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THE COCO-NUT

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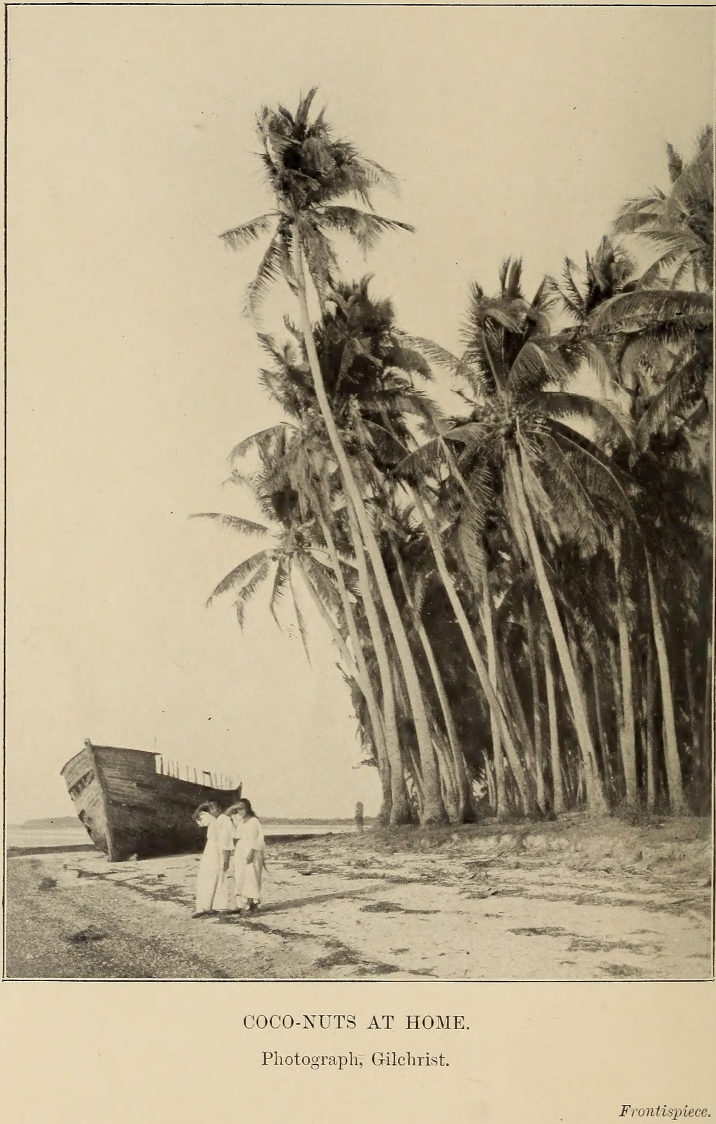

COCO-NUTS AT HOME.

Photograph, Gilchrist.

Frontispiece.

THE COCO-NUT

BY

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THE PHILIPPINES

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CHAPTER V

CHAPTER VI

ILLUSTRATIONS

ERRATA

Page xiii, line 21, read *yautia* instead of *yantia.*
,, 19, line 7, read *diseases* instead of *disease.*
,, 20, line 11, read *where the* instead of *whose.*
,, 54, line 5, read *were* instead of *had.*
,, 64, lines 5 and 6, delete *Of these* and begin sentence with *The.*
,, 65, line 11th from bottom, insert *at* before *at.*
,, 67, line 3, cut out first two letters.
,, 86, line 4, after *cut* insert *out.*
,, 107, line 15, read *runways* instead of *runaways.*
,, 140, last line, read *coco-nut* instead of *coco-nuts.*
,, 156, 2nd line of reading matter, read *very dry* instead of *ordinary.*
,, 162, last line, insert *and nitrogen* after *ash*, and read *amount* instead of *amounts.*
,, 191, 2nd line from bottom, read *Kokosbutter* instead of *Kokosbutrer.*
,, 192, 1st line, read *Uebung* instead of *Ubung.*
,, 195, 3rd line, read *salable* instead of *soluble.*
,, 198, 3rd line from bottom, read figures *65* instead of *35.*
,, 201, line 14, read *for each 100 hektares* instead of *for each hektare.*
,, 204, line 12th from bottom, read *bear* instead of *bears.*
,, 205, line 3rd from bottom, read *presses* instead of *pressures.*
,, 207, and in the places referred to, note that *Banahao* and *Banajao* are the name of one mountain. The official spelling is *Banajao*, but *Banahao* is now more common. It should be spelled alike throughout.

INTRODUCTION

The preparation of this book began in 1907 and was expected to be finished in three years. Before the time at which it was to be finished, the College of Agriculture of the University of the Philippines was established, and I found myself giving a course of instruction on the coco-nut. This course and the proposed book covered the same ground and had the same end in view. Other work did not leave me time to get this into satisfactory shape for publication, and teaching the subject gave me an opportunity to test many of the supposed facts as well as to practise their presentation. I have now given the course to five classes. The knowledge of coco-nut physiology, which before rested entirely upon my work during one season at San Ramon, has been amplified and substantiated by the work of many students here. Every student in these classes has had the care of a small group of trees and has kept full records covering every step in coco-nut culture, from the preparation of the seed bed to the utilization of the product. When I express myself positively on matters of practice it is therefore on the basis of ample personal experience.

The aim of this book and of the instruction in this college is to give the knowledge and advice which will qualify a person for the practice of coco-nut raising. There are two general methods which might be used for this purpose. One is to give rules which have been found good in practice; the other is to give the understanding on which such rules must rest. In the same way the chauffeur of an automobile might be qualified by being shown with care how the machine responds to the action of various wheels and levers, or he might be taught the principles on which his engine is built, and how these principles are applied in practice. If everything runs smoothly, the training by rule and example will be sufficient. But when things go wrong, it will leave him helpless. In the same way, and for the same reason, the coco-nut planter who has been given a good set of rules will be likely to succeed under the conditions to which the rules apply, but will not be qualified to meet changes in conditions.

This book is written in the Philippines, and may seem to deal to an unreasonable extent with the coco-nut industry of these islands. However, I believe that aside from such purely local information as the cost of labour and supplies, and means of transportation as influencing the markets, it contains everything that a planter anywhere in the tropics has most need of knowing. The behaviour of the coco-nut is intelligible in the light of the knowledge of its physiology, and surely in no other way; and the physiology of the tree is the same the world over. The diseases of the coco-nut present a problem which is increasing very rapidly in importance, and to which I have accordingly given particularly thorough treatment. In discussing the cultivation of the coco-nut and the utilization of its products, I have constantly kept emphatically in view the fact that the subject is of interest only because of its business importance. Every detail in these matters should be put into practice only after mature consideration in the light of local conditions, and every decision as to practice must be a business decision. It is not anticipated that the planter or the student will be provided with a business head. It is hoped and believed that the conditions and arguments which should be considered are suggested and discussed sufficiently to qualify each man to decide for himself, at each stage of the business, what he can do with the prospect of most complete success.

Certain matters to which much space is often devoted in works of this kind have been omitted. One of these is the presentation of statistics on the coco-nut industry of different countries and on the commerce in coco-nut products. So far as I have been able to test them, the generally current statements as to this industry in different lands are unreliable to the point where they are almost valueless. For instance, several books contain a table prepared many years ago in Ceylon, showing the number of acres devoted to coco-nuts in different countries, and in this table the Philippines are grouped with Borneo and other great areas, and for the whole group the acreage given is not far from that in one of the provinces on the Island of Luzon. It would be a very difficult matter to prepare a reliable table of this kind, but I cannot see that it would be very useful to any coco-nut planter when prepared. It would be possible to compile comparatively reliable statistics as to coco-nut commerce. But in this case, again, the statistics would not be of much interest to the planter.

Another omission which may be noted is the absence of estimates showing the cost of establishing coco-nut plantations and maintaining them, and the probable income and profit. Very many such estimates have been published. The best of these are more or less skilful guesses. In every such estimate, the cost of labour, whether expressed as such or not, is the principal item, and the only other items likely to compare with it, if the analysis of the expenditures is thorough, are land and supervision. The values of land and labour are so exceedingly different in different tropical countries, that no such estimate has other than a local value. How completely this is the case is illustrated by the fact that equally good labour varies in cost from province to province in the Philippines by fully 100 per cent. If the presentation of estimates could be trusted to show that the establishment of a coco-nut plantation in one country could be expected with confidence to pay better returns than one in another country, they would indeed be very useful to prospective investors. But I do not believe that such estimates as have been published are qualified to serve this use. Moreover, the intending investor practically always has the place of investment determined by other considerations.

Still another omission is the discussion at any considerable length of the use of coco-nut products. Beyond the reasonable limits of plantation industry I have not pursued the subject.

In a business sense it is sufficient that coco-nut raising is profitable and that its future is safe. I know no other business which seems to me quite so certain as this one to continue for a term of decades to pay large profits at all times. The returns at present cannot be described as less than unreasonable. Yet the demand for good copra and good oil is so far beyond the supply that for a very long time to come it seems certain that prices will remain above those which would merely pay a good return on the cost of production.

There are a number of other works on the coco-nut which should be mentioned here. Ferguson's *All about the Coco-Nut*, which for years had the field to itself, is a compilation of papers published in the *Tropical Agriculturist*, dealing very largely with Ceylon conditions, and written in considerable part by planters of experience. Prudhomme's *Le Cocotier* is the most pretentious work which has appeared on the subject. It is particularly thorough in its treatment of the industry in Ceylon and in its application to Madagascar. It is beautifully illustrated, and very valuable to those who read French. Smith's *Coco-Nuts, The Consols of the East*, contains the most complete and recent compilation of the statistics on the subject, and in its enthusiastic treatment gives the best expression to the business opportunities which the coco-nut offers. *Die Kokospalme und ihre kultur*, by Preuss, which was intended to be part of a new edition of Semler's great work on *Tropical Agriculture*, more than maintains the Semler standard. To those who read German it cannot be too strongly recommended. Andes' *Kokosbutter* describes methods of making the food products which are largely responsible for the great recent increase in the demand for the better grades of copra and coco-nut oil.

In statements as to money I have, as a rule, made use of local terms, and the same is true with regard to measures of various kinds. The more frequent use of the metric than of English standards will probably confuse nobody. English, American, and French money are likewise generally familiar. The Philippine peso of one hundred centavos is half of the American dollar.

There are botanical grounds, so strong that no doubt should remain on the subject, for the belief that the coco-nut palm was a native of the American tropics.[1] In prehistoric times it did not occupy all the available parts of this region, its introduction into the Greater Antilles, for instance, where its cultivation is now an important industry, having been accomplished by the Spaniards. The American aborigines had many cultivated food plants, such as cassava, potato, sweet potato, yams, yantia, taro, and maize, and the coco-nut was far from being one of the most important of them.

