THE POSSIBILITY OF EXTENDING *CINCHONA* CULTIVATION IN THE BRITISH EMPIRE*

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INTRODUCTION

The *Cinchona* plant is the base for the manufacture of quinine, which is still the most important specific for malaria, in spite of the advent of synthetic drugs, such as plasmoquene and atabrine. The former drug is not now in favour, as it is said to give rise to certain toxic effects. Atabrine is of German origin and is protected by patents. Its cost is high, and it is stated [1] that the cost of treating one malaria case with it would be 4.9s. as against 1s. for a similar treatment with quinine. In view of the fact that vast areas of the territories owing allegiance to the British Crown are subject to this scourge, it is remarkable that about 90 per cent of the quinine products consumed in the world to-day is produced in the Netherlands East Indies, and that only about 4 per cent is made in British countries. It has been estimated that there are some

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800 million people in the world to-day who suffer from malaria and that there are 2 million fatal cases annually. A large proportion of these casualties are British subjects. For example, the League of Nations Health Organization gives data showing that 100 million people in British India alone suffer from malaria, but only 8 to 10 million are treated annually, and in other tropical parts of the Empire conditions are much the same.

The increased consumption of quinine is largely a matter of price and, running concurrently, of efficient propaganda. With lower prices, a wider knowledge of the nature of the drug and efficient means of distribution, the consumption could undoubtedly be largely extended. Even at present the consumption figures are very considerable. Thus India alone consumes about 210,000 lb. of quinine per annum, of which 70,000 lb. are produced in that country and 140,000 lb. are made from Dutch East Indies bark. The real need for India is provision for 100 million sufferers, using 45 grains a year, which would require 600,000 lb. of quinine sulphate annually. In the Colonial Empire the latest figures, as shown by the imports, indicate a consumption of about 70,000 lb. per annum. Many of the smaller island Colonies, such as Fiji, Tonga, and some of the West Indian islands, do not suffer from malaria and do not, therefore, import quinine. Taking the others, the Eastern Group consumes nearly 47,000 lb., the chief importers being Ceylon (27,500 lb.), Malaya (15,000 lb.), and Mauritius (3,100 lb.) The East African Colonies absorb over 11,000 lb., Kenya, Tanganyika, and Uganda each taking between 2,500 and 3,000 lb. annually. The West African group absorbs only 7,190 lb., an amount which is obviously very much less than the potential demand. In all these Colonies the need for quinine is great, but the obstacle of price, which is greater than the average inhabitant can afford stands in the way of any immediate increase of consumption.

The whole question of malaria control was specially considered by the Health Organization of the League of Nations. The Special Malaria Sub-Committee of this body inquired into the possibility of utilizing the other alkaloids that are present in *Cinchona* bark in addition to quinine. The conclusion reached was that the stricken peoples of the world would benefit from the use of a cheap febrifuge consisting of mixed alkaloids, provided these conformed to legally defined standards. Totaquina was the result of these deliberations and it is a febrifuge standardized to contain 70 per cent of crystallizable alkaloids, of which 15 per cent is quinine. Either it may consist of the total alkaloids of low quinine-yielding species, such as *C. succirubra*, or it may be made from the high-yielding *C. ledgeriana* residues with the addition of sufficient quinine to bring it up to

specification. Medical tests, according to Field,[2] have proved satisfactory, although it is stated to be slightly less effective than quinine and is unsuitable for intramuscular injections. Here again the question of cost arises, and totaquina is not likely to displace quinine unless it is appreciably cheaper. Theoretically the extraction of total alkaloids from the bark is easier and cheaper than the separation of quinine alone, but prejudice is in favour of quinine, partly because of its more attractive colour and appearance. The price of bark is the real crux of the question, and this is largely controlled at the present time by one organization which holds a practical monopoly, namely, the Kina Bureau of Amsterdam. This controls the production of bark in the Netherlands East Indies, a region which, as has been stated above, provides not less than 90 per cent of the total world production at present. The supplies from the South American countries, which are the original home of the plant are now negligible.

