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Original and five copies (thin paper)

CINCHONA CULTIVATION IN GUATEMALA

Wilson Popenoe

About the middle of the last century, the increasingly rapid destruction of the Cinchona forests of the Andes, together with growing appreciation of the value of quinine in the treatment of malaria, resulted in the introduction of Cinchona culture into British and Dutch possessions in the Asiatic tropics. In this connection the world remembers with gratitude the work of such men as Weddell and Markham, who studied the trees in their native home, and who insistently raised their voices in support of the move; and of Hasskarl, Markham, Spruce and others, who risked their health and even their lives to secure the best types of Cinchona and transplant them to the East. Finally the work was successfully crowned through the efforts of Charles Ledger, an Englishman who lived in Bolivia, and who obtained and sent to Europe in 1865 seeds of a superior type of Cinchona, with which it became possible to develop an extensive industry in Java, today the source of most of the world's quinine.

All this interest in Cinchona cultivation during the eighteen-fifties and eighteen-sixties presumably had repercussions in many regions, Guatemala being no exception. History tells us that President Justo Rufino Barrios, whose patriotic interest in the development of his country knew no bounds, interested himself in the establishment of Cinchona cultivation in

Guatemala, and carried out an extensive planting on his property El Porvenir, in the Department of San Marcos, where the progeny of his original trees still grow today in vast numbers.

Shortly after the death of the Reformer, a serious effort was made to establish Cinchona cultivation in the Alta Verapaz, of which we have a detailed account in the memories of Franz Sarg, published in the "Deutschtum in der Alta Verapaz", 1938. Sarg states that the Minister of Agriculture, Don Manuel Herrera, offered a prize of fifteen hundred pesos to the man who would make the first planting of two thousand trees. Through the good offices of Prince Nikolaus of Nassau seeds were obtained from Ceylon in 1878, and in 1882 the ppize was claimed and paid. Difficulty in handling the bark, and falling prices in the world's quinine market, discouraged the undertaking and the project was dropped.

There seems to have been little revival of interest until the present decade, when, with the hearty cooperation of the Guatemalan government and the United States Department of Agriculture, Merck and Company of New York, through its subsidiary, Experimental Plantations Inc., undertook to sponsor the development of Cinchona cultivation for supplying the North American market with quinine. ~~The project was organised in 1934 by Victor E. Ruehl;~~ Seeds of the best Ledger types were obtained, ~~from Java;~~ and later, several through the ~~good offices of the Division of Plant Exploration and Introduction of the United States Department of Agriculture,~~ many other promising strains were brought into the country. Nurseries were established in several parts of Guatemala under the supervision of two horticulturists, Hans Franke and

Jorge M. Benitez, who had been trained at Lancetilla Experiment Station in nearby Honduras.

It is appropriate to mention the enthusiastic support which has been given the project since its inception by Don Mariano Pacheco, Director General de Agricultura of the Republic of Guatemala, and the service rendered by such active cooperators as Gordon P. Smith and his sons Owen Smith and John Smith; L.Lind Pettersen of Finca El Zapote; Gustavo Helmrich of Finca Samac; Pedro G. Cofiño of Antigua; the late Doctor Goebels and Herr Erich Zoller of Finca El Porvenir; ~~Don Mariano Maldonado;~~ Mrs. R.W.Hempstead and her sister Miss Rosita ~~Hempstead~~ Dieseldorff, of Coban; and Erwin P. Dieseldorff. All of these people placed land and facilities at the disposal of ~~Merck and Company for~~ Experimental Plantations, Inc. experimental plantings.

Though some years must still elapse before Guatemala can produce Cinchona bark of satisfactory quality in large commercial quantities, and though the economic possibilities are as yet unexplored, the time seems to have arrived when a brief review of the situation may prove useful to the increasing number of Guatemalan agriculturists who are taking an active interest in this subject.

BOTANICAL CONSIDERATIONS

Before we are prepared to grown Cinchona commercially we must determine by experimentation in many different areas those kinds which will grow satisfactorily and produce quinine in sufficient quantities to meet the ~~demands~~ requirements of the manufacturers of this drug. To do this intelligently requires knowledge of the different species of Cinchona and their characteristics.

The genus Cinchona, native to the Andine region from Venezuela to Bolivia, is an extremely variable one. The early students, limited in the number of botanical specimens at their disposal, described as species many forms which in the light of later and more exhaustive study seem more properly to be considered as variations of two species which occur over a wide range of territory. One of these is Cinchona pubescens Vahl, more commonly known as C. succirubra Pavon; the other - and it is the one which supplies most of the world's quinine - is C. officinalis L., a variable species which includes varieties described under such names as C. calisaya Wedd., C. Condaminea Humb. & Bonpl., C. ledgeriana Moens, C. calisaya var. ledgeriana Howard, C. Josephiana Wedd., C. lancifolia Mutis, C. chahuarguera Pavon, and C. urituisinga Pavon. We accept this modern view of the genus, as set forth in the writings of the well-known North American botanist Paul C. Standley, not only because it seems to us more in line with the facts, but also because we feel that it simplifies the problem from the agricultural standpoint. The so-called species of some authors break up into so many diverse forms when grown in cultivation that their acceptance results in nothing but confusion.

For agricultural purposes (we would like to say horticultural, for Cinchona culture requires the skill and technique of gardening) we have adopted a classification which seems to us convenient and useful: we speak of trees of the species C. pubescens as succirubras; those of C. officinalis in general as calisayas; and those of the so-called C. ledgeriana as Ledgers or calisayas of the Ledger type. To this classification

must be added hybrids between C. pubescens and C. officinalis, which are sometimes grown under the name of C. robusta. These we prefer to call hybrids, since they do not in fact represent a botanical species.

It must be understood and admitted that our experience with the genus Cinchona in Guatemala is limited, and that time may change our views on many features. Our aim is to increase our knowledge as rapidly as possible, admitting our mistakes when they occur, and keeping in mind at all times that our objective is a practical one, and that simplicity makes for clearness.

COMMERCIAL TYPES AND THEIR CHARACTERISTICS

As has been mentioned above, most of the world's Cinchona bark is today produced by trees of the Ledger type of calisaya grown in Java. While trees of the succirubra species (C. pubescens) grow more rapidly, are adapted to a much wider range of climate and soil, and in general are of much easier culture, their bark commonly yields but 1 to 3% of quinine sulfate, as compared with an average of more than 6% obtained from the bark of Ledgers in Java. Succirubras are abundant in Guatemala: they are scattered widely throughout the Verapaz, they are abundant on the Pacific side in the region of El Porvenir, and there is one splendid old tree in the Finca Jauja at Antigua.

Calisayas, particularly those of the Ledger type, require very special conditions of climate and more particularly of soil. They must have loose, friable soils rich in organic matter; they must have abundant moisture during most of the year; and they cannot tolerate heavy winds. To give high yields of

quinine they must be grown at considerable elevations - probably not lower than 3000 or 3500 feet in Guatemala, though it will take time to determine by actual trial just what is the profitable lower, as well as the upper, limit of cultivation.

Regarding calisayas other than those of the Ledger type we do not know a great deal in Guatemala. They seem to have been introduced into the Coban region during the eighteen-seventies, when Cinchona cultivation was attracting serious attention in that part of Guatemala; and it seems probable that they have been planted at El Porvenir. Since all Cinchonas cross-pollinate readily, and since the calisaya types are more delicate than the succirubras, the tendency has been for the true calisayas to die out, but for some of their blood to persist in the calisaya x succirubra hybrids, trees which are of vigorous growth (as is frequently the case with hybrids) and which sometimes contain sufficient quinine to make their bark of commercial value. We do not yet know what can be expected of these hybrids in Guatemala. Some of them, when propagated by grafting, may prove worthy of commercial cultivation.

We do not know, in fact, what will be the ultimate thing for commercial cultivation in Guatemala. Will it be grafted trees of the Ledger type, like the best of those grown in Java? Will it be seedling strains of the Ledger type, kept pure by prevention of intercrossing with other Cinchonas? Will it be calisayas of a broader-leaved type than Ledger, slightly lower in quinine content than those of the Ledger type but perhaps less exacting in their cultural requirements? Or will it be hybrid forms between C. officinalis and C. pubescens? Perhaps all of these may enter into the picture. Admittedly the big problem still ahead

of us is the determination of the best sorts for commercial cultivation. Nor does it seem likely - if we can judge by experience elsewhere - that the most profitable type to cultivate in one part of Guatemala may be the best in others.

RESULTS OF EXPERIMENTS TO DATE

Those pioneers who experimented with Cinchona cultivation in Guatemala back in the eighteen-seventies and eighteen-eighties are gone. Those other pioneers who are taking up the work today are having, in the main, to depend for guidance upon the scanty literature concerning Cinchona cultivation in other parts of the world. Guatemalan experience with succirubras is of little assistance: we must learn to grow the finer types of Cinchona, and to do so will require much further study and experimentation. Yet we must admit that results to date are most encouraging.

Among the publications which have been found helpful by those undertaking the establishment of Conchona cultivation in Guatemala, the following are outstanding, and can well be utilised by those who are interested in the problem:

The Cinchona (Quinine) Industry in Java, by W.N.Sands, published in the Malayan Agricultural Journal, 1922.

De Kinacultuur, by A. Groothoff, published at Haarlem, Holland, in 1925.

Le Quinquina, by E.H.J.Stoffels, published as Serie Technique No. 24, by the Institut National pour l'Etude Agronomique du Congo Belge, in 1939.