The coco-nut was introduced into Polynesia a very long time ago; long in a merely human sense, however, for it is highly probable that its introduction was the act of man, and that it was a deliberate contribution to the resources of the Island World. Here it became the crop of first importance. It made life easy on islets which without it must have been quite uninhabitable. Polynesia had little vegetable wealth, and the coco-nut supplied a folk poor in crops with food, drink, fuel, shelter, and sometimes clothing, and served a host of minor uses. In these days of commerce, it is the chief export of this region. Its culture naturally spread. Originating in America, it must have been carried westward across the Pacific; and there is good linguistic evidence that its spread was in this direction. With

[1] Cook, *The Origin and Distribution of the Cocoa Palm*, 1901.

its hundred and more uses, it naturally has a large place in the languages of the people of the sea.

From Polynesia it reached New Guinea and Malaya, but not Australia. There are quasi-historic accounts of its introduction into Ceylon. Its more recent introduction to practically all tropical coasts has been, for commercial purposes, important indeed to the various lands but offering nothing of general interest.

CHAPTER I

PHYSIOLOGY OF THE COCO-NUT

The Root.—As is true of all field crops, and of plants in general, the roots of the coco-nut serve the plant in two ways: by anchoring the plant in its place so firmly that no ordinary storm can displace it; and by taking up, from the soil, water and the mineral food which is dissolved in the water.

The evergreens and broad-leaved trees of temperate lands have each a taproot or a few stout main roots, which are firmly embedded in the soil, and on the other side immovably connected with the stem, which they hold erect by their own rigidity. The coco-nut has no taproot, and nothing like the main roots of ordinary trees. The enlarged base or bole of the coco-nut trunk is convex or conical at the lower end, and is usually buried for a depth of not more than 50 centimetres; the base of the bole is sometimes flattened, and not more than 15 centimetres deep even when the tree is grown. Its surface underground, and often for some distance above the ground, is practically covered with the bases of the roots. These roots are remarkably uniform, 0·8 to 1·0 centimetre in diameter in adult trees. They radiate from the tree on all sides, and are strongly disposed to keep the direction in which they start. A normal length for the roots of mature trees is 5 metres in firm soil, and 7 metres in sand. In poor or shallow soil they are longer, the longest reaching a length of 8 to 10 metres. The lateral branches of these roots may grow upward, downward, or horizontally, but at nearly a right angle from the parent root.

The old main roots of the coco-nut, like all other woody parts of the plant, are remarkable for both elasticity and tensile strength. Inside the proper wood, which is itself strongly developed, is a "pith" whose walls are also very thick and woody. This makes each root a very stout cord. Eighty centimetres is not a very exceptional diameter for a well-grown bole, though a majority of them are somewhat smaller. The buried part of a stem of this size will afford attachment for nearly 8000 bases of roots, each 1 centimetre in diameter; an actual count usually shows 4000 to 7000. These main roots may have few or no large branches, or may have ten to twenty, which rarely reach a length of 1 metre, or a diameter of 4 millimetres. The main roots and these major branches bear numerous fine branches, 1 to 2 millimetres in diameter. These may be the ultimate division; or they in turn may bear finer branches, at most a very few centimetres long, and about half a millimetre thick; the life of these finest roots is transitory, like that of root-hairs. A less ample system of roots is formed in sand than in firmer ground.

All the roots of the coco-nut have a rigid shell, called a hypodermis, which makes the finer roots rigid in a measure not approached by such small roots of other trees. In proportion to its size, a small root is held by the soil more firmly than a larger one. Because they are firmly fixed in their places, and are rigid, and stand at right angles to the main roots, it is practically impossible to move the branches by any pull on the main roots. And since the root can therefore not be drawn out of the ground, and can be subjected only to a direct pull, and has great tensile strength, the coco-nut's system of anchorage is a very perfect one. The tree's natural habitat is the sea-shore, where it receives the unbroken force of the fiercest storms; but unless the roots have previously been killed, or undermined by waves, no coco-nut is unrooted.

When parts of old roots die, they are replaced from the same roots. From the axial strand of the end of the living part one or two stout roots start to grow. Not at first being able to break the hypodermal shell, these are forced to grow in the same direction as the parent root, whose place in the anchorage of the plant they therefore take.

The direction of the main roots is more or less horizontal, none of them going to any great depth. Some, but not many, roots descend more than a metre below the surface; most of them are usually found at a depth of between 15 and 45 centimetres. This of course depends a great deal upon conditions.

The number of roots found in successive horizontal layers 5 cm. (about 2 inches) thick, beginning at the surface, is shown in the following table. The observation is made by digging a circular trench part of the way round the tree, 1 metre from the outside of its base, and counting the roots cut.

Layer.	Tree No. 1.	Tree No. 2.	Tree No. 3.	Tree No. 4.	Tree No. 5. (3 m. from middle of tree.)
1	12	5	0	5	17
2	7	14	7	15	36
3	6	6	3	18	92
4	14	8	8	14	78
5	4	5	4	6	28
6	4	4	8	12	38
7	19	4	3	8	12
8	6	0	6	8	5
9	2	0	6	5	1
10	0	0	5	3	3
11	0	0	8	1	1
12	0	0	3	2	0
13	0	0	4	0	0
14	...	...	8	1	...
15	...	...	5	1	...
16	...	...	4	0	...
17	...	...	5	0	...
18	...	...	2	1	...
19	...	...	2	0	...
20 and deeper	...	...	0	0	...

Of these trees, No. 2 grew in soil with a very compact stony subsoil below 35 cm., and No. 3 in soil without stone to a depth of 120 cm. The number of roots calculated for the entire circumference of the tree, at the distance at which the trench was dug, ranged from 592 (No. 1) to 2464 (No. 5). Very many counts of this kind have been made at the College of Agriculture.

No roots will grow to any distance into water, nor into a level of the soil where free water stands; and a rise in the water-level ultimately kills the submerged roots. Neither can they grow in very dry soil; a few centimetres of the surface is in most places dry so much of the time that roots cannot grow into it. Sand is drier than heavy soil, and the roots accordingly maintain a deeper level in it. The best conditions are obviously those which permit the growth of the most ample root system. So the soil should be deep, and with a deep water table, and the surface should not be too dry. The surface should be cultivated, to prevent deep drying; but it must not be cultivated deeply enough to destroy many roots, or to keep them from occupying a level as near the surface as will let them find a reasonable amount of water.

Before the absorption of water is taken up, a little more should be said about the structure of the roots. The tip of each root is protected by a thimble-shaped structure called the root-cap, which saves the growing point from injury as it is pushed through the soil. The length of the cap is somewhat greater than the diameter of the root. The young part of the root immediately behind the cap is covered by a very delicate epidermis; it is through this that the root absorbs water and the mineral food dissolved in the water. The coco-nut has no root-hairs.

The hypodermis has already been mentioned. It is formed from a layer several cells thick, just inside the epidermis. The cells are very small, and at first have very thin walls. They afterwards thicken, and soon become so thick and hard that water cannot pass through them. Only the short zone between the root-cap and the place where the walls of the hypodermis thicken can absorb water. The larger the root, the longer this zone is likely to be. In very active roots it is 5 centimetres from the tip back to the beginning of the hypodermis. In less active but by no means inert roots, 7½ millimetres in diameter, this distance may be only 2 centimetres. When the growth of the roots is checked by dryness, or by any other unfavourable condition of the soil, the hypodermis is formed closer and closer to the tip, finally even under the back part of the cap, leaving no actively absorbing zone at all.

Altogether, with its short absorbing region and the absence of root-hairs, and even of really fine roots, the coco-nut must be said to have a root system ill adapted to the absorption of large quantities of water.

But its structure enables it to endure saltiness and dryness which would be fatal to most other plants. Beach soil usually contains no salt, except in such minute quantities as chemical analysis will detect in all soils; but it sometimes happens as a result of storms that the beach is temporarily filled with sea-water. This would kill any plant with ordinary roots, but does the coco-nut practically no harm at all.

The same structures enable the coco-nut to withstand drought, not without temporary injury, but without being killed. When any layer of the soil becomes dry enough to injure coco-nut roots in any way, its first effect is to check the growth in length. The hypodermis then approaches closer and closer to the tip, until, if the dryness is severe enough, it reaches the root-cap. In this condition the root is valueless as an absorbing organ;—which does the tree no harm, because an active root could absorb no water from the soil dry enough to cause this condition. When the soil becomes wet again, the roots gradually revive, the cap grows away from the hypodermis, and absorption begins anew. If all the roots ceased to absorb water, the tree would of course be killed, but this cannot happen in any place where coco-nuts ought to be planted. Where coco-nuts become inactive, roots better fitted to absorb water would be killed.

The numerous little, white, eventually sharp and hard outgrowths scattered along the old coco-nut roots are specialized roots which serve as breathing organs. It is as impossible for air as for water to pass through the hypodermis; and the internal tissues of old roots would die for want of air, if they were not supplied with it by these breathing organs.

It has already been remarked that the coco-nut roots have a limited absorbing surface. Even the limited area which looks capable of absorbing actively is sometimes really very inactive. Dead roots will for some time absorb as rapidly as when they are alive; but if a living root is cut, the end is promptly closed by

COCO-NUTS AT ZAMBOANGA, 160 YEARS AGO.

Photograph by Shaw of Sonnerat's cut.

To face page 6.

a gummy substance, and no more water is taken up by it. Experiments show that, as was presumed from the structure, coco-nut roots are not injured by moderately strong solutions of common salts. More than this, they absorb such solutions freely. They will absorb a solution one hundred times as concentrated as ordinary soil water about as rapidly as they do pure water. In fair weather, they absorb most rapidly in the afternoon, less so in the forenoon, and very slowly at night, the most rapid absorption following closely the time of most rapid evaporation from the leaves. This indicates that the tree does not store up any considerable amount of available water. And from this it follows that anything which interferes with the evaporation from the leaves immediately checks the absorption of water and of mineral food by the roots.

In proportion to the area of apparently absorbing surface, the finer roots take up more water than the larger ones. A calculation based on the measured activity of the main roots would show that an entire tree takes up at most 24 litres in a day; but we know from determination of evaporation from the leaves that this figure is too low. It is likely that such measurements of the growth as have been made likewise fail to show how rapid it can be. The most rapid growth that I was able to measure at San Ramon for a period of a few days amounts to only about a metre a year; and measurements extending over a month or more showed only half of this rate. More recent measurements in La Laguna on eleven roots showed an average growth of 3·02 millimetres a day, or somewhat more than a metre a year.

The Leaf.—The water taken up by the epidermal cells of the root moves inward from cell to cell, into the vessels of the axial strand. In these vessels, it moves upward through the roots and trunk, to the leaves, and along the midribs and veins and veinlets of the leaflets. Finally, it moves outward again toward the epidermis, and is evaporated. As the water evaporating from a tea-kettle leaves behind it the salts it held in solution, forming a shell on the inside of the kettle; and as the water flowing in through the rivers has evaporated and left the ocean salt; so the water which evaporates from the coco-nut leaves behind it what it held in solution, and this residue makes up the whole of the mineral and nitrogenous food of the tree. The more water is boiled in the kettle, the more residue is left; and the more water evaporates from the leaves, the more mineral and nitrogenous food remains for the plants. Men cultivate the soil and thereby directly and indirectly increase the amount of food the plant can get from it. This costs money. They buy fertilizers and apply them to the soil. This also costs money. Exactly the same end can often be secured with little or no expense by increasing the evaporation from the leaves; which gives the subject a very evident practical importance.