CINCHONA AND EARLY HISTORY OF ITS CULTIVATION

The genus *Cinchona* is a native of the Andean region and grows in a wild state on the eastern afforested areas of that region, between latitudes 10°N. and 9°S., in the Republics of Peru and Bolivia. There are 65 species of the genus *Cinchona* listed in *Index Kewensis* and all are characterized by possessing bark containing the quinine alkaloids to a greater or less degree. The classification has presented some difficulty to botanists, owing to the ease with which the species hybridize with one another, so giving rise to different forms. There are, however, only four species which are, or have been, cultivated to any extent for their alkaloids. These are *C. ledgeriana* Moens ex Trimen, which is also known as *C. calisaya* Wedd. var. *ledgeriana* Howard, from which Ledger Bark is obtained; *C. succirubra* Pavon ex Klotzech, which produces Red Bark; *C. calisaya* Wedd., yielding Yellow Bark; and *C. officinalis* Linn., giving Crown Bark or Loxa. There are two hybrids which have been cultivated from time to time, namely, Ledger Hybrid (*ledgeriana* × *succirubra*) and *C.* (*robusta* × *officinalis* × *succirubra*). Nowadays practically all the *Cinchona* bark of commerce is obtained from *C. ledgeriana* and *C. succirubra*. In Java selected plants of *ledgeriana* have given higher percentages, and in fact the contents of quinine and alkaloids seem to vary somewhat according to variety and also to environment.

Cowan [3] gives the following average percentages of the three main species as grown in India:—

	Quinine	Other alkaloids	Total alkaloids
C. ledgeriana	5.49	3.03	8.52
C. officinalis	2.93	2.07	5.00
C. succirubra	1.40	4.85	6.25

Analyses of the bark indicate that *C. ledgeriana* is richer in quinine than any other species, but that *C. succirubra* possesses a high total content of alkaloids, particularly in cinchonidine. These facts are of great importance in connection with the establishment of the planting industry, as naturally efforts have been made to cultivate *ledgeriana* on account of its high quinine-content, in spite of the fact that it is more particular in its requirements and is less easy to grow than the other species.

The history of the introduction of the plant to cultivation throws considerable light on the present state of the industry. Prior to 1857 supplies of bark were obtained in limited quantity from the native home of the tree in Bolivia and Peru, hence its old name of Peruvian Bark. It had long been known as a fever-freeing drug as in 1639 the Countess of Chinchon, wife of the Spanish Viceroy of Peru was cured by a decoction of the bark. A hundred years later Linnaeus perpetuated the name of this lady by giving the genus the name *Cinchona*.

No real effort seems to have been made to cultivate the tree in the South American forests, or to maintain supplies by replanting, and as the demand for the drug increased, especially after 1820, when French chemists isolated the main alkaloid from the bark and quinine sulphate became the established specific, the importance of securing more abundant and regular supplies became evident. Between 1845 and 1848 Dr. H. A. Weddell investigated the natural occurrence of *Cinchona* trees in South America and described the species. He commented on the reckless clearing of the forests and pointed out that cultivation would have to be undertaken if supplies were to be maintained. Weddell's seed was planted in the Jardin des Plantes at Paris, and a few years later, one of these plants was taken to Java, supplemented later by importations of seed and plants from South America and by exchange from India. Stimulated by his report the East India Company decided to dispatch an expedition to South America to obtain seeds and, if possible, plants, and placed Mr. (later Sir) Clements Markham in charge. A brief account of his journey is given by Dr. George Smith.[4]