The fact that the first of these papers is in English, the second in Dutch, and the third in French is a handicap; but the first - which we consider is the most useful of all -

has recently been made available to Guatemaltecans in general through a Spanish translation published for free distribution by the Direccion General de Agricultura in August 1940.

Naturally, the recommendations of foreign writers are not always applicable here, since they are mainly concerned with practice in far-distant parts of the world. But they have furnished the basis on which to plan and conduct local experimentation. And in the past few months, the work commenced in 1934 under the auspices of Merck and Company has commenced to bear fruit. At Finca Zapote, at Finca Helvetia, at Finca Moca, at Finca Panama, and at Finca Samac (near Coban) several hundred Ledger trees of the Java type have reached sufficient size to permit analyses of their quinine content. These analyses, in many instances, have surpassed our expectations. They give grounds for believing that Guatemala has suitable conditions of soil and climate for the cultivation of high-yielding types of Cinchona; and when propagated by grafting, or when used for the production of seed, these trees should furnish material on which to base commercial cultivation.

The highest of the abovementioned plantings is at 5400 feet; the lowest at 3400 feet. How far above and below these elevations Ledger-type Cinchonas may be grown successfully we do not know, nor do we know the effect of altitude upon the quinine content. In many matters of this sort, we are forced to depend, for the moment, upon the published results of experience in other contries. Thus we are interested in the statements of Sands, who says that Ledgers are cultivated in Java chiefly between 3500 and 6000 feet elevation: that below and above these altitudes the yields of bark are not good; and that the most suitable elevations are between 4000 and 5500 feet. Sands further says that below 1500 feet the bark produced is useless

for manufacturing purposes because of the small quantity of quinine it contains. All such statements should be studied in connection with Cinchona planting in Guatemala; but we can not invariably assume that they apply here. We must determine for ourselves the upper and lower altitudinal ranges of successful Cinchona cultivation, as well as many other details.

As regards soils, we are greatly impressed by the growth made by Ledgers on the brown volcanic loams and clay loams of the Pacific side. The soils of Helvetia and Patzulin in the Department of Ratalhuleu have given excellent results. Indeed it is our feeling that the finest soils which have been planted in Guatemala to date are the chocolate brown clay-loams of virgin areas - not old cafetales, but montaña. In this last respect, it is pertinent to note that writers in Java repeatedly mention the unsuitability of old or worn lands for Ledger seedlings. Ledgers grafted on succirubra stocks, they say, can successfully be grown on old and worn lands, but Ledger seedlings definitely can not. This is worth remembering, in connection with experiments here in Guatemala.

Results obtained on the black sandy loams of the Pacific side, and on the limestone clays of the Verapaz, have in general been much less satisfactory to date, than those obtained on the brown volcanic loams and clay loams. The trees at Finca Samac, near Coban, constitute an exception with regard to the Verapaz: but these trees are on a specially favored alluvial plot in a small valley, and have been cared for by one of the most skillful agriculturists in Guatemala - Don Gustavo Heinrich.

With regard to terrain, as with regard to soils, our experience to date is wholly in agreement with the published experience in Java. Flat land is not necessary. The highly successful experimental planting at Finca Helvetia, for example, is planted on a slope as

steep as any used in the same finca for coffee. Good drainage is essential, and this is facilitated by sloping land.

As regards rainfall, we have been agreeably surprised to find that Ledgers have withstood the rather severe dry season of Finca El Zapote, in the Department of Escuintla; while on the other hand, they have also done well in such wet areas as Finca Mocá. Sands states: "A heavy and well distributed rainfall is required". And again, "It would appear certain that a minimum yearly precipitation of 100 inches is necessary for the best development of the tree." Pending further experience here, we are inclined to feel that the fine types (i.e., the Ledgers) can withstand without serious harm the dry season which is customary in the higher parts of the coffee zone of the Pacific side of Guatemala. The past two dry seasons - those of 1939 and 1940 - have been more severe than usual, yet we cannot note that any harm has resulted.

In fact, nothing could augur better for the future of Cinchona cultivation in this country than the behavior of Ledger trees on the Pacific side of Gutamala during the past few years; for it is notorious that the Ledgers are the most exacting, the most delicate, of all Cinchonas cultivated today. If, therefore, we can grow Ledgers, we can grow commercial Cinchona. The behavior of the low-yielding succirubras -which have been grown in Guatemala for many years - has little bearing on the case.

A superificial examination of the Ledgers now growing in Guatemala shows that we must expect here the same individual variation which is reported in Java and elsewhere. In spite of careful seed selection during several generations, Ledgers are not wholly uniform in growth characteristics nor in quinine content. This is one of the chief reasons for the propagation of the best

individuals by means of grafting on succirubra stocks. Another reason is the relatively weak growth of the Ledger type and its failure to succeed on poor soils when grown on its own roots. Succirubra rootstocks impart greater vigor to Ledgers; but on the other hand, the total yield of quinine is reduced by the fact that the root-bark of succirubras contains less quinine than that of Ledgers. Hence the ideal practice, it seems, is to grow high-yielding Ledgers, on their own roots, and on good land. Stoffels, the most recent writer on the subject, emphasises this feature. Possibly in Guatemala, as in Java, commercial cultivation in the future will include both seedling Ledgers and grafted Ledgers, depending upon soil conditions and other factors yet to be determined.

In addition to Java-type Ledgers, there are now under trial in Guatemala many other kinds of Cinchona, brought together from such widely diverse sources as West Africa, the Philippines, and other regions, largely through the good offices of the Division of Plant Exploration and Introduction of the United States Department of Agriculture. Also, there are numerous local seedlings, mainly of succirubra blood but showing evidence of crossing with calisaya types introduced many years ago. As mentioned above, it is too early to forecast the ultimate value of most of these, but among them may be types which, because of their vigorous growth coupled with a fair quinine content, may have commercial value. It must always be born in mind that high quinine content alone does not make a suitable tree for commercial cultivation. If, for example, a tree contains 8 percent of quinine sulfate, but in ten years' time will yield twice the amount of bark given by another tree which contains 11 percent, then the tree having the lower content is the most profitable one to grow. There are, of course, limits

to which this principle can be applied, and it is precisely the determination of these limits - the determination of those types which are most satisfactory from the grower's and the manufacturer's standpoint - which constitutes one of the most interesting problems in connection with the development of Cinchona planting in Guatemala.

PROPAGATION

It is necessary to emphasize at the start that the propagation of the finer types of Cinchona from seed - these trees of the species C. officinalis, including the Ledgers - is a task requiring a much higher degree of agricultural skill, more intensive attention to minute details, than the Guatemaltecan finquero has been accustomed in the past to give those crops with which he is familiar. This statement must be borne in mind by all those who undertake the cultivation of these trees: it is amply verified by the experience of Don Mariano Pacheco, Director General de Agricultura, an experienced nurseryman who has probably devoted more time to this subject than anyone else in Guatemala.

The production of succirubra stocks on which to graft the finer types is not so difficult. The technique, however, is the same as with the more delicate calisayas, hence there is no need to describe it separately.

Cinchona seeds are harvested by gathering the capsules when mature, and placing them in a dry room until they open, when the individual seeds may be shaken out and prepared for planting. In Java a great deal of attention is given to the elimination of poor seeds,-those not likely to germinate - but this a refinement which we shall be some time in attaining. The seeds are small and very light, 2000 to 3000 of them weighing one gram. They

are extremely sensitive to moisture, hence the necessity of storing them in tightly-corked bottles until they are planted. After harvesting, they retain their viability for several months. If kept for a year, it can not be expected that more tha half of them will germinate. Various writers assert that they lose their viability altogether by the end of the second year. Suffice it to say that they should be planted as soon as possible after they are harvested.

Semilleros. The basic principles underlying the propagation of Cinchonas from seed are these: the seeds must be given very little light while they are germinating, and must be kept uniformly moist. If allowed to dry out after having commenced to swell, they die. Immediately they have germinated, they are subjected to the risk of being destroyed by "damping off" against which they must be protected by a delicate adjustment of light and ventilation assisted, in some instances, by a judicious use of Bordeaux mixture. In a few weeks' time they have passed this stage, and must be given more light, very gradually, and without exposing them as yet to the direct rays of the sun.

Where only a relatively small number of seedlings are to be grown, a convenient method is to use small, shallow boxes, which can easily be moved about to adjust the light relation. But where large numbers are required - as is the case when commercial plantings are contemplated - seedbeds are prepared, following the technique used in Java and elsewhere. These beds can be of any length desired, but we have found it best not to have them more than three or four feet in width. They must be edged with boards or other material, so that the surface can be raised several inches above the level of the surrounding

land. Several inches of rich forest loam mixed with about 25% of clean sand should be placed on the surface, and levelled carefully to receive the seeds.

These beds must be sheltered from the sun and rain. Most of the seedbeds prepared in Guatemala to date have been ~~covered~~ protected with lamina, which is excellent material. We understand it is customary in Java to use thatch of various native materials. The chief thing is to have the roof pitched steeply from south to north, with the lower side toward the south - this means, of course, that the beds themselves should be constructed from east to west. The southern side of the roof can come close to the ground, leaving only 18 to 24 inches of light, and there must be sufficient overhang so that rain cannot reach the seedbeds. The northern side, which is open to the light, is protected during germination by using bamboo strips, or any other light material, with space between to allow a limited amount of light to enter. These details are better understood by referring to the accompanying illustrations.