The evaporation of water from plants is called transpiration. It takes place in part directly through the outer walls of the epidermis, but chiefly through small openings in the epidermis called stomata. The stomata of the coco-nut are entirely confined to the nether surfaces of the leaves. At least 98 per cent of the water transpired is given off from this surface. The stomata open to their full width in the day-time, in full sunshine, provided that the tree is well supplied with water. If the tree is not thus well supplied, the openings narrow as the water in the leaves decreases, and so check the transpiration. They are closed at night. The transpiration will be most active if the roots can take up water and supply it to the leaves as fast as it is evaporated, and the stomata thus be kept wide open throughout the day.

Besides the stomata, the coco-nut has another structure which regulates the transpiration, but less perfectly. This is a strand of tissues running along each side of the midrib, on the under side of the pinna, and acting as a hinge. The pinna is thinnest along these lines. The cells of the hinge are colourless and thin-walled. When the leaflet is well stored with water, the cells of the hinge are turgid, swollen up as large as possible; each hinge then raises its half of the pinna, making the whole leaflet as wide as it can be. When the amount of water in the leaf is decreased, the cells of the hinge are quick to feel the loss, and with any loss of water their size decreases. This results in a lowering of each side of the pinna, making the whole pinna narrower, and so lessening the exposure to the sun. The transpiration will be greatest if the tree is at all times so well supplied with water that the hinges do not let the sides of the pinna lower.

The transpiration is made active by light, warmth, dryness of the air, and wind. It is hindered by darkness, cold, and moistness and stillness of the air. The most important of the factors influencing the transpiration is light. A light haze across the sun—too light to be called a cloud—will immediately reduce the transpiration by one-third or one-half. A cloud heavy enough to conceal the sun will promptly cut it down to about one-quarter of what it is in direct sunshine. All shade has, of course, the same effect, and it makes no difference whether it comes from a cloud, or a mountain, or some shade tree, or another coco-nut planted too near. Every leaf or part of a leaf which is in the shade has its transpiration cut down to a quarter of what it might be, and therefore gets only a quarter of the food it might get dissolved in the water.

During the whole night the whole transpiration is not one-tenth as much as during one hour of full sunshine. Diffuse light increases the transpiration chiefly by causing the stomata to open. The great added action of direct light is chiefly due to the heating of the leaf. The following table gives the temperatures observed during one day, the first column giving the temperature in the shade; the second, the temperature in direct sunshine; and the third, the temperature shown by a thermometer placed near the second, but with a coconut leaflet tied around its bulb.

TEMPERATURE (C.)

Hour.	In Shade.	In Sun.	In Leaf.
7 A.M.	20°·3	21°·8	21°·9
8 „	24·3	25·2	27·4
9 „	26	30·7	33·1
10 „	26·9	32	35·4
11 „	27·8	31·5	34·7 (light cloud)
12 M.	28·3	34·7	37·7
1 P.M.	28	30	31·5 (cloudy)
2 „	28·5	31·5	38
3 „	28·8	31	36·7
4 „	28·6	30·6	36·4
5 „	27·7	30	34
6 „	26·6	27·6	28·5

With conditions as they were on this day, a surface of water at the temperature of the leaf in the sun at noon would evaporate about three times as much as a surface at the shade temperature. The increase in the evaporation from a leaf is greater still, provided that as transpiration goes on the supply of water is kept up.

If we now take up the actual rate of evaporation of the water from the leaves, we find that beginning early in the morning there is practically none. The temperature is low, the air is moist and usually still, and the stomata are at first closed. Under the influence of the light the stomata open, the air warms enough so as to no longer be saturated with moisture, and the transpiration gradually increases. This increase goes on for several hours. If it were possible for the roots to take up water and furnish it to the leaves as fast as it could be evaporated, there would be a steady increase in transpiration up to 1 o'clock or possibly later, as up to this time the factors which promote it usually operate with more and more intensity. But against this steady increase in the transpiration there operates the fact that the roots cannot take up the water nor the stems transmit it as fast as it evaporates under most favourable conditions from the leaves. Accordingly, the sides of the leaflet begin early in the day to be lowered by the hinges, and the width of the leaflet from edge to edge may be decreased as shown by this table :

Leaf.	December 7.						
	7 A.M.	8 A.M.	9 A.M.	10 A.M.	11 A.M.	12 M.	1 P.M.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
A	20·3	20·3	17·5	15	13	12·5	12·5
B	25	25	21	20	18	17	16·5

Leaf.	December 7.			December 8.		
	2 P.M.	3·30 P.M.	5·10 P.M.	6·30 A.M.	7·30 A.M.	8·30 A.M.
A	13	13	17	20·3	20·3	20
B	16	17·5	21·5	25	25	23

Leaf.	December 8.							Dec. 9.
	9·30 A.M.	10·30 A.M.	12 M.	1 P.M.	2 P.M.	4 P.M.	5 P.M.	6·30 A.M.
A	16·5	13·5	12	13	12·5	13·5	16·5	20·5
B	21	18·5	16	16·5	15	17	21	25

What this dropping of the sides of the leaf really measures is a decrease in the amount of water in the leaf below the amount necessary for the most active transpiration ; in other words, it measures. the leaf's *want* of water. And what actually regulates the amount which will evaporate from the leaves on days of brightest sunshine and greatest dryness of the air is the amount of water which can reach the leaves. At the same time, this factor is by no means the only one which regulates transpiration, even on such days ; for the leaf can draw on the supply stored in itself and in the stems, and so create a moderate deficit which will be made up during the night while transpiration is most inactive. And the greater this deficit the more water the roots will take up during the night.

As the afternoon advances, the transpiration decreases, and late in the afternoon falls to the point where water does not evaporate as fast as it comes to the leaves, and the leaflets begin to widen; so that the width by dark is about as great as it was in the morning, which indicates that the leaf has made up whatever shortage of water it underwent during the day.

By a rather complicated series of measurements the following determinations were made, showing the amount of water which evaporates in grams from one leaflet during the hours of one day.

Hour ending at	Grams.
7·30 A.M.	0·03
8·30 ,,	0·14
9·30 ,,	0·10
10·30 ,,	0·23
11·30 ,,	0·96
12·30 P.M.	0·81
1·30 ,,	3·02
2·30 ,,	1·19
3·30 ,,	1·78
4·30 ,,	1·53
5·30 ,,	0·91
Night	0·10
Total	10·81[1]

[1] For one pinna and one day.

The total water evaporated from this leaflet during the day was 10·8 grams. If we allow 150 leaflets to the leaf and 25 leaves to a tree, the calculated transpiration for the whole tree will be 40,500 grams, or 40·5 litres. Estimates based on observations made in this way range from 28 to 45 litres. In this case, the leaflets whose transpiration was being measured took their turns in the shade and in the sunshine, as the shade of other leaves fell upon them during the day; that is, they were under practically natural conditions. Observations made by a different method, which was calculated to show at each time the transpiration in full sunshine, gave figures from which the calculated daily loss of water from the whole tree is 75 litres. If we use the lowest figure based on a full set of observations, that is, 28 litres a day, the annual transpiration would be 10,220 litres.

In this water the plant takes up the mineral food to be used in its permanent growth, and enough in addition to cover the annual loss in the nuts and in the leaves which are cast. The amount of mineral food permanently bound up in the growth of the stem and roots cannot be very considerable, and that in the roots which die is already in a place where it can be absorbed again. The average dry weight of a fallen leaf may be put roughly at 3 kilograms, of which 8·5 per cent is ash and nitrogen. Allowing a fall of sixteen leaves per annum, the loss of matter taken up in solution by the roots is 4080 grams. In each nut the tree loses ash as follows:

	Grams.
In the husk . . .	33·84
In the shell . . .	3·36
In the copra . . .	13·83
In the milk . . .	5·97
	57·00

If the tree produces but twenty nuts per annum, the loss of mineral matter in these is 1140 grams, and the total loss in leaves and nuts 5220 grams. If this were absorbed in 10,220 litres of water, as already calculated, the concentration of the solution taken up by the roots would be 0·051 per cent. This is considerably above the average concentration to be found in ground water, as determined by analyses of water in wells and springs; but the water which roots absorb from any but the wettest soil, being in immediate contact with the soil particles, is sure to be more concentrated than that which would run freely from wetter ground. It is also true that from very dilute solutions roots will absorb the dissolved salts in a proportion greater than that in which they are present in the water. The estimates which have just been given are based on work at San Ramon in Mindanao, on a variety which produces remarkably large nuts. The number of nuts per annum on which this estimate is based is too low, but the loss of mineral food in each nut is greater than would be found to be the case almost anywhere else in the world.

Definite statistics, so far as they are available, on the influence of outside conditions on the rate of transpiration are of great interest. It has already been pointed out that the lightest haze obscuring the sunlight has a marked effect in cutting down the transpiration. In real shade, such as is produced by heavier clouds, or by foliage between the coco-nut leaves and sun, the transpiration will be cut to sometimes as low as $\frac{1}{6}$ of what it would be in full sunshine. How great this decrease is depends, of course, on the intensity and duration of the shade in question.

The wind makes a difference in the transpiration of all leaves, but makes a much greater one when the leaves are in full sunshine. Thus in direct sunshine a breeze estimated at five miles an hour made the transpiration four times as great as it was in still air. But in the shade the wind of this velocity did not add more than 50 per cent to the rate at which the leaves lost water.

Aside from the difference in transpiration due to varying outside conditions, the rate at which the leaf will transpire varies with its age. When the leaf has just expanded, its protective structures are not as thick as they afterwards become, and for several months after this time there is a gradual decrease in the rate of transpiration. In old leaves, on the other hand—that is, in leaves from eight months after expansion up to the time they fall—the rate of transpiration increases, so that in leaves a year or more old it is considerably more active than it is in leaves which have just reached their full size. In time of very severe drought these older leaves fall off with unusual rapidity, and since these older leaves are the ones which would lose most water, the tree manages to cut down its loss in this way to a very considerable extent.

It is of course not to be understood that transpiration is the only function of the leaves, nor even that it is the most important work which they perform. The leaves are the laboratories or kitchens in which the food of the whole plant is prepared. It is in the leaves and here only that starch or sugar is formed, and from this starch or sugar the whole structure of the tree is built up; and from this starch and sugar, again, is made all of the oil in the nuts. Light is absolutely indispensable for this assimilative work in the leaves, and the rate at which this work goes on is in general nearly proportional to the amount of direct sunlight which the leaves receive. For the sake of the plant's organic food, then, even more than for the sake of its mineral food, it is necessary that the coco-nut leaves receive as much sunlight as can possibly be obtained. A full appreciation of this fact is the necessary basis of any understanding of the serious effect which an improper choice of locality, or too close placing of the trees in planting, or poor judgment in preventing the shading of the trees at any age, will have upon the success of any coco-nut plantation.

