled in Brazil from foreign countries. The true Brazilian is said to be a descendant of the pure native Indian interbred with the Portuguese only. But people of this type are few at present, the majority being more mixed.

WHY RUBBER IS LANGUISHING.

There seems little doubt that the scarcity of people in Northern Brazil, along with its financial difficulties and other natural shortcomings, lie at the root of the economic backwardness of the country and constitute the indirect causes for the decline of the rubber industry. There are moreover some direct reasons why the industry is crumbling away. "The cost of bringing labour," observe two well-informed writers, "from Ceara is excessive; the conditions under which the *seringuero* lives render him susceptible to sickness and consequent loss of output; his supply of food is of poor quality and inadequate to fit him for sustained effort; the want of medical assistance causes him to have recourse to patent 'cure-alls' when ill, for which he pays extortionate prices and obtains little or no benefit; the iniquities of the truck system increase the cost of transport and of living in general; and until the rottenness of the whole labour system of the Amazon and the method of remunerating the men is improved, Brazil cannot expect to produce the finished rubber at prices capable of competing with those of the Eastern planters."[4]

There was yet another reason why the *seringuero* went under in the struggle with Eastern planters. Not long ago rubber was the chief crop of the Amazon valley and taxes upon it were made to yield about 80 per cent. of the State revenue from that region. This was a burden which the poor collector was unable to bear.

"Until quite recently," continue the aforesaid writers, "the Amazon *seringueros* were one of the most

[4] *The Rubber Industry of the Amazon* by Woodroffe and Hamel Smith, London, 1915, p. 146.

unfortunate and ill-treated classes of labour known to civilization. They worked in the depths of the fever-stricken jungle and lived in the midst of dangers from wild animals, reptiles and insects which in themselves made life a burden and greatly increased the risks and hence the cost of collection. The *seringuero* knew few, if any, of the benefits of civilization, neither did he enjoy the privileges and comforts of those who live in communities for mutual protection and social fellowship."[5]

"If Brazil or those who are trying to place her finances on a permanently sound basis that will last for some time, make the mistake either of ignoring the Indians, or worse still, of trying to kill them out by violent means, by neglect or misery, they can never secure the class of well-seasoned and thoroughly acclimatized labour that they need.*** Both with men and with cattle, attempts have been made to rely entirely on the imported stock, with the result that such experiments have failed every time."[6]

AN EARLY REVIVAL IS IMPRACTICABLE.

Dr. Pedro de Toledo, Minister of Agriculture during the last decade in the Republican Government of Brazil, declared at a Rubber Congress in his State that the rubber grown in the Amazon Valley could meet the world's consumption if there were enough population, finance and transport facilities. Endeavours have certainly been made by the Brazilian Government to encourage immigration in the Amazon Valley from foreign countries and even from Southern Brazil, but the efforts have usually proved abortive owing to the lack of the other requisites of success. The Akers Report issued by the Commission appointed in 1911-12 to study the conditions of the rubber industry both in Brazil and the Middle East, under the chairmanship of the late Mr. C. E. Akers, arrived at the conclusion that it would not pay Brazil in the near future to start planting in

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5 *The Rubber Industry of the Amazon* by Woodroffe and Hamel Smith, London, 1915, p. 208.

6 *Ibid*, pp. 2 and 3.

competition with the Middle East because she would first have to outlay an immense amount of capital in forest clearing, drainage, sanitation, transport, food-crop cultivation and the rearing of cattle, poultry and other live-stock.

Owing to these difficulties, rubber plantations are extremely rare in Brazil. The few that exist are along the Madeira and some other rivers as well as around Para and Manaos where old pasture lands have been sown with Hevea. Rubber planting on a large scale there does not seem a practical proposition until sufficient acclimatised labour is procurable, some profitable means are found for utilizing the timber obtained from jungle clearance, and unless the main industry is associated with the cultivation of food-stuffs. At present the average intelligent Brazilian questions the sanity of planting Hevea amid such impediments when there are many millions of wild Hevea in the forests. But he does not perceive how equally difficult it would be to make the latter a source of profit. Many of these trees have been tapped so recklessly that they are unfit for further productivity and many are in such unhealthy or inaccessible places that they would have to be left alone.

"Consideration of future economy by conservative methods of tapping and general care of trees," says a recent American report, "with a view to the promotion of future yields on the same site, is not a part of the plan for collecting rubber by the present owners of *estradas*. The rubber operator literally slashes right and left, and when the trees no longer respond to the methods employed he moves to unworked areas. This treatment of the more accessible trees has resulted in enormous damage, so that a large percentage of the wild rubber growth near the streams is in a condition no longer suitable for tapping. It is unlikely that many of these trees can be brought back to a state of health under a well-regulated forest working plan. After the more inaccessible areas are worked, the growing of rubber in plantations must of necessity be undertaken.

Since the conditions in the Amazon Valley are suitable for growing enough rubber to supply the world, provided proper measures are taken to protect the crop against diseases, this will necessarily be the next step."

In the face of these unfortunate circumstances, there is neither the will nor the means in Brazil itself to build up a regular planting industry in the Amazon Valley. Mr. Woodroffe and Mr. Hamel Smith seem to think that the continuous emigration of Chinese and Japanese agriculturists, who could live and co-operate best with the native Indians, might solve the labour problem. It is doubtful, however, if these Orientals would care at the present day to emigrate so far in large numbers when they can find similar employment nearer home in the Middle East.

CHAPTER XI.

RUBBER IN INDIA.

FAST-GROWING CONSUMPTION.

Since the future of rubber consumption is very promising in the opinion of certain economic thinkers, interest in it has been aroused in many places, and India, having probably the best immediate prospects of extending its cultivation in the Middle East, as will presently appear, should be very closely concerned with this subject. The *India Rubber World*, of New York (February, 1927), quotes Mr. A. W. Still who it seems has estimated that the world should require 1½ million tons of raw rubber, or nearly 3 times its present annual output, within 20 years.[1] This does not seem an exaggerated estimate if we consider the rate at which rubber has been consumed during the last decade when the extension of automobile transport has taken place. And the desire for such locomotion is likely to spread to most urban areas as soon as they have the means to satisfy it. It is a new desire still unsatiated and is not likely to diminish until aviation becomes equally safe and cheap. Hence the present consumption of rubber is not like that of other raw materials—such as coal, iron, wheat, rice, tea, jute and cotton—the increased use of which depends mainly on the growth of population.

Owing to her enormous consumption, it is only natural that North America should at present be the most concerned over the extension of rubber outturn. Not long ago the U. S. A. Government appointed a committee to enquire into the possibilities of rubber

[1] Mr. A. W. Still, formerly Editor of the *Straits Times*, is recognized as an authority on the economics of rubber.

cultivation in their continent. This committee has issued a bulky report showing that rubber culture could be undertaken in at least 6 million acres of northern tropical America if the great handicap of labour scarcity could be overcome. The import of foreign labour was discussed even from China which is believed to possess some of the cheapest agricultural labour in the world. Still the report concludes with the remark that the world must depend for its rubber supply on the Middle East for an indefinite period. Mr. William O'Neil, President, General Tyre and Rubber Company, of Akron, regards the enquiry as futile because it has not told the industry anything more than what the industry could have told the Government prior to the investigation. Mr. O'Neil thinks that there is every chance of a rubber shortage occurring again within the next three years, without being able to say precisely when it will come.[2]

In addition to the U. S. A., the Dutch East Indies Government is making a close study of the future of this product in its own territories, the Brazil Government has issued a report on the prospects of rubber development in the Amazon Valley, the Indo-China authorities have published an essay on the *Rubber Epic,* the Mexican Government a note on *Rubber in the Middle West* and the Burma Government a *brochure* on rubber culture in its own province. All this awakening is due to the diminishing yield of wild rubber trees and to an increase of about 15 per cent. in the world's rubber consumption during the first half of 1927 over that of the corresponding period of 1926. Several countries, including the United Kingdom,

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[2] Owing to the expected rubber shortage, rumours of increased activity in America have recently gained currency. The *London Financial Times* in November 1926 adumbrated the promotion of a British syndicate, called the Para Plantations, with Sir Ernest Birch as Chairman, to collect wild rubber and if possible cultivate the tree in Brazil. The *New York World* in September 1927 reported that Mr. Henry Ford had purchased 1,200,000 acres of land in Brazil for rubber plantations—the details of his scheme being shortly after published. Moreover, it is known that Mr. T. A. Edison has an experimental rubber farm in Florida, in which enterprise he is said to be assisted by Mr. H. S. Firestone. But how such endeavours propose to solve the labour problem is not explained.

Germany and Russia, are absorbing an increased quantity of this product. The U. S. A. Department of Commerce reports that on 1st January, 1927 there were 27,650,267 motor cars, trucks and buses operating throughout the world and that this figure shows an increase of 3,176,638 vehicles over those of the previous year. Of the aforesaid total, 22,137,334 are in the U. S. A.; 1,023,651 in the United Kingdom; 891,000 in France; 826,918 in Canada; 365,615 in Australia; 319,000 in Germany; 222,610 in Argentina; 138,177 in Italy; 135,000 in Spain; 123,224 in New Zealand and 88,767 in British India.

RUBBER PROSPECTS IN INDIA.

Probably the best prospects of extending rubber culture at present in the Middle East are in India owing to certain circumstances. According to the *Malayan Tin and Rubber Journal* (31st March, 1927) little or no land is now being given out for rubber cultivation by the Government in the Federated Malay States. Moreover in these States local labour is reported to be not only scarce but unreliable, for which reason landless agriculturists from South India are regularly taken over to Malaya where an immigration board and a labour controller are to be found. In the Dutch East Indies also much land is not available for this purpose in their limited culturable areas, unless soils intended for rice and sugar are encroached upon. Then in several of the islands of the East Indian Archipelago, facilities for transport and communication are insufficient; and in many portions of these regions labour seems to be more scarce or incompetent than in India. A recent government publication of the Dutch East Indies states: "It is a fact though that the area of the rubber gardens is now already much larger than the scanty population, without outside labour, can manage at present."[3]

Indian labour is probably the cheapest and most efficient for agricultural purposes over almost the

[3] *Rubber in the Netherlands East Indies.* (Bulletin No. 21 of the Department of Agriculture, Industry and Commerce), Weltevreden, 1925.

entire tropical Middle East. For instance, it is well known that Bengal holds the world's monopoly for jute largely owing to the exceptionally low return at which its cultivators work so skilfully. Of course, a microscopic portion only of India's rural population is acquainted with rubber culture which is a handicap. But if this cultivation is extended in India, it would sooner go to plantations in Burma or the Deccan than to those in the Archipelago. There is, however, no move on the part of Indian capitalists at present to get into this industry.

THE FUTURE FORESEEN.

Many years ago the prospects of rubber cultivation in India were indicated by Sir George Watt who observed, referring to Para rubber (Hevea brasiliensis), as follows: "This rubber tree has been successfully cultivated in Mergui and Tavoy. It has also been fully acclimatized in the south-west districts of Ceylon, where so much attention has been paid to the preparation of the rubber that it has actually fetched a higher price than that from the indigenous home of the plant. ***A great deal of interest has recently been taken in the possibility of Travancore and even of Mysore becoming hopeful localities for Para rubber cultivation. It is said by planters and others that thousands of acres of heavy forest land, below 1,000 feet in altitude, exist that possess rich soils and a liberal rainfall, eminently suited for rubber, but which at present are valueless because not put to any purpose."[4]

In recent years, writing on the same subject, Mr. C. W. E. Cotton, who is well acquainted with economic conditions in Southern India, pointed out as follows:—"There are two tracts enjoying very similar climate and rainfall, scarcely less favourable than Malaya, which pre-eminently offer potentialities for rubber growing in India, *viz.*, the Tenasserim Coast in Burma and the

[4] *Dictionary of Economic Products of India* by Watt, Article on India Rubber.

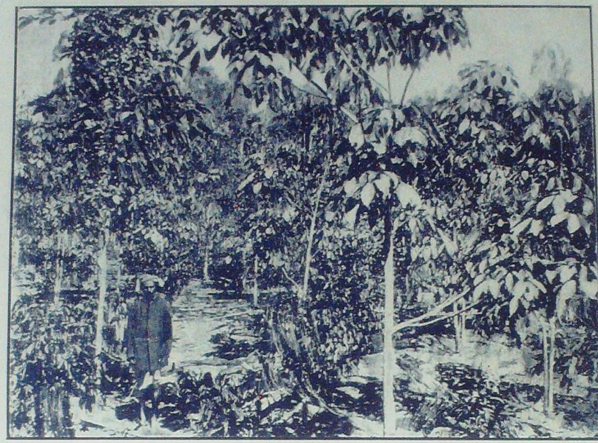
Malabar Coast below the Western Ghats from Mangalore to Cape Comorin. The more southerly districts have a more evenly distributed rainfall, closely approximating to that of Ceylon. In cultivation and transport facilities Southern India enjoys considerable advantages over Burma where communications are very backward and labour other than imported not easy to obtain. In Travancore, the Shencottah and Mundakayam districts and the Rani valley are the chief centres of the industry, the pioneer estate at Thattakad on the Periyar river being opened up in 1902 with Para rubber (Hevea brasiliensis) which has generally proved far the most suitable variety for cultivation in Southern India. In the last seventeen years a great deal of cultivation particularly in Travancore and Cochin (not infrequently in combination with tea) but also to some extent in British Malabar, Coorg and the slopes of the Shevaroy Hills in the Salem district has begun."

A Wise Plan of Development.

Though a number of rubber trees, such as *Urceola elastica, Rhynchodia Wallichii* and *Willoughbeia edulis* are indigenous to Indian forests, they cannot be obtained in sufficient quantities to carry on a commercial exploitation. Among the cultivated species, *Ficus elastica* and Ceara have been grown with tea in Assam and South India while Para rubber has been successfully acclimatized in Ceylon, South India and Burma. Hevea brasiliensis, with some other allied species, as already indicated, was originally found in the wilds of Central and Northern Brazil and in the forests of Para, south and west from the mouths of the Amazon. This region, it is said, has a climate remarkable for its uniformity of temperature, 87°F. at midday and 74°F. at night, the mean being 81°F. with 95°F. as the highest record. Here rainfall occurs chiefly from January to June, the maximum being in April when it reaches 15 inches. The entire country is not unhealthy 'with a remarkably fertile and continuously moist soil' and its climate may be compared to that of Mysore and other parts of South India. "By far the best rubber," remarks Sir George Watt, "is obtained from the species

PLATE 13.

(To face p. 137).



Young Hevea trees with Coffee in South India at 3,500 feet elevation.

(Photo taken by C. E. Weldon.)

of this genus. In fact, where Hevea can be profitably grown, it will never pay to cultivate any other rubber plant. The rubber afforded is stronger and possesses a much higher breaking strain than that of any other plant, its tenacity being due, so it is thought, to the method of coagulation. Once established, Hevea requires but little care and rough weeding will suffice. It is, however, liable to several pests, more especially canker, and has to be protected from browsing animals (deer, etc.) when in the young plantation stage."[5]

As pointed out already, no reliance could be placed on an industry which would depend on the collection of rubber from the wild indigenous plants of India. Para rubber, which has been acclimatized in this country, would have to be developed, sowing *Ceara* and *Ficus elastica* in the estates merely as disease-resisting belts, if found profitable. Some years ago a *Kew Bulletin* drew the attention of planters in India to the *Ceara* plant which it described as follows: "It is very hardy, a fast grower, free from insect and fungoid attacks, requires little or no attention when once established, and thrives in poor, dry, rocky soils unsuited to almost any other crop. ** It produces a good class of rubber, second only to the best Para. The yield is small per tree, but a return is obtained earlier than from any other species. Under skilful treatment the trees may be tapped twice yearly and last in a productive state for 15 to 20 years." This plant, once strongly recommended, has proved a commercial failure.

Early Attempts in India.

Sir Dietrich Brandis, writing in 1873 on the expediency of trying rubber culture in India, gave it as his opinion that Kanara, Malabar, Travancore and the Burma Coast from Moulmein southwards offered the desired conditions for the successful cultivation of this product; and, Sir George Watt, reviewing in 1890 the efforts made in this direction, observed that all experience subsequent to 1873 confirmed the original

[5] *Dictionary of Economic Products of India* by Watt, Article on India Rubber.

view of Brandis who it seems referred especially to the prospects of Para. Shortly after the valued pronouncement of Brandis, efforts began to be made by the Indian Government to experiment with this cultivation. The first step taken was the collection and shipment to England of 70,000 seeds of Hevea brasiliensis by H. A. Wickham, as we have related before. Of this shipment, about 2,700 seeds were germinated at the Kew Gardens in London and a large portion thereof sent on to Ceylon. When these matured, seeds were distributed to India, Burma and other British possessions in the Orient and it is beyond doubt that the present industry in the Middle East has evolved out of this original shipment.

In 1910 three well-known writers on rubber, Seeligmann, Torrilhon and Falconnet, eulogized the attempts of the British to introduce into their eastern possessions the rational culture of this product and to acclimatize those species most adaptable to the soil and climate of Asia. "These experiments," they hopefully observed, "are on the point of being crowned with full success. In their intention to make India the India-rubber producing country of the world *par excellence,* the British were to a certain extent encouraged in their enterprise by several reasons which contributed to present this design under the most alluring colours."[6]

PLANTATIONS IN COCHIN.

We gather from the aforesaid writers that the early attempts to plant rubber in South India were promising. Speaking of Cochin they say: "Rubber was first planted on any considerable scale in 1905 when Mr. K. E. Nicoll obtained a grant of forest land at Palapilly, behind the Government teak plantation. This was a well-situated block, at the foot of the hills, with the Chemoni river running through the centre. Some 40 acres were opened in 1905 and later on in the same year Mr. E. G. Windle, on behalf of a syndicate, took up an adjoining block of forest now called Padukad. In 1906 there were some 300 acres opened on each place

[6] *India Rubber and Gutta Percha* by Seeligmann, etc., London, 1910, p. 85.

and in 1907 the balance of the land was opened, Padukad being in all some 650 acres and Palapilly nearly 500, the two places making a fine sheet of over 1,100 acres of rubber. The conditions here are very favourable, the elevation being almost sea-level, rainfall about 150 inches and surrounding hills sheltering the basin from wind. As a result, growth has been remarkably fine, and, according to those who have seen both, it may challenge comparison with fine Straits growth. The plantations are some eight miles by cart-road from the Padukad Station on the Cochin Railway and about twenty miles from the coast."[7]

"In 1906 also a grant of Government forest, 6 miles from Trichur Railway Station and lying on the main road from Trichur to Palghat, was obtained by E. G. Windle and R. E. Campbell-Gompertz, who opened 400 acres and subsequently disposed of the block to the Cochin Rubber Co., Ld., of Colombo in whose name the Government title was issued. This consists of 1,000 acres in all, of which 400 acres were opened in 1906, 200 in 1907 and 200 in 1908, 200 being forest. Elevation and rainfall are much the same as at Padukad and Palapilly and growth has been excellent. There are, therefore, at present some 1,900 acres of Para opened in Cochin. *** The forest slopes, which are now being tapped by the tramway, might reasonably be surveyed with a view of opening suitable parts; there are probably 50 to 100,000 acres which would grow one or other of the above products without unduly interfering with forest resources."[8]

PLANTATIONS AT NILAMBUR AND CALICUT.

Much light has been thrown on pioneer work in rubber culture about the beginning of this century in South India by Mr. R. L. Proudlock, then Curator of the Government Botanic Gardens at Ootacamund in the Nilgiris. Mr. Proudlock states that many of the reports of the Forest Department disparaged the prospects of growing Para rubber in Malabar, but his

[7] *India Rubber and Gutta Percha* by Seeligmann, etc, p. 86.
[8] *Ibid* pp. 86-87.

experience proved that there were no substantial grounds for such a gloomy outlook. On the contrary he obtained the most encouraging results from some of the trees in the Nilambur valley (near the Wynaad plateau) and in South Malabar. He explains that the forest reports were based on incomplete experiments indifferently carried out, as forest officers have no time to devote to rubber trees in particular owing to their multifarious duties. Speaking of Ceara rubber he says: "With reference to the average yield of rubber obtained from the Ceara trees, it was practically the same as that obtained from the Para trees. ** I, therefore, consider it to be quite satisfactory. In the light of later experience it must, however, be admitted that the best method of tapping them was not adopted. *** This species grows extremely well from sea level up to 4,000 feet in south-western India and would be likely to prove a satisfactorily remunerative cultivation in the western and south-western portions of the Wynaad, which range in elevation from 2,000 to over 3,000 feet—the average being about 3,000 feet."[9]

Deploring the depressing reports of the Forest Department, Mr. Proudlock shows how they have deterred the aspirations of planters in the Madras Presidency and thus enabled the planters of Ceylon and the Malay States to get ahead of them. "The publication of the adverse opinions, already referred to, regarding these rubber trees," he explains, "has unfortunately had far-reaching effects in deterring the majority of planters in this Presidency, at least up to within the last few years, from taking up what is now proved beyond all doubt to be a highly remunerative cultivation. The result has been that the planters in Ceylon and in the Malay States have obtained an important lead over the planters in Southern India in the rubber industry despite the fact that the Indian Government paid practically all expenses connected with the introduction of the Para, Ceara and *Castilloa* rubbers to the East. No further arguments appear to be necessary to prove that

[9] *Report on the Rubber Trees at Nilambur and Calicut, South Malabar* by Proudlock, Government Press, Madras, 1908, p. 45.

the mature Para trees at Nilambur are capable of yielding rubber quite as good, both in quantity and in quality, as trees of the same species will yield in any part of the Eastern Hemisphere. In fact, the Nilambur country**contains some of the finest sites in Southern India for rubber cultivation, especially for Para rubber."[10]

THE STATE PIONEERS IN BURMA.

Scarcely anybody at the present day is aware of the fact that the cultivation of Para rubber in Burma was initiated by the Government of India and this fact is brought to light by Mr. Proudlock. "We know that the experimental cultivation of Hevea brasiliensis," affirms this writer, "was undertaken by the Government of India at Mergui in Tenasserim with the object of (*a*) demonstrating the climatic suitability of that region for rubber cultivation; (*b*) determining whether it could be made successful from a financial point of view; and (*c*) for the purpose of increasing the Forest Revenue (*vide* G. O., No. 109, Revenue, dated 6th February, 1905). The first of the above three important objects has undoubtedly been achieved, with the result that there is no longer any necessity for the Government to continue the work (except for the perfectly legitimate and desirable purpose of increasing the forest revenue) as private enterprise has been attracted and encouraged in a sound, practical way to take up the cultivation of rubber which the Government of India very wisely initiated in Lower Burma."[11] Facts relating to this introduction from 1876 to 1892 are also recalled by Mr. Proudlock who personally inspected some of the gardens at Mergui in 1892.

PROSPECTS IN SOUTH INDIA.

Speaking of Para rubber in South India early in this century, Mr. Herbert Wright says: "In some parts of India the climatic conditions are such as to allow of the cultivation of Para rubber up to 3,500 feet above sea-level, and what appear to be satisfactory rates

[10] *Report on the Rubber Trees at Nilambur and Calicut, South Malabar,* by Proudlock, Government Press, Madras, 1908, pp. 45-46.
[11] Report, Etc., by Proudlock, p. 47.

of growth are reported from many parts. ***On the Shevaroy Hills, at an elevation of 3,400 feet, Para 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 Anamalais 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 Para and Castilloa rubber."[12]

INDIAN PLANTATIONS IN 1907.

Writing in 1907, Mr. R. L. Proudlock estimates that there were probably not less than 25,000 acres planted with rubber at the time in India as undernoted. The data for this table were supplied to him by planters and others of these localities whom he mentions.

Place.	Acres.	Species of Rubber.
Assam	3,000	*Ficus elastica.*
Bombay Presidency ..	250	Para, *Ficus elastica.*
Anamalais	2,000	Para.
Cochin	1,540	Para.
Coorg	1,500	Para and Ceara.
Kanan Devan Hills ..	400	Para.
Malabar	1,000	Para.
Malabar-Wynaad ..	700	Para and some old Ceara.
Mysore, North ..	700	Para and Ceara.
Mysore South ..	200	Para and Ceara.
Nilgiris	1,000	Para, *Castilloa* and Ceara.
Pulneys	—	Para and Ceara.
Shevaroys	1,726	Para, *Castilloa* and Ceara.
Travancore	10,000	Para.
Other Places ..	1,000	Some of the above.

MAINLY IN SOUTH INDIA.

"From the above statement it will be observed," concludes Mr. Proudlock, "that the principal region

[12] *Hevea Brasiliensis or Para Rubber*, by Wright, pp. 14 and 22.

in which rubber has been and is being planted, is in the vicinity and on the slopes of the ghats in South-Western India. The chief local centre around which the largest areas, amounting to about 5,493 acres at the present time, have been planted is the small village of Mundakayam in Travancore. The belt of coastal country which lies between the sea and the foot of the Western Ghats is particularly well suited both as regards climate and soil for rubber cultivation on an extensive scale. The species that has been most largely planted in South-Western India is Hevea brasiliensis. In Coorg and Mysore besides Para a good deal of Ceara is being grown; while in the Bombay Presidency a few comparatively small plantations, chiefly experimental in character, have, I believe, been planted, principally with Para rubber. In Assam, *Ficus elastica,* which is indigenous to North-Eastern India is the species that is generally grown."[13]

POSSIBILITIES ON THE BOMBAY COAST.