The seeds are scattered uniformly over the surface of the beds at the rate of approximately two to three grams per square yard. If they are thicker than this, and germination is good, the stand of young plants will be too thick and increase the danger of loss from damping off. ~~They are not covered, but~~ We have found that it is well to scratch the surface gently after planting with a fine rake, to cover the seeds very lightly.

Watering must be done carefully, and under no circumstances must the seedbeds be allowed to dry out. Neither must they be kept too wet: if soggy, the seeds will decay. Germination takes place in three to four weeks. As soon as it is evident that the seeds are germinating well, watering should not be so heavy, else danger

of damping off is increased. At this time it is also necessary to insure good ventilation of the seedbeds, and we have found it useful to spray with Bordeaux mixture two or three times at three day intervals.

As the young seedlings develop, light is gradually increased by lessening the shade on the northern side of the beds. When the plants have reached two or three inches in height they are ready to be moved into almacigos. This is usually from the time of planting, depending upon the elevation of the place at which the semilleros are situated. For example, at Finca Patzulin, elevation 2400 feet, growth is nearly twice as rapid as at Finca El Naranjo, elevation 3900 feet.

Almacigos. These are prepared somewhat as for coffee nurseries, but the young plants must have better protection from heavy rains for some months. They may be spaced 3 x 3, or 4 x 4 inches, if they are to be moved a second time to wider spacings; if not, they should be spaced 6 x 6 inches at which distance they can grow until ready for transplanting to their permanent places in the field. The plants require shelter from the direct sun at the start, and are gradually "hardened off" as they grow larger, until they are accustomed to full sun by the time they are ready to go into the field, which is approximately two years from the time of planting the seed.

Grafting. Fortunately, trees of the genus Cinchona are not difficult to propagate by means of grafting. The essentials seem to be these: stock-plants (invariably of the species pubescens or succirubra) must be in strong growing condition with stems one-half to three-quarters of an inch in diameter; scions must be of sound, half-ripened wood; and the work must be done in damp weather.

As evidenced by the fact that Cinchona trees regenerate their bark rapidly when it is removed for the manufacture of quinine, cellular activity in the cambium layer is more vigorous and rapid than it is with many other genera of plants. This accounts for the high degree of success which attends grafting. Under favorable conditions and with varieties of robust character, 75 to 90% of grafted plants may be expected to grow.

Several methods of grafting are practiced in other countries and have been tested experimentally in Guatemala. All, however, are the same in principle and differ only in minor details. The method which is preferred by Jorge M. Benitez of Experimental Plantations Inc., subsidiary of Merck and Company -who has had more experience in Guatemala than anyone else - is roughly as follows:

Succirubra stock-plants must be in vigorous growing condition, with stems (as mentioned above) between one-half and three-quarters of an inch in diameter. Close to the ground, a vertical cut is made, two inches in length, to expose the cambium, and incidentally the wood. The latter should be disturbed as little as possible.

Scions are prepared from branchlets of the tree (is/it) is desired to propagate. These branchlets are of the thickness of a lead pencil, and not of recent growth. In other words, they should be of half-ripened wood, not old wood, nor yet tender wood which will shrivel and dry out rapidly. Scions should be about four inches in length, with two nodes toward the upper end, from which the leaves are trimmed carefully. At the lower end, a diagonal cut is made, approximately an inch and a half in length. This surface of the scion is then placed against the cut on the stock plant, so that the cambium layer of the scion comes in

contact with the cambium layer of the stock-plant. It is here that the union between stock and scion will take place. Holding the scion firmly in place with one hand, the graft is bound with waxed tape, made by boiling ordinary thin cotton cloth in a mixture of beeswax and rosin. After this is done, melted wax - warm but not too hot - is used to cover the entire graft. This prevents drying out. The wax is applied with a small brush, and the graft is then left until it unites with the stock-plant, which takes four to six weeks.

Once the scion has commenced to grow vigorously, the stock-plant is cut off, several inches above the graft. In about one year's time, the graft is ready to be transplanted to its permanent place in the field.

It may well be mentioned here that the art of grafting is something which can be learned by experience much better than by written description. During the past year, several young Guatemalan agriculturists have been trained by Jorge M. Benitez to do this work and have been practicing it very successfully. Those who desire to learn the art will probably save time and disappointment by spending a few weeks working with an experienced man, rather than attempting to master the art by themselves.

The best months for grafting Cinchona in Guatemala seem to be June and July, though the work can be carried out succesfully at any time between the onset of the rains in May and the season of heavy rains in September. The main thing is to remember that grafting is most successful in moist weather, but not during the period of heavy rains.

FIELD CULTURE.

Obviously we still have much to learn in Guatemala regarding the treatment to be given Cinchona trees in the field. As yet there are no commercial plantings on which to base recommendations. We must be guided largely, at the start, by experience in other regions.

Experience here as elsewhere has shown that few difficulties attend the transplanting of trees from the nursery (almacigo) to the field. They can be moved with bare roots, provided that they are not kept out of the groundmore than a day or two. Proper spacing in the field requires further experimentation here. In Java it is customary to plant from three to four feet apart. As the trees grew and begin to crowd one another, they are thinned out and the trees which are removed in this process are used for the extraction of quinine. This process is continued year after year until the entire planting is dug up at the end of the fifteenth year. The method is described by Sands in the paper mentioned earlier in this report, and can well be studied carefully by those interested.

Plantings made in Guatemala to date have been at widely different spacings - from close ones of 3 x 3 feet to wide ones at 12 x 12 feet. The present tendency is to plant at 4 x 4 or 5 x 5 feet, but only time will show which is the optimum distance.

Experimental plantings are being handled in much the same manner as coffee plantations. Here again, it will require much time and experience to show just what is required. Based on experience in Java, it will take approximately six years for trees to reach suitable age for harvesting of the bark; and from that time onwards there will be an annual production increasing in quantity for two or three years, then remaining at approximately the same figure until the final year when the entire planting is harvested and the

maximum yield is obtained. In all these matters we have yet to gain experience. After many years' of Cinchona cultivation, Java has abandoned the method of "stripping" or taking bark from trees and then allowing them to regenerate, and has gone over to the method of harvesting the bark from the entire tree - roots, stem, and branches. This subject is covered fully in Sands' account of the quinine industry in Java and we can not do better than to base further work in Guatemala upon his description.

PESTS AND DISEASES.

Mature Cinchona trees in Java are said to suffer from the attacks of root disease, from "pink disease" (Corticium salmonicolor), from an insect belonging to the genus Helopeltis, and several other pests of minor character. We shall not know, in Guatemala, just what we have to face in this regard, until much time has elapsed. There are indications that we must expect trouble from a root disease of the Rosellinia type, though it seems doubtful that this will be as serious here as it is reported to be in Java.

from bark canker,

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Wilson Popenoe

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Though some years must still elapse before Guatemala can produce Cinchona bark of satisfactory quality in large commercial quantities, and though the economic possibilities are as yet unexplored, the time seems to have arrived when a brief review of the situation may prove useful to the increasing number of Guatemalan agriculturists who are taking an active interest in this subject.

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Before we are prepared to grown Cinchona commercially we must determine by experimentation in many different areas those kinds which will grow satisfactorily and produce quinine in sufficient quantities to meet the demands of the manufacturers of this drug. To do this intelligently requires knowledge of the different species of Cinchona and their characteristics.

The genus Cinchona, native to the Andine region from Venezuela to Bolivia, is an extremely variable one. The early botanists, limited in the number of botanical specimens at their disposal, described as species many forms which in the light of later and more exhaustive study seem more properly to be considered as variations of two species which occur over a wide range of territory. The first of these is Cinchona pubescens Vahl, more commonly known as C. succirubra Pavon; the second - and it is the one which supplies most of the world's quinine - is C. officinalis L., a variable species which includes varieties described under such names as C. calisaya Wedd., C. Condaminea Humb. & Bonpl., C. ledgeriana Moens, and C. calisaya var. ledgeriana Howard.

We accept this modern view of the genus, as set forth in the writings of the well-known North American botanists Paul C. Standley, not only because it seems to us more in line with the facts, but also because we feel that it simplifies the problem from the agricultural standpoint. The so-called species of some authors break up into so many diverse forms when grown in cultivation that their acceptance results in nothing but confusion.

For agricultural purposes (we would like to say horticultural, for Cinchona culture requires the skill and technique of gardening) we have adopted a classification which seems to us convenient and useful: we speak of trees of the species C. pubescens as succirubras; those of C. officinalis in general as calisayas; and those of the so-called C. ledgeriana as Ledgers or calisayas of the Ledger type. To this classification

must be added hybrids between C. pubescens and C. officinalis, which are sometimes grown under the name of C. robusta. These we prefer to call hybrids, since they do not in fact represent a botanical species.

It must be understood and admitted that our experience with the genus Cinchona in Guatemala is limited, and that time may change our views on many features. Our aim is to increase our knowledge as rapidly as possible, admitting our mistakes when they occur, and keeping in mind at all times that our objective is a practical one, and that simplicity makes for clearness.

COMMERCIAL TYPES AND THEIR CHARACTERISTICS

As has been mentioned above, most of the world's Cinchona bark is today produced by trees of the Ledger type of calisaya grown in Java. While trees of the succirubra species (C. pubescens) grow more rapidly, are adapted to a much wider range of climate and soil, and in general are of much easier culture, their bark commonly yields but 1 to 3% of quinine sulfate, as compared with an average of more than 6% obtained from the bark of Ledgers in Java. Succirubras are abundant in Guatemala: they are scattered widely throught the Verapaz, they are abundant on the Pacific wide in the region of El Porvenir, and there is one splendid old tree in the Finca Jauja at Antigua.