Growth of Leaf.—During the past four years I have had made by students in the Philippine College of Agriculture a very extensive set of determinations of the rate of growth of coco-nut leaves. The total number of determinations of this kind to date is between ninety and one hundred thousand. The work is extended to give each student thorough first-hand knowledge of the rate at which the leaves of the coco-nuts may be expected to grow, of the influence of treatment, weather conditions, etc., upon the rate of growth, to qualify him to determine, by measurements of the rate of growth, the condition of coco-nut trees, or plantations, and their probable future production, and to give him such technical expertness that he can make these determinations rapidly and accurately. The trees at the College of Agriculture are on land which is not well adapted to this crop. The soil is shallow and heavy, and there is not at all times a proper supply of ground water. Moreover, the trees were largely infested by beetles when the land was purchased and such trees never grow as rapidly as healthy ones would grow. Some of the trees were about ready to come into bearing when the land was bought, but others were so young that they have not yet come to maturity. The average of all the determinations which have been made here would therefore not be a fair figure as an indication of what ought to be expected from coco-nuts. In one of the groves which is best situated and in which the sound trees are now in bearing, there are groups of trees in which the average growth of the youngest visible leaf is more than 4 centimetres a day. I believe that this figure may be taken as what ought to be expected of any coco-nuts on a tolerably well situated and managed estate.

Really good conditions or management will give higher figures than this. Thus, the nine trees observed by one student for the week ending November 25, 1911, showed the following growth in millimetres: 324, 399, 390, 427, 336, 345, 338, 375, 415. Tree No. 4, to choose one at random, showed the following growth at weekly intervals from August 24, 1911, to February 28, 1912: 316, 319, 217, 293, 395, 391, 462, 444, 422, 427, 403, 406, 798 (two weeks), 387, 367, 360, 349, 357, 347, 349, 351, 352, 365, 382, 384, 383, 382.

Young trees grow considerably more slowly than do adult trees. There is a progressive increase in the rate of growth from the time that young trees are first well established in their permanent places, at least up to the time that they come into full fruit. It is probable that the average rate in a grove continues to increase beyond this time, but on this point there are no observations. There are likewise no determinations of the rate of growth of the leaves of very old trees, but there is no doubt that such leaves grow more slowly. On shallow and therefore dry soil, the growth is constantly less rapid than where the soil is deeper and moister. We have patches of trees in which the average rate of growth is not more than 25 millimetres a day. Such trees come into bearing several years later than do trees 50 metres away on lower and deeper ground.

There is a natural and very evident relation between the rate of growth of the leaves and the amount of production of fruit. The rate of growth can be determined for most purposes within a few days so as to get an average for groves of considerable size. To get positive and reliable information as to the rate of production requires observations extending over many months. The easiest way in which one can secure reliable information as to the condition of a grove is therefore by determination of the rate of growth. This can be done in several different ways. The method which has proved most satisfactory is by drawing marks with Indian ink across the bases of the youngest and next youngest leaf, making one mark, half of which is on each leaf. The difference in height of the two halves of this mark, after one day or one week, shows the difference in rate of growth of the two leaves. A similar mark is placed on the base of the next to the youngest leaf, called No. 2, and the third youngest, called No. 3. The break in this mark after a day or a week shows the difference in growth between these two leaves. Similarly, the difference between the growth of leaf No. 3 and leaf No. 4, of leaf No. 4 and leaf No. 5, and of leaf No. 5 and leaf No. 6, are determined. The lowest mark, which remains unbroken, will be on the two youngest leaves which have ceased to grow. The sum of the observed breaks in the marks is the growth of the youngest leaf for the period in question.

On active trees at least four leaves ought always to show growth. It is common for five leaves to grow, but rare for six leaves to do so at the same time. The youngest two leaves frequently grow at the same rate. Successive older ones grow progressively more slowly, so that the oldest one which grows at all grows very slowly indeed. Growth is always more rapid during the night than during the day. The difference between night and day is much more marked in unsuitably dry weather than it is when the trees are well supplied with water. The effect of drought is likewise greater on young trees than on adult ones, and the difference between night and day is greater in younger trees when they are unduly dry than it is in older trees. Extreme drought brings a practical cessation of the growth of young seedlings.

CHAPTER II

CLIMATE AND SOIL

THE man who will establish a coco-nut plantation will, in selecting the location, take into consideration climate, soil, danger from diseases, quantity and quality of labour, the accessibility of supplies and markets, and the cost of the land. Labour supply, value of land, and markets are purely local questions, which must be settled in each place for itself. The diseases of the coco-nuts will be taken up in a separate chapter. With regard to the climate and soil, practically everything of fundamental importance follows directly from what has already been said with regard to the physiology of the coco-nut.

THE CLIMATE

Climate is made up of various factors, as temperature, moisture, wind, light, and electricity. With regard to electricity I can only quote Vanderstraaten,[1] who says: "It has been generally noticed that a highly electric condition of the atmosphere is extremely favourable (to the production of blossom), but here our knowledge ends." It is a matter of general observation that trees struck by lightning will die. And it is a widespread superstition in the Philippines that unless such trees are promptly cut down their neighbours also will die, but that if the tree which has been struck is immediately cut down, then it will be

[1] *Tropical Agriculturist*, *32* (1909), 28.

the only tree that suffers. The explanation is probably that a tree struck by lightning becomes a breeding-place for infection, and unless it is removed insects will breed in this tree and then attack its neighbours, and in this way they too are killed.

The light is a very important factor in the climate because it furnishes the energy for the formation of the organic food of plants. If other conditions are favourable the coco-nut tree cannot receive too much light. It therefore will not produce good crops in any place whose climate is characterized by prevailing cloudiness. For the same reason individual trees which are shaded by other trees by being planted too close together, or in any other way, will never be vigorous. Light also increases the temperature of the leaves, and in that way is favourable to the activity of the tree.

On the temperature the coco-nut makes such demands as are to be expected from a lowland tropical perennial plant. The figure usually given for the lowest tolerable average temperature is 22° C., and this is probably too low. At any rate no such luxuriant growth and production can be expected at this temperature as in places where the average is 3 degrees or more higher. This is to be understood as the average temperature for the year. A temporary fall to 15° certainly does no evident harm, and probably happens occasionally in all places in the tropics. Semler, whose discussion of climate and the coco-nut is most sane, suggests 10° as the lowest point temporarily tolerable. There is no evident reason why a still lower temperature, so long as it does not nearly reach the freezing-point, would do the coco-nut any considerable damage. However, the tropical climate is more distinctly uniform than it is hot, and the coco-nut thrives best where it is most constantly warm. So long as the heat is not too drying it is unlikely that coco-nuts are ever injured by too high temperature.

It is usually the temperature which fixes the limit in latitude and altitude to coco-nut culture. In individual places, however, there may be other limiting factors. For instance, in the coco-nut country immediately around Mount Banahao, the highest groves are in an exceedingly moist district, and the moisture, by favouring the spread of bud rot, makes coco-nut cultivation unprofitable in a zone where the temperature would still permit it. On any large scale this palm is cultivated only within 20 degrees of the equator, but in locally favourable places it is a profitable crop at least as far as to the tropics. There are grown trees as far south as Fort Dauphin in Madagascar, latitude about 25° south, and as far north as Lucknow in India, latitude about 27°, but they are said to be unproductive. They bear fruit at about the same latitude in Florida, but not on an industrial scale. The low shores of Florida, washed by the Gulf Stream, are probably the most northern point at which coco-nuts can be grown in the open even as curiosities.

The limit in altitude depends, of course, upon the latitude. In general, the coco-nut will grow at the greatest altitudes on, or a little north of, the equator. In Java, Ceylon, Mindanao, and Luzon there are bearing trees up to an altitude of 800 metres, but nowhere so high on a commercial scale. Grown, but unproductive, trees, are reported in India at a latitude of 12° north, at an altitude of 1350 metres. At Batan, Benguet, in Luzon, latitude 15°, and altitude 1100 metres, there are also unproductive trees, but so few and scattered that their sterility may be due to want of pollination as well as to the altitude. On a commercial scale, coco-nuts are grown only at much lower levels, the limit in general being about 300 metres in Ceylon and Malaya, and 200 metres in Polynesia. The reasons for these limits are in part climatic and in part commercial, the cost of marketing the product being likely to vary with the altitude. As one goes farther from the equator the coco-nut is naturally confined more strictly to the lowlands. In Jamaica the cultivation is chiefly below 60 metres, but few productive trees being found up to 275 metres.

In every land where there is any coco-nut industry, the moisture is a factor in the climate which requires much more careful consideration than does the temperature; for the temperature conditions are uniform over comparatively great areas, and are comparatively easily determined. The plantation of any size, which has not on itself considerable differences in the available moisture, is exceptionally uniform. Where there are considerable differences they demand their appropriate differences in the treatment of the coco-nuts, or else that parts be not used for this crop. Everything that is true and important with regard to the need of the coco-nut for moisture, follows obviously from what has already been explained about transpiration. The simple general rule is that conditions should be such as to permit the most active possible transpiration, without the tree's suffering from the loss of water.

The moisture needs to be considered in three forms: as rainfall, atmospheric humidity, and ground water. No rule can be given as to the tree's need of any one of these independently of the others. Speaking of whole islands, or of large tracts of country, the ground water depends upon the rainfall, but in small localities this is not at all the case. To a less extent still the humidity depends upon the rainfall; nor is there any nearly exact dependence of rainfall upon humidity.

The annual rainfall in a part of Ceylon which is noted for its coco-nut industry is 70 inches (178 cm.), and from the development of the coco-nut industry in this part of Ceylon the figure is often given as representing the need of the coco-nut. However, the tree flourishes in places in Ceylon (Negombo) where the rainfall is 2 metres. In various other parts of the world there is a prosperous coco-nut industry with still heavier precipitation; as 3 metres in part of Java, the Seychelles, Zanzibar, etc., $3\frac{1}{2}$ on the eastern coast of Samar, and even 4 metres in Dutch Guiana and the

Marshall Islands. On the other hand, the coco-nut thrives in the Puttalam district of Ceylon with a rainfall of 127 centimetres. On the Constance estate, the largest in Trinidad, the average rainfall is 156 centimetres, but there are years when it falls to 115 centimetres without injury, there being no dry season. Zamboanga has the best coco-nuts and the lowest rainfall in the Philippines. The average precipitation is probably less than 1 metre. Trees especially favourably placed are uninjured even when it drops to 413 millimetres, as in 1903, and even this limited amount almost all in one half of the year. In any dry season it can be observed that the trees begin to suffer when their supply of ground water is reduced, but not before that time.