Mr. Proudlock, it appears, also inspected the Government experimental rubber plantations in the Bombay Presidency about 1909 as in connection with them he made a report to Government which concludes with the following observations: "The best district in the presidency for rubber is Kanara. In the fine evergreen forest region along the foot of the ghats from near Bhatkal to Kanara, where the climate is hot and moist for a good part of the year, the conditions are upon the whole favourable for the successful growth of rubber, especially for Ceara and for Para. Next to Kanara, comes Thana, where the climate is also hot and moist and fairly suitable for rubber. I do not, however, think that the Thana district is quite so promising as Kanara for rubber growing, but still the conditions are not altogether unfavourable. *** With regard to Belgaum and Poona, I would not recommend them as rubber-growing districts."[14]

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[13] *Rubber, Etc.* by Proudlock, p. 48.

[14] *Report on the Government Experimental Rubber Plantations in the Bombay Presidency* by Proudlock, Government Press, Bombay, 1909, p. 28.

RUBBER IN ASSAM.

Sir George Watt declares that rubber was found originally in the East by the celebrated botanist, Roxburgh, early in the nineteenth century. Prior to this discovery the world believed that the product existed only in tropical America. It is affirmed that in 1810 Roxburgh, assisted by Mr. M. R. Smith of Sylhet, found *Ficus elastica* growing wild in the forests of Assam and traced the tree by its dried latex which formed the inner lining of a pot of honey presented to him through Mr. Smith.[15] Thus it is obvious that this tree is an indigenous product of Assam and very probably existed there for centuries. Also it is significant that the rubber, known as *gutta rambong,* which has long been produced in the Malay Peninsula, is now identified as this particular species.

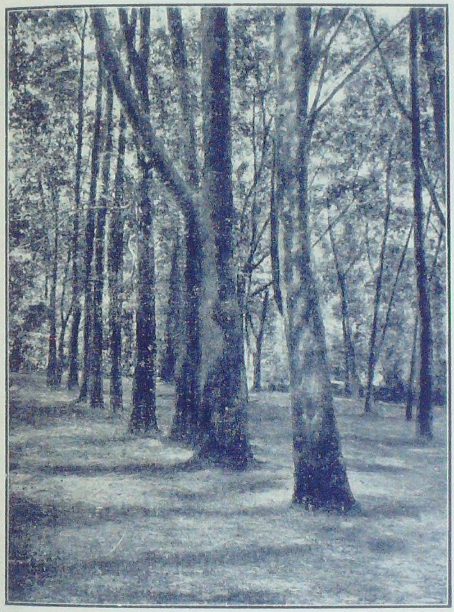
Ferguson describes in his book *All About Rubber and Gutta Percha* thus: "*Ficus elastica* grows wild along the foot and in the low tropical valleys of the Himalayas, from the Mechi river on the Nepal boundary at 88°E. Long, to the extreme eastern limit of Assam in 79°E. Long., as well as along the foot and in the valleys of the southern mountains of the Brahmaputra valley, *viz*: the Patkye, Naga, Khasi Jainthia and Garro Hills. It is not abundant until east of the Bor Nuddi, where it is common in the forests at the foot of the hills in the Khaling, Burigoma and Kuriapara Duars. *** In the Chardwar forests, between the Mura Dansiri or Ruta Nuddi and Borali river, the plant is abundant. ** This is the Gutta Rambong produced also in Malaya. ** The rapid destruction by the natives of the wild rubber trees in Assam called forth efforts to establish their cultivation in regular plantations. *** That at Chardwar has an area of some 80 square miles."

These plantations of *Ficus elastica* in Assam were chiefly experimental farms conducted by Government. Some of them appear to have been sown by planters as adjuncts of tea, as in many gardens to this day in South

[15] *Economic Products of India* by Watt, Vol. IV. *See* 'India Rubber.'

PLATE 14.

(To face p. 144).



Para trees in the old Experiment Garden at Mergui, Burma. The old system of tapping is seen high up on the trees.

(Photo reproduced from "Rubber in Burma.")

India. Though little information is available on this point, it would seem that the planters who took up *Ficus elastica* had little or no experience in it, obtained no expert advice from any scientific department and probably cared little for their secondary crop. Yet they seem to have derived some gain from it for many years until the slump in rubber about 1921 put an end to their casual enterprise.

THE SCOPE FOR EXPANSION IN INDIA.

Great credit is due to Mr. Proudlock for his careful study of the outlook for rubber culture in India and the accurate picture he presents of some of the facilities and difficulties which the industry is likely to meet with. He rightly holds the opinion, we have already expressed, that India possesses a distinct advantage over other rubber-growing countries in regard to labour. Along with this superiority is the exceptional healthiness of climate in most parts of South India suitable for this cultivation. These are no mean facilities compared with some of the conditions that obtain in Malaya and the Dutch East Indies. "Although rubber cultivation in India," explains Mr. Proudlock, "is comparatively speaking still in its infancy, it is reasonable to anticipate that further large extensions will be made in the near future. In the highly important matter of obtaining an abundant supply of reasonably cheap labour, India certainly possesses a great advantage over most other rubber-growing countries and this fact is bound to have a favourable influence on the industry in the future, more especially during periods of low prices."

"The vast tracts of good land which lie between the sea and the base of the mountains, as well as in the valleys of the mountains, along the western side of India from Bombay to Cape Comorin, up to an elevation of 1,000 feet and which are fairly well sheltered from high winds, where the rainfall is not less than 80 inches a year, are eminently suitable for the successful growth of Para, Castilloa and Ceara rubber trees. While in regard to Ceara, it can also be grown with a fair prospect of success in frost-free localities over the greater part of India (cf. para. 93). It is undoubtedly the best species of rubber tree to plant in the drier parts of the country. (*vide* para. 57.)"

Rubber's Economic Benefits to India.

"If we take into consideration," continues Mr. Proudlock, "the great and ever increasing demand for rubber, which is required in so many of our modern industries, the cultivation is bound to become a still greater and more important one. The industry, when established on a large scale in the parts referred to, will necessarily give employment to a large amount of labour; and, moreover, it will eventually become a material source of increased wealth to the country. Rubber cultivation, ought, therefore, to continue to receive the earnest attention of the Government; and, it would be a wise policy to continue to give every reasonable encouragement to private individuals and companies to take it up. The Government have already shown a sympathetic attitude and have offered a fair inducement to rubber planters by allowing all lands already planted, or to be planted, with rubber to be occupied free of assessment for three years in the Wynaad and for five years in the Nilgiris (G. O. No. 1353, Revenue, dated 10th December, 1904); also for three years in the Anamalais—*vide* G. O. No. 181, Revenue, dated 28th January, 1907. This, of course, is an important concession: but there is no gainsaying the fact that planters complain of almost insuperable difficulties in obtaining grants of suitable land for rubber growing."[16]

Some Proposals of Great Interest.

The aforesaid concessions in land tenure that Government made over twenty years ago, without attracting a sufficiency of planters, might now be enhanced to 8 years which the Government offers at present for rubber-growing lands in Burma. The

[16] *Report, Etc.* by Proudlock, p. 49.

reason for it is that it takes almost this period for a rubber estate to be well established and to begin the recoupment of its capital outlay. In 1918-19 the Indian Industrial Commission urged the need of developing the rubber industry in India and declared that it was one of those industries that are essential in the national interest and should be encouraged, if necessary, by special measures. The adoption of such measures by Government has now become insistent. Mr. Proudlock makes another suitable suggestion. "One of the ways," he proposes, "in which further encouragement might be given to planters would be to select tracts of good land suitable for growing rubber and demarcate them into contiguous blocks of 250 and 500 acres each, respectively or in lots, that would be likely to suit investors, and then advertise them for sale, briefly mentioning the terms of occupation in the *Fort St. George Gazette,* in the district gazettes and also in the Indian, Ceylon and London papers."

"It might be advisable to limit each area of land that is to be devoted to the cultivation of rubber to 2,000 acres, or eight blocks of 250 acres or four blocks containing 500 acres each. This would enable both small and large investors to buy just as much land in contiguous lots as they require. The question of leaving, or providing for the planting of, intervening belts of forest or other cultivations between each 2,000 acres of rubber land is an important one for consideration; as the existence or provision of such belts would provide a natural means of checking the spread of any harmful diseases or pests which might break out among the rubber trees in any particular plantation."

A Rubber Policy for India.

"If a policy approximating that roughly outlined above were adopted and modified when and where necessary to suit both state and investors' requirements and circumstances, planters would know exactly what lands were available in each district for rubber cultivation. They could then go and inspect them thoroughly before the dates on which they would be put up for sale. This would save planters and investors much trouble and disappointment in searching for land suitable for rubber growing, which they may afterwards find out is not available, or that there are so many formalities to be gone through and complied with, which often cause long and embarassing delays, before they can obtain possession of the land they wish to have, that they become discouraged and try elsewhere. It is, therefore, in the direction indicated above that the Government, if so disposed, might find further opportunities for giving encouragement which would be very acceptable to, and which would be greatly appreciated by private individuals, syndicates and companies who are willing to invest capital in the cultivation of rubber in the presidency."[17]

Mr. Proudlock further suggests the appointment of a special officer to advise on the organization, planting, propagation and establishment of rubber estates. "It would be an important part of his duty," he proposes, "to discover the best localities to suit the requirements of each particular species that is already introduced or that it is desired to introduce and establish **to decide matters relating to cultivation, distance of planting and pruning, besides many other questions relating to and connected with such work which would require expert knowledge."[18]

The Need of Official Organizations.

For the benefit of rubber growers, it would, of course, be necessary for the Government to establish more experimental farms than exist at present, especially in South India, when private enterprise comes forward to extend this culture. The experience derived from rubber trees in the botanical gardens is of very little value to practical growers. There are at present only two government institutions of this nature in Cochin and Travancore. The Rubber

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[17] *Report, Etc.* by Proudlock, p. 49.
[18] *Ibid*, p. 50.

Experiment Station at Mooply is situated on Palapilly estate in the Mooply valley, Cochin, 10 miles by road from Padukad Railway Station on the Cochin State Railway. It is situated in the middle of a large area of rubber of some 7,000 acres in one unbroken block.[19]

The Rubber Experiment Station at Tenmalai is situated in the Pathanapuram taluk of the Travancore State, on the Quilon-Shencottah line, by the side of the main road 41 miles from Quilon, and half a mile to the west of the Tenmalai Railway Station. The elevation is about 600 feet above sea level and the station which is typical of the district is situated in the large tract of over 10,000 acres of rubber.[20]

Apart from these Government institutions, the organizations of the United Planters' Association of Southern India, Coimbatore, in this direction consist of a Scientific Department with three experts (including a Rubber Mycologist with 7 Experimental and Research Stations) and a Labour Department with 6 Divisional officers and agents throughout South India in 1926.

PRESENT STATE OF INDIA'S RUBBER.

At present the cultivation of the Para, Ceara and Ficus elastica species of rubber is an established industry in India and the areas under them in the provinces in 1926, were as follows:—

Province or State.	Para in acres.	Ceara in acres.	Ficus elastica in acres.	Total in acres.
Burma	68,916	265	3	69,184
Travancore ..	41,167	1,956	542	43,665
Madras	13,022	140	117	13,279
Cochin	8,986	—	—	8,986
Coorg	2,861	—	—	2,861
Mysore	557	107	—	664
Total ..	135,509	2,468	662	138,639

[19] *Report on the Rubber Experiment Station, Mooply*, published by the Department of Agriculture, Madras, 1923.

[20] *Report on the Rubber Experiment Station, Tenmalai*, published by the Department of Agriculture, Madras, 1923.

The total area in India has grown steadily during the last 8 years. It was 118,536 acres in 1919; 124,167 acres in 1920; 124,719 acres in 1921; 125,967 acres in 1922; 128,002 acres in 1923; 129,422 acres in 1924 and 132,580 acres in 1925.

In 1926 the number of rubber plantations in India was 1,171 covering an area of 203,654 acres as against 1,070 with an area of 201,222 acres in the preceding year. New lands planted with rubber in the estates amounted to 9,366 acres and old cultivation abandoned by them amounted to 3,307 acres in 1926, resulting in a net increase of 6,059 acres in the year, *i.e.*, 5 per cent. above the area of the previous year. Of 138,639 acres, the total cultivated area in 1926, only 101,329 acres were tapped. From the table shown it appears that of the total area under cultivation in 1926, 50 per cent. was in Burma, 31 per cent. in Travancore, 10 per cent. in Madras, 6 per cent. in Cochin, 2 per cent. in Coorg and 1 per cent. in Mysore.

During 1926 the total production of raw rubber in India was about 10,270 tons or 23,004,167 lbs. (Hevea 22,813,285 lbs.; Ficus elastica 155,748 lbs. and Ceara 35,134 lbs.). India's negligible outturn of rubber at the present day, despite the early efforts of the Government to encourage this culture, serves to show how greatly the industry has been ignored by capitalists in this country and what enormous wealth has been lost to them. This is very deplorable when we come to consider that countries which have far less chances of success and little need of increasing their wealth-production—such as the U. S. A.—are getting frantic over the development of rubber culture.

In 1926 the yield per acre of tapped area was 234 lbs. in Cochin, 233 lbs. in Travancore, 230 lbs. in Burma, 216 lbs. in Madras, 157 lbs. in Coorg and 41 lbs. in Mysore. In the same year, the daily average number of persons employed in the plantations was returned at 48,383, of which 42,574 were permanent and 5,809 temporary. This labour force was located as follows: in Burma 16,902; in Travancore 20,226; in Madras 6,719; in Cochin 3,300; in Coorg 1,050; and in Mysore 186.

DETAILS OF CULTIVATION IN 1926.

Districts.	Number of Estates.	Acres under Hevea.	Acres Ceara.	Acres F. elastica.	Acres still uncultivated.	Total Acres in Estates.
In Burma—						
Mergui ..	301	20,090	—	—	5,640	25,730
Amherst ..	278	9,379	—	—	1,920	11,299
Thaton ..	146	13,296	—	—	3,391	16,687
Tavoy ..	68	5,518	—	—	1,190	6,708
Insein ..	39	4,546	38	3	2,328	6,915
Toungoo ..	20	6,447	—	—	1,057	7,504
Henzada ..	12	641	—	—	74	715
Hanthawaddy	11	8,139	54	—	3,684	11,877
Salween ..	8	135	—	—	10	145
Pegu ..	2	513	—	—	28	541
Bhamo ..	1	170	—	—	101	271
Arakan Hills	1	—	173	—	2	175
Akyab ..	1	30	—	—	18	48
Maubin ..	1	12	—	—	—	12
In Travancore	214	41,167	1,956	542	24,994	68,659
In Madras—						
Malabar ..	26	10,671	—	—	15,172	25,843
Nilgiris ..	9	1,031	40	117	936	2,124
Salem ..	6	1,320	100	—	751	2,171
In Cochin ..	6	8,986	—	—	1,084	10,070
In Coorg ..	5	2,861	—	—	2,018	4,879
In Mysore—						
Kadur ..	9	557	77	—	252	886
Hassan ..	6	—	—	—	158	158
Shimoga ..	1	—	30	—	207	237
Total India ..	1,171	135,509	2,468	662	65,015	203,654

EXPORT FROM INDIA.

All the raw rubber produced in India is exported to foreign countries. In 1926-27 the export to the United Kingdom amounted to 10,245,699 lbs., to the Straits Settlements to 5,180,770 lbs., to Ceylon to 4,799,539 lbs., to the United States to 2,342,309 lbs. and to other countries to 116,102 lbs.[21]

[21] *Indian Rubber Statistics*, Calcutta, published by the Government of India (Department of Statistics), 1927.

CHAPTER XII.

PARA RUBBER IN BURMA.

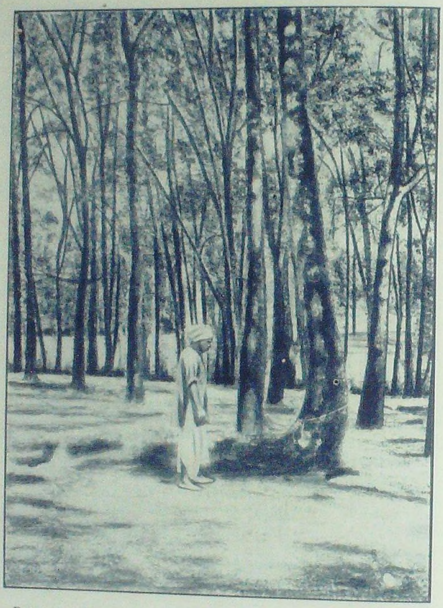
ITS PROMISING FUTURE.

Of all provinces in India, the best prospects for the immediate expansion of rubber culture seem to lie in Burma, and its administration has recently issued a *brochure* with a view to encourage its rubber industry. The Burma Government offers extensive lands for rubber cultivation in 5 districts—Toungoo, Amherst, Thaton, Tavoy and Mergui. Lands are offered in perpetuity without any premium or rent, no land revenue being chargeable for the first 8 years. The authorities notify that in the aforesaid districts there is no difficulty in procuring labour and there are no restrictions on the immigration of labour from India. Moreover, the Stevenson Act has not been applied to Burma. Regarding transport, the facilities by rail, road and river are fairly sufficient in the Toungoo, Thaton and Amherst districts. But in the Tavoy and Mergui districts, transport is still rather deficient. An extensive road scheme, however, is on hand and a railway between Tavoy and Mergui is being constructed. Moreover, there are two steamer services along the sea-coast between Rangoon and Penang which call at Mergui and Tavoy. The Federated Malay States, the biggest rubber-producing country, are not larger in area than the lands now being offered in Burma.

Regarding the comparative conditions of rubber-planting in the F.M.S. and Burma, the opinion of Mr. J. F. S. Taylor, Manager of the Tamok Rubber Estate, Mergui, is valuable as he had been a rubber planter for ten years in the F.M.S. before going to Burma. He is confident that at least the Tavoy and

PLATE 15.

(To face p. 153).



Para trees in Burma, showing the amazing hardiness of a Hevea. Its tap root died of disease and the trunk fell, but it put out a limb which is quite healthy and is being tapped.

(Photo reproduced from "Rubber in Burma.")

Mergui districts have a big advantage over the F.M.S. in rubber growing for the following reasons: "Firstly cost of production is considerably less; secondly there is an almost entire absence of disease amongst trees in Burma; and thirdly the yield per acre on a well-managed estate is actually higher in Tavoy and Mergui than in the F.M.S., and this in spite of the fact that tapping can only be carried on for nine months out of the year owing to climatic conditions. On a part of one estate in the Mergui district, the yield is as high as 500 lbs. per acre and with increased experience there is every possibility of this figure being exceeded."[1]

Burma compares favourably with the F.M.S. regarding output per acre and cost of production. In the former, where the plants are largely immature, the average outturn is roughly 225 lbs. per acre with 9 months' tapping. In the latter, consisting mostly of older estates, it is probably around 315 lbs. with 11 months' tapping. Tapping is usually commenced when the rubber plant is 5 or 6 years old, the yield per acre then being only about 100 lbs. per annum. This increases to about 400 lbs. (wet) as the tree grows older. In Burma the average 'all-in' cost (including London charges) is reported to be about 8.2*d.* per lb. while in the F.M.S. the same cost is 10.3*d.* Rubber trees nearly half a century old are said to exist in Mergui. The many private estates and rubber syndicates now working there seem to be carrying on a lucrative business. Surely the province offers a good opening for enterprising capitalists who could keep themselves going during the period of maturity with some other kind of farming. For large syndicates there is the added attraction of tin and wolfram mining in the southern districts.

Major H. R. Pelly, lately Deputy Commissioner of Tavoy and Mergui, compares these districts with the F.M.S. thus: "A comparison between this tract of country (*i.e.* the Tavoy and Mergui districts) and the F.M.S. is instructive. The area of the former is about

[1] *Rubber in Burma* issued by the Government of Burma, 1926, p. 29.

15,000 sq. miles or more than half the size of the F.M.S. which measure 27,000 sq. miles. The climate is similar but the F.M.S. are not so healthy. The rainfall in the F.M.S. is rather less, being a little under 100 inches. Both countries are rich in tin and forests, and both are suitable for rubber and cocoanut growing. As regards rubber, however, Burma has the advantage, as not only is the cost of production less than in the F.M.S., but there is an almost total absence of disease in the trees and comparatively little sickness amongst coolies owing to the absence of malaria. Moreover, no premium is charged by the Government of Burma for jungle land taken up for rubber planting, whereas in the F.M.S. $25 per acre premium is charged in addition to the rent which is considerably larger than the land revenue charged in Burma."[2]

Extensive Suitable Tracts.

Mr. T. D. Stock, Offg. Director of Agriculture, Burma, in a note, dated 28th May, 1926, on Rubber Cultivation in the Tavoy and Mergui districts, throws a flood of light on the present position and latent possibilities of rubber culture in the two districts. "In Tavoy and Mergui alone," he affirms, "it is estimated that there are 120,000 acres suitable for rubber extension. In speaking of a tract where there is so little land developed and so much lying waste or under jungle, an estimate of suitable land for agricultural purposes is almost certain to embrace only the most suitable areas. The present estimate includes only the more level lands and gentler slopes. I am of opinion that the estimate is therefore a conservative one, for outside the areas which have been demarcated are steeper lands which must suggest themselves for planting schemes when the more eminently suitable sites have been taken up. The lands which have been pronounced suitable for rubber extension in these districts comprise blocks up to 6,500 acres or more in extent. Some of these are in close proximity to established areas. I have no hesitation in saying that all

[2] *Rubber in Burma*, p. 25.

the areas demarcated will grow rubber, but some of them will grow better rubber than others, and I propose to indicate these in dealing briefly with the various localities."[3]

IN THE TAVOY DISTRICT.

"The total area under rubber in Tavoy is 6,506 acres, while the area pronounced to be suitable for further extension is 18,900. That local interest in rubber cultivation has been stimulated by prevailing good prices is indicated by the fact that during the past year 17 applications have been made for small areas up to 300 acres in extent. In the Yebyu township the suitable area is estimated to be 8,500 acres. Of this the most promising site is the Egani tract of 4,500 acres situated between the villages of Egani and Yalaing and within two miles of the Tavoy river. Here the soil is a good clay loam at present covered with mixed forest. The land is flat or slightly undulating and the whole area would make an excellent site for a large estate. Further north near Pachaung on the Kambauk road and also between Nankye and Kaleinaung other sites are available. Conditions here are not so good: the soil is poorer and the land in most parts is covered with mixed bamboo jungle. Apart from the area of 3,000 acres of fairly level land on the road from Nankye to Kaleinaung there are few promising sites. The country is hilly and much broken up and does not impress me as having possibilities for development on any extensive scale."[4]

"In the Tavoy township along the Myitta road there are small sites at Khatyua village and in the neighbourhood of Myitta. At Kyaukmedaung there is an established plantation of 1,600 acres, but apart from these areas the land is too hilly for plantation work. In the Launglon township rubber is in evidence on the road from Tavoy to Maungmagan. There are in this township about 4,500 acres in scattered areas available for further development. With the excep-

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[3] *Rubber in Burma*, pp. 17-18.
[4] *Ibid*, p. 18.

tion of the lower lying areas, however, the land is not of the best quality and the bulk of the rubber which has been planted is not in a very flourishing condition. In the Thayetchaung township we have, in my opinion, some of the best land in the district. Excellent sites for rubber suggest themselves in the neighbourhood of Pyibyutha between the 30th and 33rd mile, between Yange and Kadwe and again between Kayichaung and Aukthayetchaung river. Another large area extends from Pe village to the Tavoy-Mergui border. These for the most part are level areas with good drainage. The soils vary from sandy to light clay loam with a good proportion of organic matter and overlying sand and gravel sub-soils. The sites vary from 1,000 to 6,000 acres in extent and possess a tremendous advantage in being on the main trunk road between Tavoy and Mergui."[5]

In the Mergui District.

"In the Mergui district, it is estimated, there are at least 100,000 acres which might profitably be opened up for rubber, but in the absence of a detailed survey it is not possible to refer to more than a few specified areas which lying on or near the main lines of communication, permitted of examination in the short time at my disposal. On the main trunk road from Tavoy to Mergui are many excellent sites. I am particularly impressed with certain localities between Pe and Palauk and between Palaw and Tamok where level or gently undulating areas up to 6,000 acres in extent are to be found between the hill ranges and the coast. The soil is a light sandy loam overlying gravel or laterite sub-soils. Good drainage is obtained and the soil, except where it has been denuded by *taungya* fellings, is usually of good depth and quality."[6]

"On the Tenasserim river there is an area extending north of Tharabwin along the Tharabwin *chaung*, and in the valley of the Little Tenasserim an

[5] *Rubber in Burma*, pp. 18-19.
[6] *Ibid*, p. 19.

area of perhaps 30,000 acres lying south of the Thakyetchaung down to the Ngawunchaung. Here the soil for the most part consists of clay loam of good depth and quality. On the higher slopes the soil grades into sandy loam or disintegrated laterite. The hollows have a tendency to waterlogging in the rains and for planting purposes should, therefore, be avoided. The whole area is covered with heavy jungle. On King Island the bulk of the rubber land has been taken up, while Kissering Island, I am told, is subject to cyclonic disturbances."[7]

"It appears, therefore, that further development will be confined to the main-land where any land which is not flooded during the rains and which is not too steep for planting will be found suitable for rubber. The manager of one of the larger Burma estates—a man with wide experience of rubber in the Federated Malay States—has expressed the opinion that we have here the finest rubber land in the East and his opinion is endorsed by one of the Visiting Agents who comes up periodically from Malaya. On one estate last year two blocks of rubber gave an average yield of 550 lbs. to the acre. The same area is expected to yield at the rate of 600 lbs. to the acre this year. It will be difficult to find in the Federated Malay States figures to compare with these: they indicate, perhaps more than anything else can, what a rosy future there is for rubber in this part of Burma."[8]

THE TREND OF DEVELOPMENT.