Calisayas, particularly those of the Ledger type, require very special conditions of climate and more particularly of soil. They must have loose, friable soils rich in organic matter; they must have abundant moisture during most of the year; and they cannot tolerate heavy winds. To give high yields of

quinine they must be grown at considerable elevations - probably not lower than 3000 or 3500 feet in Guatemala, though it will take time to determine by actual trial just what is the profitable lower, as well as the upper, limit of cultivation.

Regarding calisayas other than those of the Ledger type we do not know a great deal in Guatemala. They seem to have been introduced into the Coban region during the eighteen-seventies, when Cinchona cultivation was attracting serious attention in that part of Guatemala; and it seems probable that they have been planted at El Porvenir. Since all Cinchonas cross-pollinate readily, and since the calisaya types are more delicate than the succirubras, the tendency has been for the true calisayas to die out, but for some of their blood to persist in the calisaya x succirubra hybrids, trees which are of vigorous growth (as is frequently the case with hybrids) and which sometimes contain sufficient quinine to make their bark of commercial value. We do not yet know what can be expected of these hybrids in Guatemala. Some of them, when propagated by grafting, may prove worthy of commercial cultivation.

We do not know, in fact, what will be the ultimate thing for commercial cultivation in Guatemala. Will it be grafted trees of the Ledger type, like the best of those grown in Java? Will it be seedling strains of the Ledger type, kept pure by prevention of intercrossing with other Cinchonas? Will it be calisayas of a broader-leaved type than Ledger, slightly lower in quinine content but perhaps less exacting in their cultural requirements? Or will it be hybrid forms between C. officinalis and C. pubescens? Perhaps all of these may enter into the picture. Admittedly the big problem still ahead

of us is the determination of the best types for commercial cultivation. Nor does it seem at all likely - if we can judge by experience elsewhere - that the most profitable type to cultivate in one part of Guatemala may be the best in others.

RESULTS OF EXPERIMENTS TO DATE

Those pioneers who experimented with Cinchona cultivation in Guatemala back in the eighteen-sixties and eighteen-eighties are gone. Those other pioneers who are taking up the work today are having, in the main, to depend for guidance upon the scanty literature concerning Cinchona cultivation in other parts of the world. Guatemalan experience with succirubras is of little assistance: we must learn to grow the finer types of Cinchona, and to do so will require much further study and experimentation. Yet we must admit that results to date are most encouraging.

Among the publications which have been found most helpful by those undertaking the establishment of Conchona cultivation in Guatemala, the following are outstanding, and can well be utilisedd by those who are interested in the problem:

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The fact that the first of these papers is in English, the second in Dutch, and the third in French is a handicap; but the first w-which we considerable the most helpful of all -

has recently been made available to Guatemaltecans in general through a Spanish translation published for free distribution by the Direccion General de Agricultura.

Naturally, the recommendations of foreign writers are not always applicable here, since they are based on practice in far-distant parts of the world. But they have furnished the basis on which to commence experimentation.

And in the past months, the work commenced in 1934 under the auspices of Merck and Company has commenced to bear fruit. At Finca Helvetia, at Finca Mocá, at Finca Panama, at Finca El Zapote, and at Finca Samac in Coban are several hundred Ledger trees grown from the seed obtained from Java, which have attained sufficient size to permit analyses to be made of their bark, and which show definite promise of proving satisfactory for commercial cultivation in the form of grafted clones (varieties) or as seedlings, if protected from cross-pollination. Furthermore, they are furnishing us our first definite information, based on experience, regarding the climatic and soil requirements of Ledger Cinchonas.

Grafting. Fortunately, trees of the genus Cinchona are not difficult to propagate by means of grafting. The essentials seem to be these: stock-plants (invariably of the species pubescens or succirubra) must be in strong growing condition with stems one-half to three-quarters of an inch in diameter; scions must be of sound, half-ripened wood; and the work must be done in damp weather.

As evidenced by the fact that Cinchona trees regenerate their bark rapidly when it is removed for the manufacture of quinine, cellular activity in the cambium layer is more vigorous and rapid than it is with many other genera of plants. This accounts for the high degree of success which attends grafting - under favorable conditions and with varieties of extreme vigor, not less than 90% of grafted plants may often be expected to grow.

Several methods of grafting are practiced in other countries and have been tested experimentally in Guatemala. All, however, are the same in principle and differ only in minor details. The method which is preferred by Jorge M. Benitez of Experimental Plantations Inc., subsidiary of Merck and Company - who has had more experience in Guatemala than anyone else - is roughly as follows:

Succirubra stock-plants must be in vigorous growing condition, with stems (as mentioned above) between one-half and three-quarters of an inch in diameter. Close to the ground, a vertical cut is made, two inches in length, to expose the cambium, and incidentally the wood. The latter should be disturbed as little as possible.

Scions are prepared from branchlets of the tree is it is desired to propagate. These branchlets are of the thickness of a lead pencil, and not of recent growth. In other words, they should be of half-ripened wood, not old wood, nor yet tender wood which will shrivel and dry out rapidly. Scions should be about four inches inllength, with two nodes toward the upper end, from which the leaves are trimmed carefully. At the lower end, a diagonal cut is made, approximately an inch and a half in length. This surface of the scion is then placed against the cut on the stock plant, so that the cambium layer of the scion comes in

contact with the cambium layer of the stock-plant. It is here that the union between stock and scion will take place. Holding the scion firmly in place with one hand, the graft is bound with waxed tape, made by boiling ordinary thin cotton cloth in a mixture of beeswax and rosin. After this is done, melted wax - warm but not too hot - is used to cover the entire graft. This prevents drying out. The wax is applied with a small brush, and the graft is then left until it unites with the stock-plant, which takes four to six weeks.

Once the scion has commenced to grow vigorously, the stock-plant is cut off, several inches above the graft. In about one year's time, the graft is ready to be transplanted to its permanent place in the field.

It may well be mentioned here that the art of grafting is something which can be learned by experience much better than by written description. During the past year, several young Guatemalan agriculturists have been trained by Jorge M. Benitez to do this work and have been practicing it very successfully. Those who desire to learn the art will probably save time and disappointment by spending a few weeks working with an experienced man, rather than attempting to master the art by themselves.

The best months for grafting Cinchona in Guatemala seem to be June and July, though the work can be carried out succesfully at any time between the onset of the rains in May and the season of heavy rains in September. The main thing is to remember that grafting is most successful in moist weather, but not during the period of heavy rains.

FIELD CULTURE.

Obviously we still have much to learn in Guatemala regarding the treatment to be given Cinchona trees in the field. As yet there are no commercial plantings on which to base recommendations. We must be guided largely, at the start, by experience in other regions.

Experience here as elsewhere has shown that few difficulties attend the transplanting of trees from the nursery (almacigo) to the field. They can be moved with bare roots, provided that they are not kept out of the groundmore than a day or two. Proper spacing in the field requires further experimentation here. In Java it is customary to plant from three to four feet apart. As the trees grow and begin to crowd one another, theyare thinned out and the trees which are removed in this process are used for the extraction of quinine. This process is continued year after year until the entire planting is dug up at the end of the fifteenth year. The method is described by Sands in the paper mentioned earlier in this report, and can well be studiddcarefully by those interested.

Plantings made in Guatemala to date have been at widely different ppacings - from close ones of 3 x 3 feet towide ones at 12 x 12 feet. The present tendency is to plant at 4 x 4 or 5 x 5 feet, but only time will tell what is the optimum distance.

Experimental plantings are being handled in much the same manner as coffee plantations. Here again, it will require much time and experience to show just what is required. Based on experience in Java, it will take approximately six years for trees to reach suitable age for harvesting of the bark; and from that time onwards there will be an annual production increasing inquantity for two or three years, then remaining at approximately the same figure until the final year when the entire planting is harvested and the

maximum yield is obtained. In all these matters we have yet to gain experience. After many years' of Cinchona cultivation, Java has abandoned the method of "stripping" or taking bark from trees and then allowing them to regenerate, and has gone over to the method of harvesting the bark from the entire tree - roots, stem, and branches. This subject is covered fully in Sands' account of the quinine industry in Java and we can not do better than to base further work in Guatemala upon his description.

PESTS AND DISEASES.

Mature Cinchona trees in Java are said to suffer from the attacks of root disease, from "pink disease" (Corticium salmonicolor), from an insect belonging to the genus Helopeltis, and several other pests of minor character. We shall not know, in Guatemala, just what we have to face in this regard, until much time has elapsed. There are indications that we must expect trouble from a root disease of the Rosellinia type, though it seems doubtful that this will be as serious here as it is reported to be in Java.

CINCHONA CULTIVATION IN GUATEMALA

Wilson Popenoe

About the middle of the last century, the increasingly rapid destruction of the Cinchona forests of the Andes, together with growing appreciation of the value of quinine in the treatment of malaria, resulted in the introduction of Cinchona culture into British and Dutch possessions in the Asiatic tropics. In this connection the world remembers with gratitude the work of such men as Weddell and Markham, who studied the trees in their native home, and who insistently raised their voices in support of the move; and of Hasskerl, Markham, Spruce and others, who risked their health and even their lives to secure the best types of Cinchona and transplant them to the East. Finally the work was successfully crowned through the efforts of Charles Ledger, an Englishman who lived in Bolivia, and who obtained and sent to Europe in 1865 seeds of a superior type of Cinchona, with which it became possible to develop an extensive industry in Java, today the source of most of the world's quinine.