Markham succeeded in collecting 529 plants, together with a quantity of seed, chiefly of the *calisaya* variety from 'the Province of Caravaya' in Peru. He arrived at Southampton in 1860, and after transmitting a portion that were dying to Kew,[5] he proceeded with the remainder to the Nilgiri Mountains in Madras Presidency, and eventually 270 survived the passage of the Red Sea. Meanwhile seed had been dispatched to Kew where, under Treasury instructions, a forcing house had been erected. A large number of seedlings were raised there in 1860-1, young stocks grown, and competent gardeners recommended to take charge of the new plantations in India. At the same time seed was supplied to the West Indies and Ceylon. The plants thus collected appear to have been chiefly of the two species *succirubra* and *officinalis*, neither of which possesses a high quinine-content. The next step was the introduction into cultivation of *C. ledgeriana* in 1865. Charles Ledger was an explorer and merchant, and an interesting account by Holland [8] relates how his henchman managed to collect seed from fifty trees of the 'rojo' sort from the banks of the Mamore river in Bolivia. Ledger sent the seed to London, where it arrived in good condition, and asked his brother to sell it to the British Government. He was unable to do this and sold the greater part of the seed (about 13 lb.) to Mr. J. W. B. Money, who owned *Cinchona* plantations in India. The latter did not use the seed himself, but exchanged it for *C. succirubra* seed with McIvor, the head of the Government Cinchona Plantations in Madras, since this variety appeared to be well suited to Nilgiri conditions. Little care seems to have been taken with Ledger's seeds in Madras, and although about 60,000 seedlings were said to have been raised, they were allowed to die out because the policy at that time was to concentrate on *succirubra*. A small pinch of seed had meanwhile been obtained by G. A. Gammie, the Superintendent of Cinchona Plantations in Bengal, and 800 seedlings were raised. Partly because the species appeared to do better in the Himalaya foothills than in the Nilgiris, and partly also because the true value of the *Ledgeriana* species was better appreciated, it was multiplied rapidly and soon began to replace the inferior varieties in the Bengal plantations. Meanwhile Ledger had disposed of his remaining seed amounting to 1 lb. to the Dutch Government, who sent it to Java, where it came into the possession of the Director of Cinchona Cultivation, J. C. Moens, in 1865. The new species took kindly to the soil and climate of Cheribon and Preangar, where most of the *Cinchona* is still grown to this day. The value of the new introduction with its high quinine-content was at once realized, and the Dutch with their usual thoroughness immediately began a system of rational selection which has borne abundant results.

According to Kerbosch,[7] the planters in Java early formed the opinion that the large-scale production of *Cinchona* bark with a low quinine-content would have no economic future. Accordingly, when *Cinchona* plants were first introduced by Markham, Hasskarl, and Schuhkraft, the planters took little interest, since these species, mainly *officinalis* and *succirubra*, produced bark with a low quinine-content. There was a change in the situation in 1873, by which time the first consignment of bark with a high quinine-content was produced from the plants raised from the seed purchased from Ledger in 1865. Private enterprise then began to develop plantations on a large scale, more especially as the medical profession was advocating more and more strongly the use of the drug, with the result that the market strengthened and widened. Ceylon was at that time a keen competitor of Java, as the planters had been anxious to find a substitute for coffee, which was being destroyed by the fungus disease *Hemeleia vastatrix*, and had substituted *Cinchona* for it. The area planted to *Cinchona* in Ceylon jumped from 1,500 acres in 1873 to 64,000 acres in 1883, but by then over-production had taken place and the price of bark fell from 72 Dutch cents in 1880 to 7½ cents ten years later. The Ceylon bark with the low quinine-content was at a serious disadvantage with the Ledger bark produced in the Dutch East Indies, and the industry declined rapidly. The area in 1893 was only 5,000 acres, and the *Cinchona* trees were grubbed up to be replaced by the new plantation crop — tea — which was then coming into favour and was found to grow well under the same conditions as *Cinchona*. To-day the Ceylon industry is dead.

In India the position was in some ways similar to that in Ceylon, with the difference that Government-owned plantations were maintained in the Nilgiri Hills of Madras and in the north-east of Bengal on the Sikkim border. These two regions are still the centres for quinine production in India, but private enterprise has ceased and only the Government plantations remain. At the height of the boom in 1880 it was estimated that the Government and private plantations in the Nilgiris and other parts of southern India amounted to 5,800 acres, with a production of 400,000 lb. of dry bark per annum. The Government plantations at Munsong and Mungpoo in Bengal covered 2,400 acres and private plantations in Darjeeling another 1,800 acres, the former producing 400,000 and the latter 150,000 lb. of bark per annum. In Ceylon at the same time the corresponding figures were 33,500 acres and 1,000,000 lb. of bark, Java at that time possessing 7,500 acres and 450,000 lb. In all parts of India the slump in prices caused by over-production saw the elimination of private plantations during the next decade.

There were essential differences in the management of the Government plantations in Madras and Bengal. In Madras, the policy had been to grow *succirubra* and to a less extent *officinalis* and *robusta* — species possessing a much lower quinine-content than *ledgeriana*. The reasons for this policy were partly that these species were those first introduced at the time of Markham's successful expedition, and also because conditions of soil and climate seemed to suit them better than *ledgeriana*. In Bengal, on the other hand, the value of *ledgeriana*, on account of the high quinine-content of its bark, was realised from the time when the first small consignment of seed had been secured with so much difficulty, and efforts were largely concentrated on the problem of establishing this species, so that up to the present time by far the greater part of the area is still planted in *ledgeriana*.