"Most of the older estates are extending their area. During the past year the applications for rubber grants in the district amounted to 41,226 acres. There are already 25,000 acres of planted rubber in the district and of all other crops 116,925 acres under cultivation. For the extension of field crops little scope is offered: the population is small and conditions generally unfavourable. Some of the low-lying areas might be utilized for paddy but this would depend on the opening up of the district, the development

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[7] *Rubber in Burma*, p. 19.
[8] *Ibid*, pp. 19-20.

of plantation crops like rubber, cocoanuts and possibly oil-palm and the influx of labour which would naturally follow the extension of planting interests. The point I would stress is that the bulk of the land in the Mergui district is suitable only for plantation crops and it is upon the development of these that the prosperity of the district will largely depend. The oil-palm is likely to do well. Where it has been tried, it has made magnificent growth and come into bearing after three years whereas the usual period is four years. Land in the Federated Malay States is getting scarce and should the palm-oil industry go ahead in the East, as there is every reason to believe it will, attention is sure to rivet on to areas in Burma. What is needed now is a more thorough survey of the areas in Mergui which are suitable for plantation crops. The areas once demarcated will permit of classification into (*a*) those suitable for capitalised planting, and (*b*) those suitable for the small planters."[9]

Some Excellent Suggestions.

In view of the fact that land in the Federated Malay States is getting scarce, as this report informs us, it is indeed fortunate that the Burma Government is offering such excellent sites for rubber cultivation as above described. Mr. T. D. Stock's suggestions to the Government, to provide both for the small and large capitalist, as well as for their assistance from scientific experts, are very opportune and deserve early adoption. "I would strongly advise," remarks Mr. Stock, "against the indiscriminate issue of grants. It is difficult to find large compact areas, and capitalised concerns will require areas of at least two to three thousand acres in extent. To issue one or two small grants of a few hundred acres in an area of say three thousand acres would tend to spoil it as a site for a large plantation. The smaller areas might be entirely reserved for the small planter, and to safeguard his interests further certain specified areas of larger size might be cut up into blocks of a hundred acres."[10]

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[9] *Rubber in Burma*, p. 20.
[10] *Ibid*, pp. 20-21.

"The planting industry in Burma is receiving more and more attention from the man with small capital. At present his interests are mainly concerned with rubber and this is likely to continue. In visiting these small plantations, one can hardly fail to observe evidence of faulty and insufficient knowledge—bad spacing, drastic bark consumption and tapping wounds. If the need for better methods is realized at all, the small planters have nobody to go to for advice. More often than not they carry on in blissful ignorance of the fact that the trees are not being given a proper chance. The larger plantations have their Visiting Agents and occasional visits from experts of the Rubber Growers' Association. The Agricultural Department must, therefore, in the interest of the small grower take early steps to fill one of the vacant Senior Agricultural Assistant's posts with a man having special training in plantation crops and a knowledge of mycology. He should have attached to him an expert tapper as fieldman and his main line of attack will be to arrange simple lectures illustrated with lantern slides at district and township headquarters and to carry out demonstrations in methods of tapping on small native estates."[11]

Transport Development in Burma.

The success of rubber culture in the Federated Malay States is in no small measure due to their extensive means of transport. Major M. T. Porter, R. E., Engineer-in-Chief, Burma-Siam Railway Survey, indeed affirms 'there is not the least doubt that the successful production of rubber in the F.M.S. on the scale to which it has reached is due to the excellent communications, both road and rail, with which that country is provided.' In Burma, though transport facilities by rail, road and river are fairly sufficient for the present in the Toungoo, Thaton and Amherst districts, they are still rather deficient in the Tavoy and Mergui districts, as already indicated. It is for this reason that the Burma Government has begun an extensive road and

[11] *Rubber in Burma*, p. 21.

rail construction scheme for the Tenasserim division. A trunk road to connect Mergui with Tavoy and feeder roads from it into the districts, as well as the metalling of the existing roads are programmed. The proposed Ye-Tavoy-Mergui Railway is expected to be mostly along the trunk road and if possible to tap Prachuab. At present the chief means of communication in this region are steamers and taxis.

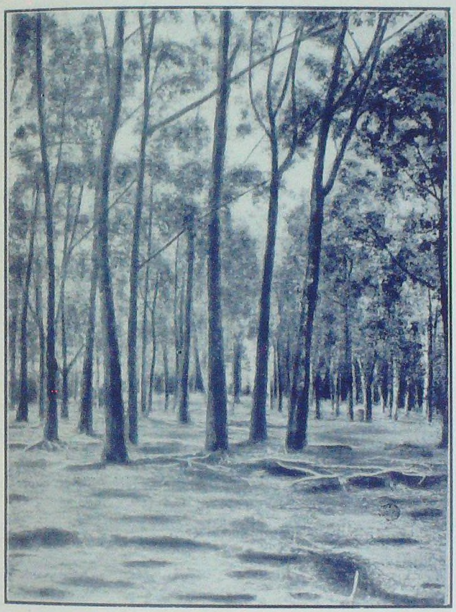
A fortnightly coastal steamer service, calling at Victoria Point, Mergui and Tavoy, is maintained between Penang and Moulmein, and a weekly coastal steamer service between Victoria Point and Rangoon, calling at Mergui and Tavoy, is also conducted at present. It is believed that the bulk of the passenger traffic in the Tenasserim division will be carried by rail, instead of by steamers as at present, when the railway comes through owing to the intense dislike to travelling by sea of the average Burman and Indian. This is evident from the fact that taxis are now running in relays between impassable rivers, the passengers being carried across the latter by boat, and a through service between Tavoy and Mergui is thus kept up. These taxis are being extensively used in preference to the B.I.S.N. Co.'s steamers and launches, although the rates are usually doubled during the monsoon owing to the bad condition of the roads. The promoters of this railway are confident that it will stimulate trade in general and open up large areas for rubber, paddy and fruit cultivation as well as offer a better facility for tin and wolfram mining.

Disease Control and the Life of Para.

Tapping is conducted in Malaya for 11 months in the year and in some estates without cessation throughout the 12 months. In Burma the trees are tapped only for 9 months because the heavy rains of the monsoon restrict the flow of latex during July, August and September. But it has now been definitely established that by this rest the trees are positively benefited. Their vitality is thus increased, which confers on them greater immunity from disease, their bark is conserved which

PLATE 16.

(To face p. 160).



A portion of the Crown Rubber Estate at Mergui, showing soil-wash as a result of clean weeding.

(Photo reproduced from "Rubber in Burma.")

PLATE 17.

(To face p. 161).

A portion of the Crown Rubber Estate at Mergui, showing terraces constructed to prevent further soil-wash and the herring-bone system of tapping.

(*Photo reproduced from "Rubber in Burma."*)

is a valuable asset especially in young plants and these conditions generally tend to lengthen the life of rubber trees in Burma where the Hevea is known to be a good latex yielder even at an advanced age. Planters think that the cessation from work recuperates the energy of the tree at the right time when diseases are most prevalent. Some years ago, Dutch research workers in Java came to the conclusion that Para rubber yields most latex between the ages of 11 and 15, after which time its yield tends to diminish and that 30 years is its normal period of production. Consequently, many companies in that region still deduct 5 per cent. for depreciation after the trees attain the age of 15 years.

Mr. J. Burns, Manager of the Mergui Crown Rubber Estates, Ld., however, claims to have disproved this theory by showing that in his plantations trees between 30 and 47 years old are as good yielders as the younger ones. " No one yet knows," he remarks, " how long a rubber tree will live for and there is conclusive proof to show that in the same way no one yet knows at what age a rubber tree ceases to be a paying proposition. Certainly, age does not seem to have any effect on its output. Some of the oldest trees have proved better yielders than the younger ones. It is fortunate that we have some of the oldest plantation rubber trees in the world in Burma."[12] Few scientists probably possess sufficient knowledge of rubber plant physiology to be able to refute Mr. Burns' statement regarding the occasional greater yielding capacity of older trees. However illuminating may be his experience, it merely seems to signify that the vitality of rubber trees can be greatly enhanced under improved conditions of climate and treatment, but it can hardly serve to disprove the biological fact of ultimate decay in rubber trees or the economic ' law of diminishing productivity ' from rubber culture. This is also one of the reasons why wild rubber sources are gradually diminishing.

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[12] *Rubber in Burma*, p. 32.

Diseases of Para in Burma.

Hevea brasiliensis is in a favoured position with regard to fungoid diseases in Burma, in the opinion of Mr. D. Rhind, B. Sc., Mycologist to the Burma Government. "The climate is such," he observes, "that the dry period from November to May checks many diseases effectively so that it is only during the rainy months that fungi can flourish to any extent. Compared with the Federated Malay States, rubber in Burma is particularly well off in this respect. The dreaded *Fomes lignosus* (*semitostus*) root disease has not been recorded here so far. Mouldy Rot is unknown and Brown Bast occurs to a negligible extent only. Thus three of the most destructive diseases, all directly affecting yields, are still of no importance or quite absent."[13] Burma has a small share of rubber diseases nevertheless and planters cannot afford to neglect them.

In other rubber-growing countries, root diseases are especially dreaded, but they do very little damage in this country though of general occurrence all over Lower Burma. "The commonest form met with," explains Mr. Rhind, "is due to *Ustulina zonata*, commonly a wound parasite, a fungus which rarely kills more than one tree at a time and which can easily be controlled by trenching round the tree affected. The losses from this disease probably do not exceed one tree per a hundred acres per annum. Brown Root disease is much rarer, only two cases having come to the writer's notice during the last three years. Wet Root rot due to *Fomes pseudo-ferreous* occurs in an isolated patch in the Mergui district only. While this disease is more destructive than the two former, it is at present confined to one place and is of little importance."[14] White ants occasionally cause trouble in the extreme south of Burma, but the species that attack rubber do not occur in the middle zone.

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[13] *Rubber in Burma*, p. 13.
[14] *Ibid.*

The most important of all rubber diseases in Burma, according to Mr. Rhind, is Black Thread Canker of the renewing bark, a very prominent stem disease. "This disease, caused by a species of *Phytophthora*," he explains, "only occurs during the monsoon, but no estate is free from it and unless care is taken, it is capable of doing much damage. *** It has been found that the application of suitable disinfectants to the cut controls the disease perfectly and all well-managed estates now do this. Patch Canker occurs to a small extent and, except in the South, does not usually require treatment, the diseased bark drying up and separating from the tree spontaneously during the dry weather."[15] Though it is never serious, all estates can show some cases of Pink Disease.

Speaking of Brown Bast, the Government Mycologist says that at present (1926) there is remarkably little of this obscure disease in Burma. "Recently," he observes, "it has been attracting considerable attention in the F.M.S., Java and Sumatra, and a treatment cheap and effective, has been worked out; so that should the disease ever increase the means of dealing with it are at hand. **A leaf disease occurs to a greater or less extent during the monsoon. It is caused by a *Phytophthora* related to that which causes Black Thread. Leaves which are attacked soon fall and this has earned the disease the name of 'abnormal or secondary leaf-fall.' The severity of the disease depends entirely on weather conditions. If there is a break in the monsoon with a few days' sunshine the disease is checked at once. Fortunately such a break frequently occurs about the beginning of July."[16] Planters who possess the experience of rubber culture both in Burma and Malaya, such as Mr. J. F. S. Taylor, General Manager of the Tamok Rubber Estate, Mergui, seem to be of opinion that Burma is not troubled with rubber plant diseases to the same extent as Malaya.

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[15] *Rubber in Burma*, p. 14.

[16] *Ibid*, pp. 14-15.

Labour and Cost of Production.

There is no difficulty in procuring a sufficient supply of labour in Upper Burma and no restriction is imposed on the indenture of garden coolies from abroad. Burma in consequence seems to be in a better position regarding the provision of workers for rubber estates than most places in the Middle East excepting South India which in itself is the recruiting ground for a portion of the labourers employed in Malaya, Ceylon and Dutch East Indies. Cheap labour is, therefore, a reason for the low cost of rubber production in this province of India, another reason being the comparatively easy terms on which land is obtained there for this cultivation. Reliable estimates place the average 'all-in' cost of rubber production in Burma around 9*d.* a lb. A detailed statement of the Moulmein Rubber Plantations, Ld., published in December 1925, shows the estate cost as 7.926 annas and the 'all-in' cost as 8.508 annas per lb. (At 1*s.* 4*d.* per rupee exchange in 1925, 1 penny=1 anna.) Compared with this 8½*d.*, the average 'all-in' cost in Malaya has been worked out at 10.3*d.* in 1925. This is the chief reason for the very lucrative nature of rubber culture in Burma—a fact which is supported by the high dividends paid by some of the rubber concerns there. To give instances, for the year ended July 1925, the Burma Para Rubber Co., Ld., paid 30 per cent., for the year ended August 1925, the Moulmein Rubber Plantation, Ld., paid 18 per cent. and, for the year ended May 1925, the Tenasserim Hevea Plantations, Ld., paid 17½ per cent. on capital invested.[17]

[17] *Rubber in Burma*, p. 26.

CHAPTER XIII.

RUBBER IN CEYLON

BUD-GRAFTING EXPERIMENTS.

As foreshadowed in a previous chapter, there is much activity at present in Ceylon to bring about improvements in rubber culture, especially along the line of bud-grafting. These efforts have been initiated in the island apparently as a result of the economic pressure that is being felt everywhere in this industry; but, as Ceylon is the pioneer rubber-cultivating land, much valuable experience will be derived from its endeavours. In the Ceylon Agricultural Conference held at Peradeniya, in May 1928, the Governor presiding, Mr. T. H. Holland, Manager of the Peradeniya Experiment Station, read an interesting paper on "The Budding of Rubber and Transport of Bud-wood." Among the conditions which affect the success of budding, he indicated and discussed such points as the nature of the bud-wood, the actual process of grafting and weather conditions best suited to the operation.

"If the bud-wood is too mature," he indicated, "or for any reason dried up, it will be impossible to successfully remove the bud which will probably remain attached to the branch. The best results can be obtained from bud-wood which is still green or has only recently turned brown. In 1927 a separate record was kept of the successes obtained from the use of green bud-wood and brown bud-wood; 15 per cent. more successes were obtained from green wood. This was possibly not a fair test as the brown wood included a good deal of bud-wood which arrived from estates or other countries in poor condition. It is clear, however, that green wood can be used and that chances of success are at least as great as with brown wood. The best bud-wood is obtained from pollarded trees, and, at Peradeniya it is necessary to pollard the trees at least a year before the bud-wood is required. It is probable that the manuring of the pollarded trees will both increase the rate of production and improve the quality of the bud-wood. Any mixture used for this purpose should include a fair proportion of a quick-acting nitrogenous manure."

After describing the actual process of grafting, as done by trained coolies in his Station, Mr. Holland proceeded to remark that no budding in the field had yet been done at Peradeniya. Mr. C. E. A. Dias had found budding in the field more successful than budding in the nursery, because his experience was that shoots from plants budded in the field grew more quickly and uniformly than those from plants budded in the nursery and transplanted. Speaking on the weather suitable for grafting, Mr. Holland found that a dry period following the operation was fatal to a large percentage of successes. Light showers and a fairly humid atmosphere were the desirable conditions. It was not possible to predict exactly when such conditions occur in Ceylon, but in a normal season September, March and April would be good months for grafting in the island. Mr. Holland further observed that the influence of stock on scion in rubber budding was a problem still under investigation, but it was obvious that a vigorous free-growing stock was desirable. On this point, the views of Mr. F. Summers (recorded in pp. 78 and 79 of this book) may be consulted.

In regard to the transport of bud-wood, Mr. Holland had some experience to relate. "Bud-wood has been received," he stated, "from other countries packed in two ways. In a consignment received from Java, each shoot was separately wrapped in damp jute hessian and the hessian was in turn surrounded by a plantain sheath. These bundles were packed in damp saw-dust in a wooden case. Fifty per cent. of successes was obtained from this bud-wood though weather conditions were most unfavourable, no rain falling for 10 days after budding. Another consignment of bud-wood was received from the Federated Malay States. In this case the shoots were wrapped in jute hessian and packed in dry charcoal in wooden cases. This bud-wood arrived in a very dry state, and buds peeled badly and only 16 per cent. of successes was obtained. In this case again weather conditions were unfortunate, but not more so than in the case of the Java consignment. Since writing these notes, another consignment of bud-wood was received from Sumatra. Each bundle of two pieces was wrapped in plantain sheaths, but no jute hessian was used. The ends were waxed. This bud-wood had the appearance of having heated considerably and was practically useless. Eight buds were put on but it will be surprising if any successes are obtained."

BUD-GRAFTING AND SEED-SELECTION.

In the discussion which followed at this Conference, Mr. J. W. Oldfield, a prominent planter, said that he had no doubt as to the efficacy of bud-grafting but what he would like to stress was the importance of seed-selection. His view was that *bud-grafting could only extend the existing plant, but it could not improve its yield.* The only method of *improving the yield* was *by seed selection* and the gradual elimination of poor yielders. He admitted that bud-grafting was a short-cut in the preliminary stages of that work, but, so far as other plants were concerned, experience pointed to the possibility of increasing the supply of good yielders, but not of improving their yield. Seed selection would improve the strain and thus gradually result in higher yielders than at present.

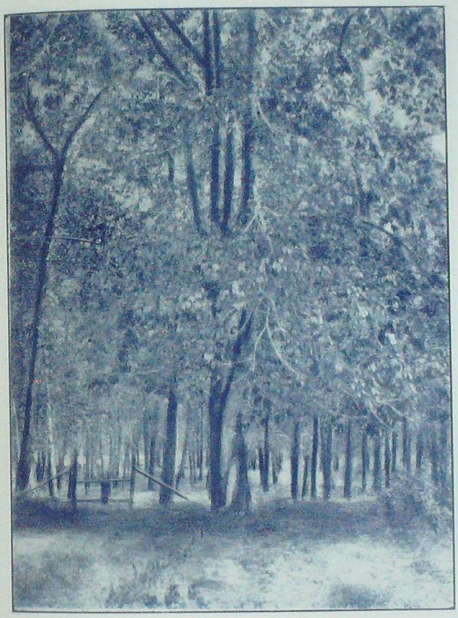
Mr. Oldfield is quite right in stressing the point that bud-grafting is essentially a process in vegetative propagation or extension (as we have explained in a previous chapter) and that it possesses no inherent power of improving the yielding capacity which may be imparted to it merely by seed-selection. In other words, *bud-grafting is purely a method of transmitting parent characteristics* (see pp. 60 and 61), whatever these characters may be; and, the present policy is to utilize it for the purpose of increasing the yield of rubber estates. Hence, the immediate object is an improvement in quantity rather than in quality. But these distinct functions should not lead to the confused notion that bud-grafting by itself is able to improve the quantity or quality of latex.

Regarding this argument, Mr. F. A. Stockdale, Director of Agriculture, urged that it was quite true yields could be increased by means of seedlings. If one had a population of seedlings of which one knew the origin, one might get a certain number of high yielders. This was being done on estates where, by picking up and planting a number of high yielders, it was possible to get areas composed only of high yielding plants. An example of this was the old rubber at Henratgoda. Henratgoda No. 2 still stood tapping and had yielded the equivalent of 4.95 lbs. last year. There were other trees in Ceylon which were known to give higher yields. He had heard of one tree which had yielded over 100 lbs. during the year.* They should try to isolate these good yielders for budded plantations and test whether they budded true or not and at the same time establish seed gardens of budded material for the production of seed from these particular trees.

Mr. Stockdale moreover said that the only figures available for Ceylon at present were those of the progeny of Henratgoda No. 2, areas of which had been planted at Peradeniya and Henratgoda. The Peradeniya figures had shown that, where they knew only the parent on one side, namely Henratgoda No. 2, they secured a 40 per cent. increase over other rubber of mixed parentage of the same age. In other words,

*This is a very exceptional outturn. Usually healthy mature trees, by a conservative system of tapping, yield from 3 to 11 lbs. of dry rubber per tree each year. With a more liberal system, the best yielders would give from 12 to 25 lbs.

PLATE 18.
(To face p. 168).



Para trees in the old Experiment Garden at Mergui. The tree in front, though 48 years old, has a luxuriant foliage and was photographed during the worst stage of secondary leaf-fall.

(Photo reproduced from "Rubber in Burma.")

PLATE 19.
(To face p. 169).

Budded Hevea Trees Planted in 1918 on the United States Rubber Co.'s Plantations in Sumatra.
(Reproduced from the "India Rubber World.")

merely by this simple process of selection, they had increased their yields by 40 per cent. One could easily conceive what that meant to an industry compelled to reduce the cost of production per pound as much as possible. If they isolated these trees and used only pure seed, crossing from one tree to the other of the same original budded stock, it was possible that they could get even higher yields. At the same time he thought it most desirable that the budding scheme should go on simultaneously with the seed selection programme, because the only way in which one could prove the value of any tree or its seedlings was by analysis of the seedlings and one could imagine how long that would take, considering that the figures of Henratgoda No. 2 took 15 years to produce.

At the same time, Mr. Stockdale thought it was very necessary that these good trees should be tested for their budding ability. It had been found in the Straits and the Dutch East Indies that several trees did not bud true. There were no figures of the yield of budded rubber at Peradeniya, but these were being allowed out for tapping and figures should be available in the course of the year. Mr. Dias had tapped some of his trees, but, in the case of the older ones, he had not any record of their origin. He thought that, whereas seed selection was desirable, it was a very long process and the commercial situation at the present time required that they should have available both bud-wood and selected seed as early as possible.

Dr. P. J. S. Cramer also advises Ceylon planters to import proved bud-wood from Malaya and Dutch East Indies for the present since Ceylon has few or no tested mother trees yet and it will take at least 4 or 5 years to prove them. Hence bud-grafting cannot be undertaken there from unproved mother trees just yet on a commercial scale. But to have their own material as early as possible, they ought to start the work now and test their clones in due course.

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(To face p. 169).

Budded Hevea Trees Planted in 1918 on the United States Rubber Co.'s Plantations in Sumatra.

(Reproduced from the "India Rubber World.")

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SOIL EROSION.

At the aforsaid Agricultural Conference, an instructive paper on Soil Erosion was read by Mr. C. E. A. Dias. This subject is of special interest to Ceylon because many estates there are prone to surface denudation owing to their being located on the sloping lands of this hilly island. Opening his discourse with the accepted theory that the surface contains the largest proportion of organic matter, thereby being the richest and most productive portion of the soil, he proceeded to further explain that the removal of any appreciable amount of the top stratum reduces the constituents of plant food especially the nitrogen. It also exposes the yellowish or reddish sub-soil which is heavier and more difficult to work than the original surface soil. He put forward the contention that, even by applying manure, these sub-soils could not be rendered so productive as the surface soil. To prevent soil-erosion, he indicated the well-known remedies by which *stone-terraces* are built and *silt-pits* dug on the lower sides of the trees so as to retain the washed-off soil. He explained that this soil is brought back and put on the exposed roots which are thus re-covered, and then creeping leguminous plants are sown.

THE PROBLEM OF MANURING.

Ceylon planters seem to be interesting themselves at present with suitable methods of manuring. Possibly some of their estates, being among the oldest in the Middle East, possess a certain proportion of aged trees the yields of which are declining. The need of manuring of course arises everywhere occasionally, not only owing to aged trees but to leaching, soil-erosion and other causes. Efficient fertilization, such as would procure in the long run a net result of economic gain, however seems one of the most perplexing problems in agriculture generally; and, there is less faith in the efficacy of manuring at the present day than in former times. Agricultural chemists are now the first to admit that the processes so far adopted in the system of fertilization leave much room for improvement.

Under the existing system, when a plant shows signs of poor growth or inadequate outturn, the defect is attributed to infertility of the soil, *i.e.*, to a meagreness of the elements in it that go to provide food for the plant. To ascertain the nature of the deficiency, the soil is analysed mechanically and chemically; and the plant is also examined by a chemical analysis of the ash obtained by burning portions taken from the tree. Next, the analyses are compared with the approximate standards which usually exist of what the constituents should be in either case and the defect is sought to be remedied by the application of suitable manures to the soil. The ash analysis does not seem to be of such value as the soil analysis, but it serves at least the purpose of roughly checking the accuracy of the other, both being obtained from similar chemical sources. There are still some shortcomings in the system itself.