All this interest in Cinchona cultivation during the 1850's and 1860's presumably had repercussions in many regions, Guatemala being no exception. History tells us that President Justo Rufino Barrios, whose patriotic interest in the development of his country knew no bounds, interested himself in the establishment of Cinchona cultivation and carried out an extensive planting on his property El Porvenir, in the Department of San Marcos, where the progeny of his original trees still grow today in vast numbers.

Shortly after the death of the Reformer, a serious effort was made to establish Cinchona cultivation in the Alta Verapaz, of which we have a detailed account in the memories of Franz Sarg, published in "Deutschtum in

der Alta Verapaz", 1938. Sarg states that the Minister of Agriculture, Don Manuel Herrera, offered a prize of fifteen hundred pesos to the man who would make the first planting of two thousand trees. Through the good offices of Prince Nikolaus of Nassau, seeds were obtained from Ceylon in 1878, and in 1882 the prize was claimed and paid. Difficulty in handling the bark, and falling prices in the world's quinine market, discouraged the undertaking and the project was dropped.

There seems to have been little revival of interest until the present decade, when, with the hearty cooperation of the Guatemalan government and the United States Department of Agriculture, Merck and Company of New York, through its subsidiary Experimental Plantations Inc., undertook to sponsor the development of Cinchona cultivation for supplying the North American market with quinine. Seeds of the best Ledger types were obtained, and later, several other promising strains were brought into the country. Nurseries were established in several parts of Guatemala under the supervision of two horticulturists, Hans Franke and Jorge M. Benitez, who had been trained at Lancetilla Experiment Station in nearby Honduras.

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Those pioneers who experimented with Cinchona cultivation in Guatemala back in the 1870's and 1880's are gone. Those other pioneers who are taking up the work today are having, in the main, to depend for guidance upon the scanty literature concerning Cinchona cultivation in other parts of the world. Guatemalan experience with succirubras is of little assistance: we must learn to grow the finer types of Cinchona, and to do so will require much further study and experimentation. Yet we must admit that results to date are most encouraging.

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Naturally, the recommendations of foreign writers are not always applicable here, since they are mainly concerned with practice in far-distant parts of the world. But they have furnished the basis on which to plan and conduct local experimentation. And in the past few months, the work commenced in 1934 under the auspices of Merck and Company has commenced to bear fruit. At Finca Zapote, at Finca Helveita, at Finca Moca, at Finca Panama, and at Finca Samac (near Coban) several hundred Ledger trees of the Java type have reached sufficient size to permit analyses of their quinine content. These analyses, in many instances, have surpassed our expectations. They give grounds for believing that Guatemala has suitable conditions of soil and climate for cultivation of high-yielding types of Cinchona; and when propagated by grafting, or when used for the production of seed, these trees should furnish material on which to base commercial cultivation.

The highest of the above mentioned plantings is at 5400 feet; the lowest at 3400 feet. How far above and below these elevations Ledger-type Cinchonas may be grown successfully we do not know, nor do we know the effect of altitude upon the quinine content. In many matters of this sort, we are

forced to depend, for the moment, upon the published results of experience in other countries. Thus we are interested in the statements of Sands, who says that Ledgers are cultivated in Java chiefly between 3500 and 6000 feet elevation: that below and above these altitudes the yields of bark are not good; and that the most suitable elevations are between 4000 and 5500 feet. Sands further says that below 1500 feet the bark produced is useless for manufacturing purposes because of the small quantity of quinine it contains. All such statements should be studied in connection with Cinchona planting in Guatemala, but we can not invariably assume that they apply here. We must determine for ourselves the upper and lower altitudinal ranges of successful Cinchona cultivation, as well as many other details.

As regards soils, we are greatly impressed by the growth made by Ledgers on the brown volcanic loams and clay loams of the Pacific side. The soils of Helvetia and Patzulin in the Department of Retalhuleu have given excellent results. Indeed it is our feeling that the finest soils which have been planted in Guatemala to date are the chocolate brown clay-loams of virgin areas - not old cafetales, but montana. In this last respect, it is pertinent to note that writers in Java repeatedly mention the unsuitability of old or worn lands for Ledger seedlings. Ledgers grafted on succirubra stocks, they say, can successfully be grown on old and worn lands, but Ledger seedlings definitely can not. This is worth remembering, in connection with experiments here in Guatemala.

Results obtained on the black sandy loams of the Pacific side, and on the limestone clays of the Verapaz, have in general been much less satisfactory than those obtained on the brown volcanic loams and clay loams. The trees at Finca Samac, near Coban, constitute an exception with regard to the Verapaz: but these trees are on a specially favored alluvial plot in a small

valley, and have been cared for by one of the most skillful agriculturists in Guatemala - Don Gustavo Helmrich.

With regard to terrain, as with regard to soils, our experience to date is wholly in agreement with the published experience in Java. Flat land is not necessary. The highly successful experimental planting at Finca Helvetia, for example, is on a slope as steep as any used in the same finca for coffee. Good drainage is essential, and this is facilitated by s loping land.

As regards rainfall, we have been agreeably surprised to find that Ledgers have withstood the rather severe dry season of Finca El Zapote, in the Department of Escuintla; while on the other hand, they have also done well in such wet areas as Finca Moca. Sands states: "A heavy and well distributed rainfall is required," and again, "It would appear certain that a minimum yearly precipitation of 100 inches is necessary for the best development of the tree."

In fact, nothing could augur better for the future of Cinchona cultivation in this country than the behavior of Ledger trees on the Pacific side of Guatemala during the past few years, for it is notorious that the Ledgers are the most exacting, the most delicate, of all Cinchonas cultivated today. If, therefore, we can grow Ledgers, we can grow commercial Cinchona. The behavior of the low-yielding succirubras - which have been grown in Guatemala for many years - has little bearing on the case.

A superficial examination of the Ledgers now growing in Guatemala shows that we must expect here the same individual variation which is reported in Java and elsewhere. In spite of careful seed selection during several generations, Ledgers are not wholly uniform in growth characteristics nor in quinine content. This is one of the chief reasons for the propagation of the

best individuals by means of grafting on succirubra stocks. Another reason is the relatively weak growth of the Ledger type and its failure to succeed on poor soils when grown on its own roots. Succirubra root stocks impart greater vigor to Ledgers; but on the other hand, the total yield of quinine is reduced by the fact that the root-bark of succirubras contains less quinine than that of Ledgers. Hence the ideal practice, it seems, is to grow high yielding Ledgers, on their own roots, and on good land. Stoffels, the most recent writer on the subject, emphasises this feature. Possibly in Guatemala, as in Java, commercial cultivation in the future will include both seedling Ledgers and grafted Ledgers, depending upon soil conditions and other factors yet to be determined.

In addition to Java-type Ledgers, there are now under trial in Guatemala many other kinds of Cinchona, brought together from such widely diverse sources as West Africa, the Philippines, and other regions, largely through the good offices of the Division of Plant Exploration and Introduction of the United States Department of Agriculture. Also, there are numerous local seedlings, mainly of succirubra blood but showing evidence of crossing with calisaya types introduced many years ago. As mentioned above, it is too early to forecast the ultimate value of most of these, but among them may be types which, because of their vigorous growth coupled with a fair quinine content, may have commercial value. It must always be born in mind that high quinine content alone does not make a suitable tree for commercial cultivation. If, for example, a tree contains 8 percent of quinine sulfate, but in ten years' time will yield twice the amount of bark given by another tree which contains 11 percent, then the tree having the lower content is the most profitable one to grow. There are, of course, limits to which this principle can

be applied, and it is precisely the determination of these limits - the determination of those types which are most satisfactory from the grower's and the manufacturer's standpoint - which constitutes one of the most interesting problems in connection with the development of Cinchona planting in Guatemala.

PROPAGATION

It is necessary to emphasize at the start that the propagation of the finer types of Cinchona from seed - trees of the species C. officinalis, including the Ledgers - is a task requiring a much higher degree of agricultural skill, more intensive attention to minute details, than the Guatemaltecan finquero has been accustomed in the past to give those crops with which he is familiar. This statement must be borne in mind by all those who undertake the cultivation of these trees: it is amply verified by the experience of Don Mariano Pacheco, Director General de Agricultura, an experienced nurseryman who has probably devoted more time to this subject than anyone else in Guatemala.

The production of succirubra stocks on which to graft the finer types is not so difficult. The technique, however, is the same as with the more delicate calisayas, hence there is no need to describe it separately.

Cinchona seeds are harvested by gathering the capsules when mature, and placing them in a dry room until they open, when the individual seeds may be shaken out and prepared for planting. In Java a great deal of attention is given to the elimination of poor seeds, - those not likely to germinate - but this is a refinement which we shall be some time in attaining. The seeds are small and very light, 2000 to 3000 of them weighing one gram. They are extremely sensitive to moisture, hence the necessity of storing them in tightly-corked bottles until they are planted. They retain their viability for several months. If kept for a year, it can not be expected that more than

half of them will germinate. Various writers assert that they lose their viability altogether by the end of the second year. Suffice it to say that they should be planted as soon as possible after they are harvested.