Cinchona was also tried in the early days in many parts of the British Empire, and apart from Ceylon and India, experiments were carried out in Malaya, the Sudan, St. Helena, Jamaica, Trinidad, Mauritius, and parts of Australia and New Zealand. In most of these places climatic conditions proved to be unsuitable, but in Jamaica a small industry flourished during the boom period. The area cultivated in 1880 was estimated at 800 acres and the production at 50,000 lb. of bark per annum, but the economic conditions that proved so fatal in Ceylon and India also applied to Jamaica, and the industry speedily declined, so that at the present time all that remains to perpetuate the attempt is the name "Cinchona" which is given to a pleasant old house which is situated high up in the Blue Mountains and the headquarters of an old experimental garden of the Department of Agriculture.

This record of failures in the British possessions is in marked contrast to the state of the industry in the Dutch East Indies where it continues to flourish today. It will be interesting to examine the reasons for this success and the methods by which difficulties have been met and overcome.

CAUSES OF SUCCESS OF THE DUTCH INDUSTRY

Kerbosch [7] mentions that the effect of the slump in prices during the 'eighties caused by over-production was felt for twenty years afterwards, and the price reached such a low level that many undertakings in Java could hardly work at a profit. In fact, there was a danger during this period that *Cinchona* cultivation might be abandoned in favour of another crop, as happened in Ceylon. The first real improvement came in 1913 when the producers in the East

Indies came to an agreement with the manufacturers of quinine whereby the supply and sale of bark was regulated to keep pace with the world's consumption. This arrangement probably saved the estates from financial ruin, but has not really prevented the possibility of over-production, for far more bark could be obtained by the normal working of the estates than is now allowed to be produced by the agreement. A rapid expansion in output could, therefore, become effective, if the position of the market warranted such action.

Mention has been made of the measure of co-operation maintained between the growers and the quinine manufacturers which was achieved through the Cinchona Agreement of 1913. The administration of the Cinchona Agreement lies with the Kina Bureau in Amsterdam, which is made up of representatives of both growers and quinine manufacturers. Government influence is of importance, as about 10 per cent of the production of bark comes from Government-controlled plantations. Since 1934 bark production has been further controlled by the introduction of an export quota system, and Government decrees the amount of bark that shall be exported annually. Thus, in 1936 the export quota was fixed at 1,646,851 lb. (expressed as quinine sulphate equivalent), but in order to meet the world's heavy demand the quota was increased in November by another 157,630 lb. The figures for 1937, 1938 and 1939 have been progressively lower. The producers of bark have benefited greatly by this restriction scheme, which was extended for another ten years on January 1, 1937. The feasibility of this agreement was only possible because the Netherlands East Indies possessed by 1913 a virtual monopoly of production. At least 90 per cent of the world's supply was in their hands, owing to the collapse of private enterprise in Ceylon, South India, and other places. It must not be imagined, however, that this position has been easily reached, as prior to 1913 the industry had many bad periods.

Some of the reasons for the survival of the Java industry when its competitors failed may be briefly mentioned. In the first place, the climate of those parts of Java where *Cinchona* is grown appears to be particularly favourable to its growth, and especially to *ledgeriana*. The light volcanic soils also seem to be very suitable. But apart from this, due credit must be given to the way in which the early Dutch adopted the policy of concentrating on varieties producing bark with a high quinine-content. The industry has also been the subject of unremitting research by the Government Cinchona Plantation at Tjinjeroean, and rigorous control in the selection and breeding of new high-yielding varieties has given planting material of the highest quality. At the same time field

experimental work has been undertaken with the object of overcoming the difficulty of growing *ledgeriana* in old soils and in the introduction of grafting technique and the selection of root-stocks. Work to combat soil losses from erosion by terracing, drainage, and the use of green manures, has been continued, and manurial experiments carried out. These factors, in addition to the economic agreement, have served to place the industry in its present satisfactory position.