High atmospheric humidity is commonly regarded as beneficial to coco-nuts. This idea is justified only in so far as too dry air may result in the tree's losing water faster than the roots can replace it. The absence of coco-nuts from Egypt and from the hottest part of Australia is due to dryness rather than to the heat. The plant has too poor absorbing structures to be expected to thrive beside the date. But if such extremes be left out of consideration and attention confined to such lands as have some coco-nut industry, it is probably safe to say that dryness of the air never hurts the coco-nut, except when it is accompanied by dryness of the soil. Coco-nuts on the sides and tops of hills, and on ground underlain by porous limestone, need to have the air quite humid, and very uniformly so, and the rainfall evenly distributed throughout the year. Coco-nuts are often planted in such places; but even with the best possible atmospheric conditions they cannot be expected to thrive like trees whose roots can constantly supply them with water for a more active transpiration.

Not humidity but dryness of the air is really favourable for coco-nuts whose roots are always and adequately supplied with water, and the wise man with free choice will plant his coco-nuts where this condition can be realized.

The injurious effect of very moist air is not confined to the checking of transpiration and consequent poor supply of mineral food. Extreme humidity is an indispensable condition for the spread of at least a part of the pests causing bud rot, and in this way can put geographical limits on coco-nut culture—limits sharper than are anywhere put by the dryness of the air. It is also reported that in Deli (Sumatra), too great humidity causes premature decay of the fruit. The bad effect of prevailing cloudiness has already been indicated.

The wind increases the transpiration, and, therefore, as long as enough water can be supplied by the roots, is beneficial; beyond this point it injures the tree. The point above which an increase in the amount of wind—whether in force or in constancy—will injure the tree, depends obviously on the amount of water the roots can take up. Where the soil is dry, but little wind is desirable; where the roots are constantly well watered it is desirable that the climate be decidedly windy. Where the soil is not moist enough for the trees to endure much wind, coco-nuts would probably still prove the most profitable crop, but the location is not a good one. On a little hill about 30 metres high on one of the Visayan Islands I counted the nuts on many trees, and found the average number more than twice as great at the foot as near the top.

Storms are, in their action on the tree, altogether different from ordinary, accidental or seasonal winds. Their effect on the transpiration might be good or bad, according to circumstances, but is in either case not important.

Reports are frequently seen of the destruction of considerable numbers of coco-nut trees by typhoons. As the chief coco-nut producing districts of the Philippines are subject to typhoons, and as the tree thrives in exposed situations, I have been interested in seeing what damage is actually done to it by storms. During several years of attention to this subject, including observation of the effect of a storm-wind reaching 168 kilometres an hour, I have yet to see the first sound trunk broken by the wind, or the first tree uprooted, unless its root system had already been exposed or weakened. Typhoons certainly do break sound coco-nut trees, but it is rarely indeed. Trunks extensively channelled by beetles are comparatively often broken; and trees, the roots of which have been laid bare by washing away the soil, or which grow in ground too wet to permit the healthy growth of the roots, are often overturned. The loss of such trees is not a serious matter.

Very severe storms weaken the trees and set them back materially by breaking the leaves; and they sometimes destroy a considerable part of the crop in sight by throwing down immature nuts, even the very young ones, but vigorous trees entirely outgrow such injury within a year.

However, in places where beetles, especially coco-nut weevils (red beetles), are a serious pest, violent storms furnish conditions for their entrance and multiplication, and in this way do damage which is neither insignificant nor transient. This will be discussed more fully in the treatment of diseases and pests.

THE SOIL

In books which deal with particular crops it is customary to give rules as to the soils which are suitable to the crops in question. In general, the same soils are described as desirable for all crops; so that any one who would undertake to follow such rules would find very little by which to decide whether a given soil ought to be used for coco-nuts or for some other purpose. Instead of giving directions of this kind, I propose to refer to what we know about the root system and the water relations of the coco-nut, and to trust to an understanding of these to give a better idea as to what can be expected of any particular soil than can possibly be done in a discussion based on descriptions of the soil itself.

There are, of course, certain general principles. These depend upon the facts that the coco-nut roots will not grow into water, and that they must always have a reasonable supply of water available for absorption. Exceedingly porous soils from which the water is drained readily are unsuitable because too dry. Still, the most porous soils can be used for the most successful coco-nut cultivation, provided for any reason their porosity does not result in their containing too little water for the use of the tree; this is the condition we find on the beach. Soils with an impermeable hard-pan near the surface are unsuitable for coco-nut cultivation because during rainy seasons they become full enough of water to seriously injure the roots. Very stony soils are unsuitable to coco-nut cultivation because in general sterile, and because they are likely to be dry. Still an almost ideal development of coco-nuts is possible on soils of this kind provided they contain water which bears the food necessary for the tree.

Under the head of suitable soils the first place for coco-nuts, as well as for most other crops, must be given to deep alluvial plains. Such soils are rich in food, easily worked, and even without cultivation usually permit a very perfect development of the root system. The most prolific trees I have ever seen were on such soil on the plantation of the Moro Plantation and Development Company near Zamboanga. One tree in this grove yielded 112 and 106 nuts at two successive cuttings only two months apart. I saw it less than two months later, and another similar crop was ready. The nuts were small, but even so the yield was at a rate of more than 100 kilos of copra a year.

As a matter of universal observation sandy sea-shores are suitable places for coco-nut cultivation. The reason for this is that they have back of them higher country, and the rainfall which falls on this higher country sinks into the soil and then moves in the soil toward the sea, carrying with it food which it dissolves as it moves. In time of drought, the amount of such water naturally decreases, but the seashore itself, being the place where such water necessarily comes close to the surface of the ground, is the last place to suffer from the scarcity of it. So long as there is enough water in the soil anywhere back of the beach to permit it to move through the ground, the beach itself will contain ample available fresh water, and in general the less of this water there is the richer it is in dissolved food. Beaches which have lagoons at the back of them instead of high grounds do not in general show an especially vigorous development of coco-nuts.

Since it is moving water in the ground which is primarily responsible for the high development of coco-nuts on seashores it follows that other situations which likewise have constant moving water in the soil furnish excellent conditions for coco-nut culture. Thus plains sloping upward from the sea, even for great distances, are good coco-nut country so long as there is still higher ground back of them from which they can derive a constant supply of soil water. The country around the bases of mountains, whether near the sea or far removed from it, is therefore good coco-nut country. One of the largest coco-nut forests in the world is situated in this way surrounding Mount Banahao. In this district, with only a few breaks between groves, there are more than ten million bearing trees. The country around the foot of an old volcano is more certain to be suitable than that at the foot of mountains of other origin, because the volcano is usually porous. The water which falls upon it sinks into the volcanoes more than it does into ordinary mountain ranges, and comes back to the surface, well-charged with dissolved food, at lower levels. Old volcanoes usually have great springs surrounding their bases. From the highest zone at which these springs appear downward, the land can be trusted to be excellent for the production of coco-nuts.

In general, soil which constantly contains free water is unfit for coco-nuts, and is unlikely to permit the development of a root system sufficient to hold the tree in its place or properly supply it with food. Still, if the level of the land is such that the water is moving in the soil, coco-nuts will be found in excellent condition on the edges of rice paddies, not more than half a metre above the level of the paddy. In the Kedoe plains of Central Java, and in the district already mentioned in Southern Luzon, and on the Coromandel coast in India, rice paddies and coco-nut groves are found mixed, with the patches of land most easily made into paddies devoted to rice. In such cases it will usually strike the eye at once that the coco-nuts standing at the edge of the rice are the most productive. This is probably due to their receiving the most light. While their being in this position is very good for the coco-nut, the contrary is the case with the rice.

There is a widespread belief that the coco-nut needs salt for its best development. This probably arises from the fact that coco-nuts are found thriving naturally on the seashore. It has been observed in Northern Ceylon that the largest crops are harvested from May to August, and some planters of that district explain this by believing that the south-west monsoon brings considerable salt in the rain-water. As a matter of fact, I do not know of any good evidence that the coco-nut demands salt for its best development; and the sea beach, even though it be beside the ocean, is found when analysed to be as free of salt as any of the land which lies above it. The coco-nut roots can indeed endure considerable salt, and are sometimes obliged to do so as a result of especially violent storms. Their power of resistance lets them thrive there in spite of occasional inundations with salt water which would kill the majority of plants. But the fact that the coco-nut can endure salt water is by no means a proof that

IDEAL COCO-NUT COUNTRY.

A crater lake at the foot of a volcano.

COCO-NUTS AND RICE PADDY FIELDS.

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it needs it, or even can make use of it. It has been observed in Singapore by Mr. Ridley, and I have seen the same thing in Mindanao, that trees planted on flats which are subject to inundation by high tide are strikingly precocious. Where I have seen this, however, there was ground water moving seaward through the flats; and I am not ready to conclude from the especially rapid growth and development of the young trees that this will prove to be a profitable place for bearing groves.

With regard to the chemical composition of the soil, it would be possible to say a good deal too much. Proper physical composition is of a great deal more importance than the ground's chemical composition, if only the plants are able to secure sufficient water. The water will usually contain enough food to permit the satisfactory development of the trees. Good chemical analysis is often impracticable for a coco-nut planter; and even if made, can by no means be trusted to show what the trees will be able to take from the soil. On large plantations where the obvious steps to ensure proper production have been taken, or when a man is preparing to invest very large capital in the establishment of a plantation, it is worth while to supplement care as to the soil's proper physical condition with some knowledge as to the food which seems likely to be available. It must always be borne in mind, however, that the food in the soil has no value so long as it remains there, and that only what is taken up by the tree itself will do any good. Chemical analysis will almost invariably show the soil of sandy beaches to be remarkably poor, and the same thing may equally well be true of other places where coco-nuts will do well because constantly supplied by moving soil water with fresh supplies of food. On the other hand, stagnant marshes will frequently show up remarkably well by chemical analysis, but still cannot be used for coco-nuts.

When chemical analysis is used as a guide to the prospective use of fertilizers, it should be remembered that the best natural conditions are likely to be those under which the profitable use of fertilizers is most difficult. For the moving water in the soil, which brings to the trees a natural supply of food, will likewise tend to carry away from them the food which may be artificially applied about their roots.

CHAPTER III

DISEASES AND PESTS

A. Constitutional Weakness and Diseases.—Under this head are understood all ailments which are not caused by living enemies. The most universal of these are the various effects of malnutrition, but the most certainly fatal, directly or indirectly, is old age. Sure as old age is ultimately to overcome every tree which escapes all other ills, the time of its coming, and the loss it entails, are by no means beyond control. Trees unfavourably located or badly treated, suffer the same decrease in thickness of trunk, in size and number of leaves, and in productiveness, finally reaching sterility, which mark the coming death of very old trees. Trees of less than middle age do not usually follow the course of very old trees to the extent of dying, but linger until their weakened condition makes them succumb to some more sudden death. Such trees are as useless before they die as afterward. When trees show symptoms of premature old age it is the planter's business to ascertain and remedy the cause as best he can. Unless the cause is climatic, and sometimes when it is so, the remedy will be clear if the cause can be found. The real cause may turn out to be a living enemy, or it may be too little or too much moisture, or faulty nutrition, or mechanical injury. When no cause can be found, the trees should be destroyed, to get rid of possible points of attack by, and centres for the spread of, living enemies. Very old trees inevitably become less productive, and at the same time the expense of harvesting the nuts and the danger of their breaking as they fall increase. The time comes when they are no longer worth taking care of and they should then be destroyed.