Early in this century, the essential principles of manuring were lucidly exposed by M. Georges Ville, then leader of the French school of agricultural chemists, and by Sir William Crookes, the eminent British chemist. Ville gave the analyses of various kinds of soil and species of plant, also discoursed fully on their chemical composition and the methods of restoring fertility in land for different crops. In propounding the basis of agricultural chemistry, these authorities wrote thus: "Chemical analysis shows that about 14 elements enter into the composition of all kinds of plants; they are divided into organic and inorganic elements, the former being carbon, hydrogen, oxygen, nitrogen, and the latter phosphorus, sulphur, chlorine, silicon, iron, manganese (?) calcium, magnesium, sodium and potassium.[1]

DEFECTS IN THE PRESENT SYSTEM.

Since the days of Ville, the system of manuring has made little progress, as may be gathered from the writings of subsequent agricultural chemists. "If a plant is burnt," says Dr. Griffiths, "the organic con-

[1] *Artificial Manures* by Ville, translated and edited by Sir William Crookes, London, 1909, p. 4.

stituents pass away in the form of gases due to their oxidation and the ash that remains consists of the mineral or inorganic constituents which the plant derived from the soil." He explains that the fertility of a soil principally depends upon the presence of organic and inorganic elements. "According to the *law of minimum*," says Griffiths, "a soil destitute of any one of these mineral ingredients may become more or less barren, since it is the minimum of any one essential ingredient, and not the maximum of others, which is the measure of fertility." Then, the vital point is not what the soil contains but what is *available* for the plant. "A soil may contain," he continues, "an abundance of potash, lime, phosphoric acid, iron, etc., and yet be almost barren if these substances exist as *insoluble* compounds. All the ingredients found in the ashes of plants must be present in a soil and in such a form that they are capable of being absorbed by the roots."[2]

Speaking on the methods of ascertaining the chemical nature of soils, Adie and Wood refer to the defect in one of the methods thus: "In making an analysis of a soil, we may go to work from either of two points of view: (1) To find out how great a store of plant food substances the soil contains, in which case we require to find the total percentages of lime, potash, phosphoric acid and nitrogen present. (2) To find out the amounts of each of these substances *available* for plant food at the time of taking the sample. This is a much more difficult matter than to determine the total quantities, for we are not as yet completely informed of the manner in which plant food substances are dissolved out of the soil for absorption by the roots."[3] Wrightson and Newsham are more destructive in their criticism of the existing system of soil analysis. "There can be no doubt," they affirm, "that a soil may be rich according to analysis and unproductive in practice, and the reverse is equally true.*** Fertility depends upon such a large

[2] *A Treatise on Manures* by Griffiths, London and New York, pp. 3, 13 and 15.

[3] *Agricultural Chemistry* by Adie and Wood, London, Trubner and Co., Vol. II. pp. 16 and 17.

number of circumstances, above, below, around and in the soil, that a mere chemical analysis is insufficient."[4]

Equally insufficient is the plant analysis because it reveals nothing of the organic matter that was in the portion of the plant burned and analysed. This matter which has passed out of the ash went to form, along with the inorganic matter, important substances such as proteins (albuminoids), carbohydrates and cellulose. Carbohydrates include the sugars and starches found in the roots and seeds of plants. Cellulose goes to form the cell-walls and fibrous portions of plants. Then, the protoplasm (seat of plant life), after removal of water, contains nucleo protein 40 per cent., carbohydrates and fats 24 per cent. and other proteins 15 per cent. About 16 per cent. of the proteins consists of nitrogen. In fact from the present methods of analysis, it is found that nitrogen, phosphorus and potash are more essential to plant food than the other constituents.*

In regard to soil analysis, the recent pronouncement of an agricultural chemist is not more encouraging. "It is generally admitted now," says Corrie, "that the actual chemical analysis of a soil really possesses much less value in this direction than might naturally be assumed, and with the possible exception of the lime content, one is only able to obtain limited information of value for practical purposes, although, of course, if an analysis showed poverty in any essential constituent, there would be little question as to the need for supplying this to the soil. Chemical analysis of

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[4] *Agriculture, Theoretical and Practical* by Wrightson and Newsham, London, Lockwood, 1921, p. 13.

*In chemistry there were some misconceptions originally regarding the so-called 'organic' and 'inorganic' elements. In the last century carbon, hydrogen, oxygen and nitrogen were regarded as organic elements because they were believed to be the products of some 'vital force.' But since many so-called organic substances have been made artificially from inorganic materials, the distinction between organic and inorganic elements has begun to disappear. And, since almost all the important groups of chemical substances found in plants and animals have been manufactured in the laboratory without the aid of living matter, the astonishing conclusion is inevitable that both the chemical substances and the chemical processes of living Nature are of the same general character as those in the non-living or inorganic world.

the soil may, however, be used for comparative purposes."[5]

FERTILITY OF FOREST LANDS.

Until an improved method of soil analysis is devised, manuring will continue to be more or less a speculative operation. Nevertheless it must be resorted to in cases of urgency which are fortunately rare in rubber estates. These plantations are usually sown on forest lands which remain fertile for a long period. Speaking of such soil recently, an eminent authority on agriculture, Sir E. J. Russel, observes as follows: "Being the remains of previous generations of plants, it contains all substances necessary to the life of the plants, and, in addition, material synthesised by the plant during its life and still containing energy fixed by chlorophyll from the sun's rays. In the soil this energy material supports a multitude of micro-organisms:*** Thus, the remains of one generation of plants afford food for a later generation."[6]

A view similar to the above was expressed on rubber lands many years ago by Wright. "It must be remembered," he said, "that Para rubber trees form a forest vegetation, and that they will grow well in relatively inferior soils, providing there is a fair balance of plant food and the climatic conditions are favourable. The soil under forest vegetation improves in mechanical and chemical composition with age, owing to the protection which the trees afford to the soil, to the action of the roots and the accumulation of leaf mould. The annual fall of leaf from Para rubber trees ultimately effects an improvement in the soil in which the trees are being grown. This is borne out by the analyses of the soils at Henratgoda, the results proving that the organic matter, potash and nitrogen are greater in the soil which has been under rubber for 29 years than that which has been under pasture; the lime and magnesia

[5] *Manures and Manuring* by Corrie, London, Chapman and Hall, 1927, pp. 9 and 10.

[6] *Encyclopaedia Britannica*, 13th Edit. 1926, Vol. I. Article on Agriculture.

have decreased under the old rubber, while the phosphoric acid is the same under both conditions."[7] When manuring has become imperative, the procedure which the planter has to adopt is too well known to need any indication.

THE SYSTEM OF MANURING.

Apart from the chemical composition of a soil, its physical properties and climatic surroundings are of no little value in determining its fertility. It is for this reason that the dictum of Wrightson and Newsham, already quoted, does not seem too sweeping. Physical properties chiefly consist in the nature of the soil (alluvial, sandy, clayey or otherwise) and the level at which water is usually present in it. A plant largely depends upon finely-divided soil particles for its food-supply, without which even the aeration and moistening of the upper stratum would be incomplete. Hence in the mechanical analysis, if some 30 per cent. of the soil passes through a 90 mesh, about 30 per cent. through a 60 mesh, some 6 per cent. through a 30 mesh and about 34 per cent. consists of sand and small stones, the soil is regarded as satisfactory. Alluvial land with a perennial water-level 5 to 7 feet below the surface is considered about the best for Hevea.

Good physical properties in the soil seem to be essential, if all the chemical constituents in it are to be made available for the plant, but on this point our knowledge is still rather limited. Anyway, if the soil possesses good physical properties, we may proceed to analyse it chemically so as to ascertain what kind of manure it may require. A circular of the Royal Botanic Garden, Peradeniya, reports that "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." Compared with the soils in this island, the mineral contents of the F.M.S. soils are very often inferior, the

[7] *Hevea Brasiliensis* Etc., by Wright, p. 43.

chief deficiency being potash rather than phosphoric acid, according to Mr. Kelway Bamber.

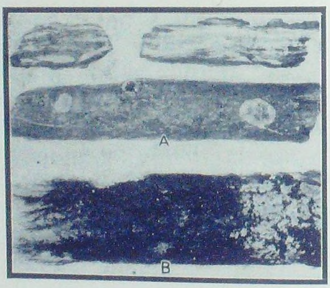
In regard to manuring, it must be recognised that, if a certain system or composition has proved successful for Hevea in Java, it may not prove equally good for Hevea in Ceylon, because fertility depends on various conditions, apart from the species of plant cultivated. After a comparison of the soil analysis with the plant analysis, the defects in the soil may be sought to be remedied by the application of artificial manures. Where nitrogen is deficient, it may be supplied in the form of sulphate of ammonia, nitrate of soda, blood meal, groundnut cake, castor cake, etc. When phosphoric acid is wanting, it may be provided in the form of superphosphate, phosphate of lime, basic slag, bone dust, etc. If potash is required, it may be added in the form of chloride, sulphate or nitrate of potash.

PLATE 20.
(To face p. 176).

Leaves, flowers, fruits and seeds of Hevea Brasiliensis.
(Photo by H. F. Macmillan.)

PLATE 21.
(To face p. 177).

Fructifications of *Fomes lignosus* on a Hevea stump. The brackets are about a foot above the ground.



Mycelium of *Fomes lignosus* on Hevea roots. A=Young mycelium beneath and on the outer surface of roots. B=Septo-basidium on stem.

CHAPTER XIV.

DISEASES AND PESTS OF HEVEA.

THE ORIGIN OF DISEASES.

Like most plants, Hevea is prone to maladies which are known to be caused chiefly by the attack of some fungus on a part of the tree. Pathological study is still new on this subject, yet mycologists are doubtless of opinion that it is possible for a disease in Hevea to arise, not merely in the aforesaid manner, but from some irregular function in its physiology or by an abnormal condition in its morphology. Entomologists occasionally find this tree attacked by insects, but they observe that the inroads of these pests rarely lead to much damage.

In recent times bacteria have been associated with plant pathology, but so far no conclusive evidence has been adduced to show that even the most obscure Hevea disease is due to bacteria. Almost all these maladies are caused by fungi, and it is very rare that any such disease has been attributed to functional disorders or structural abnormalities in the tree. Even the attacks of insects have scarcely ever done any serious damage to the plant. Parasitic fungi have, however, caused no little injury to Hevea and economic loss to the planter, to prevent which the general sanitation of an estate and the timely treatment of disease should be provided for.

THE SANITATION OF ESTATES.

From the present experience of pathologists, it is quite obvious that when a Hevea plantation is to be sown on reclaimed forest land, the stumps of all trees should be uprooted to guard against the origin in them of fungi and insects. Often this work is postponed till the estate is planted, and sometimes it is even delayed until fungoid diseases actually appear on the trees, the neglect being condoned on the ground that the initial outlay should be curtailed. But this is false economy, as, apart from the loss by disease, the extraction of stumps from a planted estate is accompanied by damage to the roots of neighbouring trees. And, not only do the decaying stumps, trunks and other debris of forest trees germinate fungi and bacteria, but those of other trees including Hevea are equally fertile in this respect. It is for this reason that mycologists are against the practice of 'thinning out' estates unless the stumps and roots of the eliminated Hevea are carefully extracted.

A clean under-soil and an uncongested surface are among the primary requisites of a healthy estate. On the one hand it should be borne in mind that, if there were no dead stumps in the sub-soil, there would very rarely be any root disease. On the other, we must not forget that close-planting obstructs fresh air and sunlight, apart from the other objections to it as recorded in previous chapters. Moreover, it is believed that the yield falls off sooner in closely planted areas as the tree grows older, also that close-planting leads to poor bark renewal owing to the crown of the tree being too small to provide for sufficient food-supply. Of course, distant-planting tends to wash away the surface soil, but this may be prevented by low cover crops.

Intercropping seems also a delusion in the long run, as under it the Hevea would finally predominate and the other crop have to be exterminated, resulting in stump-extraction which is likely to damage the roots of the surrounding Hevea. If an intercrop is desired as a means of preventing the spread of disease, mycologists think that it is very rare to find a useful plant which would not be prone to some of the diseases of Hevea. For similar reasons, even disease-resisting belts of Ceara and *Ficus elastica* (at one time greatly recommended) seem to be of little practical utility, especially as a diseased Hevea can always be isolated by digging a trench around it.

REGIONAL PECULIARITIES.

Experience teaches us that a disease may be virulent and wide-spread in one soil or climate and not in another, which shows that there are regional peculiarities as regards the occurrence of Hevea diseases. For instance, a malady commonly affecting the plant in Brazil, may seldom attack it in Malaya. Even in Brazil itself, Hevea on the flood lands and moist climate of the lower Amazon shows a high rate of attack from fungi and other diseases, while on the higher soils and drier air of the upper Amazon, it is usually free from some of these same enemies. Such is also the case in the Middle East, where many of the maladies that Hevea is heir to have not appeared. Of those that have occurred here a few only have been reported from every rubber-growing country. And some of them have been more virulent or persistent in one country and less in another.

With such varied experience, it should be possible to bring about a certain degree of natural immunity from disease in the cultivated Hevea. This might be done by the avoidance of noted unhealthy localities, by the total destruction of jungle debris, by the selection of seeds from mature, disease-resisting and vigorous trees, by uprooting the stumps of Hevea that may have to be eliminated, and by establishing drainage in water-logged portions of estates. With such precautions, the services of the plant physician and surgeon would probably be seldom requisitioned.

HEVEA STRUCTURE AND FUNCTIONS.

Since these diseases appear in different parts of Hevea, a brief sketch of the structure and functions of these portions, to afford a clear insight into the subject, may here be given.

Like all trees, the main parts of Hevea may be known as the organs of *nutrition* and *reproduction* while those portions which relate mostly to growth or development might be provisionally regarded as *vegetative*. In botany the original conception was that plants have mainly the reproductive and the vegetative (non-reproductive) portions. But this vague generalisation has given place to a clearer physiological anatomy owing to the detailed analysis which the structure and functions of plants have been subjected to. Still this science, without further investigation, is unable to clearly distinguish between certain portions in individual species, that is, whether they come within the first or the last category. Generalised in the above manner, the leaves and roots would come within the first, the fruits, flowers and seeds within the second, and the stem and branches within the last group.[1] But this crude conception of structure, originally due to an insufficient knowledge of functions, might now be discarded.

Plant life is primarily divided into two main classes—'phanerogams' or plants bearing flowers and 'cryptogams' or plants having no evident flowers.[2] The higher plants possess chlorophyll, a green colouring substance, with the aid of which by the action of sunlight (a process now termed as 'photo-synthesis') they convert gases from the air and mineral constituents

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[1] Under the old structural conception, plants have mainly the organs of *vegetation* and *reproduction*, as recorded by Julius von Sachs. But this writer regrets the obscurity thus: "Any one who has been exclusively concerned with the formal morphology of the vegetable kingdom prevalent during the last thirty or forty years, can scarcely conceive the importance which the vegetative organs possess physiologically." *The Physiology of Plants* by Sachs, translated by Ward, Oxford, 1887, pp. 1 and 2.

[2] There are, however, many divisions and sub-divisions in the vegetable kingdom, as evident from the position assigned to each plant according to its structure. Classed in this manner, the Para rubber tree belongs to the species *brasiliensis* of the genus *Hevea*, in the family of *Euphorbiaceae*, in the sub-class *monochlamydeae* in the class of *dicotyledons*, in the sub-phylum *angiosperms* of the phylum *phanerogams*. This classification is according to Kerner and Oliver whose system differs slightly in detail from those adopted by the earlier authorities like Linnæus, Bentham and Hooker.

from the soil into plant-food.* From the economic standpoint, the whole life of the globe depends on the photosynthetic power of green plants. They alone are able to create in themselves their own food. Non-green plants and animals do not possess this power but are entirely dependent on the green plant for their sustenance. It is for this reason that photosynthesis has been regarded as a very vital phenomenon of life.

The *leaves* are the respiratory and transpiratory organs while they help also in the function of food assimilation. Respiration is the inhaling and exhaling of atmospheric gases which takes place mostly through the 'stomata' (pores) in the leaves. Transpiration is the exudation of water from the plant by a stream which arises from the roots and escapes through the stomata. The leaves absorb carbon dioxide from the air, of which the carbon goes to form sugar, starch and other food-stuffs for the use of the tree while the oxygen is exhaled and returned to the air.[3]

The *roots* imbibe from the soil (through the root-hairs) the water necessary to the growth of the tree together with certain mineral constituents (such as nitrogen, phosphorus and potash) which form part of the food-supply, while they put into the soil certain substances which they do not require. Moreover, the roots maintain the position of the tree in the ground. Such being the root functions, when a tree suffers from a root-disease, mycologists say that it suffers largely from the ill-effects of a protracted drought.

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*This process, first disclosed by Baeyer, has come to possess a name which is not very accurate. Photosynthesis means 'synthesis by the action of light,' but it is not certain that the actual synthetic process is due to such action.

[3] In recent years Drs. G. Haberlandt and E. Strasburger have observed many special functions and features in plants, mostly contributing towards the three main organisms above-named, which they discuss in their writings. These are among the most recent contributions to plant physiology and morphology. "Even the founders," remarks the former writer, "of vegetable anatomy and physiology could not altogether fail to observe that the various members of the plant body are endowed with special functions.*** The earlier work in this field, however, produced little more than a mass of disconnected observations, which admitted only of the vaguest generalisation." *Physiological Plant Anatomy* by Haberlandt, translated by Drummond, Macmillan, London, 1918, p. 12; also see Strasburger's *Handbook of Practical Botany*, 1924.

The *stem* or trunk carries the nourishment between the roots and the crown, stores up usually a reserve stock of food and supports automatically the branches and foliage.[4] The stem consists of five layers: (1) the outer corky bark, (2) the cortex or laticiferous bark (including the bast), (3) the cambium, (4) the sap-wood, and (5) the heart-wood. That part of Hevea which largely concerns the rubber planter is the outer stem and of this the most important layer is the cortex containing the 'latex cells.' Here it should be remembered that trees of different species differ somewhat in morphology which, for instance, is not the same in a laticiferous as in a coniferous tree.

Describing the stem in general, a botanist remarks: "Included in the cortex are the 'sieve-tubes,' a system of conducting channels which convey the manufactured food downwards from the leaves and branches. These tubes lie close to the wood and together with certain other elements form what is known as 'the bast.' Between the cortex and the sapwood lies a delicate glutinous layer called the 'cambium' as thick as an ordinary sheet of paper but which supplies the growing cells for the increase in thickness of stem, branches and roots."

The *cambium* lies between the xylem (wood) and the phloem (bast). It is made up of cells capable of dividing and forming new tissue. It builds up bast on its outer and wood on its inner surface. Such being its function, it should be left protected by a thin wall of cortex, which if pierced in the process of tapping results in a wound or rupture in the cambium. Even the sapwood may be injured if the tapping is violent.

It is well-known that 'latex-cells' occur only in laticiferous plants and that Hevea latex consists mainly of water and caoutchouc globules with small quantities of sugar, proteid, gum, resin, etc. The theory has been urged, quite reasonably, by certain Hevea botanists that

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[4] Some of the old theories in plant physiology (including those on *the ascent and descent of sap*) have been destructively assailed by the researches of scientists in this century.

most of these constituents cannot be regarded as forming reserve food for the plant, and, in any case, the water is more important than the others for the above purpose. Wright seems inclined to accept this view and quotes Warming as well as Parkin to the effect that the latex does not play an important part in nutrition but that the laticiferous system serves as channels for holding water in reserve to be drawn upon during times of drought.[5]

Present Ideas of Plant Life.

There can be no question that a condition precedent to the successful diagnosis of plant disease is the correct study of plant morphology and physiology—not as separate entities but as a series of connected phenomena. In the last century the pathologist was greatly handicapped in his researches by these two sciences being wrapped in embryonic obscurity. The manifold organs and complex functions of plant life baffled even the botanist in his simpler pursuits. His conception of the vegetative and reproductive organs was largely subjective and similar to the abstract idea of 'the economic man' as conceived by the classical economists. But a more lurid light is now dawning on the horizon and there is hope that Nature will yield her secrets less reluctantly.

The old formal morphology, which dealt with conformation in the abstract, has given place to the study of organography largely introduced by Karl von Goebel between 1913 and 1923. The recent progress in this science is well described by a leading living botanist, Prof. F. O. Bower, twice president of the botanical section of the British Association. "Thus, within half a century," he observes, "we see evidence of an extreme swing of the pendulum, from 1870 when systematic botany ruled and physiology was ignored, to a present position when physiology is advanced by some at the expense of morphology. It must be borne in mind that systematic botany is but the methodised product of

[5] *Hevea Brasiliensis*, Etc., by Wright, pp. 6 and 7.

morphology and morphology the record of continued physiological action. The several branches can never be detached with impunity."[6]

During this generation, the patient researches of eminent scientists, in the West and even in the East, have met with success sufficient at least to encourage the pursuit of their efforts. And, at the present day we find that plant life, partly as a result of investigations by Sachs, deBary, Goebel, Schleiden, Bose and other pioneer workers, is being studied from various points of view—such as its mechanical system, absorbing system, vascular or conducting system, storage system, aerating or ventilating system, motor system, sensory system, secretory and excretory systems. These aspects of plant structure and functions have been systematically recorded and discussed by Haberlandt in his famous work from which we have already quoted.

FUNGI AND DISEASE.

Fungi form an extensive group of inferior plants classed under Thallophyta which is a sub-division of Cryptogams. Their position in the vegetable kingdom may be readily perceived from the undernoted classification which is according to the scheme of Engler and Prantl:—

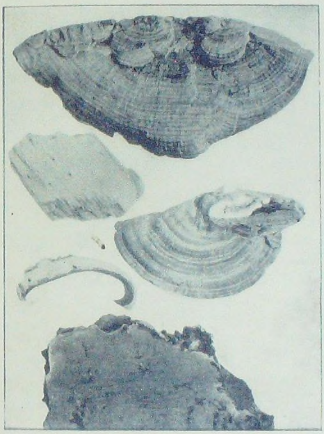
CRYPTOGAMS.

- Bryophyta, (Mosses, etc.)
- Thallophyta
  - Fungi
  - Algæ (Seaweeds, etc.)
  - Bacteria
- Pteridophyta. (Ferns, etc.)

All fungi agree in not possessing chlorophyll, the green colouring substance of almost all plant life. Here it might be recalled that the higher plants

[6] *Encyclopaedia Britannica*, 13th Edit., 1926. Vol. I. under Botany.

PLATE 22
(To face p. 184).



Fructifications of *Fomes lignosus* on Hevea, showing the horizontal semi-circular brackets, the last being reversed.

PLATE 23.

(To face p. 185).

Pink Disease in a Hevea showing the corticium stage.

(Photo prepared from Drawings.)

derive one portion of their food from the air and another from the soil. These elements are mostly inorganic, that is, they are not the direct products of a living body. But coming under the influence of chlorophyll, they get converted into plant food which is an organic substance. Fungi are destitute of chlorophyll and so they cannot assimilate inorganic food constituents, but require some organic food-stuff. This they obtain by feeding on the bodies of other plants, alive or decayed.

Those fungi which feed on dead organic matter, such as decayed wood, rotten leaves and manure, are termed *saprophytes,* while those which live and feed on living plants, known as their 'hosts,' are referred to as *parasites.* These are not terms of classification, however, because some fungi are able to live either as parasites or as saprophytes, and they are known as *facultative* forms. But those restricted to either the parasitic or the saprophytic habit are termed as *obligate* forms. In the processes of life, certain fungi exude poisons and act in other ways detrimental (possibly also to some degree beneficial) to their hosts, as will presently appear. In these circumstances, it is evident that plant diseases are caused mostly by parasitic fungi which seem responsible for more damage in the vegetable kingdom than done by saprophytes or other organic bodies.

A well-known writer on mycology explains that the *mycelium* or spawn of a fungus is the vegetative part of it, doing the same kind of work as done by the roots and leaves of higher plants, which consists in obtaining and assimilating food.[7] Another mycologist describes that the vegetative system of a fungus consists of filiform cells called the *hyphae* and the *hyphae* taken collectively is termed the *mycelium.* Here it may be remarked that the structure of this system is not the

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[7] Mycelium has also been described as the cellular filamentous spawn of fungi, consisting of whitish filaments spreading like a net-work.

same in every class of fungi. A fungus usually develops its mycelium underground or in the nutrient substratum, but its spores (*conidia*), which are equivalent to the seeds of higher plants, are found in its fruiting portion called *fructification*. This is often superficial. Spores come above the ground or reach the air through the sporophores. Fruiting is said to be the final act of development in the life of a fungus.

On decaying stumps the fungus lives as a saprophyte, growing in dense clusters between the dead tissues. Its mycelium consists of thin, cord-like strands which radiate in all directions within the substratum. If any of these strands come into contact with the roots of a living tree, it attacks the root tissues, when the fungus adopts a parasitic mode of life. Then the parasite grows and spreads until it envelops at least the root-system with its mycelium. Speaking generally, the parasitic fungus lives within the tissues of the host plant, occupying the spaces between the cells and into which suckers (termed *haustoria*) are sent. By means of these it absorbs the contents of the cells.