C. ledgeriana requires rather special ecological conditions in order to flourish. As regards climate, it will not stand great heat, and frost is fatal. The ideal mean temperature is probably about 75°F. with a mean minimum of 60°F. and mean maximum of 85°F. The limits of rainfall fall between 75 and 150 in. per annum, but the distribution is far more important than the total precipitation. The plant cannot stand long periods of drought and it is therefore found in the East that it is cultivated only in those districts experiencing two monsoons in the year. 'Ledger' also is particular in its soil requirements. Sands [9] mentions that in Java it grows on light loams of volcanic origin of good depth, rich in plant-food, and easily worked. Clay soils are said to be quite unsuited and free drainage is essential. In India it is also found that soils derived from granitic and volcanic formations are the best. They are acid and have a fairly wide range from a pH of 5.23 to 4.58. As regards elevation, *Cinchona* is grown in Java between 3,500 and 6,000 feet above sea level. Below or above these levels the yield is not good. In India the upper limit is 5,000 feet, and the lower about 1,500 feet. At low levels the tree grows rapidly, but has a short life, is liable to disease, and the bark has a low percentage of alkaloid. At the higher levels the growth is slower and the yield of bark is smaller. *C. succirubra* is somewhat less exacting in its requirements both as regards elevation, soil, and rainfall, but the same general conditions apply to it as to *ledgeriana*. It will thus be seen that the plant is exacting in its requirement, and it is natural, therefore, that the number of localities suitable, and the areas of land available, are somewhat limited.

CULTIVATION

In India the sequence of operations is as follows. A suitable area of virgin rain-forest is selected and felled during the cold season (November to March). If steep, this land is terraced and staked 4 × 4 ft. to mark the sites of the young trees, which are planted out from the nursery beds in specially prepared holes, during May, and continuing for the next two months when rainy conditions prevail. In Darjeeling light shade-trees only are needed, but

heavier shade is required in Madras and Burma. Seedlings are raised and used as plants, and although experiments with grafting have been made the practice of planting out seedlings still prevails in India. The soil of the nursery-beds is carefully prepared from leaf-mould collected from the forest. It needs to be worked to a fine consistency, since the seed is very small and light and one ounce will give 20,000 seedlings. It germinates in about three weeks. The nursery-beds are sheltered by sloping roofs of thatch to protect the young seedlings from heavy rain or sun, and seeds are sown in March. They must be carefully watered with a fine spray at regular intervals. The seedlings are transplanted twice, first when the seed leaves are just fully expanded to a distance of 1 in. apart, and later at the age of three months, in May and June, when they are 2 or 3 inches high, and then the spacing is 3 × 3 in. They are planted out after they have been in the nursery for about two years, and a fortnight before they are transplanted the roofing of thatch is gradually removed to harden off the plant. The young plantation is cleared about twice a year for the first two or three years, but later periodical hoeing round the tree is all that is required. Harvesting of the bark begins about the fourth year when thinnings and prunings are dealt with. The final uprooting is made in the 10th year, as the figures available indicate that a 10-year rotation gives the greatest return in quinine per unit of area. At the final harvest, the whole tree is uprooted, and the bark stripped from roots, stems and branches, which is then dried, stored and passed to the factory. This method is said to give better results than a system of coppicing, which has also been practised.

The system employed in Java differs essentially, as grafted plants are utilized as well as seedlings. The methods employed for raising seedlings are essentially similar to those described above, except that the seed-beds are more elaborate and the times of transplanting somewhat different. The *ledgeriana* plants are all raised from specially selected trees. These are chosen for their strong, healthy growth, erect stem and erect branching habit, size and colour of leaves, thickness of bark, quinine content, age at which first flowers are formed, and resistance to disease. The age at which the tree flowers is important, as early flowering is correlated with loss of vegetative vigour. Strains with reddish levels of medium size are favoured by planters, and trees with an erect branching habit are not so apt to crowd each other as types with a spreading habit. The original trees produced from seed purchased from Ledger, many of which are still living at the age of 60 years, showed considerable variability, particularly in the quinine content, which is stated to range from 3 to 13 per cent. The care which has been exercised over so many years in selecting material with a high

quinine-content for planting, is one of the reasons why the industry has been able to weather so many vicissitudes in the past and is now in its present profitable state.

C. succirubra is grown on a few small estates where the elevation and soil are not so suitable for *ledgeriana*, since it is hardier, more adaptable and possesses a stronger root-system. It is for these reasons grown on all the large estates, not for its bark, but as a root-stock for grafting purposes. Sands gives an interesting account of the method of grafting, and states that the percentage of grafts which grow is usually over 90. The grafted plants are ready for the field in 8 or 12 months after grafting. From the time of planting of *succirubra* seed to the planting of the grafted plant in the field, a period of about three years is necessary. *Ledgeriana* seedlings are usually planted on newly cleared forest land; but it is said to be hard to establish on old land, and as the area of virgin forest that remains is now limited, resort has been had to grafting selected *ledgeriana* material on to *succirubra*.