The effect of inadequate or improper nutrition may be shown by the same symptoms as old age, or in other ways. A tree growing without enough light will for some time bear at least as large leaves as any other plant, but the production of fruit will not continue long, because the shade makes the proper supply of the plant in both carbohydrate and mineral food impossible. Malnutrition may be with regard to the total food or to a single kind of food. The remedies in the former case are thinning the trees, cultivation, and irrigation or drainage. When the absence of only one or two of the food-elements is responsible for the bad condition, the want can usually best be remedied by the use of fertilizers. Unless the cause of weakness is very clear, or the need of action is much more urgent than it usually is, any proposed remedy (as drainage, irrigation, cultivation, thinning, or the use of various fertilizers) should be tested on a few trees before it is tried on a whole plantation.

In all cases, then, in which coco-nuts are in poor condition but no living enemy is to be found, the treatment consists in invigorating them by sanitary measures and better nutrition.

B. Pests.—General Considerations.—If a small community of men lives by itself, never seeing or having anything to do with other men, its members are in no danger from smallpox or syphilis. If, however, they had rats, and the rats came and went and associated with other rats, the community might be attacked by plague. With the growth of cities and nations, the opportunity for the spread of disease, and consequently the danger to each individual, and the necessity for strict sanitation, quarantine, and skill in medicine, are manifolded. Commerce and general intercourse between peoples add still more to the danger, having, for instance, introduced smallpox to America and syphilis to the Old World. The situation of any crop is in principle identical with that of man. When plants are cultivated on a small scale, and are widely and sparsely scattered, they are comparatively safe, but the development of a great industry in one of them multiplies its danger from disease. And this is made greater still by commerce; as, for instance, the coffee rust would probably not have reached Java and the Philippines by natural means of dissemination.

The most of the diseases of the coco-nut are like the plague of man in having other hosts as well, and may therefore attack a solitary and healthy tree. But every one of its infectious or epidemic diseases, so far as known, unlike the malaria of man, or the classic rust of wheat, can go through its whole life-cycle in the one host, and spreads directly from one coco-nut tree to another. Plantation cultivation on a large scale furnishes ideal conditions for epidemics. When great areas are brought under almost continuous cultivation, as in Ceylon, on the Godaveri delta in India, on the coast of Trinidad, and in Central Luzon, the danger from disease grows at least apace with the industry. The fact that almost nothing was published on coco-nut diseases until the last few years, or that as recently as 1906 Prudhomme could state that the important enemies and parasites are all animals, does not prove that fungus and bacterial pests previously did not exist and do damage. The bud rot in the West Indies and in Luzon existed so long before it attracted outside attention that nothing is known about its origin or first appearance in either region. But these and other diseases have increased very much in destructiveness, and as the opportunity for their spread improves they must be expected to become yearly more destructive, unless they are guarded against with a care which was formerly not suspected of being necessary.

It is worth while to remember, moreover, that the coco-nut is a perennial, and that it and its diseases find conditions in general constant throughout the year. Nature places no bar of winter to the spread of its pests. The field crops of the farmer in the temperate zones can at least easily be made to begin each season free of disease. No pest of temperate lands has ever wiped out a great industry, as the coffee rust did the coffee business of Ceylon. In the forests of temperate countries the great bulk of the vegetation over extensive areas is made up of at most a very few species, often of a single one. In the tropics the climatic opportunities for epidemics are so much greater that a characteristically different type of forest has been evolved, in which a great number of kinds of trees are present, and each is comparatively widely and sparsely scattered. Such a formation as a pine forest, or oak forest, or coco-nut forest cannot exist in nature in the tropics; and if men will plant and maintain forests of coco-nut, or any other single tree, in the tropics, it will prove to be possible, in the long run, only by greater care in guarding against disease than any crop of temperate lands requires.

The preceding discussion was written in 1909 as an introduction to a series of lectures on coco-nut pests. During the intervening four years about as many new pests have been described as all that were previously known, and more has been written on the subject than in all previous time. The end is of course not yet. In the study of coco-nut diseases the last eight years show an excellent record. The immediate future should show much greater devotion to practical interference with pests. Knowledge of the nature of pests and of the mischief they do, or even of methods of combating them, is not of great value unless it is applied.

FUNGI

A considerable number of fungi are known to live upon the coco-nut. Among these are two of the woody fungi (*Fomes*), which are parasitic on the trunks in the Philippines. These doubtless do some injury to the tree; and this will probably prove to be true of various others. Up to the present time, however, only four species are positively known to be destructive, and our knowledge of these is very recent. One of these, *Pythium*, will be taken up in discussing the bud rot.

Thielaviopsis ethacetica.—This fungus causes the bleeding diseases of coco-nut trunks in Ceylon. It usually shows itself at a height of 2 metres, more or less, above the ground. It is described by Petch, in papers read before the Ceylon Agricultural Society, as follows:

> A brown liquid oozes out through the cracks in the cortex, and forms a rusty patch which usually turns black afterwards. On cutting into this patch, the internal tissues are found to be discoloured and decaying; they are brownish and finally turn black. If the diseased area is cut in wet weather, the liquid sometimes squirts out; in fact, it may in some stages be collected in a glass by simply pressing on the diseased patch. After some time other black patches appear on the trunk, usually on the same side. When this happens, it will generally be found that this is not a new infection, but that the disease has worked up or down inside the stem, and the liquid has found a new outlet. I have seen trees which looked as if a bucket of tar had been poured down one side of the stem. It is important to note that there is no sign of the disease until the liquid oozes out, and that when this occurs the internal tissue is already decayed to some extent.

In about two or three years the hard outside of the trunk falls away. The crown gradually becomes smaller; and the roots wither more or less completely at a depth of about a metre. The tree may die in five or six years, sometimes more quickly.

Young bearing trees, up to say twenty years, are most susceptible. Very old trees are attacked, but comparatively little injured. The disease occurs on all soils, swampy, sandy, or rocky, manured or not, near the sea, and inland.

With regard to treatment, Petch says:

At the first appearance the diseased part should be cut out, the wound burnt with a torch, and then covered with hot coal tar. The pieces cut out must be burnt. When the disease has advanced so far that this local treatment is impossible, the tree must be cut down and burnt. This treatment is said to have been successful.

Reports in subsequent years indicate that the disease is well under control.

One planter stated that he had known the disease for sixty years, but it was first made a subject of report in 1903. It was found along the Negumbo Canal, at Hendala, also at Nalla, where in 1906 more than 3000 trees were found infected. None had died, and the yield was not evidently affected, but the disease was spreading. The disease is also known at Veyangoda, Kurunegala, Mirigama, Heneratgoda, Marawila, Ambalangoda, and Dumbala. It is also found in India. However, Butler has found the same fungus on the trunks of various apparently vigorous palms in India, and does not regard it as at all injurious. The same fungus does not necessarily produce the same effect under different conditions; and, as is true of various human diseases, there may be light forms and dangerous forms of the one pest.

This fungus is also charged with causing the pineapple disease of Javan cane, another disease of cane in Hawaii and the West Indies, and the canker of coffee. Rorer reports a bleeding disease of coco-nut trunks in the West Indies caused by *Thielaviopsis paradoxa*, the same fungus also attacking sugar-cane and pineapple.

Pestalozzia palmarum.—This is a microscopic fungus parasitic on the leaves of the coco-nut. It was first described from British Guiana, but seems to occur throughout the tropics. While it must always weaken the trees, it does not often itself kill them, and is not known to have become even locally very destructively epidemic except at Kempit, in the Banjoewangi Presidency, Java. This outbreak was studied and reported upon by Bernard. The first symptoms are the appearance of minute whitish spots; these grow and become grey-brown, with a narrow white border; finally the centre dries. The spots are usually elliptic in shape.

The disease was first reported at Kempit in August 1905, and the Director of Agriculture recommended that the infected parts of plants be burned, and that the plants be sprayed with Bordeaux mixture. In January 1906 it was reported that the disease was making destructive progress, and Bernard was sent into the field. It was found that in order to burn the diseased leaves they had been cut and then carried across a field hitherto free of infection to the place of burning. One field of 50 bouw, 5000 trees, and an adjacent one of 70 bouw, 7000 trees, had almost all the trees infected. The soil was virgin and rich, and there was no dry season. There were 150 bouw, 15,000 trees, a little over a year old, 3 kilometres away, separated from the diseased fields by forest; these were free from the disease. In the field of 50 bouw more than half of the trees were so seriously attacked that there was already no hope of saving them. About 1000 were already dead, and 650 had already been replaced. In this field the trees were just over a year old. In the 70-bouw field the trees were recently set out, and the disease was doing less injury.

The period of incubation, as determined by putting some diseased leaves in the crown of a sound isolated tree, is about two months. The failure to get results from the use of Bordeaux mixture in these fields is attributed to the probable fact that the trees were generally infected before it was used. The disease is not regarded as dangerous except to weak trees. At about the age of a year, they have used up the nourishment in the parent nut, and are not at once in a condition to vegetate without it vigorously enough to resist the fungus.

Bernard's recommendations are:

1. That plants likely to be exposed be sprayed with Bordeaux mixture—2 kilograms of copper sulphate in

50 litres of water, poured into 2 kilograms of lime in 50 litres of water—at intervals of fifteen days. One should take especial care to reach the youngest leaves. The use of corrosive sublimate is also suggested.

2. Cut all infected leaves and burn them *in situ*.

3. Watch for the reappearance of the disease.

4. In the case in question, sacrifice the 50 bouw worst infected, and use the land for some other crop for a year or so.

5. In planting, avoid planting great numbers of equally old trees at once, so that many may not at once reach the susceptible age. Also, leave barriers of other crops, or interplant crops which will overtop the young coco-nuts until they pass the time of danger.

Another fungus, *Helminthosporium incurvatum*, follows *Pestalozzia*, and contributes to the injury. *Pestalozzia* is also found in Java on tea, Pará rubber, guttapercha, and other plants, to which it usually does no evident harm. It should always be kept in such check as is practicable, to keep it from doing serious damage when conditions become temporarily more favourable for the fungus than for the host.

Horne states that, though never known to be itself fatal, this is probably doing more damage than any other fungus disease of coco-nuts in Cuba. Because of its prevalence, it was at one time supposed to be the cause of bud rot.