Semilleros. The basic principles underlying the propagation of Cinchonas from seed are these: the seeds must be given very little light while they are germinating, and must be kept uniformly moist. If allowed to dry out after having commenced to swell, they die. Immediately they have germinated, they are subjected to the risk of being destroyed by "damping off" against which they must be protected by a delicate adjustment of light and ventilation assisted, in some instances, by a judicious use of Bordeaux mixture. In a few weeks' time they have passed this stage, and must be given more light, very gradually, and without exposing them as yet to the direct rays of the sun.

Where only a relatively small number of seedlings are to be grown, a convenient method is to use small, shallow boxes, which can easily be moved about to adjust the light relation. But where large numbers are required, as is the case when commercial plantings are contemplated, seedbeds are prepared, following the technique used in Java and elsewhere. These beds can be of any length desired, but we have found it best not to have them more than three or four feet in width. They must be edged with boards or other material, so that the surface can be raised several inches above the level of the surrounding land. Several inches of rich forest loam mixed with about 25% of clean sand should be placed on the surface, and levelled carefully to receive the seeds.

These beds must be sheltered from the sun and rain. Most of the seedbeds prepared in Guatemala to date have been protected with lamina, which is excellent material. We understand it is customary in Java to use thatch

of various native materials. The chief thing is to have the roof pitched steeply from south to north, with the lower side toward the south - this means of course, that the beds themselves should be constructed from east to west. The southern side of the roof can come close to the ground, leaving only 18 to 24 inches of light, and there must be sufficient overhang so that rain cannot reach the seedbeds. The northern side, which is open to the light, is protected during germination by using bamboo strips, or any other light material, with space between to allow a limited amount of light to enter. These details are better understood by referring to the accompanying illustrations.

The seeds are scattered uniformly over the surface of the beds at the rate of approximately two to three grams per square yard. If they are thicker than this, and germination is good, the stand of young plants will be too thick and increase the danger of loss from damping off. We have found that it is well to scratch the surface gently after planting with a fine rake, to cover the seeds very lightly.

Watering must be done carefully, and under no circumstances must the seedbeds be allowed to dry out. Neither must they be kept too wet: if soggy, the seeds will decay. Germination takes place in three to four weeks. As soon as it is evident that the seeds are germinating well, watering should not be so heavy, else danger of damping off is increased. At this time it is also necessary to insure good ventilation of the seedbeds, and we have found it useful to spray with Bordeaux mixture two or three times at three day intervals.

As the young seedlings develop, light is gradually increased by lessening the shade on the northern side of the beds. When the plants have

reached two or three inches in height they are ready to be moved into almacigos. This is usually four to six months from the time of planting depending upon the elevation of the place at which the semilleros are situated. For example, at Finca Patzulin, elevation 2400 feet, growth is nearly twice as rapid as at Finca El Naranjo, elevation 3800 feet.

Almacigos. These are prepared somewhat as for coffee nurseries, but for some months the young plants must have better protection from heavy rains. They may be spaced 3 x 3, or 4 x 4 inches, if they are to be moved a second time to wider spacings; if not, they should be spaced 6 x 6 inches at which distance they can grow until ready for transplanting to their permanent places in the field. The plants require shelter from the direct sun at the start, and are gradually "hardened off" as they grow larger, until they are accustomed to full sun by the time they are ready to go into the field, which is approximately two years from the time of planting the seed.

Grafting. Fortunately, trees of the genus Cinchona are not difficult to propagate by means of grafting. The essentials seem to be these: stock-plants (invariably of the species pubescens or succirubra) must be in strong growing condition with stems one-half to three-quarters of an inch in diameter; scions must be of sound, half-ripened wood; and the work must be done in damp weather.

As evidenced by the fact that Cinchona trees regenerate their bark rapidly when it is removed for the manufacture of quinine, cellular activity in the cambium layer is more vigorous and rapid than it is with many other kinds of plants. This accounts for the high degree of success which attends grafting. Under favorable conditions and with varieties of robust character, 75 to 90% of grafted plants may be expected to grow.

Several methods of grafting are practiced in other countries and have been tested experimentally in Guatemala. All, however, are the same in principle and differ only in minor details. The method which is preferred by Jorge M. Benitez of Experimental Plantations Inc., who has had more experience in Guatemala than anyone else, is roughly as follows:

Succirubra stock-plants must be in vigorous growing condition, with stems (as mentioned above) between one-half and three-quarters of an inch in diameter. Close to the ground, a vertical cut is made, two inches in length, to expose the cambium, and incidentally the wood. The latter should be disturbed as little as possible.

Scions are prepared from branchlets of the tree it is desired to propagate. These branchlets are of the thickness of a lead pencil, and not of recent growth. In other words, they should be of half-ripened wood, not old wood, nor yet tender wood which will shrivel and dry out rapidly. Scions should be about four inches in length, with two nodes toward the upper end, from which the leaves are trimmed carefully. At the lower end, a diagonal cut is made, approximately an inch and a half in length. This surface of the scion is then placed against the cut on the stock plant, so that the cambium layer of the scion comes in contact with the cambium layer of the stock-plant; it is here that the union between stock and scion will take place. Holding the scion firmly in place with one hand, the graft is bound with waxed tape, made by boiling ordinary thin cotton cloth in a mixture of beeswax and resin. After this is done, melted wax - warm but not too hot - is used to cover the entire graft. This prevents drying out. The wax is applied with a small brush, and the graft is then left until it unites with the stock-plant, which takes four to six weeks.

Once the scion has commenced to grow vigorously, the stock-plant

is cut off several inches above the graft. In about one year's time the graft is ready to be transplanted to its permanent place in the field.

It may be mentioned here that the art of grafting is something which can be learned by experience much better than by written description. During the past year, several young Guatemalan agriculturists have been trained by Jorge M. Benitez to do this work and have been practicing it very successfully. Those who desire to learn the art will probably save time and disappointment by spending a few weeks working with an experienced man, rather than attempting to master the art by themselves.

The best months for grafting Cinchona in Guatemala seem to be June and July, though the work can be carried out successfully at any time between the onset of the rains in May and the season of heavy rains in September. The main thing is to remember that grafting is most successful in moist weather, but not during the period of heavy rains.

FIELD CULTURE

Obviously we still have much to learn in Guatemala regarding the treatment to be given Cinchona trees in the field. As yet there are no commercial plantings on which to base recommendations. At the start we must be guided largely by experience in other regions.

Here as elsewhere few difficulties attend the transplanting of trees from the nursery (almacigo) to the field. They can be moved with bare roots provided that they are not kept out of the ground more than a day or two. Proper spacing in the field requires further experimentation here. In Java it is customary to plant from three to four feet apart. As the trees grow and begin to crowd one another, they are thinned out and the trees which are removed in this process are used for the extraction of quinine. This is continued year after year until the entire planting is dug up at the end of

the fifteenth year. The method is described by Sands in the paper mentioned earlier in this report, which can well be studied carefully by those interested.

Plantings made in Guatemala to date have been at widely different spacings - from close ones of 3 x 3 feet to wide ones at 12 x 12 feet. The present tendency is to plant at 4 x 4 or 5 x 5 feet, but only time will show which is the optimum distance.

Experimental plantings are being handled in much the same manner as coffee plantations. Here again, it will require much time and experience to show just what is required. Based on experience in Java, it will take approximately six years for trees to reach suitable age for harvesting of the bark; and from that time onwards there will be an annual production increasing in quantity for two or three years, then remaining at approximately the same figure until the final year when the entire planting is harvested and the maximum yield is obtained. In all these matters we have yet to gain experience. After many years of Cinchona cultivation, Java has abandoned the method of "stripping" or taking bark from trees and then allowing them to regenerate, and has gone over to the method of harvesting the bark from the entire tree - roots, stem, and branches. This subject is covered fully in Sands' account of the quinine industry in Java and we can not do better than to base further work in Guatemala upon his description.

PESTS AND DISEASES

Mature Cinchona trees in Java are said to suffer from the attacks of root disease, from "pink disease" (Corticium salmonicolor), from bark canker, from an insect belonging to the genus Helopeltis, and several other pests of minor character. We shall not know, in Guatemala, just what we have to face

in this regard until much time has elapsed. There are indications that we must expect trouble from a root disease of the Rosellinia type, though it seems doubtful that this will be as serious as it is reported to be in Java.

CINCHONA IN GUATEMALA

Wilson Popenoe

The comprehensive summary of recent progress in Cinchona cultivation throughout the world, published in the Bulletin of the Imperial Institute, 1939, includes only brief mention of the work which has been done in the Republic of Guatemala. Since this work shows considerable promise, it is hoped a general survey of results obtained to date may prove of interest.

Botany

To render intelligible this discussion it is necessary to consider briefly the botanical status of the plants grown as sources of the drug quinine. Weddell, who devoted exhaustive study to the genus Cinchona in the early days, published in 1848 a list of 21 species. Later, in 1870, he revised his classification, extending it to include some 37 species and 15 subspecies. Many of these, in the light of later study, seem more properly to be considered as geographical forms or varieties. The summary made by the Imperial Institute, mentioned above, states:

"Four species only have been cultivated to any extent as a source of alkaloids. These are: C. ledgeriana Moens ex Trimen (known also as C. calisaya Wedd. var. ledgeriana Howard), from which Ledger bark is obtained; C. succirubra Pavon ex Klotsch, the source of Red Bark; and finally C. calisaya Wedd. and C. officinalis Linn., yielding Yellow Bark and Crown Bark or Loxa

respectively. Two hybrids may also be mentioned, namely, ledgeriana x succirubra, known as Ledger hybrid or sometimes as C. hybrida, and officinalis x succirubra, which is usually called C. robusta. At the present time practically the entire supply of cinchona bark in commerce is obtained from C. ledgeriana and C. succirubra."