CLASSIFICATION AND PECULIARITIES.

Fungi are distinguished in the abovenamed manner chiefly according to their behaviour in nutrition. They are classified more scientifically according to their structural development, modes of life and reproduction. *Phyco mycetes* (algal fungi) form the lowest class in this order. They are alga-like fungi which include the aquatic species and the simplest land species. Reproduction in them is of a simple type, the nuclei usually fusing in the same cell. Their characteristic fructification is the *sporangium*. *Asco mycetes* (sac fungi) constitute the next class which includes a great number of species all having spores developed within a mother cell (the *ascus*). *Basidio mycetes* (basidial fungi) form the highest class which encloses a fairly large number of superior fungi whose spores are formed from special, fertile cells, termed the *basidia*.

In the phycomycetes, the hyphæ are either quite undivided or very faintly divided. But in the higher fungi, the hyphæ are divided by transverse *septa* and so they are often referred to as septate filaments. "The mycelium in the true or higher fungi (ascomycetes and basidiomycetes)," describes a well-known writer, "is usually composed of hyphæ with cross-walls or septa at regular intervals and formed in succession at the back of the apex of the hyphæ, which thus shows a definite apical growth." It may be noted that the spores of basidiomycetes are known as *conidia* when they are non-sexual. These spores are borne upon special structures termed *basidia* which are usually undivided club-shaped cells.

In the early stage of mycology, it was supposed that the mode of reproduction in fungi was either obscure or mainly asexual. But in recent times their sexual reproduction has been clearly understood, at least for most of the higher classes. At present, the largest class of fungi is believed to be the ascomycetes which exhibit a great variety in size, structure as well as in habits. Reproduction is still regarded as asexual for some of them however. They may produce several kinds of spores, both sexual and asexual, like many of the fungi, but the characteristic type is the ascophore.

The singular nature in some fungi of changing from one state of existence to another is known as 'polymorphism.' Possibly this is induced by the varying conditions of food-supply and may be a highly developed form of what is known as 'adaptability to environment.' But this ability is quite different from the facultative habit some fungi assume, and 'polymorphism' has been defined as the capacity of some fungi, especially the *ascomycetes*, to assume different forms at different periods of their full development. In consequence much of the difficulty of identifying a fungus and of diagnosing fungoid diseases appear to be due to these varying conditions. Again, these are distinct from the structural development which every fungus undergoes in its life cycle, and with the phases of which growth are connected more or less the stages of a fungoid disease.

The Causation of Fungoid Diseases.

The dissemination of a fungus takes place in various ways, of which the most common may here be described. A parasitic fungus spreads by the wind carrying its spores and depositing them on the leaves, fruits and other parts of the host plant. As a rule short distances merely are so encompassed, but spores may be conveyed further by other agencies such as birds, hares, running water and insects. Spores thus disseminated enter the tissues of the host plant where they germinate. Another ordinary way of parasitic fungus infection is by the mycelium coming into contact with the roots of a neighbouring tree. Still another manner is by 'wound parasites' depositing their spores on cut or open portions of a plant by one of the aforesaid means of communication. These parasites are fungi whose spores are incapable of directly penetrating living tissues, and so they first germinate on the decaying tissues of a wound and then gradually attack the adjoining living tissues.

When a fungus attacks the roots of a tree, the latter suffers not only from the symptoms of poor feeding or malnutrition but from the ill-effects of a drought. Dr. E. J. Butler, the eminent mycologist, explains that a fungus may attack the leaves of a plant and destroy so many of the starch-making cells that there is not enough left to complete its development and so it remains stunted and unable to mature its fruit. He describes well the causation of diseases when he says that "some fungi manufacture poisons which kill the cells, others consume the food which should go to feed the plant, others prevent it forming its seeds by destroying the flower or fruit, others set up rotting of some vital part, such as the base of the stem, so that the aboveground part collapses and is cut off from the roots."[8]

[8] *Fungi and Disease in Plants* by Butler, Calcutta, 1918, p. 75.

It may be explained, however, that a particular species of fungus very seldom causes more than one type of disease.

THE NATURE OF BACTERIA.

Though from their structure and functions, it is not easy to distinguish between some of the lower orders in the organic world, bacteria are recognised within the realm of vegetables and outside the animal kingdom. Dr. Butler observes that bacteria belong to a very low order in plant life and like fungi possess no chlorophyll. Dr. A. C. Abbott, the American bacteriologist, discusses these minute organisms as follows: "Bacteria constitute a genus of lowly organized microscopic plants.** In the parasitic group of bacteria, we encounter those species that exist always at the expense of a living host, either animal or vegetable, and in doing so not only appropriate materials necessary to life but give off in return waste products that may act as direct poisons to the host."[9]

Here it may be pointed out that bacteria act largely as the scavengers of Nature and not merely as the agents of disease, as formerly supposed. They are usually innocuous towards plants and even perform functions which are beneficial to them by helping to effect chemical changes in the food constituents of the soil. But they often cause injury to animals (especially to men) by their harmful infection. In consequence of their relations with diverse spheres in the organic world, bacteria have been the objects of close investigation by bacteriologists since the days of Koch and Pasteur. Massee explains that bacteria, popularly termed as 'germs' or 'microbes,' are better known as the cause of diseases in the animal kingdom. Further he states that in recent times bacteria have been connected with plant pathology and numerous plant diseases have been attributed to them, some rightly and some wrongly.[10]

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[9] *Encyclopaedia Americana, New York, Vol. II.*

[10] *A Text Book of Plant Diseases* by George Massee, London, 1907.

In this survey, the diseases of *Hevea brasiliensis* which have appeared in the Middle East will be recorded and mere passing references to some common Hevea maladies in Brazil will be made. Mycologists usually group these diseases according to the parts of the tree—root, stem, leaf, pod, bark, etc.—which they attack and so the same order will be followed as far as possible. But this is obviously not meant to be regarded as the best scientific classification. The pathology on this subject is still young, and so the present grouping, progressively regarded, seems no other than provisional.

ROOT DISEASES.

WATERY ROOT-ROT.

The watery root-rot fungus, originally recorded as *Fomes semitostus* a different species, is now known in the Middle East as *Fomes lignosus,* Klotzsch, and in the Amazon Valley as *Polyporus lignosus,* Klotzsch. (Its other synonyms are *P. Kamphoveneri,* Fr. and *P. diffusus,* Fr.)

The malady caused by this fungus is the most widely-known root disease of Hevea. It has wrought serious damage to this tree for many years in different countries. In 1904 it was first reported by Ridley at Singapore and in the following year it was also found in Ceylon. Since then it has been known to cause serious injury to rubber estates in Malaya and Ceylon where it is probably the commonest root-disease, large sums of money having been spent there on its eradication. It also occurs in South India, the Dutch East Indies, West Africa and throughout the Amazon Valley. The host range of this fungus is very extensive and it has been found on the decaying timber, stumps and roots of an endless variety of trees. What makes the fungus extremely difficult to extirpate is that, unlike most fungi, its mycelium seems to travel underground for short distances unaided by any root or dead wood.

ITS SYMPTOMS, FRUCTIFICATION AND COLORATION.

Mr. T. Petch, the great authority on diseases of the rubber tree, says: "As a rule this disease is readily identified by the mycelium on the exterior of the roots. This takes the form of stout smooth cords firmly attached to the bark, running more or less longitudinally along the root and uniting here and there to form a network. These cords may be white or yellowish white or reddish.*** It is rare that the mycelium extends up the stem above ground. When it does the strands usually divide into finer threads, or separate hyphæ, which can only be detected with difficulty among the rough bark at the base of the stem. This, however, in general, only occurs when the tap root has been almost completely destroyed.*** The external mycelium gives rise to threads which penetrate into the tissues of the root and bring about their decay; and the whole of the wood and cortex is ultimately permeated with fine fungus threads which render them soft and friable. The type of rot varies, but in Ceylon the decayed wood is often wet and sodden."[11]

Mr. J. R. Weir, a leading plant pathologist of the United States, after his recent admirable study of Hevea diseases in Brazil, writes on *P. lignosus* as follows: "The internal symptom of the fungus is the presence of a soft watery decay. The diseased wood in the last stages of decay may be squeezed in the hand into a shapeless mass. The bark of the infected roots may exhibit a darker brown color than normal and when removed may exhibit white, yellowish, or reddish strands of mycelium on the under surface or embedded in the decayed wood. In some cases there was a development of a mycelial net-work of strands on the exterior of roots, as has been reported for the fungus in the East. This soft, spongy, watery decay was found in the roots of a Hevea tree that had been injured by fire.*** The fruiting bodies of the fungus are

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[11] *The Diseases and Pests of the Rubber Tree* by Petch, London, 1921, pp. 28 and 29. Mr. T. Petch is now Director of the Tea Research Institute in Ceylon as he is also an authority

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among the most conspicuous of all tropical species. Originating as a small knob-like protuberence, the fungus develops horizontally into a bracket of a semi-circular shape. It is from a fourth to half an inch in thickness at the point of attachment and thins out regularly toward the margin. In exceptional cases the brackets may attain a length of 8 inches and a breadth of 20 inches, but the usual dimensions are about 3 by 4 inches. The brackets may appear singly or in numbers, one above another. *** The most conspicuous visible character of the fungus is its brilliant color when fresh. The upper surface is a rich red-brown with a buff-yellow margin. As the fungus reaches maturity, alternating zones of red, brown, and yellow appear which finally becomes less conspicuous as the fungus dries. When dry it is a more or less uniform yellowish brown or wood color, with concentric zones of darker color. The lower surface when fresh is a bright orange, which deepens to a reddish brown with age."[12]

Describing the fruiting bodies and coloration of this fungus, Petch presented a similar picture years ago thus: "The fructification first appears as a small orange-yellow cushion. This grows out horizontally into a flat plate, more or less semi-circular in outline, attached to the stump along its hinder margin. In general, this plate is up to four inches in diameter, but in favourable situations it may be as much as a foot. It is about half an inch thick behind, and thins out regularly towards the margin. From their shape fungi of this class are known as bracket fungi: *** *Fomes lignosus* is identified by its colour, but the colour varies enormously according to the age of the fungus and the amount of moisture in it. At first the bracket is a rich red-brown on the upper surface, with a bright yellow margin, while its lower surface is bright orange. If it dries in that stage, the red-brown colour of the upper surface gradually disappears, not uniformly all over, but in concentric zones,

[12] *A Pathological Survey of the Para Rubber Tree* (*Hevea Brasiliensis*) *in the Amazon Valley* by Weir, Washington, 1926, pp. 7 and 9.

PLATE 24.
(To face p. 192).

Claret-Coloured Canker in Hevea.
(Photo prepared from Drawings.)

PLATE 25.

(To face p. 193).

Black lines in the wood caused by *Ustulina zonata*.

so that it becomes banded with broad alternate zones of red-brown and yellow-brown. When fully developed, it is still red-brown, but paler than in the earlier stages, and is marked with fine, concentric, darker red-brown lines; at the same time it loses its orange margin, and the lower surface becomes red-brown."[13]

How it Spreads and Develops.

Though this disease has done much harm in Ceylon and Malaya, for reasons which we shall see presently, it was until recent years scarcely known in South India or Burma. Dr. E. J. Butler, now President of the Imperial Mycological Bureau in London, writes in 1918 that "*Fomes lignosus* has only once been reported in Southern India," and we have seen that Mr. D. Rhind, the Burma Mycologist, in a report written in 1926, says that "the dreaded *Fomes lignosus* (*semitostus*) root disease has not been recorded here so far." Until recent years, rubber planting suffered much through inexperience in Ceylon and Malaya. Jungle stumps were not uprooted in time, the estates were 'thinned out' leaving hevea stumps buried underground, intercrops (such as tea, cocoa and cassava) got rid off merely by cutting down the plants at ground level with similar neglect, and this disease working below the soil was seldom discovered until in an advanced stage. The effect of all this disregard was the frequent or extensive occurrence of the disease.

Petch relates how on one occasion in Ceylon 700 hevea trees, over an area of about 80 acres, blew over in one night. The tap roots of these trees were attacked and destroyed, leaving only the lateral roots to support them. When this occurs, the tree may not show any external symptom of the disease. In this perilous form of attack, the lower part of the stem sometimes becomes fluted, by which the disease may be discovered. Weir remarks that the fluted condition of the base may indicate that the tap root has been destroyed and Petch explains that the tap root being

[13] *The Diseases and Pests of the Rubber Tree*, pp. 30-31.

decayed the increase of girth in the stem is most apparent over the main lateral roots, so that a vertical ridge is developed above each of them, giving the lower trunk a fluted appearance. Apparently this symptom would be clearly visible only when the tap root is entirely destroyed. In the early stage, it could hardly be detected.

Further observations are clearly necessary to discover some other external symptoms when the tap root is attacked, as, in such a case, the fluted base does not invariably appear, and, in the absence of any sure indication, the tree may be overthrown without even a suspicion of the disease. This seems the most deceptive condition in the attacks of this fungus. When the tap root is attacked, the tree should however suffer from the ill effects of a drought or from inadequate nutrition generally, the symptoms of which would appear on the tree.

When the laterals are first attacked, the smaller branches in the crown may die back. In some cases, the flow of latex ceases at an early stage, while in others it continues until the leaves wither; but, a case is also described where the laterals were covered with a network of mycelium without showing any die-back in the crown or falling off in the yield of latex. Petch is of opinion that this fungus usually makes its appearance in a new clearing when the trees are 1 to 3 years old and that probably in the majority of attacks, the tree dies within 12 months.

Treatment.

Mycologists opine that there is little chance of saving a tree that is attacked by a root disease unless it be in the first stage of infection. The fungus working underground is seldom discovered until at least the first tree is too far gone to be saved. Root diseases are generally treated by cutting out the affected roots, removing any decaying stumps or timber that may lie buried near by and burning them all on the spot at once. Then the affected patch or area should be isolated by digging a deep trench around it and next lime should be well forked into the soil. The wounds in the cut roots should be painted with some preservative.

"The treatment of *Fomes lignosus*" observes Petch, "follows the usual lines of digging out and burning diseased roots and all dead stumps or rotting timber, liming the patch, and surrounding it by a trench. It is very important that the diseased laterals should be followed up as far as possible and lime scattered especially along their path. Lack of success in treating *Fomes* is frequently due to neglect of this point. Another cause of failure is the unwillingness of the planter to put the trench far enough away from the original dead tree. By the time one tree has died, the lateral roots of the surrounding trees have in many cases been attacked, and if these have not been isolated the disease will in all probability have travelled a row farther on before they in turn die. The trench should always be cut so as to include the four nearest trees, even if the latter appear quite healthy. Many estates practise double trenching, especially where more than one tree has died."[14]

Every tree in the patch should be examined by laying bare its tap and lateral roots. "If only one or two laterals," indicates the aforesaid writer, "are decayed, these may be cut back into sound tissue and the wound tarred. In some cases, where the disease has only just attacked the roots, it has been possible to treat them by scraping off the superficial mycelium and painting them with Brunolinum or other preservatives, or even with tar. This possibility depends on the fact that the superficial mycelium frequently spreads for some distance along a root before penetrating it. But if the bark and wood beneath the mycelium is attacked, either the diseased part or whole root must be cut out."[15]

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[14] *Diseases and Pests of the Rubber Tree*, p. 40.
[15] *Ibid*, p. 41.

BROWN ROOT DISEASE.

The fungus of this disease is identified both by Petch and Weir as *Fomes lamaoensis*, Murr. but Butler describes it as *Hymenochaete noxia*, Berk, which Weir regards as merely a synonym of *Fomes lamaoensis*, Murr. Petch is also aware of this fungus having a second name but he objects to it technically.

Butler says that this fungus has been identified in India, while Weir writes that it was not found on Hevea in the Amazon Valley but has been reported by a mistaken identity from the West Indies. Petch thinks that it leads to probably the commonest root disease of the rubber tree in Ceylon where it was first recorded on Hevea, though it does not usually cause such damage as *Fomes lignosus*. Unlike that formidable parasite which bridges over the gaps in its medium of progress, thus fungus spreads very slowly and only along the roots of a tree. It cannot infect the root of a neighbouring tree unless it is in contact with it.

This disease is not confined to Hevea. It attacks many cultivated plants as well as rubber trees such as Ceara and *Castilloa elastica*. In South India and the Federated Malay States it has occurred among Hevea. But the disease does not seem to be a common Hevea complaint except perhaps in Ceylon, and it is very rare in Burma where Rhind reports in 1926 that only two cases had come to his notice during the three previous years.

IDENTIFICATION AND TREATMENT.

Brown root disease may be identified, according to Petch, by the following symptoms:—" Roots encrusted with sand, earth, and small stones, fastened to the root by fine brown mycelium which is collected here and there in brown masses. When old a black crust develops over the brown masses. Wood permeated, sometimes honeycombed, by brown lines or bands with sometimes a few thin black lines. Fructification rarely developed—a very hard, purple-brown bracket, pale or dark brown in section."[16]

The treatment indicated is the same as for *Fomes lignosus* without the need of having a double trench round the infected tree. Lime should be forked into the soil at the rate of 60 lbs. for every diseased tree. Trees at an early stage of the disease, indicates Petch, may usually be detected by finding the occurrence of patches of decayed bark at the collar where a diseased lateral joins the tap root.

BLACK LINE ROT.

This disease, also known as 'Dry Root and Collar Rot,' is caused by the fungus *Ustulina zonata*, Lev. As a root disease of Hevea, it is common in the Federated Malay States and Burma, but less so in Ceylon. It also attacks Hevea in the Amazon Valley, Java and Fiji.

In 1915 Mr. F. T. Brooks first reported it (in Bull. 22, Dept. of Agr., F. M. S.) as a disease which chiefly affects the collar and root system of old hevea trees. In 1916 Mr. A. Sharples wrote (in Bull. 25 of the same Department) that it is a wound parasite causing dry-root and collar rot. "This root disease," he described, "is common on most of the older plantations in the Federated Malay States, though its presence is unsuspected. The fungus works slowly and insidiously, the crown of leaves becoming thin as it progresses in the collar. The diseased tissue is usually confined to one side of the collar, and from this side latex cannot be obtained. The opposite side may give a good yield, and tapping is continued till the amount of latex obtained begins to diminish. When this stage is reached the tree soon dies and is taken out." He stated that the fungus grows on decayed stumps and spreads from one tree to another by a contact of roots, but pointed out that, as it appears in the older

[16] *Diseases and Pests of the Rubber Tree*, p. 75.

estates where very few stumps remain, there are probably other means of infection.

Petch explains that, as there is seldom any way of knowing how long ago a tree has been attacked, it is possible that infections may date from the time when stumps were present. But he adds that an infection of this disease may be caused through wounds by means of wind or insect-borne spores and that this does happen is obvious from the attacks of *Ustulina* on the stem, several feet above the ground without any such disease being present in the roots. He observes that the progress of the disease seems slow in Ceylon. It may arise at the collar independently of any attack on the laterals and the decayed bark and wood often weathers out, leaving a large hole at the foot of one side of the trunk. In some cases it attacks the tap root when the tree may be blown over before any disease is suspected, but usually the decay of the collar or roots is accompanied by a die-back of the branches in the crown. When the collar is attacked, the latex still flows from the opposite side, sometimes yielding an abnormal quantity.

"The affected wood at the base of the stem," describes Petch, "is permeated with conspicuous black lines. These run irregularly up and down the stem or transversely.*** There is no external mycelium, such as is found in *Fomes lignosus* or Brown Root disease.*** Between the bark and the wood there is generally a thin film of white or brownish mycelium, arranged in fans, frequently with black lines bordering the outer ends of the fans. This last is the most characteristic feature of roots attacked by *Ustulina,* whether rubber or tea.*** The fructification is formed at the collar, a flat or undulating plate, at first white, then greenish, then purple-grey and finally black. When old, the fructification is crust-like and brittle. The plates are often concentrically zoned."[17]

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[17] *Diseases and Pests of the Rubber Tree,* pp. 57, 58 and 76.

Weir describes this disease as follows: "The black line-rot fungus (*Ustulina zonata* (Lev.) Sacc.), the cause of a serious root and stem decay in the Orient, was found associated with cankers in the root crotches of Hevea at three different stations. Since the presence of no other fungus could be demonstrated in relation to the cankers it is believed that they were caused by this Ustulina. The cankers had apparently originated on the sides of the lateral roots and had spread to the base of the tree, affecting a strip on the main trunk about a foot above the root collar. The area affected was in each case still partially covered by the dead bark, but the wood was rotted, checked, and shrunken so that it could be easily picked out with a knife, leaving a cavity. The solid but dead wood immediately surrounding the cavity was invaded transversely and vertically with broad conspicuous zig-zag black lines.***

"The bark to the right and left produced latex when cut, but the living bark above the canker appeared dry and produced no latex. The bark covering the zone of black lines bore the fructifications of the fungus in various stages of development.*** The normal fructifications were congregated at the root collar. They consisted of broad flat plates with irregular surfaces and were loosely attached to the bark.*** When several plates develop in close juxtaposition their margins fuse and a crust may be formed over a considerable area.*** The upper surface of the crust is dotted with numerous small black points (ostiola.) Each of these corresponds to a cavity below and is the opening through which the spores are expelled.** These spores are the first to be developed and, since they may be carried about by the wind, serve as a ready means of distributing the fungus.**

"The progress of the disease appeared to have been very slow.** Mycelial fans bounded by black lines were present on the under surface of the bark or on the wood of the root. The latter condition appears to be more or less characteristic for the disease, not having been noted in other fungi of this group on Hevea.** It is unlikely that the fungus can enter the tree without the intervention of wounds. These are more likely to be at the base of the tree."[18]

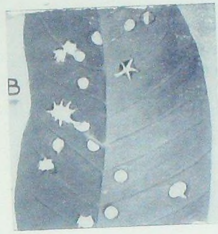
Treatment of the Disease.

There is no special treatment indicated for *Ustulina zonata* and it should follow the lines laid down for root diseases in general. Though the fungus does not produce free strands of mycelium in the soil, Petch suggests that it is safest to trench round the affected area and thus isolate the diseased tree. Cut root ends or collar wounds should be tarred and lime forked into the soil. "Modern methods of tree surgery," he adds, "might be applied in such cases, and the hole filled up with cement concrete or brickwork to give support to the stem. Such measures have not yet been extensively tried in the tropics, and it is doubtful how far they can be employed, and whether the tree will survive long enough to make the operation profitable. But if the tree is not to be treated it should be removed."[19] This is the only alternative, as a diseased tree is sure to infect those around it.

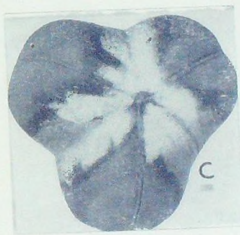
18 *A Pathological Survey of the Para Rubber Tree,* Etc., pp. 13 and 14.
19 *Diseases and Pests of the Rubber Tree,* p. 63.

PLATE 26.

(To face p. 200).



Hevea leaf attacked by *Gloeosporium alborubrum*.



'Pod-Rot' of Hevea caused by *Phytophthora faberi*.

PLATE 27.
(To face p. 201).

Brown Bast of Hevea, exposed by bark shaving.
(Photo prepared from Drawings.)

CHAPTER XV.

DISEASES AND PESTS OF HEVEA.—*Contd.*

STEM AND BRANCH DISEASES.

PINK DISEASE.

The pink-disease fungus (*Corticium salmonicolor,* Berk and Br.) is widely distributed all round the world's tropical belt. It was originally reported from Ceylon about 1870 and it attacks Hevea as well as an endless variety of plants in India, Burma, Ceylon, the Malay Peninsula, the Dutch East Indies, the Phillipines, Indo-China, Brazil, the West Indies and West Africa. Petch declares that 141 species of plants are known to be attacked by it in Java, and Butler observes that its hosts belong to the most diverse families, a range perhaps wider than that of any tropical parasitic fungus yet known.*

"On Hevea the disease generally originates," describes Butler, "at the fork of a tree or where several branches arise close together from the main stem. The Corticium stage of the fungus is usually the most readily observed, forming a pink incrustation on the bark. This gradually extends and may ultimately surround the stem and the branches arising from the affected part for a length of several feet. The bark then splits and peels away from the wood, and the latter

*This seems to be the most wide-spread tropical fungus yet known. It appears in four stages which are discernible from its mycelium. In the *early* stage, the mycelium creeps over the substratum either as fine white threads of forming thin, silky, silver-white sheets. In the *next* stage, it usually appears in cracks (lenticels) in the bark as small, white or pink, sterile nodules. In the *corticium* stage, the mycelium forms thin, fertile, effused, rose-pink or ochraceous incrustations. Finally, in the *necator* stage, it appears alone (or with the *corticium* stage) as spherical orange-red pustules.

may also become infected, but to a much less extent and chiefly in the smaller branches. Even after the bark has been killed, the fungus spreads more rapidly over the surface than within the tissues, so that the margin remains generally superficial.*** The pink layer is extremely thin, and, when old, splits everywhere in lines more or less at right angles to one another. For this reason it has been called the 'writing fungus' in Malaya, being thought to resemble hieroglyphics. Old specimens lose their pink colour and become ochraceous, or, when very old, bleached to white.***

"The disease appears to attack Hevea stems mostly of between one and three years old, and after that to be chiefly confined to the upper branches.** When the penetrating mycelium reaches the laticiferous tissues, an exudation of latex frequently occurs, which assists in indicating the presence of the disease even high upon the tree. Growth takes place continuously during the monsoon period; the bark is killed off uniformly; side branches at the point of attack are ringed and killed; and the bark of the main stem peels off in large patches.** But in many cases the disease has not advanced far enough to kill the tree by the time the rain ceases. The fungus then stops growing, having killed off part of the cortex and cambium of the main stem and probably some of the side branches also. This leaves an open wound, over which there is no cambium to produce new tissue. The result is a 'canker'—an open wound—exposing the wood and surrounded by an elevated callus ring.