Stockdale has investigated what he regards as merely a geographical variety of the same disease in Trinidad, and furnishes the following information in regard to it:

> Many trees have leaves which appear to be drooping, and with the tips of the distal leaflets of a greyish colour. An external examination of the leaflet shows that whereas the tip is quite dry and dead and many parts of the edges of the leaflet are in a similar condition, there are small yellowish spots, more or less regular in shape, which may be observed to increase in area. . . . During the growth of the spots, they gradually change from a yellowish colour to a greyish white, and each is bordered by a margin which is of a dark colour,

generally an intense greenish brown. . . . After a time, when a large number of disease spots have made their appearance, the whole leaf assumes a yellowish appearance, and gradually becomes greyish and withered. . . . When a large number of the leaves have been badly attacked the terminal bud is left standing alone, and it is only a question of time before this falls over, and the death of the palm results. . . . Close examination of the upper surface of the leaf of one of the disease spots when it has assumed the grey colour shows minute warts not larger than the head of a small pin. They are blackish-grey in colour, and are irregularly distributed, often being very numerous. . . . These small pustules bear the spores of the fungus. . . . The distribution of this fungus appears to be fairly general in Trinidad, but it is a serious pest in only two districts.

Stockdale advises that all dead trees be cut down, and all dead material burned. If a tree has but a few diseased leaves, these should be cut off and burned, and the tree watched for more. If a fungicide is tried, Bordeaux mixture is recommended.

Preuss reports *Pestalozzia* as doing serious mischief to seedlings in the Bismarck Archipelago.

Diplodia.—The exact botanical standing of the fungi which cause the disease or diseases to be described next is still in doubt. This is not a matter of merely scientific interest, but one of very practical importance; for so long as we do not know just what organisms cause each of the forms of disease in question, we are not likely to know that the diseases of petioles and those of roots are or are not identical, nor whether or not the coco-nut and cacao harbour pests dangerous to each other. Without such knowledge preventive measures must be taken partly in the dark, or else grave risks be run.

The following account of the Trinidad "root disease" is extracted from the report of Stockdale, who regarded it in 1906 as the most dangerous of the three diseases he found on that island:

An attack of this disease is generally first shown by the leaves. They show a slightly wilted appearance, then turn yellow, first at the tips, and then gradually all over the leaflets. These dry up, blacken, hang down from the "cabbage," and often remain for a considerable time before they are shed.

The petiole partly or completely breaks. Sometimes the outermost, sometimes some other cycle of leaves is first to wilt.

After the yellowing of the leaves, trees bearing a good crop of nuts as a rule gradually shed most if not all of them, irrespective of their size and state of development, and the flowers subsequently produced do not set. In fact, it is possible for a person to pick out with certainty trees that are diseased, before any yellowing of the leaves is noticed, by carefully looking at the condition of the leaves and at the latest flowers that are being put forward.

The general appearance is similar to that produced by drought. Petioles of badly diseased trees, after they fall to the ground, almost always show a large number of minute ruptures of the epidermis. The first point of attack appears to be where the petiole merges into the sheath. The fungus bears hyaline, unicellular spores, capable of germinating in this state, but these at full maturity become two-celled and brown. Patouillard classified it as a *Botryodiplodia*.

The roots of the same trees always have a fungus, which destroys the cells of the cortex. This fungus has not been seen to fruit, but is believed to be the same as that which attacks the petioles. The wood in the trunk is reddish in the parts connecting with diseased roots and petioles. As the trees die with the symptoms of drought, and in some cases diseased roots were found on trees with sound petioles, it is believed by Stockdale that it is by attacking the roots that the fungus does most serious injury. In the Guapo and Cedros districts "three or four months is usually the time that intervenes between the first external symptoms to the death of the tree, and usually within another three months a ring of diseased trees is noticed around the dead stump. In Mayaro the disease is much less prevalent, and the death of diseased trees does not take place so rapidly," taking nine to twelve months.

It would appear probable that the disease may spread:

(1) By mycelium through the soil from root to root.

(2) By spores blown from tree to tree.

(3) By germinating tubes of spores from petioles attacking either the roots of the same tree or the roots of another.

(4) By germinating "chlamydospores" from decaying petioles.

There are six principal ways in which we may hope to attack this disease. They are:

(1) Destruction of all diseased material.

(2) Isolation of diseased areas (by a trench 30-45 centimetres deep).

(3) Resting of infested land before planting "supplies."

(4) Spraying and application of chemicals.

(5) Improved cultivation and drainage.

(6) Searching for and propagating disease-resistant varieties.

The first of these ways is the most important. If chemicals are to be used, unslaked lime is recommended for the soil and Bordeaux mixture for the leaves.

While it has not been found possible positively to identify the fungus on the roots in Trinidad, a fungus infesting the roots in Travancore has been cultivated by Butler, and found to develop as a *Botryodiplodia*. It is highly probable, but not certain, that this is the same fungus which causes the root disease in Trinidad.

The disease has long been known in Travancore, but has only of late years been recognized as the cause of great damage.

Very recently Hart has inoculated a healthy cacao pod with the *Botryodiplodia* from coco-nut petioles, and produced all the symptoms of the "brown rot" of the cacao. The fungus growing on this infection differs from *Diplodia cacaoicola*, the specific cause of the brown rot, only in having slightly larger spores. It is not yet possible to state positively that the brown rot of cacao is identical with the coco-nut disease. But it is certain that they are very nearly related, and that in at least one direction an infection may pass from one tree to the other. *Diplodia epicocos* is a very common fungus on dead coco-nut leaves in the American tropics, which has generally been regarded as quite harmless. *Diplodia* and *Botryodiplodia* have spores exactly alike, but are supposed to differ in that the former bears its reproductive structures directly on the vegetative ones, while the latter develops from its vegetative filaments a solid dark mass of fungus tissue, on which in turn the reproductive cells arise. It is perfectly possible that the same fungus should produce its reproductive bodies directly from the vegetative under some conditions, as on the pod of cacao or on the dead leaves of coco-nut, but indirectly under others, such as it finds on the coco-nut petiole and roots.

The latest word on these fungi is that of Bancroft, recently Mycologist of the Federated Malay States, who raised an ascospore form of the *Diplodia* on Hevea, certainly the same as that infesting cacao, and showed that its proper name is *Thyridaria tarda.*

According to Fredholm, the fungus causing the petiole disease, which he calls *Diplodia*, very generally initiates the bud rot in Trinidad. From the careful description of the symptoms of the latter in Cuba, given by Horne, this seems possibly to be the case in that island as well. The damage done by *Diplodia* by creating conditions favourable to the spread of bud rot might prove many times as serious as anything it can do directly and by itself. However, Bancroft writes that he has often found it on diseased buds of coco-nut in the Malay States, but regards it as a mere saprophyte.

An unknown fungus is said to attack the nuts themselves in British Guiana. Another is reported from Vitilevu, where it destroys the lamina of the leaves, leaving the midrib naked; this reads more like the work of some insect.

As already noted, there are many fungi saprophytic on the coco-nut. There are several dozen of these in the Philippines. It is very probable that some of these have the power to advance the decayed tissue in which they live, at the expense of any living tissue which may adjoin it. But there is no reason to suspect any one of these of being able to attack a sound tree, or of being a serious additional enemy of injured trees.

BUD ROT

The most incurable and, unless strongly handled, the most dangerous diseases of the coco-nut are the bud rots. These attack the soft young tissue at the apex of the stem, and sooner or later destroy the growing point itself. Since the coco-nut does not branch, and never renews its growing point, this immediately stops the formation of new leaves and flowering branches, and very soon kills the tree.

Except in the case of the Godaveri River bud rot and that of the West Indies, the organisms causing these diseases are not positively known. Whether or not they themselves cause the disease, gas-producing bacteria are always present in the rotting mass and produce a vile odour. From a diseased or dead tree, spores or germs can be carried by insects or by the wind to other trees. When a tree is once infected by bud rot, it is practically impossible to save it in any way, and energetic action must be taken to prevent the spread of the disease. Bud rot has been reported in the West Indies and about the Caribbean Sea, in Portuguese East Africa, in Ceylon, in the delta of the Godaveri River in India, and in Luzon. Since different organisms seem to cause the bud rot in different parts of the world, and the disease therefore does not everywhere run through the same course, it is worth while to describe the symptoms and the methods of treatment tried in the different regions.

India.—A bud rot in Travancore is described in the *Indian Forester* of 1894 and in a letter in Ferguson's *All about the Coco-nut.* It is a

. . . decay of the tender, unexpanded leaf-shoot. At first, the lower end of the shoot grows discoloured, and in a few days general putrefaction of this and more or less of the cabbage ensues; the shoot droops, and in some cases falls to the ground; the tree decays soon after, and we are left lookers-on and losers. . . . It is only the most vigorous trees that are, as a rule, affected.

The natives were said to ascribe it to falling stars.

A bud rot of the Palmyra and other palms near the mouth of the Godaveri River is said to have been seen as long ago as 1894, but was not reported until 1904, and not, at this point, on the coco-nut until 1905. Butler published a careful study of this disease in 1907, at which date it infested a circle of about 14 miles radius. The first symptom is a discoloration of a recently expanded leaf, which then turns white and withers; other leaves follow; the nuts fall prematurely and no more are formed.

The leaf-sheaths of all diseased trees are marked by irregular sunken spots in greater or less number. In the earlier stages . . . the spots are white; later on they become brown. They are always sunken, and usually have somewhat raised edges. They begin in the outer sheaths and may be traced in through succeeding ones toward the heart of the bud. As the inner layers are softer, the inside patches are often larger than those outside, and may even give rise to new patches which extend out again to the outside sheath. . . . The earlier patches are dry and either free from any appearance of a parasite on the surface or covered with a white mycelial felt. Very soon a wet rot follows, which extends with great rapidity in the delicate central tissues and converts the whole heart into a foul-smelling mass of putrefaction, in which everything is involved and the original agent is lost sight of.

It is only in the early states before the wet rot starts that the true cause can be made out. This is a fungus of the genus *Pythium*. . . . In quite young spots the mycelium is found only within the leaf tissues, where its threads extend between the cells, sending little branches or haustoria into them. . . . Later on it comes out on the surface, forming often a dense white felt of filaments bearing sporangia. There is no positive information as to its dissemination. No remedial measures intended to cure trees already attacked are possible.

It was at first recommended by Butler that all infected trees be burned, and that apparently healthy trees in infected districts be treated with Bordeaux mixture. A considerable force of men was employed in the immediate restriction of the disease in this locality. As a result of experience under the local conditions, the use of fungicides was given up, and the work concentrated in the cremation of the sources of infection.

A report of Mr. Macrae, Entomologist of the Government of Madras, reports that in spite of all that it has been possible to do to restrict this disease, it is up to the present time continuing to advance at the rate of a little over a mile a year. With minor exceptions the area affected remains continuous. The advance has naturally been impeded for a time by such barriers as river channels and palmless areas, but on the whole has progressed in all directions at a remarkably even rate. The campaign against it has resulted in a considerable decrease in the mortality. The intensity of the disease varies. Along water channels, on the side of paddy lands, and on heavy or wet soil in general, the mortality is greater and more rapid than in drier situations. There is enough evidence now available to show that the disease spreads:

1st. Chiefly by palm climbers.