This classification, though greatly reducing the confusion in which the subject was left by the early botanists, is considered by certain American students as requiring still further simplification. Paul C. Standley, who has devoted much study to the Rubiaceae of tropical America, reduces the species involved in commercial quinine production to C. officinalis Linn. and C. pubescens Vahl (C. succirubra Pavon), justifying his stand in the following words (cf. The Rubiaceae of Ecuador, Field Museum of Natural History, Publication No. 285, Chicago, 1931):

"Because of the great economic importance of the trees concerned, and especially because of the varying quinine content in the inhabitants of the various regions, several botanists have devoted a great deal of time and hundreds of printed pages and plates to a discussion of the species of the genus. The result of their work has been the description of a great number of so-called species, based on characters that certainly would not be considered valid or important in other genera of the Rubiaceae. The writer has examined a large amount of herbarium material of the genus, as well as photographs of many of the types involved. He is quite unable to discover any conservative basis for recognizing the many species to which names have been given, and he believes that these names relate to variable races of a few not very clearly defined species

which may be recognized for botanical convenience. The mere fact that the variations of these races are important from the standpoint of the pharmacist does not justify their recognition, if such were possible, as species in the ordinary sense of that term."

Admittedly the last word has not been said regarding the botanical status of those forms of Cinchona which yield quinine commercially. Admittedly further study may alter the classification adopted by Standley. But the simplification of the agricultural problem by the elimination of numerous questionable species, which do not invariably come true when grown from seed, seems so logical and so practical that Standley's classification has been accepted by those working with Cinchona in Guatemala at the present time. C. ledgeriana is therefore not recognized as a species; neither is C. calisaya. Both are forms of C. officinalis, a widely variable species which hybridizes freely with the other one which produces commercial quinine - C. pubescens (more commonly known as C. succirubra), giving rise to forms which often go under the name of C. robusta but which more properly are to be termed officinalis x pubescens hybrids.

Agriculturally, it is becoming the practice in Guatemala to refer to trees of the species officinalis as calisayas; those of the form known elsewhere as C. ledgeriana as Ledgers or calisayas of the Ledger type; trees of the species pubescens as succirubras; and all hybrids between officinalis and pubescens as hybrids rather than C. robusta. Without presuming to say that this terminology will stand the test of future botanical investigation, it is felt that its simplicity recommends it.

Historical.

The stimulation of interest in Cinchona culture shortly after

the middle of the last century, resulting from the successful efforts of the British and the Dutch to transplant Cinchona trees from their native home in the Andes to plantations in the Eastern tropics, had repercussions in several regions, of which Guatemala seems to have been one. For we can only attribute to this cause the introduction of Cinchona into this country, about the year 1870, a work which seems to have been fostered by that remarkable man, President Justo Rufino Barrios. Details are difficult to obtain at this latevday, but it is known that Barrios planted Cinchona extensively on his property "El Porvenir", in the Department of San Marcos, where the progeny of his original trees still grow in vast numbers. An examination of these half-wild trees today suggests that Barrios brought in both C. officinalis and C. pubescens. As would be expected, the latter is the one which has survived, most of the present trees being unquestionably of this species; but there are sufficient indications of calisaya blood to convince one that hybridization has taken place, and that while the more delicate officinalis has disappeared, its memory still lingers in the narrow, smooth leaves, the white flowers, and the relatively high quinine content of numerous trees still scattered over the slopes of the volcano Tajumulco which dominates this beautiful property.

Shortly after the death of Barrios the Reformer, a serious effort was made by Germans to establish Cinchona cultivation in the Department of Alta Verapaz, of which we fortunately have an account in the memories of Franz Sarg, published in "Deutschtum in der Alta Verapaz", 1938. Sarg states that the Minister of Agriculture, Don Manuel Herrera, offered a prize of fifteen hundred pesos to the man who would make the first planting of two thousand trees. Through the good offices of Prince Nikolaus of Nassau, seeds were

obtained from Ceylon in 1878, and in 1882 the prize was claimed and paid. Difficulty in handling the bark, and falling prices in the world market, discouraged the undertaking and the project was dropped. But two old trees at the Finca Sachamach, near Cobán, still remain to testify that here again the effort was not limited to the introduction of the relatively inferior succirubras, but that calisayas also were involved; for these two trees, which may be seedlings of some of the first ones planted, show definite evidence of calisaya blood - again in their leaves, their flowers, and their relatively high quinine content.

After these early efforts, from which no pecuniary profit seems ever to have been derived, interest lapsed for more than half a century. Then, with a view to developing a Cinchona industry capable of supplying the North American market with quinine, experments were started which had the support of the Guatemalan and the United States governments. These were actively put on foot in 1934 by Merck and Company of New York, through their subsidiary Experimental Plantations Inc. Seeds of the best Ledger types were obtained, and later, through the good offices of the Division of Plant Exploration and Introduction of the United States Department of Agriculture, several other promising strains were brought into the country. Nurseries were established in several places; Don Mariano Pacheco, Director General of Agriculture for the Republic of Guatemala, gave the subject his personal attention; and work was under way which in the past two years has commenced to show promising results.

Commercial Cinchonas and Their Characteristics.

Naturally, these recent experiments in Guatemala have had as background the available literature upon the general subject of

Cinchona cultivation in other regions, particularly Java, which at present supplies some 95% of the world's quinine. The literature, while by no means extensive, is sufficient to point out the objectives which must be attained if success is to be achieved. Of particular value has been W.N.Sands' account of the Cinchona Industry in Java, published in the Malayan Agricultural Journal, 1922; and "De Kinacultuur", by A. Groothoff, published at Haarlem, Holland, in 1925. A more recent work of value, from a different region, is E.H.J.Stoffels' bulletin "Le Quinquina", published by L'Institut National pour l'Etude Agronomique, Belgian Congo, 1939.

These publications by no means exhaust the list, of course, and it is perhaps well to mention once again the excellent summary compiled by the Imperial Institute, referred to at the head of this paper. From this last-named publication, and bearing in mind the fact that the Ledger type of calisaya is today the source of most of the quinine produced commercially, the following quotation is of more than passing interest:

"It has already been mentioned that C. ledgeriana is more exacting in its requirements than any other species. The most suitable climatic conditions for satisfactory bark production of high quinine content would appear to be those obtaining in Java at elevations of 4000 to 5000 feet. The character of the soil is also of great importance in the case of this species; its first essentials are that it should be friable and of good depth, the best results in Java having been obtained on such soils recently cleared of forest. Other species, especially C. succirubra, on the other hands will thrive and give relatively good yields of alkaloids under conditions where C. ledgeriana would fail. For this reason, and owing to the uncertainty of successfully re-establishing ledgeriana on old cinchona lands attention has

been paid to the question of grafting the latter species on the more vigorous succirubra stock. This has proved highly successful and practically all the Ledger bark now being produced in Java is harvested from grafted trees."

Work in Guatemala commenced with full appreciation of the fact that experimentation is required to determine which types are best suited to profitable commercial exploitation under the particular conditions of soil and climate existing in this country; but also, with understanding that high-yielding Ledgers such as those grown in Java have fully demonstrated their value and might here prove to be the best. More time will be required to determine, for any given area, just what is right. The situation, so far as can be judged at long range (since Java is accepted as the guide) sums itself up about as follows:

Ledger seedlings on their own roots. These are known to be the ideal thing, where conditions for their development are satisfactory. They have the advantage that roo-bark as well as stem-bark contains relatively high percentages of quinine, whereas Ledgers grafted on succirubra rootstocks suffer from the disadvantage of the relatively low quinine content of the root-bark. There is the further advantage that the expense of grafting is avoided.

Ledger clones on succirubra roots. These can be grown on soils not sufficiently rich for Ledgers on their own roots. Vegetative propagation provides foreknowledge regarding quinine content of the ultimate tree, a distinct gain since it is a notorious fact that Cinchona seedlings are in nearly all instances subject to a certain amount of variation.

Calisayas other than those of the Ledger type. These were given a trial in the Asiatic tropics before the advent of Ledgers (the

history of which is too well known to require mention here), and the fact that Ledgers have completely superseded them speaks volumes. Nevertheless, the literature makes little mention of new trials in the past half century, and there seems a definite possibility that the Andean region, native home of the Cinchonas, may yield still unknown forms of C. officinalis which, under certain conditions of climate and soil, will have great commercial value.

Succirubras on their own roots. These are of more rapid growth than Ledgers, and can be cultivated successfully on many soils not suited to the latter; but their quinine content is low and they are not considered commercially very satisfactory - except where there is an interest in alkaloids other than quinine, such as cinchonidine and quinidine, of which succirubras sometimes contain relatively large percentages.

Hybrids, C. officinalis x C. pubescens. These are frequently mentioned in the literature and there can be no doubt that some of them have played a part in commercial production. Many have the advantage of being more robust than Ledgers, and of more rapid growth. As a rule, their quinine content is lower than that of good Ledgers; but the volume of bark produced at a given age may be considerably greater, hence the lower quinine content is in part offset. There is the added circumstance that hybrids often grow well on soils which will not support Ledger seedlings. Due to their mixed genetic constitution, however, it seems probable that it will be necessary to graft hybrids onto succirubra stocks if uniformly good results are desired.