Progress has also been made in the Belgian Congo in recent years. Stoffels [9] gives a good account of the methods employed in raising seedlings and in grafting *ledgeriana* scion on to *succirubra* stocks, which differ in certain details from those used in Java. It is obvious from this brief account that research has played a vital part in the Java industry from the early days. In a recent report to the Imperial Council of Agricultural Research for India, the need for systematic research on similar lines in India is stressed. In the early days outstanding work was done by McIvor in Southern India and Gammie in Bengal, and much of the *Cinchona* was propagated by vegetative methods on the Government Cinchona Plantations, but in recent years research has played a subordinate part, and the small and inadequate staff has had to concentrate on the work of supplying bark, extracting the alkaloid, and despatching the produce of the factories. The policy has been so to work the departments that they entailed no loss to the State. The Java Reports for 1938 show that the *Cinchona* bark produced in that country worked out at 8 per cent of quinine sulphate, whereas the corresponding figure for India was about 4 per cent. It is recognised that the soil conditions and rainfall distribution are not so favourable in India [10] as they are in Java, but it is believed that a properly organised research station ought to be able to raise the percentage to 7 within a reasonable time. Attempts to graft *ledgeriana* on to *succirubra* stocks in India have met with indifferent success up to the present, but it is suggested that three-quarters of the failure is due to ignorance of

the correct technique. In Java, trained artisans can make over 200 grafts a day with an astonishing degree of success, and there seems little doubt that with perseverance and due encouragement, similar results ought to be obtainable in India.

POSSIBILITIES OF EXTENSION IN THE BRITISH EMPIRE

Too complete a reliance on one country for supplies of this vital product, which might prove dangerous in times of war, have recently caused another enquiry to be held into the possibility of extending the cultivation of *Cinchona* within the borders of the Empire. This has shown that the areas with the exacting conditions of climate and soil suited to its growth are definitely limited, but it will be of value to record the progress that has been made in recent years to establish or extend new plantings.

India and Burma.—In India the present position is that the possibility of extending in Bengal is very limited, whilst in Madras new areas are being tried out in the Anaimalais, and a recent report by Wilson and Mirchandani [11] indicated that enough first-class land existed for an early resumption of *Cinchona*-growing, about 38,000 acres of first-class land being available in Bengal, Assam, Orissa, Bhutan, Sikkim, Madras, Mysore, and Coorg. The production of *Cinchona* by planters has now practically ceased. The old plantings in the Darjeeling district have long ago been replaced by tea and those in Southern India have been grubbed up and abandoned or replaced by coffee or some other crop. Further recent attempts to interest the planting community in this crop have not proved successful. A manifesto addressed to the Government of Madras by the Planters' Association, as lately as August, 1938, laid down the following conditions as essential to any such project:—

1. A guarantee to absorb the production from *Cinchona* estates, provided the bark is of good quality.
2. A guarantee to pay the market rates subject to a fixed minimum.
3. Partial remission of land assessment on areas planted in *Cinchona* for a certain period.
4. The planters to guarantee not to sell their bark to anybody except the Government.
5. Government to have the right to limit the areas to be planted.

The matter of a guaranteed minimum price had been the subject of repeated representations from 1895 onwards, and finally in 1925 the Government refused. Accordingly, after an agreement with the Planters' Association, new lands in the Anaimalai Hills were opened up by Government in 1925 in order to supplement the supply of bark from the Nilgiri plantations. These new plantations appear to be doing well and unlike other areas in South India, the *ledgeriana* species seems to be doing better. There the matter rests at present.

Practically all the quinine now produced in India is grown and manufactured by Government, but this is only sufficient to meet one-third of the annual consumption, the rest being purchased from Java. It seems improbable that private enterprise will undertake *Cinchona*-planting unless a guaranteed minimum price is forthcoming, and the alternative to continued dependence on Java is for the Government to expand its own plantations.