"Treatment: The affected part should be cut off at least 18 inches below the attack and burned. Attempts made to cut out the affected bark only, even when the wound has been washed with Bordeaux mixture and tarred, have generally failed, about 70 per cent. of such treated areas having developed the disease again the following year. Consequently the whole branch or stem should be cut off.*** The diseased parts should be burned on the spot at once, to prevent dissemination of spores.*** All the wounds and cut surfaces of branches should be tarred.** To prevent new infections, the use of Bordeaux mixture has been found very successful in young rubber. The strength of Bordeaux mixture used in successful experiments on a large scale, in 1910-11, was 6 lb. copper sulphate, 4 lb. lime and 45 gallons water. The cost was from 1 to 2 rupees an acre, on over 200,000 trees treated in 1910-11 and the result was a reduction of the disease by from 50 to 75 per cent."[1]

"The pink-disease fungus (Corticium salmonicolor)," describes Weir, "is widely distributed in the American Tropics. ***The fungus may appear, in any one of four different stages. The typical or Corticium stage here described was the only one observed on Hevea. On lime and cacao all stages were found. At the margins there is frequently an extension of the mycelia in the form of fine silky hyphæ which form a thin silvery white semi-transparent sterile layer over the bark, or this layer may be formed in small patches not connected with the more mature parts. This stage may be followed by the appearance of small sterile pink or white pustules arranged in parallel rows in the cracks of the bark. This stage may appear over the surface covered with the thin white film or on areas not previously fruiting. A third stage appears in the form of irregularly rounded or elongated orange-red bodies. These are at first embedded in the cortex, but later rupture it and appear singly or in clusters on the surface. These bodies when they emerge resemble species of Nectria and consist of masses of spores. This spore-bearing stage was originally considered to be a distinct fungus and was described as *Necator decretus*, Mass.***

"The type of injury caused is usually first shown by the yellowing of the leaves of the parts above the infection. The infection encircles young stems or spreads from basal infections of branches to others at

[1] *Fungi and Disease in Plants* by E. J. Butler, Calcutta and Simla, 1918, pp. 500-505.

the point of union, and if complete girdling results all parts above the canker die. If the fungus is arrested by dry weather, the bark over the affected area cracks, causing the formation of open wounds. The vigor of the fungus is known to depend largely on moisture and exposure. Hence, the usual measures for reducing the ravages of the parasite in plantations have been to regulate spacing, to provide drainage, to avoid intercrops that serve as hosts, and to keep trees in a high state of vigor. Direct control would require that all infected branches be cut out and burned. The branches should be cut several inches beyond the visible zone of infection. This is necessary, for the reason that in practically all fungous infections of this nature the mycelium has advanced considerably beyond the immediate cankered area. All branch knots and larger wounds on the main stem should be thoroughly saturated with coal tar. Spraying uninfected trees regularly after rains may prevent infection by newly distributed spores."[2]

Weir remarks that *Hevea, Castilloa* and *Ficus* are especially susceptible to the disease. Brooks and Sharples state that the Necator form of the disease is found more frequently in Malaya than the basidial form. Petch states that the disease is especially prevalent under conditions of high humidity and close planting; that in Ceylon, where a distinct dry season prevails, it is only sporadic and that its attacks on Hevea are getting rarer now that the estates are being thinned out. As means of identifying the malady, he indicates a pink patch, more or less cracked by short lines at right angles to one another, overlying the diseased bark; or diffuse bands of long, silky hyphæ running longitudinally along the stem or minute pink cushions in cracks in the bark or orange-red pustules embedded in the bark. The chief attack of the disease is indicated in the upper stems and branches, beginning at a fork and finally causing death to all parts above the injury.

Petch informs us that the following methods of treatment for pink disease have been recommended:

"When the disease appears for the first time on an estate, and only a few trees are attacked, all diseased branches and stems should be drastically pruned off and burnt. Even in such cases it is advisable first of all to paint the diseased areas which bear the fungus with tar, or a mixture of tar and liquid fuel (crude oil) in the proportion of six parts of tar to four of liquid fuel, in order to minimise the risk of spreading the disease by scattering the spores, and to render harmless any pieces of infected bark which may fly off when the branches are cut. The tar will also assist in thoroughly scorching the bark when the branches are burnt. All diseased material must be burnt as soon as possible.*** Where the number of trees is below a hundred to the acre, or where more than ten trees per acre are attacked, the following modification is recommended. All dead branches, and all affected branches not thicker than a man's arm, should be tarred, cut off, and burnt, as in the previous cases. On the thicker branches and the main stem the infected parts should be painted with the tar and crude oil mixture, taking care to cover thoroughly not only the diseased parts, but a length of stem one foot above and one foot below the apparent limit of the disease. The mixture must be well rubbed into all cracks in the bark, particularly at the forks."[3]

DIE-BACK.

The die-back fungus (*Botryodiplodia Theobromae*, Pat.) occurs on Hevea in South America, the West Indies, Oceania, Africa, Ceylon, South India, Burma, Malaya, Java, etc. Since the fungus is variable, it has received a number of names but it was originally described by Patouillard in 1892 under the above name. The means of identifying it, according to Petch, are as follows: "Tree dies back from the top, the branches being killed in succession, the lower parts meanwhile remaining healthy. Progress generally rapid. A brown slimy layer along the cambium in the dead parts. Bark finally covered with a black powder resembling

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[3] *Diseases and Pests of the Rubber Tree*, p. 141.

soot."[4] Die-back is lucidly described by Weir in the following manner: "The general aspect of infected trees is the presence of dead terminal twigs. One such tree, about 10 feet high, in the edge of the jungle near a small plantation in the vicinity of Para was carefully examined. Ten different twigs were dead, and the disease had extended downward to the first lateral branches, which in turn were either dead or in a languishing condition. The wood of the infected stems was blackened by the reflected color of the dark-gray or brown mycelium, after the manner of Ceratostomella species in the sapwood of timber trees. Examination of the wood ahead of the blackened areas shows the mycelium to have extended beyond the zone of evident infection from 1 to 4 inches and to be colourless. For this reason, as Petch has pointed out, discolored wood does not indicate the most forward region invaded by the fungus. The bark on the infected branches dries and cracks, exposing a dark film on the surface of the wood."[5]

Though widely distributed, *Botryodiplodia Theobromae* causes little damage if precautions are taken to prevent its development which is not difficult. Petch states that "the fungus is not a direct parasite of Hevea, but can only attack it through wounds or dead branches. ***If dead branches are regularly removed and burnt, it is not likely to cause much loss." As treatment of the disease he recommends the pruning of the dead tops about a foot below the diseased part and burning them on the spot to prevent the spread of infection by spores.

PHYTOPHTHORA DISEASES.

In Hevea a normal leaf-fall takes place in the winter (January and February), but sometimes on diseased trees there is an abnormal leaf-fall in the monsoon rains, about July and August, often described as second leaf-fall, in Ceylon, South India, Burma and Java. This diseased state is connected with a fungus (*Phytophthora Meadii.* Mc.Rae) which attacks the

[4] *Diseases and Pests of the Rubber Tree*, p. 166.
[5] *A Pathological Survey of the Para Rubber Tree*, Etc., p. 21.

fruits, leaves and branches, causing pod-rot, leaf-fall and die-back, and passes on to the stem causing 'Black Thread.'* When the disease attacks the fruits and leaves, causing pod-rot and leaf-fall, and passes on to, or affects by means of an independent local infection, the stem causing 'Claret-Colored Canker' or 'Patch Canker,' it is attributed to a fungus (*Phytophthora Faberi,* Maubl.) largely reported from the Dutch East Indies, Malaya and Ceylon.[6] There is, however, some diversity of opinion as to the species of Phytophthora that are responsible for these diseases in certain countries.

BUTLER'S STUDY OF PHYTOPHTHORA.

Butler seems to have thrown some definite light on the nature of these diseases when the pathology about them was still in an embryonic stage. While his discourses, as given below, apply in general to Phytophthora all over the Middle East, they seem to have special value for the diagnosis of these diseases in South India and Burma.

"Pod-rot and canker† (*Phytophthora Faberi* Maubl.) This fungus is best known as the cause of the formidable canker and pod-rot of cocao.** The Hevea attacks are quite similar.*** A rot is produced, characterised by a sodden, watery discoloration of the pods while still attached to the tree. The fruits then turn black, and the outer soft layer ultimately shrivels and splits, but the woody wall below does not open to liberate the seeds. From the fruits, the rot may pass back through the stalks to the green branches and kill these for a short distance, but no case is known in which it

* Black Thread is also known as 'Stripe Canker,' 'Bark Rot,' or 'Decay of the Renewing Bark.'

[6] Investigations on Phytophthora diseases have been recorded by Bryce (in Bull. 29, Dept. Agri. Ceylon, 1916), by McRae (in Planters' Chron. v. 11, 1916 and Agri. Jour. India, v. 14, 1919), by Rutgers (in Arch. Rubbercult. Nederland—Indie, v. 1, 1917, etc.), by Sharples, Etc. (In Bull. 31, Dept. Agri., F. M. S., 1920), by Dastur (in Bull. 14, Dept. Agri. Burma, 1916) and by others. McRae states that leaf-fall, fruit-rot, die-back and bark-rot are due to *P. Meadu,* while Rutgers opines that both patch canker and stripe canker are caused by *P. Faberi.*

† This is better known as 'claret-coloured canker.'

has reached the main stem and set up canker. The stem canker, when it occurs, is said to be always the result of an independent local infection.***

"The symptoms of Hevea canker are sometimes inconspicuous on external examination. On young trees, the bark may appear darker than normal, but this is not visible once the thick, brown bark develops. In some cases, the bark exudes a reddish or purplish liquid, which may be noticed in very wet weather, even when the patch of disease is small, but usually only happens when a large area is involved. No latex is produced in the diseased area, and the stoppage of the flow in one or several cuts is often the first symptom of the disease. On scraping away the bark of an affected patch, the underlying tissues are found discoloured. The part outside the laticiferous tissue is blackened, while the inner bark turns at first gray, with a distinct black border, and later on, claret-coloured. The discoloured area is often much more extensive in the inner than in the outer layers.*** Frequently the bark is dirty red when cut, but darkens to purple red soon after exposure. In the laticiferous vessels, the latex becomes coagulated, probably by substances produced during the growth of the fungus.***

"Excision of the diseased tissue is, therefore, the recognised treatment for Hevea canker. Once the cankered spot is detected (by no means an easy matter), all the discoloured tissue should be cut out and burnt. Stoppage of the latex flow should be a danger signal leading to careful search for canker. After removing the tissue, it is recommended in Ceylon to apply a mixture of cowdung and clay to the wound, to promote healing if the wound be small. Large surfaces cannot be expected to heal and should be tarred or otherwise protected.

"Black thread and leaf fall (*Phytophthora Meadii* Mc.Rae). The name 'black thread' is used in Burma for a serious disease of the tapped surface of Hevea stems, marked by the appearance of vertical,

PLATE 28

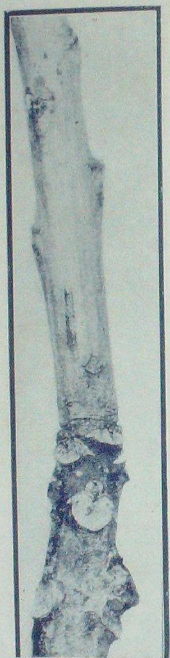
(To face p. 208).

Brown Bast.

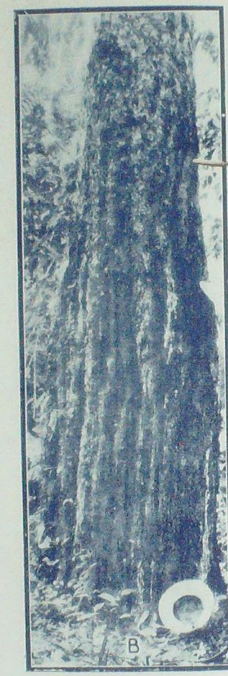
B=Nodules formed in the cortex. C=Scaly bark and brown lines in the cortex.

PLATE 29.

(To face p. 209).



Botryodiplodia Theobromae on the last internode of a Hevea twig.



Hevea with a fluted trunk due either to decay of the tap root or to excessive tapping.

slightly depressed, black lines. It is also known in Ceylon, Malaya, Java and South India. In Ceylon, Burma and South India an abnormal second leaf fall in Hevea, associated with dying back of the branches, has been observed and seems to be due to the same fungus.*** The dark lines of black thread extend in through the exposed bast and may penetrate the cambium and reach the wood. The blackening spreads laterally also and may eventually cover the whole surface of the cut area. Vertical cracks and deeply sunken areas, from which white latex exudes, result. Where renewal of the bark is taking place from the margin of the cut, a thick pad of coagulated latex may collect, causing the bark to bulge and ultimately decay; large gaping wounds—true cankers extending down to the wood—may eventually be formed. The tree is not killed but the blackened parts soon cease to yield latex and the death of the cambium seriously interferes with the smooth and even regeneration of the bark, on which successful tapping depends. The cankers heal irregularly and with roughened 'wound tissue' (callus) and, as the disease extends, it becomes more and more difficult at each round to find bark suitable for tapping. *** In South India, not only are the fruits and bark affected, but the leaf-fall and die back have assumed serious proportions.

"The leaves of Hevea fall naturally in December and January, but in diseased trees there is a second fall in the rains. The branches, from which these leaves fall often die back in the following cold weather, and fresh shoots that appear in February below the dead parts, begin to wilt in March. Tiny drops of latex may show on the leaves and leaf-stalks; and the leaflets shrivel, dry up and fall off. The shoot ultimately dies back to the parent branch. The fruit rot begins early in the monsoon, and, soon after, leaf-shedding becomes marked. Some affected trees lose all their leaves, others only a portion.*** The disease makes its appearance soon after the rains set in and disappears after the close of the monsoon. It seems to be closely dependent on climatic conditions and is fostered by humid, stagnant air within the plantation.

TREATMENT OF THE DISEASES.

"Hence, the chief treatment should be in the directions of securing good ventilation and of protecting the newly-cut tapped surface from infection. Thinning the trees is strongly recommended or, where shade is still too dense, heavy prunning.*** Excellent results are said to have been obtained in South India by a combination of cessation of tapping on infected trees, with the application of a thin smear of a mixture of tar and tallow to the diseased spot. The mixture is applied with the finger and then rubbed with a piece of sacking so as to cover the attacked part of the bark. The tar acts as an antiseptic, while the tallow forms a waterproof covering. After the monsoon, the treated areas gradually shed a thin scale of tar-coated bark and expose a clean, healthy surface beneath. Covering the tapped surface with a mixture of clay, cowdung and sulphur has also been recommended; while in Java and Malaya, antiseptics such as carbolineum and izal have been used with success."[7]

For 'leaf-fall' and 'pod-rot,' Petch suggests that all rotten fruits and dead branches after winter and before the monsoon rains should be removed. For 'claret-coloured canker' he recommends the excision of all discoloured bark and painting the wound with a 20 per cent. solution of Brunolinum, Brunolinum Plantarium, Carbolineum Plantarium, Agrisol, Solignum or Jodelite, also putting tar on wounds which extend to the wood. For 'black-thread' his treatment is to paint the affected tapping cuts with a 20 per cent. solution of any of the abovenamed liquids every three days for 6 applications, resting the trees in the meanwhile. Where rubber pads are formed he suggests that they should be cut out, it being unnecessary to cut out the wood.

[7] *Fungi and Disease in Plants* by E. J. Butler, 1918, Calcutta and Simla, pp. 490-498.

PETCH'S OPINIONS ON PHYTOPHTHORA.

"Though it has been considered convenient," explains Petch, "to discuss the various Phytophthora diseases together, and the development and progress of these diseases on the different parts of the tree—fruit, leaf, and stem—are similar in all cases, the species of Phytophthora which cause them are not, as far as the evidence at present available shows, the same in all the countries in which these diseases occur. The question of the identity of the different species is not yet completely settled, and the following summary must be regarded merely as representing the facts which have been considered established by various investigators."

Petch summarizes that 'abnormal leaf-fall' and 'pod-rot' occur, usually during the South-West Monsoon when the fruits are ripening, in Ceylon and South-India. The symptoms are that the outer wall of the fruit becomes dirty watery green, finally blackish, sodden and soft. The fruits do not dehisce (open) but remain hanging on the tree. Soon after, the leaves begin to fall and then some of the green twigs die back. He observes that in 'claret-coloured canker' there are no marked external indications except the slight exudation sometimes of a rusty-coloured liquid. The layer beneath the outer brown bark is black and internally the cortex is discoloured, at first yellowish gray, then claret-coloured, the discoloured area being surrounded by a black line. The canker frequently occurs on the renewing bark above the tapping cut. Petch indicates that 'black-thread' begins as a series of narrow, vertical, black lines, parallel to one another, just above the tapping cut, the black lines extending into the wood. These may broaden out laterally and coalesce, forming a continuous wound parallel to the tapping cut. It occurs during wet weather especially on newly-opened tapping cuts.

"The evidence indicates," concludes Petch, "that there are two species of Phytophthora which can attack both Hevea and Cacao, *viz.*, *Phytophthora Meadii* and *Phytophthora Faberi;* and that, in the case of Hevea, the former causes fruit rot, leaf-fall, and Black Thread, while the latter causes fruit rot, leaf-fall, and Claret-coloured Canker.**** The most important difference from the economic stand-point, between the two species lies in the effect of the fungus on the general condition of the tree. When trees suffer from the leaf-fall and pod disease caused by *Phytophthora Faberi,* the yield of latex is not notably affected; but when they are similarly attacked by *Phytophthora Meadii,* the yield falls off enormously and it may not be worth while to tap."[8]

WEIR'S RESEARCH ON PHYTOPHTHORA.

Despite the admirable efforts of mycologists, it would appear that the experience so far gained on Phytophthora diseases has not been sufficient to yield a very complete pathology about them. In addition to Petch's frank opinion on this subject, expressed in the true spirit of the scientist searching for the greater truth, Weir also concludes that "the identity of the species has not been satisfactorily determined. In Ceylon it has been shown that two species of Phytophthora are found on Hevea, *viz., P. faberi* and *P. meadii,* but the latter has not been obtained from 'black-thread.' On the other hand, Rutgers in Java has shown by inoculations that 'black-thread,' 'pod-rot,' and 'claret-colored canker' are all caused by *P. faberi.* Other investigators have obtained varying results in different countries."[9] Weir has attempted to throw some fresh light on these diseases by his researches on Phytophthora in the Amazon Valley, which are as follows:

"The disease known as claret-colored canker, referred both to *Phytophthora* and *Pythium* and reported to be destructive to Hevea in the East, was not found in the Amazon Valley during the present investigation. *** In a small plantation near Para where the trees were associated with secondary jungle growth a gray leaf-spot (*Phytophthora faberi,* Maubl.) was found

[8] *Diseases and Pests of the Rubber Tree,* p. 132.
[9] *A Pathological Survey of the Para Rubber Tree,* Etc., pp. 29 and 30.

both on recently fallen leaves and on leaves still attached to the tree. After several heavy rains the leaves fell in greater numbers and the green pods began to show infection. On this estate and in the jungle near the waterworks at Utinga similarly infected leaves were found. These leaves were variously mottled with yellow and purple, particularly along the midrib, where the grayish spots were most in evidence. The leaf stalks showed shrunken discolored spots and fell with the leaves. An examination of the gray splotched areas showed the characteristic fructification of a Phytophthora. The fungus in all essentials is apparently the same as that attacking the pods and will be discussed under that head.***

"A Phytophthora disease (*Phytophthora faberi*, Maubl.) of the pods of rubber was found near Utinga at Para during the heavy rains in November. It was characterized by a sodden greenish watery discoloration of the outer fleshy wall at the base of the stem. From this point it extends along the line of sutures between the lobes of tho pod to the distal end. Here the three zones of infection meet and spread to the sides, the entire green outer fleshy wall of the pod becoming soft and rotten, so that the epidermis can be slipped off with the thumb. The decay rarely begins at the distal end or on the sides of the pods. The discolored zones between the lobes of the pods soon develop a whitish or grayish film, which extends over the entire pod as the rot advances."[10]

INCIDENCE OF HEVEA DISEASES.

The relative importance of rubber diseases and their incidence in countries of the Middle East have been referred to by some writers incidentally. Mr. H. W. R. Bertrand, writing in *Trop. Agr.* v. 62. 1924, states: "The various forms of *Phytophthora* are, in the writer's opinion, responsible for more damage in estates than all the other diseases put together." Messrs. T. H. Holland and H. A. Deutrom, writing in *Bull.* 70, *Dept. of Agr. Ceylon*, 1924, declare that

[10] *A Pathological Survey of the Para Rubber Tree*, Etc., pp. 23, 46 and 51.

Fomes lignosus gives the most serious trouble, 'brown bast' is a negligible quantity and other diseases cause little trouble. Mr. J. G. C. Vriens, writing in *Rubber-planters Oostkust, Sumatra, Meded. Adviseur*, 1915-16, enumerates *Fomes lignosus, Phytophthora Faberi, Corticium salmonicolor, Hymenochoete noxia* and *Thyridaria tarda* (Die-Back) as the serious diseases of Hevea. Messrs. W. R. T. Tromp de Haas and C. J. J. van Hall, in a paper on 'Para Rubber Culture in Java,' (read at the Inter. Rub. Cong. and Exhib., Batavia, 1914) described canker, pink disease, white-root disease and brown-root disease as the most frequently occurring diseases of Hevea in Java.

UNCOMMON HEVEA DISEASES.

BROWN BAST.

This disease which has been reported from Java, Borneo, Malaya and Ceylon, generally attacks the stem of trees that are in tapping. Its first indication is that the cut does not yield any latex and the cortex is discoloured. "In some cases," explains Petch, "the discoloured cortex appears sodden, and exudes a watery liquid when pricked; hence it was originally designated 'water-logged bark.' This appearance, however, is not universal. Between the brown line and the cambium the cortex is still laticiferous, and hence, if it is pricked down to the wood, latex will issue from this inner layer.*** Sometimes the latex from cortex just attacked is very thick and coagulates on the cut.** In order to make certain that Brown Bast is present, the tapping cut should be reopened.** If Brown Bast is present, the cortex will be found to be yellowish-grey, with greyish streaks and patches, and here and there red-brown streaks and spots.

"In well-defined cases there is a continuous discoloured layer about 1 or 2 millimeters from the cambium and no latex exudes until the shaving has penetrated beyond this layer.*** The disease derives its name from the occurrence of the brown layer near the cambium.*** The cause of Brown Bast has not yet been ascertained. It seems reasonably certain that no fungus is to be found in the affected tissues. In one quarter it is claimed that the effect is due to bacteria, but little evidence has yet been put forward in support of that contention.** The opinion is gaining ground that the effect is due to physiological causes, *i.e.*, that it is not caused by fungi or bacteria, but is due to some interference with the normal physiological functions of the tree, or is a response to some condition induced by the treatment to which the tree is subjected.

DIVERSITY OF DIAGNOSIS.

"Rands writes: 'It appears, therefore, that Brown Bast is an accentuated condition of gum secretion probably resulting from the response on the part of the tree to the present methods of tapping.' Bobilioff, who dissents from the view that the brown substance is wound gum, agrees that the disease is physiological. Both these investigators appear to regard it as due to a degeneration of the tissues owing to the removal of latex from the cortex.*** On the evidence it would appear that there is a probability that Brown Bast may be due either to too frequent tapping or to too fine tapping, or to prolonged tapping on the same section. But up to the present it has not been possible to associate Brown Bast with any one of these factors. *** Further investigations are required before any conclusions can be arrived at."[11]

Opinions differ so widely on the nature of Brown Bast that it is obvious the disease needs further investigation. In a paper read by Mr. A. S. Horne, at the Imperial Botanical Conference held in London in 1924, the writer remarks: "The discovery of sieve-tube necrosis in Hevea brasiliensis places the brown-bast disease in the category of obscure diseases in which the occurrence of phloem necrosis is a prominent feature, and the use of the expression does not necessarily imply the agency of a casual organism." Messrs. A. R. Sanderson and H. Sutcliffe, in their monograph on

[11] *Diseases and Pests of the Rubber Tree*, pp. 169-175.

discovery of sieve-tube

Brown Bast (London, 1921) say: "Considering as we do, that 'brown bast' is physiological in origin, it must be regarded in the first instance rather as an abnormality than a disease, though one state may lead to the other, owing to interference with the functions of a portion of the tissue."