Results of Experimentation to Date

The pioneering done in the 1870s and 1880s has left large numbers of Cinchonas -mostly succirubras, with a few evidences of calisaya blood at Coban and El Porvenir - scattered over Guatemala, chiefly in the Alta Verapaz and on the coffee plantations of the Pacific side. But the information gained in the early days regarding the adaptability of Guatemalan soils and climates to the culture of calisayas is lost. Present efforts to determine the commercial possibilities of Cinchona culture in this republic have had to be based on the fact that nothing is known and everything is to be learned.

Seeds of high-grade Ledgers were obtained in 1934 and nurseries formed at several places which in the light of information gleaned from the literature seemed promising. Lack of experience naturally resulted in the loss of many seedlings; but sufficient were saved to plant several small experimental areas, chiefly at Finca Helvetia (Department of Retalhuleu), Finca Samac (Alta Verapaz), Finca El Zapote (Escuintla) and Finca Panamá (Sololá). These plantings ranged in elevation from 3500 to 4500 feet, and represented a very considerable range of climatic conditions.

Many of these trees have attained sufficient size to show interesting responses to their environmental conditions, and to permit of bark analysis. Best growth has been obtained on the brown, deep, volcanic fine sandy loams and silt loams of the Pacific side, and on the alluvial clay loams of the Coban region. On the black sandy loams - one of the chief soil types of the Pacific side - results have not been so good; though it must be noted that in all cases these Ledger seedlings have been planted on land which for many years previously had grown coffee or other crops. The

Since writers on Cinchona cultivation in Java repeatedly stress the necessity of using virgin lands for Ledger seedlings, it can not fairly be said that experience in Guatemala on old lands of the black sandy type is in any way discouraging.

In considering the results of bark analyses it must be remembered that samples are taken from precisely that part of the tree which contains the highest percentage of quinine, sulphate, the trunk at about three feet from the ground. Bark from the smaller branches does not show such high percentages, nor does that from the roots. On the basis of the available literature, Ledger seedlings which show 12 to 13% of quinine sulphate when bark-sampled at the age of five to six years can be considered good; and such trees are now growing in Guatemala.

From these trees it should be feasible not only to develop satisfactory sources of high-grade seed for further planting, but also, and perhaps even more important, select the most vigorous and disease-resistant individuals, and those with the thickest bark, for the establishment of clones to be propagated by grafting on succirubras. Not a few such clones have already been chosen and are being propagated as rapidly as possible. W.N.Sands (loc. cit.) has enumerated the principal factors which should be taken into account when selecting individuals for vegetative propagation, and his description of the Java technique has been accepted as the best guide until such time as adequate experience has been gained locally.

In addition to the trees of Ledger type now established in Guatemala there are numerous others, obtained from several sources through the cooperation of the United States Department of Agriculture.

And their are numerous seedlings from the old trees at Sachamach near Coban, broad-leaved types of apparently mixed blood, vigorous in growth and suitable for cultivation on lands not rich enough for Ledger seedlings. Some of these, and some of the broad-leaved trees pfesumably of hybrid origiin which have been introduced from other regions, have shown quinine contents of 5 and 7%, which is considered satisfactory in view of their rapid growth and thick bark.

U fortunately, the altitudinal range of the first experimental plantings does not include elevations above 4500 feet. Recently, therefore, small plantings have been made at higher levels - up to 6200 feet in one instance - to test the possibilities of the zone immediateky above that in which coffee is profitably grown in this republic. For it will greatly facilitate the development of a Cinchona industry if coffee planters can use for this crop lands between 5000 and 6000 feet in elevation. Many planters possess suchllands which because they were not considered suitable for coffee are still in virgin forest.

Propagation

The production of succirubra seedlings on which to graft Ledgers offers few difficulties. Successful production of Ledger and other calisaya seedlings, on the other hand, requires good technique and attention to details; while grafting is in this case, as with many other trees, something which can be successfully carried out only when it is backed by a certain amount of experience and knowledge of essential factors.

To the skilled horticulturist, in other words, there is nothing in the propagation of Cinchona, asexually or sexually, which presents serious problems; but the tropical agriculturist accustomed only to the simpler techniques of cane, coffee or banana culture (for example) will find the propagation of Cinchona difficult until he has devoted much time to a conscientious study of details.

Seed beds. The basic principles underlying the propagation of Cinchona from seed appear to be these: the seeds must be kept uniformly moist while they are germinating, and must be given very little light. If allowed to dry out once they have commenced to swell, they die. Immediately they have germinated, they are endangered by the risk of "damping off" against which they must be protected by a delicate adjustment of light and ventilation, assisted in some instances by a judicious use of Bordeaux mixture. In a few weeks' time they are out of danger, so far as damping off is concerned, and must be given more light, gradually, without exposing them to the direct rays of the sun.

The type of seed bed used in Guatemala differs in no major respect from that described in the literature; indeed it has been patterned after the latter. Obviously, local experience is still meagre in this as in many other respects. Protection from the sun is usually provided by sheet-iron ("lamina") roofing which is easily obtainable in most parts of tropical America and which can be used repeatedly for many years. Seed beds should not be wider than three or four feet: the length is optional. The roof should have a steep slope, from north to south. It is important that good ventilation be provided on both sides, and the bed should run from east to west so that light can be admitted, in gradually increasing intensity, on the northern side without letting the sun

have direct access to the plants. During the first few weeks (germination usually takes place in 20 to 30 days) the beds are kept dark by using bamboo mats, canes, or other convenient material along the northern side. Adjustment from time to time permits the necessary increase of light as the plants develop and require it.

The beds are suffaced with an inch or two of rich forest loam or leaf-mould. The seeds are sown at the rate of two to three grams per square yard of surface (a gram contains 2000 to 3000 Ledger seeds): if sown more thickly, it has been found that the danger of damping off is greatly increased. Though it is not necessary to cover the seeds with soil, it is local experience that drawing a very fine-toothed rake gently over the surface after sowing aids in securing a good germination.

Nurseries. The time which must elapse before seedlings are ready to be transferred from seed beds to nurseries varies greatly with the climate - in other words, the altitude above sea level. In general it ranges between six and ten months. Before they are moved, the seedlings - which should be about two inches high - are hardened gradually by exposure to more light. If not sufficiently hardened, moving is fraught with considerable risk of loss. If hardening is attempted too suddenly - that is, if the plants are exposed suddenly to the full force of the sun's rays - the risk is just as great.

Nursery beds are carefully prepared and provided with shade of some sort to reduce the amount of light which reaches the young plants at the start. Here again experience and assiduous attention to details are essential. Plants are spaced 2 x 2 inches to 6 x 6 inches apart, the spacing depending upon the size they have reached

at the time they are moved, and the program to be followed later: if spaced closely a second transplanting is necessary, six 6 x 6 inch spacing is required during the last few months before the trees are ready to be transferred to permanent locations in the field.

Fortunately, Cinchona seedlings, if properly grown and "hardened off", transplant very readily, even when moved with bare roots.

Grafting. The technique at present employed in Guatemala is that which has been developed by Jorge M. Benitez, Plant Propagator of Experimental Plantations Inc. at Finca El Naranjo, Chicacao - principal base of experimental Cinchona cultivation in this republic. It differs slightly from standard practice in Java if one can judge by published descriptions of the latter.

The essentials of grafting seem to be these: stock plants (invariably of the species pubescens or succirubra) must be strong and vigorous, with stems one-half to three-quarters of an inch in dimater at the ground. Scions must be of sound, half-ripened wood. And the work should be done in damp weather if best results are expected.

In other words, the principles are the same as with other trees, and are familiar with experienced horticulturists. Fortunately, trees of the genus Cinchona are not difficult to propagate by grafting. The percentage of success varies, however, with different varieties, the strong-growing hybrids such as those known in several countries as "robustas" being much easier to graft than the more delicate Ledgers.

Young trees in vigorous growth provide better scions than older trees. Blossoming wood should not, of course, be used. The scions should be about four inches in length, and of the thickness

of a lead pencil. They do not need to be terminals, but should have two nodes toward the upper end. The leaves are carefully trimmed off with the grafting knife and a diagonal cut is made toward the lower end, about two inches in length. This cut is placed against a long shallow cut on the side of the stock-plant, so that the cambium layer of the scion comes into direct contact with that of the stock. Holding the scion firmly in place with one hand, the graft is then bound in place with waxed tape, made by boiling cheap muslin in a mixture of beeswax and rosin. After this is done, the graft is covered completely with warm melted wax applied with a one-inch brush.

Union takes place in four to six weeks. After the scion has commenced to grow vigorously, the stock-plant is cut off several inches above the graft. In about one year's time the grafted plant is ready for moving into its permanent location in the field.

The best months for grafting in Guatemala are considered by Benitez to be June and July, though the work can be done very satisfactorily at any time between the onset of the summer rains in May and the season of heavy rains in September-October.

Field Culture

Obviously, Guatemala lacks extensive experience regarding this subject. Plantings now being made are spaced variously, from a minimum of 4 x 4 feet to a maximum of 10 x 10 feet. Practice in Java is again as described by Sands and others - suggests close planting and later thinning out for the exploitation of the bark. The culture given in the field is much the same as that used for coffee - another rubiaceous plant - primarily because this technique is familiar to Guatemalan agriculturists.

Little is known, as yet, regarding pests and diseases which must eventually be faced by the Cinchona planter in this country. It seems usually to be the case that enemies develop more abundantly when their host plants are cultivated on an extensive commercial scale.