Attempts to establish *Cinchona* plantations in Burma were made following the report of Lt.-Col. A. T. Gage,[12] who was commissioned to inquire into the possibility of increasing *Cinchona*-planting in the Indian Empire, under instructions from the Government of India. In this report the suggestion was made that the hill ranges of Tavoy could probably furnish all the quinine needed by the British Empire, and also that the proposed plantations should come under the direct control of the State. Work establishing in the new plantations was started in 1920, but those in Tavoy were destroyed in heavy rains in 1921 and 1922. Accordingly, a new site was chosen in Mergui district in 1923. This also was not a success, because of the low elevation and the abnormally long dry season. Difficulty was also experienced with labour. This plantation was closed down in April 1937, when under the new constitution Burma became separated from India, and she refused to assume the financial responsibilities involved. There are many who remain convinced that there are considerable possibilities for *Cinchona* in Tavoy, particularly in the ranges farther inland from the coast where the rainfall is not so torrential.

East Africa.—It has already been shown that trials of *Cinchona* were made in earlier years at a number of places where it was considered that conditions offered a reasonable chance of success. Many of these experiments failed, but in one or two colonies, such as Ceylon and Jamaica, better results were obtained and a considerable industry was built up, only to collapse during the period of over-production in the 'eighties. In the post-war period the unsatisfactory position of Empire-grown supplies was considered by the Imperial Government. In 1925 the Committee of Civil Research

appointed a sub-committee to enquire into Empire supplies and reported that any scheme for extension would be premature, pending further information about synthetic products, but that in any event it would probably be necessary to create new plantations if the Empire was to be self-supporting in quinine and *Cinchona* alkaloids. As a first step, a grant of £2,000 a year was made to Amani in Tanganiyka to enable that research station to carry out experimental work and restore the old plantations. It must be remembered that the Germans had imported seed of *ledgeriana*, *succirubra*, and the hybrid from Java, as early as 1901 and had established plantations and a factory at Amani for the production of quinine. These plantations were all cut down during the East African campaign, and the quinine so produced was an important factor in preserving the health of their forces. The old plantations had coppiced or ratooned freely, and the grant was utilised not only to regenerate the old German plantation, but also to plant new areas. Following a progress report in 1930, a sub-committee of the Colonial Advisory Council of Agriculture was appointed in 1931, and it advised against any further work, mainly on the grounds that the use of quinine as a specific for malaria was likely to be displaced by more efficient synthetic products. As a result, all the *Cinchona* trees at Amani were cut down and the bark stripped, except a plot of *C. ledgeriana* which was kept for seed. An interesting account of *Cinchona* in Amani at the present time is given by Worsley [11] together with analyses of the different kinds of bark and costs of production. It is noted that at Amani, as elsewhere, *ledgeriana* produces less bark than *succirubra*, but gives higher quinine percentages, which were on the whole satisfactory. In 1936, following representations made by certain Colonial Governments, the quinine position was again reviewed by the Colonial Agricultural Advisory Council, and as a result *Cinchona* research is now included in the programme of the Amani Institute. The most recent reports show that in addition to the plantations controlled by the Institute, there are about a dozen privately owned plantations in the Usambara Mountains, which have areas of old plantings as well as young trees. Research at Amani indicates that the soils are patchy and that the best areas are situated in the wetter parts of the Western Usambara Range, where the rainfall is heavier and better distributed. Young *ledgeriana*, when grown in suitable situations and on the right type of soil, is showing considerable promise. The work so far carried out indicates that there is much to be learnt, since the methods of cultivation employed in India or Java cannot be adopted wholesale in this part of Africa. As an instance, trees growing under shade are promising, whereas this practice is not the rule in India. Further, the old *Cinchona* trees at Amani have regenerated surprisingly

well from coppicing, which is not the case in other *Cinchona*-growing countries, where the trees after they have reached the age of eight years or so are grubbed up, barked, and replanted with young trees. Whether coppicing will prove the best practice in the long run remains to be seen. Investigations are also being conducted into the control of the *Armillaria* root disease, which, together with *Helopeltis*, causes some loss. In the meantime, the Amani nurseries are supplying seedlings to the private planters in the area. The varieties issued consist chiefly of *ledgeriana* and its hybrid, together with *succirubra*, which seems to grow particularly well and possesses a fair quinine-content. The question of establishing a factory depends on whether the consumption of quinine in East Africa would justify the cost.