In a paper read by Mr. A. Sharples on 'Brown Bast' at the Imperial Botanical Conference in 1924, the writer declares: "After three years' experimental work in the field, the view is advanced that the affection is a purely physiological disturbance resulting from the extraction of excessive quantities of latex." All this diversity of diagnosis continues in spite of a Brown Bast Investigation Committee which enquired into this disease in the F.M.S. so early as 1919. It may here be noted that Hevea trees do not die of this disease but run dry and stop yielding latex. If properly treated and allowed enough rest, they should recover completely.

A Recent Study of the Disease.

"The brown bast disease," describes Weir, "which is the cause of much damage in eastern rubber estates, concerning which an extensive literature has developed, occurs in the American Tropics, but apparently in a mild form. Dr. Carl D. La Rue discovered near Para a tree which exhibited all the symptoms usually attributed to this disease, and the writer located several others in the same locality. These trees, which averaged about 14 inches in breast-high diameter, had been excessively tapped by the usual method, whereby a small axe is driven through the cortex into the wood. The wounds in healing had produced numerous callous formations, a result which usually follows this mode of tapping. It was noted that the cortex around some of the unhealed wounds did not produce latex, appeared watery, and was of a yellowish gray color intermixed with brownish spots. Since these symptoms indicated the presence of brown bast a close examination of several trees was made.***

PLATE 30.
(To face p. 216).

Dendrophthora poeppigii in the crown of Hevea showing the dead branches and reduction of foliage.

"Out of five trees discovered with brown-bast symptoms a considerable variation in the appearance and location of the discolored areas in the cortex was noted. A peculiar feature was the breaking up of the surface bark in the form of brittle scales.** When pried off with a knife a greenish yellow watery appearing surface was exposed. A cut on this surface appeared dry without a flow of latex.** By shaving off the exposed tissues, grayish yellow spots or reddish brown streaks were exposed. These discolored spots were of varying depth in the cortex and were rarely united to form a continuous brown line. This brown zone when present was next the cambium and was usually separated from it by a narrow laticiferous layer. This layer was separable from the cortex along the brown line. In the worst cases examined the isolated discolored areas external to the brown line had become confluent in one plane, so that the cortex in radial sections gave a banded or zoned appearance. Later, these bands become fused, so that the entire cortex was uniformly brown.** By shaving off the surface dead cortex these reddish brown areas were exposed. In late stages the tissues of these areas become hard and brittle and separate from the rest of the cortex.**

"The disease was not found on untapped trees and was by no means common on the tapped ones. Only on those that had been excessively mutilated could the disease be expected to occur. In one such case the disease was present from the ground level and for 3 feet above the last tapping cut, a total distance of about 15 feet. In all cases the vigor of the trees appeared to be in nowise impaired. The cambium in every tree examined appeared to be healthy. The failure of the cortex on some of the large callous nodules, leaving the wood exposed so that it had become hard and weathered, was apparently the only permanent form of injury aside from the general mutilations by the axe that the trees had suffered.*** In the lower Amazon region, where many trees grow on swampy land or where the land is subject to frequent inundations, the variety with light-colored cortex predominates. It was from this variety with a few exceptions that the seeds were obtained to establish the plantations in the Orient.*** So far as the investigations were carried, the symptoms of brown-bast were observed only in the white variety, which leads to the conjecture that this form may be more susceptible to the disease."[12]

The foregoing opinions of Petch, Rands, Bobilioff, Horne, Sanderson, Sutcliffe, Sharples and Weir go to favour the theory that Brown Bast is a disease of physiological origin. It neither kills Hevea nor impairs its general vitality but seems to interfere with the normal functions of only its latex-yielding portion. Weir states that the disease was found in the Valley only on the white variety with the light-colored cortex from which most of the seeds were obtained to establish the plantations in the Orient. He explains that several varieties of Hevea based on the color of the bark are recognized in the Amazon Valley. These are the black (preta), the white (branca), the red (vermilha), the barriguda (Hevea spruceana) and the Itapura (Hevea guyanensis). On the basis of resiliency the rubber of these varieties is rated differently. That from the black Hevea is classed as 'fina' and that from the others as 'fraca' (weak). There is considerable confusion in the application of these colour terms. In one part of the Valley the terms refer to the 'outer colour of the bark,' in another they apply to the 'colour of the tissues of the cortex.' The normal colour of the cortex should be borne in mind when investigating Brown Bast in the different varieties.

TREATMENT OF BROWN BAST.

The Mycological Departments in the F.M.S. and Ceylon are of opinion that trees attacked by this disease usually recover in the early stage if sufficient rest is given to them. But when they develop burrs and nodules, the Departments suggest their immediate treatment. For this purpose three methods are adopted in

[12] *A Pathological Survey of the Para Rubber Tree*, Etc., pp. 56-58.

Malaya, the Dutch East Indies and Ceylon—stripping, scraping and tarring. By the first system (which is officially recommended in Malaya) 'the whole of the affected cortex is stripped off down to the wood. Thus, not only is all the diseased tissue removed, but also the inner layer, overlying the cambium, in which the nodules develop.' Since this is rather a drastic step, leading to injuries in inexperienced hands, it has fallen into disfavour in Malaya.

"In the scraping method," explains Petch, "the diseased cortex is shaved away until latex begins to exude, and is then painted with Brunolinum Plantarium.*** But the Brunolinum solution should not, of course, be so strong that it kills the cortex down to the wood.*** Twenty per cent. Brunolinum Plantarium should be tried first, and if that causes wounds when applied immediately after scraping, application on the day after scraping should be tried. If the twenty per cent. solution does not cause wounds, the strength should be increased.*** A few trees should be treated by scraping only, to see whether the cortex dies back when the Brunolinum is not applied. If, in the latter case, the cortex dies back, the patches must not be scraped so deeply."***

"The tarring method," describes Petch, "was invented by Harmsen in Java, where it is said to have given very good results. The extent of the affected patch is determined, as above, and it is then partly isolated by deep horizontal and vertical channels. These channels should not extend to the wood, as a completely isolated patch may die back. If the affected patch does not extend across the vertical (tapping) channel, the latter may be deepened to form one boundary. The patch is then shaved to half the thickness of the cortex, and is then painted with hot coal tar, heated until it begins to bubble. If the disease extends into the renewing bark, the latter should have the outer brown layer only removed and then tarred.*** In old cases, where nodules have already formed, the nodules should be cut out in the usual manner and the wounds painted with 10 per cent. Brunolinum, or tarred.*** The whole of the area affected by Brown Bast must be treated. This will often involve the treatment of the tap root and the lateral roots. The holes which are dug round the trees should be left open and drained so that water does not lodge against the treated patches."[13]

OTHER RARE DISEASES.

Among rare diseases of Hevea which seldom cause any serious damage are Red Root Disease (*Poria hypobrunnea*, Petch), Wet Rot (*Fomes pseudo-ferreus*, Wakef.) and *Sphaerostilbe repens*, Berk and Br.). These root diseases have occurred occasionally in certain countries of the Middle East and are usually attributed to infection from buried stumps or decaying timber, the removal of which from rubber estates has already been indicated as an imperative necessity. Another rare Hevea disease is 'leaf-fall,' other than the normal or abnormal occurrence already described. This is due to a fungus known as *Gloeosporium alborubrum* which causes no serious injury. Leaf-fall has also taken place, merely as a result of heavy rainfall, on trees where no fungus has been found.

It seems somewhat fortunate that the most serious leaf disease of Hevea in the American Tropics—the South American Leaf-Blight caused by the fungus known as *Dothidella ulei*, P. Henn.—has not yet been reported from any place in the Middle East. Weir states that, so far as his observations go, the white variety (branca) of Hevea appears to be very susceptible to this disease, and it was the seeds of this variety that were chiefly taken originally from Brazil by Wickham. Since these facts appear to be correct, the immunity from this disease which the Eastern plantations seem to have acquired is certainly remarkable.

Hevea appears to be the victim of more diseases in the American Tropics than in the Middle East, and the probable reason for this is that its enemies are more

[13] *Diseases and Pests of the Rubber Tree*, pp. 177-180.

varied and numerous in the forests of Brazil and the adjacent lands than in the planted estates of the Orient. Apart from innumerable fungi, lichens and lianas, Weir found seven species of mistletoe (the phanerogamic plant) on Hevea of which the typical sort is *Dendrophthora poeppigii*. He reports that an attack of this parasite on the lower branches of Hevea may cause the upper portion of the crown to wither, giving rise to the deformity termed 'stag-head,' and that a severe infection in the crown may result in the eventual death of the tree.

Disease as affected by the condition of soil has been commented upon by mycologists, to which attention may here be drawn. "Petch has found," remarks Weir, "that the roots of Hevea except in certain well-known cases will not live permanently under water. The early conception was that Hevea was a species of swampy soils. It is interesting to read the recommendations by Cross and others for planting the tree on wet soils in the East.[14] This at first was practised, but with disastrous results. Petch reports that when Hevea is grown in swampy soil, where the water table lies near the surface, the tap-root does not grow below the water level, or, if it does, it soon decays. In some cases such trees had to be propped up to keep them from falling over. This is exactly the condition noted in one or two places in the Amazon Valley."[15]

PESTS OF HEVEA.

Entomologists seem to have little to say so far on the destructive action of insects and pests on Hevea trees in particular in the Middle East, but Petch observes that "a large number of insects have been recorded on Hevea plants, but the only serious pests observed up to the present time are the White Ant

[14] The opinion of this school of thought is well expressed by Herbert Wright. "It should be recorded," he remarks, "that Hevea Brasiliensis grows exceedingly well on land which is frequently innundated, 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 lbs. of rubber per tree per year." *Hevea Brasiliensis or Para Rubber*, p. 7. In all such controversy, the best judges should be the rubber planters.

[15] *A Pathological Survey of the Para Rubber Tree*, Etc., p. 77.

(*Termes gestroi*), the Rubber Leaf Mite, the Root Borer (*Batocerarubus*), and, in Java, the Locust (*Cyrtacanthacris nigricornis*)."[16] *Termes gestroi* attack the tree by a line of communication from their nest in some dead timber or decaying stump which should be burnt forthwith and the nest fumigated with the 'universal ant exterminator.' If an attack of Leaf Mite is serious, spraying the leaves with a solution of lime and sulphur is said to remove the pests. The Root Borer attacks only one tree at a time and so it causes no widespread damage. No preventive measure against it is suggested. The invasion of locusts is so very rare that the subject is not worth considering.

[16] *Diseases and Pests of the Rubber Tree*, p. 224.

CHAPTER XVI.

SYNTHETIC RUBBER AND THE RUBBER MARKET.

SOME THEORETICAL CLAIMS.

If in the near future, the price of rubber remains below a shilling a pound either by over-production or the removal of ' restriction,' the efforts of chemists seeking to produce the synthetic stuff would doubtless be relaxed. But if after that stage, the price rises gradually owing to increasing consumption, the efforts of these chemists would again be revived. It is necessary, therefore, to enquire into such latent possibilities and see how they could develop. Dr. Von Winberg, Director of the German Dye Trust, Frankfurt-on-Main, recently declared that great improvements in the production of the elements for synthetic rubber had been effected but he did not claim that the proper method of combining these elements had yet been discovered.

In regard to this announcement, some German chemical journals explained that the formula for rubber had long been known to chemists, the chief element in it being Isoprene, but the proper combination of the elements had so far baffled all research. They opined that in the event of a real scarcity of the natural product and its consequent high price, a sort of substitute could be produced as was actually done in Germany during the War. At the outset it should be explained that synthetic rubber must be sold cheaper than the natural product—in addition to its possessing all the singular properties of real rubber such as plasticity, tensile strength and durability—if it is to serve the functions of the latter. Tyre makers aver that no artificial stuff has yet been offered which could come up to these requirements and unless it can take the place of the natural product as the raw material for tyres, it must fail in the crucial test.

An Admirable Chemical Record.

Owing to these shortcomings, it has not been possible to make synthetic rubber a marketable commodity even after half a century of research and experiment. "Few stories in the romance of chemistry," declares a chemist in a noted journal, "are as interesting as that concerning the hunt for the obscure something which differentiates real from approximate rubber. Finally a hint as to the nature of the missing link, which has so long eluded chemists and microscopists, has been afforded in the X-ray studies of rubber by Katz and Hock."[1] But this link has not yet been discovered.

Since 1879 efforts to produce synthetic rubber have been made by Bouchardatt in France, Tilden in England, Harries in Germany and in recent years by a host of other chemists in the U. S. A. Owing to acute shortage of the natural product in Germany during the Great War, 'Methyl' rubber was made in that country, but it lacked the cheapness and plasticity of the genuine stuff. Dr. W. C. Geer, of the Goodrich Tyre Company, ascribes the failure of synthetic rubber to 'the poor physical properties of the product, to the lack of knowledge regarding the elasticity of rubber as related to structural formulæ, and to the high cost, low yield and multiplicity of steps in the process.'

Apart from the artificial product, attempts have been made to produce rubber from certain natural resources by chemical or mechanical methods. Rubber is obtained from an endless variety of plants yielding gums and juices, but none of them have so far been able to turn out products on such a commercial scale or of such utility and cheapness as Para, Ceara and Ficus elastica. Excepting these three, the rest are consequently of little or no practical value.

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[1] *India-Rubber World*, May, 1927, p. 71.

THE SAFETY OF A LOW RUBBER PRICE.

Those who have been long enough in the rubber trade doubtless remember the reluctance with which manufacturers took to the use of plantation rubber and how they preferred to pay a shilling per pound higher for the wild rubber they were then using. To-day the life of a motorist sometimes depends on the quality of his tyre, a fact which is not unknown to tyre-makers. In such circumstances, no manufacturer would risk the reputation of his firm unless years of trial had first established the quality of the raw material he could use in his works. Synthetic rubber must in consequence stand the test of time and establish public confidence before manufacturers could consider it seriously. At the same time it should be borne in mind that the low price of natural rubber (about 12*d.* a lb.) is an economic safeguard against the introduction of any artificial product however serviceable it may be, and if steps are taken by rubber planters to keep to a moderate limit for this product, say 15*d.*, no fear of synthetic rubber need be entertained. Dutch planters are doing more than this at present. By the adoption of improved methods in cultivation, they hope to lessen its price lower than the aforesaid level.

THE TASK BEFORE THE CHEMISTS.

Stuffs like synthetic dye and artificial silk were comparatively easy to fabricate as no very unique quality or exacting properties were required of them. But rubber belongs to a very special order of natural products, which seems virtually impossible to devise. Anyway, though all past experience has failed to reveal the secret of rubber's elasticity and has actually indicated that this product cannot be prepared in the laboratory as cheaply as it can be grown in Nature's fields, if a working type of the artificial stuff is ultimately made by chemists, it should prove of some service to the manufacturing industry. It could then supplement the supply of the natural product even to a small degree during periods of war or scarcity.

In any case, we may rest assured that the world will continue for a long time yet to depend mostly on plantation rubber, for prior to any artificial stuff coming into vogue, its working properties and durability must stand a very crucial test. Moreover, it must gain the confidence of the consuming public by extensive use which is usually delayed owing to the cheapening of the genuine product in all such eventualities.

The Rubber Market.

A study of rubber prices since the beginning of this century indicates boom and depression periodically depending on various factors connected with the production, trade and consumption of the raw product. Sometimes it is difficult to ascertain to what degree these factors influence the price-level because artificial conditions—such as political wire-pulling, restriction and gambling—vitiate the natural economic causes. Probably the price of no raw product at the present day is influenced by so many circumstances as that of rubber and the vagaries of its market seem often to upset the best of economic theories. There have been times of panic, of undue pessimism and of unbounded optimism, though at the same time production and consumption have not been much disturbed.

Speaking roughly a period of boom in rubber should be followed about 8 years later by a period of depression, assuming that too many estates come into existence in the former and arrive at maturity in the latter period. Here it must be borne in mind that, though rubber trees begin to be productive about the age of six (when they yield about 150 lbs. of latex per acre yearly), they do not give their maximum yield until about the age of ten (when their output is roughly 300 lbs. an acre annually). But this fundamental theory, good enough to begin with, is usually upset in practice by many counteracting circumstances. Extensions in the use of rubber are more usual than the introduction of a rubber substitute, but all of them would affect the demand and supply, resulting in price fluctuations. Thus while economic conditions connected directly with the industry have the greatest influence on the rubber market, social and political causes have an indirect effect on it occasionally. Such is the case very rarely with other products. The investigation of a rubber crisis naturally needs an enquiry, conducted both logically and chronologically, into many far-reaching facts. Unreliable data and statistics, however, frustrate the labours of investigating committees occasionally.

"In 1909-10," elucidates Mr. H. Eric Miller, "owing to increasing consumption and shortage of supplies, coupled with speculation, there was a dramatic rise in the price of rubber to over 12*s.* per lb. which attracted a very large amount of capital to embark in the plantation industry. In addition to large investments made in London, a considerable amount of continental capital was put into the Dutch East Indies, whilst at the same time the Chinese agriculturists and Malay smallholders in British Malaya went in largely for rubber planting. Whereas in 1903 the plantation rubber industry consisted of a few thousand acres planted and producing a few tons of rubber, to-day it covers about 4,750,000 acres capable of yielding under normal conditions about 650,000 tons of crude rubber. Of this area, approximately 3,000,000 acres are within the British Empire, in addition to which some 350,000 acres are owned by British companies in Netherlands East Indies.

"About two-thirds of the planted area is in organised estates largely in European hands, while the remainder is in small native holdings. This large development has been rendered possible because the teeming population of India, Java and China offer an adequate supply of efficient workpeople who can earn good wages on a rubber estate where they enjoy a much higher standard of living than was possible for them in their villages. Nothing of the kind could have been done in South America where the supply of labour is scanty and unsatisfactory." The gradual decline in the price of rubber in recent times may be largely attributed to the increasing output of unrestricted areas which have virtually been in competition with British growers at a reducing cost of production. "Whereas in 1910," remarks Mr. Miller, "a cost of 2*s*. per lb. or thereabouts was usual, by 1915 the figure was nearer 1*s*. per lb. and to-day an average estate on full economic output can land its rubber in London warehouse at an 'all-in' cost of about 10*d*. per lb."[2]

While a disconcerting feature of rubber culture or manufacture lies in the vagaries of the market—much as it is in the trade of every raw product—the past history of the rubber market shows that prices never remain unusually high or low for any length of time. Early in this book it was suggested that the Stevenson Scheme must fail largely in effect until all rubber planters can be brought under its sway, for the very obvious reason that restriction in only a few areas cannot prevent rubber going into the world's markets from unrestricted sources. This is just what was last year observed in the London market and the sponsors of the scheme were unable to account for the excess stocks that accumulated there during the autumn of 1927.[3]

Not only were there many loop-holes through which rubber could escape from the restricted areas—such as smuggling and unused coupons—but it was ascertained that the unrestricted areas were shipping to the full extent of their productive capacity. The scheme was consequently having little or no effect in limiting the export of rubber from the Federated Malay States, the Straits Settlements and Ceylon. Hence it was feared that the Middle East was supplying to the world virtually all the rubber that it could produce and the propaganda for the removal of restriction was revived in New York and London. Responding to this agitation, Mr. Eric Macfadyén, Chairman of the Rubber Growers' Association, of London, spoke vigorously in defence of the Stevenson Scheme at a press interview.

[2] "Regulation of Rubber Supplies" by Miller in the *Bulletin* (R. G. A.), December, 1927.

[3] A well-known authority explained that the accumulation was due to American buyers drawing on their supplies in the U. S. A. Rubber Pool instead of buying from London so as to depress the price of rubber and show the futility of Restriction.

IN DEFENCE OF RESTRICTION.

"Since it was introduced in 1922," explained Mr. Macfadyen, "the effect of the scheme has been to reduce the wide fluctuations in the price of rubber so disturbing in the past to producers and consumers alike. A graph showing the range of prices of rubber over a period of years before the Stevenson Scheme resembles the temperature chart of a fever patient. The price mounted as high as 12*s.* 10*d.* per lb. and fell as low as 7*d.* per lb. In the 4½ years since the scheme was adopted, the quarterly average prices have ranged between 11*d.* and 1*s.* 9*d.* throughout the whole period except between May 1925 and January 1926. ****How has the British investor benefited?* A reliable estimate of the normal exports of Malaya and Ceylon for the first 4 years of the scheme is 1,245,000 tons. Under the scheme this potential export was reduced to an actual export of 990,000 tons, representing a restriction of 255,000 tons. In the 12 months preceding the adoption of the scheme, overproduction had reduced the average price for rubber of all grades to 8*d.* per lb., and, if this additional 255,000 tons had been thrown upon an already overstocked market, it is clear that the price must have fallen further."

"*Who wants the scheme abandoned?* Certainly not the British grower. His enthusiastic belief in the scheme may be inferred from his support of it where such support is voluntary. In Sumatra and Java British Companies are free to do as they please: their only inducement to conform being their belief in the wisdom of the scheme and their knowledge that abstention on their part would tend to weaken it. About 90 per cent. of them have adhered to it throughout. Nor does the manufacturer wish to see it abandoned. His bug bear is a jumpy market, and no one was better pleased than the tyre manufacturers of the world at the recent pronouncement in Parliament of the Government's unabated confidence in the scheme. The opposition to the scheme comes from neither producers nor users, both of whom require stability of price at a fair level, but from those who desire to fish in the troubled waters of a speculative market. To both the former it would be a disaster if the scheme were scrapped.

"*Have the Dutch gained?* Certainly—just as the British have and in certain cases more. British and Dutch alike would have gained still more if the Dutch planters had joined us. We still hope they will. But to suggest that we scrap our scheme because, taking a narrow view, certain other interests have so far gained more by it than we, would be merely asking us to cut off our own nose to spite our face. ****Is the scheme hostile to America?* The scheme makes no distinction of nationality and is not aimed at Americans, Germans or any one else. It is not a case of our Government trying to make foreigners pay more for the rubber produced in our Colonies than our own manufacturers pay. It is however the case that we are the chief producers of rubber and the U. S. A. are the main consumers of it. That being so, America has a huge bill to pay for rubber and the settlement of the account has been an all-important factor in English-American exchange and in the return to gold. Our Government has therefore an obvious interest in the production of rubber and in the price the British producers get for it.***

"*Has Reclaiming increased?* Undoubtedly and rightly. The properties of rubber are so remarkable that many articles containing rubber are discarded before the rubber is used up. Was it likely that the huge waste involved in scrapping all this rubber would not sooner or later be saved? ***

"*Is the scheme sound?*. One of the greatest problems of post-war industry is in dealing with potential over-supply. To persist in turning out more rubber than the world can use would be as stupid and ruinous as to persist in growing too much cotton: to turn out as much of either as the world is willing to pay a reasonable price for is just economic commonsense, and the British rubber growers have done the world a service in keeping their own particular industry solvent without profiteering."[4]

A Summary of the Scheme.

The Stevenson Restriction Scheme is at present worked under regulations issued by the Colonial Office in October, 1926. In summary they are as follows:—

(1) They are to rule exports from Malaya and Ceylon for one year at a time from 1st November to 31st October.

(2) Four price rates will govern the exports— 1*s*. 3*d*., 1*s*. 9*d*., 2*s*. and 3*s*.

(3) If the average price in London in any quarter is less than 1|9 but not less than 1|3, the percentage of standard production which will be exported for the ensuing quarter will be reduced by 10—provided that if the reduction is from a figure of 100, the percentage for the ensuing quarter will be 80.

(4) If the average price is not less than 1|9 but less than 2|-, there will be no change in the ensuing quarter—provided that if the average price is not less than 1|9 for three consecutive quarters, the percentage will be increased by 10 in the ensuing quarter.

(5) If the average price in any quarter is 2|- or over, the percentage will be increased by 10 for the ensuing quarter—provided that if the increase is from a figure of 80, the increase in the ensuing quarter will be to 100.

(6) If the average price is below 1|3 in any quarter, the percentage will be reduced to 60 for the ensuing quarter.

(7) If the average price is over 3|- in any quarter, the percentage will be increased to 100 in the ensuing quarter.

[4] *The Bulletin* of the Rubber Growers' Association of London, for June 1927. *The Financial Times* of London reports that the Hon. Mr. Choo Kia Peng, Chairman of the Asiatic Rubber Planters' Association, of Malaya, is in favour of Restriction.

(8) In no case will the percentage be increased above a figure of 100 or decreased below a figure of 60.

Revised Working of the Scheme.

The 6th. year of Restriction began on 1st. November 1927. To remedy the shortcomings observed in its former working, the Colonial Government introduced steps to tighten up measures against smuggling, to prevent the accumulation of export rights and to provide for a system of tapping which will be the basis of assessment for standard production. The system will not exceed the equivalent of one cut on half the circumference of the trunk which will be tapped every third day. Further, the system permits a minimum period of 6 years for the first, 9 years for the second, and 12 years for subsequent bark renewals.

In assessing standard production, the following scale has been adopted:—180 lbs. per acre on area planted in 1922, 240 lbs. per acre on area planted in 1921 and 300 lbs. per acre on area planted in 1920 and previously. Provided that (*a*) no area planted in 1922 shall be assessed unless the assessment committee or district officer is satisfied that not less than 60 per cent. of the trees, or alternately at least 75 trees per acre, measure not less than 22 inches in circumference, 20 inches from the collar; (*b*) area burnt out or abandoned or otherwise unfit for tapping shall not be assessed; (*c*) if trees on holdings are deemed incapable of producing the amount of rubber allowed under the system of tapping which complies with the standard, the assessment committee or district officer may vary such scale.

The estimated standard production for Malaya for the restriction year ending 31st October 1927, was 340,000 tons, which included the allowances for Singapore and Penang Islands. The standard tapping system recognized till then was one cut on a quarter daily or its equivalent, and the change in standard is, therefore, equivalent to a reduction of 16-2/3 per cent. In practice, however, the aggregate assessment for Malaya will probably not be reduced to the full extent of this percentage as rubber not yet fully mature is automatically entitled to an increased standard at each annual reassessment.

It will be noticed that these regulations say nothing about allowances to small holders, which probably means that these will not be much affected.

Market calculations put the possible reduction on 'standard' which will be brought about by these new regulations, if strictly carried out, and after making allowance for automatic increases, at about 35,000 tons. On the basis of a 60 per cent. exportable quota this would mean 21,000 tons less in actual shipments on a full year or 1,750 tons per month. It was anticipated that the effect of the revised assessments would show itself in shipments after some months.

RUBBER PRICES DURING 5TH RESTRICTION YEAR.

According to the reports of the Rubber Trade Association of London, the average price for spot sheet from 1st November 1926 to 31st January 1927, was 1*sh.* 7.265*d.*, from 1st February 1927 to 30th April 1927, it was 1*sh.* 7.696*d.*, from 1st May 1927 to 31st July 1927, it was 1*sh.* 6.165*d.*, and from 1st August 1927 to 31st October 1927, it was roughly 1*sh.* 4.680*d.* On 1st December 1927, the price of ribbed smoked sheet on the spot was 1*sh.* 8¼*d.*

RESTRICTION TO BE ABANDONED.

Early in 1928 rubber prices began to drop rather rapidly which led the Singapore Chamber of Commerce to pronounce against 'restriction.' This was followed by a resolution adopted by rubber planters at Kuala Lumpur who argued that any control which did not embrace all exports from the East would be of little practical use. They urged that since the advent of the Stevenson Scheme, planting had greatly extended in Dutch East Indies which would result in a heavy expansion of output in the near future. In the meanwhile the Kuala Lumpur Chamber of Commerce suggested that if complete control was out of the question, some modification of the Restriction Scheme should be adopted, such as a reduction of the pivotal price from 1*s.* 9*d.* to 1*s.* 3*d.* The Chamber believed that if the price were stabilized at a low figure, consumers would buy more readily and the use of 'reclaimed rubber' would be diminished.*

Owing to these circumstances, and probably some wire-pulling from Washington rather than New York, the British Government appointed a Civil Research Committee to enquire into and report on this scheme. A few weeks later the Government announced (on 4th April, 1928) that, on the recommendations of this Committee, it had decided to remove the restriction on the export of rubber as from 1st November, 1928, the scheme to continue unaltered till that date. This decision completely disorganised the rubber markets in London and New York for a few days. It caused a great shock to the trade because only a modification of the scheme was expected. On the day of the announcement the price of rubber all along the line dropped about 2¾*d.* per lb. in London and over 5 cents per lb. in New York, though prior to it the average price had declined from 1*s.* 6½*d.* to 1*s.* 0½*d.* in three months. Stock-holders in particular incurred heavy losses by the sudden decline.

While the decision of the Baldwin Ministry might have been taken to serve the best interests of rubber in general, it was at variance with the views put forward by the Rubber Growers' Association representing the British estates, the London Stock Exchange standing for the rubber investors and the Rubber Trade Association composed of those who distribute rubber to the manufacturers. Even the India Rubber Manufacturers' Association would have welcomed a more gradual removal of Restriction. And, it is strange that though American politicians agitated for this measure, the suddenness of it hit very badly the U.S.A. manufacturers who had large stocks on hand bought at high prices.

*Reclaimed rubber is not likely to be abandoned. Its use lessens the consumption of the fresh product and also obstructs the prospects of synthetic rubber.

The New York Rubber Pool, formed to protect manufacturers against high prices induced by 'restriction,' was also placed in a similar predicament. There is now, of course, no justification for the continuance of this Pool.

THE OBSCURE OUTLOOK.

The precipitous method of the aforesaid Cabinet will continue to cause a rather unsteady tone in the market, which is likely to develop into a veritable crisis when 'restriction' is actually removed, if the market is thereby flooded with unwanted rubber which now seems highly probable. Already some estates are thinking of tapping 'all out,' so as to reduce their cost of production, but such a step would in the long run be to their own detriment. In the words of Mr. Macfadyen it would be like cutting one's nose to spite one's face. A reckless move of this kind would result in cut-throat competition among producers in which they alone would suffer. Instead of such needless rivalry among themselves, a policy of widespread co-operation between Dutch and British growers, with pools and combines as far as possible within their respective territories, should be adopted. There is no better weapon than co-operation to overcome unnecessary friction in the industrial world.

There is every probability that the end of the Stevenson Scheme will witness the advent of an extraordinary glut in the rubber market with a protracted slump in prices, unless some scheme such as outlined above is formulated in time and brought into operation by 1st November next, or unless some unusual good luck intervenes which it is unreasonable to expect. Current reports go to show that many estates in Malaya, Ceylon and Dutch East Indies carry extensive stocks meant to cover shipments for at least 3 or 4 months. Some of these concerns have already effected forward sales at 8*d.* and 9*d.* per lb. for the whole of 1928 and a few even for 1929. The wisdom of these sales is not quite apparent. At any rate they indicate a very weak feature in the situation and foreshadow heavy shipments from 1st November onwards. The argument that the fall in price will displace 'reclaimed rubber' and thus increase the consumption of the original product eventually will afford little consolation to growers in the meanwhile.

Though it is quite certain that a brighter situation will develop in course of time, it would be sheer folly to sit idle in the face of an impending crisis and hope for better times at the back of beyond. If no steps are taken immediately to avert a depression from November, 1928, a continuous flood of unwanted rubber may be expected to flow into the market until the price goes down to about *7d.* a pound. In such an eventuality, 'reclaimed rubber' and the inferior products of petty estates may have little or no demand, while the quest for the superior grades of crude rubber may become greater than their supply. The latter may possibly be assisted by the results of the first rubber crisis. During the last great slump in the industry between 1921 and 1924, very few rubber estates were opened out and those that were, cannot yield for about 7 years.* In consequence the crop cannot augment substantially between 1928 and 1931. Then, bud-grafting effected during the slump was inconsiderable and in any case its final results are still uncertain. Attention has also been drawn to the declining yield of the older plantations but this would be compensated by the improving yield of the younger ones.

How to Combat the Crisis.

Some time ago the N. E. I. Committee of the Rubber Growers' Association reported that companies controlling 285,857 planted acres had signed agreements, unconditionally or with certain reservations, for the voluntary restriction of rubber exports during the year ending 31st October, 1928. Probably these are British companies working on Dutch territory. But if they are Dutch companies, the point is whether they would be willing to continue the undertaking after

*See Table I in the next Chapter.

the close of the Stevenson Scheme, though it is well-known that the restriction of output in only a section of the industry would not suffice. There is, however, some hope in the fact that many of the Dutch growers now seem to realise that the difficulties of the situation can only be overcome by a general plan of restriction into which they must enter on an equal footing with the British. In these circumstances, efforts to bring about an Anglo-Dutch agreement should have a fair chance of success. Sooner or later, some thing in the nature of an understanding among rubber growers must be reached. It may come spontaneously from the timely wisdom of producers backed by skilful negotiation or it may come as the forced culmination of a ruinous spell of mutual under-selling. Which of these two alternatives is the more prudent course can never be doubted.

Often has the tea industry in India been saved from a threatened crisis by the voluntary restriction of output suggested by its central organisation, the Indian Tea Association. Similarly, the Rubber Planters' Associations in Malaya, Ceylon and the Dutch East Indies could have a controlling Union, say at Batavia, Singapore and Colombo, to restrict exports and maintain prices, working somewhat on the lines of the Stevenson Scheme. No better remedy could be suggested to fight against the impending glut. Incidentally such an organization might also undertake propaganda work in Western countries to extend the use of rubber, much as the British Rubber Growers' Association is doing in London by means of periodic exhibitions. The Indian Tea Cess Committee has been engaged for some years on a similar undertaking to push the sale of tea in different parts of the world. In times of over-production, the policy of restriction has been applied with some relief to producers in many other industries, such as sugar production in Cuba, coal-mining in Bengal and cotton manufacture in Bombay.

The world's production and consumption of raw rubber during 1927 have been roughly estimated at

615,000 tons and 590,000 tons respectively. Since there are always stocks on land or afloat belonging to manufacturers, warehousemen and planters, these have been estimated at 262,000 tons by Messrs. Symington and Sinclair, of London, and at 250,000 tons by the President of the New York Rubber Exchange as on 1st January, 1928. The world's production and consumption in 1928 are expected to be about 775,000 tons and 700,000 tons respectively by the aforesaid firm. The second last figure seems somewhat excessive as the crop can hardly augment by 160,000 tons in 1928. Anyway, according to it production this year added to old stock would amount to over 1 million tons and the natural inference to be drawn from it is that there will be more than enough with 'reclaimed rubber' for the world's consumption in 1928, in spite of the Stevenson Scheme. If these figures are correct, the theory of a coming shortage (based chiefly upon slender sowings during the last crisis and the 15 per cent. annual increment in consumption) must be abandoned until 'reclaimed rubber' goes out of use. In the meanwhile, therefore, a rather gloomy outlook threatens the industry if no steps are taken to prevent the crisis from reaching a climax.

The Proposed Anglo-Dutch Agreement.

A constructive proposal for the uplift of prices was not long ago advanced by a recognised authority. Mr. James Fairbarn, speaking at a meeting of the Barrier and General Finance Company in London suggested the creation of a central Anglo-Dutch selling agency, a drastic reduction in the number of agency firms, the prohibition of new planting and the consolidation of estates. Should the Dutch growers refuse to co-operate in such a policy, as they did over the Stevenson Scheme, and the ruinous practice of price-cutting is finally established in the industry, the only concerns that would not feel the crisis would be those which are well financed and could work efficiently at a reduced cost of production. Moreover, in such circumstances the Asiatic growers would probably flood the market with their fast increasing output chiefly in

Dutch territory. These tendencies seem to adumbrate that if the Dutch planters still hold aloof from the Anglo-Dutch scheme of co-operation that is now proposed, they would stand to suffer more than the British by their intransigence.

Reuter reported last June that a scheme for the *valorisation of rubber* was drawn up by M. Kloppenburg, a banker of The Hague. The plan it seems has been presented for consideration to the British Rubber Growers' Association and the International Association for Rubber Cultivation. *The India Rubber Journal* (9th June, 1928) gathers that the scheme contemplates the establishment of a bank with a capital of, say, 15,000,000 guilders (£1,250,000). Of this amount 75 per cent. would be earmarked for subscription by producers to shares of £100 each. A third of the value of each share is to be paid for in cash and two-thirds by delivery of 2,000 lbs. of rubber at 8*d*. per lb. between October and December 1928. The balance (25 per cent.) of capital is to be raised by public subscription.

The aim of the bank would be to take over any surplus production as soon as the market price dropped below 1*sh*. per lb. and to release such accumulated surplus when the market price rose above 2 *sh*. per lb.

In exchange for the above delivery, producers would receive bonds bearing no interest, but entitling holders to 25 per cent. of the bank's surplus profit. On the other hand, the bank would undertake to supply (for the purpose of road-making or paving) 75 per cent. of their rubber stock to the British and Netherlands Governments at a price of 12*d*. per lb.

A Trend of Modern Industry.

Modern industrial history teaches us that the vicissitudes of trade are due largely to the miscalculations of producers as to the quantity of products likely to be demanded in the market from time to time. There exists, of course, a compensatory action between supply and demand, but though automatic, it is not sufficiently rapid to make production keep a perfectly uniform pace with consumption at all times. Thus, we find in many industries, where the tendency is towards mass production so as to reduce cost, either a gradual lowering of prices or frequent periods of depression taking place. Hence to fight against overproduction, a regular policy of restricting output, strictly in accord with the needs of the day, has become imperative.

The modern world can augment production very readily, but it cannot with equal rapidity improve the purchasing power of men. Naturally it is obvious that industrialism has long been blind and uncontrolled leading to ruinous competition, depression and crisis. Economic laws on the other hand do not operate fast enough to remedy these evils in time. While the State is right in being slow to interfere with the freedom of trade, it is the duty of those engaged in it to work on a more scientific and enlightened basis in future. And the avoidance of competition in business is actually a very economic method. But an essential point in the policy of voluntary restriction is its adoption by all producers, as otherwise it cannot bring complete success, because those who keep out of it continue the competitive regime.

There can be little doubt that the economic soundness of restricting output is coming to be recognised even in the United States. In 1925 Mr. Herbert Hoover denounced the Stevenson scheme because it was hitting hard the American consumers. To-day he is prepared to spend millions of dollars to foster combinations among American farmers to restrict the output of wheat and cotton. No industry can stand a continual wearing away of profits. When it is so circumstanced, the interests of producers must be protected sooner than those of consumers, else the industry cannot survive. Hence a restriction of output must be resorted to as much as protective tariffs for future economic welfare. In this manner both internal and external friction could be lessened in many industries and the present age of grinding competition mollified into one of greater co-operation.

CHAPTER XVII.

STATISTICS ON THE INDUSTRY.

INCOMPLETE FACTS AND FIGURES.

Statistics relating to the world's rubber industry are not very reliable, as suggested early in this book. When the data for such estimates are procured, it is found that many items are either inaccurate or incomplete. The British Rubber Growers' Association, however, has recently published the most trustworthy information so far obtainable in this connection. The Association has also represented to the Colonial Government the urgent need of having more full and reliable data on this industry, but until the Governments of the Dutch East Indies and other rubber-producing countries take action along similar lines, complete world figures will not be available. The following tables are abstracted from *Statistics relating to the Rubber Industry* issued by the above Association about the end of April 1928.

Since reliable data should form the basis of calculations on the working conditions of an industry, it goes without saying that inaccurate information leads to conjecture and speculation which in turn are apt to cause losses in business. When faulty figures have no visible ill-effect, they at least help to create an uncertain tone in the market by the distrust that business people have in trade forecasts and calculations based on them. Reliable statistics are, therefore, quite indispensable to the full and proper understanding of production, consumption and distribution in this industry, as in the entire economic world. Moreover, a correct interpretation of figures is essential, for which reason sufficient details must accompany statistics. For instance, if at any time it is reported that the U. S. A. is using crude and reclaimed rubber in the ratio of 68 and 32 per cent, it is necessary to ascertain what percentage of manufacturers have sent in returns on this point, and then the obvious inference must be drawn that the estimate is correct only for that portion of the country's absorption. There are other points on the correct reading of figures, which cannot be discussed here.

TABLE I.

THE WORLD'S AREA UNDER PLANTED RUBBER.

Year.	Total Area.
1911	1,850,000 acres.
1912	2,250,000 ,,
1913	2,500,000 ,,
1914	2,750,000 ,,
1915	3,000,000 ,,
1916	3,250,000 ,,
1917	3,450,000 ,,
1918	3,650,000 ,,
1919	3,850,000 ,,
1920	4,100,000 ,,
1921	4,200,000 ,,
1922	4,250,000 ,,
1923	4,300,000 ,,
1924	4,400,000 ,,
1925	4,550,000 ,,
1926	4,750,000 ,,

The area tappable in any year may be taken to include all rubber over five years old at the beginning of that year. The area tapped depends largely on the tapping policy of the various producers.

TABLE II.

THE PLANTED AREA IN DIFFERENT COUNTRIES.

End of 1926.	*Total Acres.*
Malaya	2,250,000
Netherlands East Indies ..	1,600,000
Ceylon	450,000
Sarawak and British North Borneo	150,000
India	140,000
French Indo-China	90,000
Siam, Africa, etc.	70,000
	4,750,000

The above figures which are only approximate include all plantation rubber both estate and native. The figure for the Netherlands East Indies includes native holdings the area of which is *highly conjectural.*

TABLE III.

DISTRIBUTION OF PLANTED AREA ACCORDING TO NATIONALITY OF OWNERSHIP AT END OF 1926.

Nationality of Ownership.	Malaya (acres.)	Ceylon (acres.)	N. E. I. (acres.)	India (acres.)	Borneo and Sarawak (acres.)	French Indo-China (acres.)	Other Countries (acres.)	Total (acres.)	Percentage of Total.
British (U. K.) ..	825,000	160,000	350,000	70,000	60,000	..	10,000	1,475,000	31·1
Do. (out of U. K.)	375,000	80,000	30,000	20,000	..	..	20,000	525,000	11·0
Dutch ..	..	..	525,000	..	..	..	..	525,000	11·0
French	..	..	45,000	..	..	90,000	..	135,000	2·9
American ..	20,000	..	75,000	..	..	..	10,000	105,000	2·2
Belgian ..	8,000	..	45,000	..	..	..	..	53,000	1·1
Swiss, etc. ..	2,000	..	20,000	..	..	..	..	22,000	·5
Asiatic Estates ..	380,000	120,000	10,000	40,000	5,000	..	30,000	585,000	12·3
Small Holdings ..	640,000	90,000	500,000	10,000	85,000	..	..	1,325,000	27·9
Total ..	2,250,000	450,000	1,600,000	140,000	150,000	90,000	70,000	4,750,000	100
Percentage of total ..	47·4	9·5	33·6	3·0	3·1	1·9	1·5	100·0	

TABLE IV.

EXPORTS OF CRUDE RUBBER FROM THE PRODUCING COUNTRIES.

Year.	Plantation.								Wild.		Total.
	British Malaya.	Dutch East Indies.	Ceylon.	India.	British North Borneo.	Sarawak.	French Indo-China.	Siam etc.	South America.	Other Wild.	
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1920	181,000	80,000	39,000	6,400	4,100	2,200	3,100	800	29,000	8,000	353,600
1921	151,000	71,000	40,200	5,300	3,200	2,100	3,600	800	19,000	4,000	300,200
1922	214,000	94,000	47,400	4,900	3,800	3,800	4,500	1,300	23,000	3,000	399,700
1923	201,000	117,000	37,100	6,400	4,200	5,700	5,100	2,400	22,000	6,000	406,900
1924	183,000	149,000	37,400	7,700	4,600	6,700	6,500	2,800	23,000	7,000	427,700
1925	210,000	189,000	45,700	10,100	5,400	9,000	6,300	4,000	28,000	10,000	517,500
1926	286,000	204,000	58,800	9,900	5,800	10,000	7,400	4,000	25,000	9,000	619,900
1927	242,000	229,000	55,400	11,300	6,600	11,000	8,000	4,000	28,000	10,000	605,300

The exports of plantation rubber have been adjusted to allow for moisture, etc., in native rubber. The figures for the Dutch East Indies include rubber smuggled out of British Malaya. In 1927 the amount of rubber so included is estimated to have been from 15,000 to 20,000 tons.

TABLE V.

THE WORLD'S IMPORTS OF CRUDE RUBBER.

Year.	United Kingdom. (1)	France. (2)	Italy. (3)	Germany (4)	Austria-Hungary. (5)	Russia. (6)	Holland. (7)	Belgium. (8)
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1920	56,800	16,300	6,100	12,600	1,300	100	5,500	3,400
1921	42,100	14,800	3,900	21,600	2,400	200	1,000	1,700
1922	11,700	27,700	6,400	27,600	2,600	3,100	3,800	200
1923	12,700	31,200	8,500	18,500	2,600	4,500	800	2,200
1924	11,600	34,600	8,800	22,700	2,500	1,500	800	2,700
1925	4,100	37,500	11,100	33,900	2,500	7,500	900	2,900
1926	84,900	36,900	10,200	22,800	3,000	7,000	2,700	2,500
1927	60,200	36.000	11,300	38,900	3,000	12,500	600	6,500

TABLE V.—*contd.*

THE WORLD'S IMPORTS OF CRUDE RUBBER—*contd.*

Year.	Scandinavia. (9)	Spain. (10)	United States. (11)	Canada. (12)	Japan. (13)	Australia. (14)	Other Countries. (15)	World's Total. (16)
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1920	2,300	4,100	249,500	11,900	6,000	3,500	1,300	380,700
1921	1,300	3,600	179,700	8,200	21,000	3,000	1,400	305,900
1922	1,700	600	296,400	9,400	15,000	2,500	2,000	403,100
1923	2,200	600	301,500	13,200	14,000	2,000	3,000	417,500
1924	2,900	1,000	319,300	14,300	16,000	3,000	3,500	420,400
1925	2,800	1,200	385,600	19,800	11,100	5,000	3,900	529,800
1926	3,300	1,500	400,000	20,400	17,000	9,000	4,500	625,700
1927	3,400	2,000	403,500	26,400	18,700	9,500	5,000	637,500

TABLE VI.

PRODUCTION OF RUBBER IN DUTCH EAST INDIES IN TONS.

Year.	Estate Rubber. British. (a)	Estate Rubber. British. (b)	Estate Rubber. Other.	Native Dry Rubber. (c)	Total.
1922	27,000	..	50,000	17,000	94,000
1923	20,000	3,000	59,000	35,000	117,000
1924	21,000	3,000	69,000	56,000	149,000
1925	25,000	4,000	75,000	85,000	189,000
1926	36,000	4,000	80,000	84,000	204,000
1927	33,000	4,000	90,000	102,000	229,000

(*a*) Estates which have agreed to regulate their exports according to the Stevenson Scheme.

(*b*) Estates which have *not* agreed to regulate their output according to the Stevenson Scheme; most of these estates have adopted a similar form of restriction.

(*c*) Includes smuggled rubber.

TABLE VII.

ABSORPTION OF CRUDE RUBBER IN TONS BY MANUFACTURERS.

Year.	United States.	United Kingdom.	Other Countries.	Total.
1920	215,000	24,000	71,000	310,000
1921	170,000	18,000	77,000	265,000
1922	285,000	10,000	95,000	390,000
1923	305,000	27,000	103,000	435,000
1924	335,000	22,000	113,000	470,000
1925	390,000	30,000	140,000	560,000
1926	365,000	40,000	140,000	545,000
1927	375,000	45,000	170,000	590,000

TABLE VIII.

AVERAGE ANNUAL SPOT-PRICE PER LB. OF FIRST LATEX CREPE IN LONDON.

Year.	*Price.* s.	d.
1906	5	10½
1907	4	11½
1908	4	2¾
1909	7	1
1910	8	9
1911	5	5½
1912	4	9
1913	3	0¼
1914	2	3½
1915	2	6
1916	2	10¼
1917	2	9¾
1918	2	3½
1919	2	1¼
1920	1	11
1921	0	10½
1922	0	9⅛
1923	1	3¼
1924	1	1⅞
1925	2	10¾
1926	1	11¾
1927	1	6¼

Table IX.

STOCKS IN BRITISH MARKETS ON 31ST DECEMBER.

Year.	London.	Liverpool.	Singapore.	Penang.
	Tons.	Tons.	Tons.	Tons.
1925	5,697	631	16,256	2,584
1926	48,918	2,402	21,522	4,921
1927	68,793	2,468	21,761	4,037

In November 1922 when the Stevenson Scheme began to work, the stocks in the above markets amounted to about 122,000 tons as compared with only about 80,000 tons expected to be there when the Scheme will terminate. From this supposed diminution together with the fact that the world's consumption has increased from about 400,000 tons in 1922 to something like 650,000 tons in 1928, it has been argued that the expected glut at the end of Restriction will not be so great as is generally supposed. But this forecast does not consider the stocks with planters which are expected to total about 70,000 tons on 1st November 1928, nor does it regard the surpluses that the manufacturers will have on that date both on land and afloat.

TABLE X.

RELATIVE ABSORPTION OF CRUDE AND RECLAIMED RUBBER IN THE UNITED STATES OF AMERICA.

(Figures published by the Department of Commerce, U. S. A.)

Year.	Crude Rubber.	Reclaimed Rubber.	Ratio of Reclaimed to Crude.
	Long tons.	Long tons.	Per cent.
1917	157,371	89,168	56·7
1919	202,303	73,535	36·3
1920	196,270	75,297	38·4
1921	169,308	41,351	24·4
1922	283,271	54,458	19·2
1923	274,956	69,634	25·3
1924	301,778	76,072	25·2
1925	387,629	137,105	35·3
1926	366,000	164,500	44·9
1927	375,000 (Est.)	180,000 (Est.)	48·0

Note.—The official figures given above for the years 1923 and 1924 are based on the returns of crude rubber absorbed by manufacturers and do not allow for the fact that returns are made only by a percentage of manufacturers.

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In p. 187, 14th line ..	undivided ..	divided
In p. 187, 25th line ..	ascophore ..	ascospore
In p. 196, 17th line ..	thus fungus ..	this fungus
In p. 201, foot-note, 4th line	of forming ..	or forming
In p. 207, foot-note, 6th line	In Bull ..	in Bull.
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In p. 251, 7th line ..	68,793 ..	63,793

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