West Africa.—Experiments are being conducted in the Mandated Territory of the Cameroons. As in Tanganiyka, *Cinchona* was first introduced by the Germans about thirty years ago, and three small plantations were established, two being near Buea at altitudes of 3,200 and 3,500 feet, and another higher up the mountain at Musaka (5,600 feet). Many trees were cut down during and after the war and no further interest was taken until 1923, when these areas were surveyed, new seedlings planted, and 1,047 trees counted. By 1927 the number of living trees had been reduced to 521. The old trees were found to have coppiced quite well in some places, and the proportion of trees still alive was considered satisfactory in view of the years of neglect that had elapsed. The soils are of volcanic origin and the rainfall conditions appear to be favourable. Recent work has led to the conclusion that *succirubra* is more suited to conditions than *ledgeriana*, which is giving disappointing results when grown on its own roots. As it was thought that the only hope of establishing an industry was to produce ledger bark, selection work on this species was commenced in 1937, and 23 of the most promising trees were selected for vegetative propagation. Care is being taken to preserve these trees by manuring, as some of them are in a bad way, owing to long years of neglect. Meanwhile investigations to inquire into the possibility of budding or grafting on to *succirubra* stocks were started in 1939. Budding was found to be impracticable, but grafting was more successful. It has been found that by using young, vigorously growing twigs, which were only slightly woody, and had a soft pliable, light-coloured bark, a fair percentage of successful grafts could be made. By the end of 1939, 1,140 grafts had been made and 43 per cent were successful, dealing with 12 clones. More success was obtained with some of the clones than others, but this is probably

due to the actual condition of the parent tree. In the meantime, the supply of *succirubra* stocks is being increased, and it should be possible by the end of 1940 to supply small quantities of grafted plants for experimental planting on estates. Further progress will depend on the manner in which these plants flourish and the price of bark and other economic factors.

Malaya.—Much work has been done in recent years at the Agricultural Station in the Cameroon Highlands. Here excellent growth has been made by both *C. succirubra* and the hybrid seedlings, but seedlings of *C. ledgeriana* are slow in growth and lack vigour. On the older areas this species was also in an unhealthy condition, being attacked at the base of the stem by the parasite *Phytophthora cinnamoni*, which is associated with weak, unhealthy trees. Experiments made here also seem to indicate that *ledgeriana* growing on its own roots is not likely to be successful, and steps are now being taken to graft it on to *succirubra* seedlings, which grows much better under local conditions.

New Guinea.—Trials with four kinds of *Cinchona* have been made at the newly established Agricultural Station at Aiyura, which is situated at about 6,000 feet on the divide between the headwaters of the Ramu and Markham rivers. Although these trials are still in their early stage, growth is satisfactory and soil and climate are said to be suitable for *ledgeriana*.[14]

Ceylon.—Interest has again revived in *Cinchona*, and a recent report by Haigh [15] expresses the opinion that Ceylon has a reasonable chance of producing quinine more cheaply than she can buy it. Preliminary trials have been made and seed-beds planted at Malpota. A survey of suitable areas between 3,000 and 5,000 feet has been made, and it is proposed to plant one-acre test plots on nine representative areas as a preliminary step. Budding and grafting trials are also being carried out with the object of determining the most suitable technique.

SUMMARY

In conclusion, it is important to remember the factors that are necessary to establish a *Cinchona* industry. They are not only concerned with the successful production of bark. As indicated in this note, there is probably sufficient suitable area in the Empire to provide all the quinine it requires. It has been estimated that India alone possesses 38,000 acres of first-class land for this purpose, and there are other large potential areas scattered throughout the Empire, in many of which experiments are now being conducted with promising results. The costs of production have proved

difficult to estimate, but in Bengal it may be assumed to be around Rs. 10 per lb. (the rupee = 1s. 6d.) But the experience of the Cinchona Departments of India indicates that the difficulty was chiefly that of distribution. Production is one thing — consumption is another. Given the necessary financial backing and an organised official drive against malaria, much could be accomplished. Lacking these preliminaries, success for a planting industry would appear to be problematical. It must be remembered that the Kina Bureau controls the quinine market, and, as has already been pointed out, it is regulating production from the Java plantations, which can readily expand their output to a very considerable extent, should the necessity arise.

The desire to render the Empire less dependent on outside sources for supplies of this essential specific is natural, but if production is to be increased, it will either have to be done by the establishment of *Cinchona* plantations and factories by the Government, as in India, or by private enterprise. If the latter is to be encouraged, the need will arise to consider State assistance in the shape of a guaranteed minimum price for bark over a period of years, to be accompanied by an organised drive to popularise the use of quinine, and the establishment of an adequate system of distribution.

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