2nd. To a smaller extent by insects (palm weevils and rhinoceros beetles).

3rd. Occasionally by the wind and by birds.

The disease continues to attack the Palmyra palm chiefly, the coco-nut being comparatively immune and the Areca still more so. The coco-nut is rarely tapped for toddy and the Areca never, and this is probably the reason for their comparative immunity. There is no doubt as to the share which is played by insects also in carrying this disease. The rot has been found especially prevalent near certain fishing villages, where there were piles of decaying refuse, in which the coconut beetles could multiply freely. Getting rid of coconut beetles is one of the methods of restricting the spread of the disease.

From numerous infection experiments it appears that the time from infection up to the death of the growing point is up to ten months. Field observations would extend this period almost to two years, and three years or more may pass before the palm is reduced to the bare pole. It is reported that there are rare cases of recovery even after a great part of the crown has withered. This is due to the growing points having escaped injury. Such trees remain susceptible and usually die as a result of renewed attack.

Ceylon.—Bud rot is reported by Petch as having appeared in Ceylon in 1906. It was found only in a small isolated patch of 10 acres, about 800 trees, of which 50 were dead or dying. The infected trees were three or four years old, and old trees were not found ailing.

The first indication of the disease (in the case of young plants) is the withering of the youngest unfolding leaf. This turns brown, and can be pulled out of its sheath; it is then found to end in a soft brown mass. . . . The decay of this leaf is followed by that of the other fronds in succession, commencing with the youngest and proceeding outwards and downwards. The fronds decay and fall off until only a conical stump remains. If the dying fronds are removed and the bud exposed, there will be found, instead of the white cabbage, a pale-brown semi-liquid mass, which becomes dark brown with age and possesses an odour resembling that of a tan yard. In an advanced stage this rot includes the whole of the cabbage, and stops only when the woody portion of the stem is reached.

The organisms responsible for this decay are bacteria, which are found in abundance in the rotting tissues; they are short thick rods with rounded ends which form whitish colonies of slow growth on sugar agar. . . . These bacteria appear to find an entrance to the cabbage along the youngest leaf.

Diseased trees should be felled and the terminal bud burned. It should not be allowed to lie on the ground and become dry. . . . If steps are taken to remove dead and dying palms as soon as they are observed, there need be no fear that this disease will become a serious menace to coco-nut cultivation. Felling and burning diseased trees is no doubt an expensive process, but it must be remembered that the work is of the nature of an insurance effected on the remaining trees, and its cost should be estimated in terms of the survivors, instead of being compared with the actual value of the trees destroyed.

Close planting favours the spread of the disease, by preventing the evaporation of moisture from the young shoots.

The bud rot in East Africa is known from a letter cited by Petch, who quotes from it: "If the dead tree is not immediately destroyed by fire, the disease rapidly spreads to the neighbouring trees, and finally throughout the whole plantation."

Luzon.—The history of epidemic bud rot in the province of La Laguna, in the Philippines, is here given at some length because the measures employed against it have in this case proved their thorough efficiency. The disease was first reported in 1907, but had existed in the region for many years. The description of it is taken from a report made by myself in 1908.

In the badly infested districts there are patches where almost every tree is smitten, and larger ones where fully half of the trees are dead or dying. Under conditions favourable to it the disease will kill half of the trees in a single year. Under less favourable conditions it is less violently epidemic; and in its present form it will never prove violently destructive in most parts of the Philippines. The fact that a given tree escapes one year is no guarantee that it will not be killed the next. Under conditions favourable to the disease it is only a question of time, unless vigorous restrictive measures are carried out, when practically every tree will succumb.

The climatic condition permitting the disease to be exceedingly destructive is a very moist atmosphere. Bud rot is epidemic only in the upper belt of coco-nut country about Mt. Banahao, which is one of the most humid districts in the Islands. The coco-nuts at the foot of San Cristobal, which are comparatively unreached by the wet ocean winds, are free from bud rot. Below the zone where the bud rot is most at home, there is of course a region in which infection can occur under conditions temporarily favourable, or affecting single trees or small localities. As every tree for miles around is likely to receive the germs, it is inevitable that in this lower zone some will be infected each year. As these die the damage is cumulative, and the gaps caused in lower groves increase in number or size.

But there is no good evidence that the region in grave peril is widening downward.

Further evidence that humidity is a condition of contagion is found in the fact that young trees are more susceptible than old ones. About the crown of old tall trees the air moves comparatively freely, and keeps them comparatively dry. For every old tree killed, two which are just coming into fruit, or would do so within a year or so, die, although the total number of such trees is naturally much less than that of adults. On the other hand, very young trees, of two years or less, are comparatively rarely attacked. Since humidity is the condition of easy infection, the extension of the disease occurs principally during the most humid season.

The first symptom, always in young trees, and almost always in old ones, is the yellowing and wilting of the youngest still folded leaf. The disease attacks the soft undifferentiated tissue of growing points. It is likely that infection normally occurs where the germs can get direct access to these points without penetrating through mature tissue; but the germs might also be borne by insects which could carry them in through mechanical lesions in old tissue. In young trees the youngest leaf presents the only possible path of direct unaided infection; and, however infection may occur, the youngest leaf is directly inserted in the tissue susceptible to rot, and must die before the rot embraces the most of the soft tissue commonly called the cabbage. As soon as the youngest leaf is noticeably discoloured, it can easily be drawn out. The next youngest leaves follow in rapid succession. Within from two to four months after the disease can first be detected, the most of the leaves will have fallen. A few of the oldest leaves grow from tissue so hard that the rot makes little or no progress in it; these leaves, four to a dozen in number, persist for months after the younger leaves are gone. It is in this stage, with a thin whorl of old leaves crowning the stem, that the most of the diseased trees are found. These leaves very likely fall only when their natural time comes, uninfluenced by the rot.

In the case of old trees, the young flowering branches, like the youngest leaves, spring from the soft heart. Infection can occur along these branches, and they can give the first external sign of disease; but these are exceptional cases. Branches whose nuts are more than half grown are grounded in tissue so mature that the disease does not usually prevent the nuts from ripening. But no new nuts are set after the appearance of the rot, and the youngest nuts almost or quite always fall without becoming ripe.

As is true of bud rot everywhere, the decaying tissue has a powerful and vile odour. The stench is very characteristic, but not easily described; one of its components is the smell of tan. Several organisms have been isolated from the decaying bud, but no one has been proven to be the cause of the rot.

Some of the owners of groves have found that if the first leaves affected are pulled out, and the rotten mass removed as completely as possible, new leaves will sometimes appear afterward, and that in some of these cases the tree recovers. One planter states that 25 per cent of cures can be effected in this way; but I believe that if any trees ultimately recover they are exceedingly few. For practical purposes the tree, once it shows any symptoms of the disease, is valueless, and the thing to be done is to prevent the spread of the disease from it to other trees. The use of any disinfectant chemicals, unless in the hands of experts, cannot be expected to be effective, because of the difficulty in making them reach every part, or even any part, of the diseased tissue.

The only agent which can be relied upon to destroy the organisms is fire. Every tree which shows symptoms of the disease should have its heart, and the structures immediately around it—the apex of the trunk and the bases of the leaves—completely burned. During the drier months this is a matter of but moderate difficulty, but during the rainy season it can be done only by the use of kerosene. A vigorous campaign of six months should so restrict the disease that it will cease to be a serious menace to the coco-nut industry.

This recommendation had been made a year earlier by a botanist of the Bureau of Science, without any result whatever. It has been made by every one who has made a study of bud rot; but a mere recommendation will not stop a pest. In this case, while the field study was being made, and after it was finished, pains were taken to talk with as many as possible of the men owning or in charge of coco-nuts in the affected region, and to give practical demonstrations of what ought to be done. The municipal councils were then persuaded to pass ordinances requiring the burning of all infected trees. These ordinances had no legal force, being beyond the power of the municipalities. But they showed the disposition of the people and officials of the towns, and so made it easy to get similar legislation by the Provincial Board, and then to keep up the interest of the town officials in its enforcement. The Act passed by the Provincial Board of La Laguna and still in force is as follows:

Whereas it has been represented to the provincial board by duly qualified inspectors of the Bureau of Education and by the owners of coco-nut plantations and the municipal officials of various municipalities that in certain districts of this province, especially in the jurisdiction of Lilio, Nagcarlan, and Magdalena municipalities, the agricultural pest known as bud rot has killed many coco-nut trees, is becoming widespread, and is a serious menace to the coco-nut groves throughout the province: Therefore, be it hereby

Resolved, That by authority of law the provincial board hereby approves for the entire Province of La Laguna the following resolution:

Any owner or lessee or person or persons having the management of coco-nut plantations, coco-nut groves, or coco-nut trees shall, upon the appearance of the pest or disease known as bud rot, immediately report same to the president of the municipality in which such trees are located.

Further, Such owners, lessees, managers, person or persons who receive information, either by observation or otherwise, that the coco-nut trees are dying because of the pest or disease known as bud rot, or from any cause known or unknown, shall immediately report the matter to the municipal president of the municipality in which such trees are located.

Each municipal president is hereby designated as an inspector *ex officio* of the provincial board, for the purposes of this resolution, and shall, upon receipt of information that the disease known as bud rot exists or has appeared, immediately inspect such trees and require the owner, manager, or "encargado" of such coco-nut trees to cut down such trees and destroy completely, by burning, the crown or top of every tree so cut down and having the disease known as bud rot.

Further, Any municipal president, as inspector, who fails to take the action required by this resolution and especially the foregoing paragraph, shall be punished by a fine not exceeding P. 200 or thirty days' imprisonment, as may be decreed by the court having jurisdiction.

Further, That when any owner, manager, or "encargado" of coco-nut trees refuses to cut down and destroy completely the top or crown, by burning, of all trees having the disease known as bud rot, the destruction of which is authorized or directed by the municipal president as inspector, he shall be subject to a penalty consisting of a fine not exceeding P. 200 or thirty days' imprisonment, as may be decreed by the court.

For the purposes of this resolution, all inspectors duly appointed by the director of education have the same authority as conferred by this resolution on the municipal president as inspector *ex officio*. Such inspectors appointed by the director of education are hereby authorized to enforce the provisions of this resolution in the same manner as the municipal president, *i.e.* by charging any person (or persons) who refuses or fails to comply with the inspector's order to destroy the trees having the disease known as the bud rot before the court of proper jurisdiction.

For the purposes of this resolution, and under authority of section 13 of paragraph (*k*) of Act No. 83 as amended, the provincial board of the Province of La Laguna hereby confers jurisdiction upon all justices of the peace of the Province of La Laguna to try violators of the foregoing resolution or regulations, and there is hereby appropriated out of any funds in the provincial treasury not otherwise appropriated a sufficient amount for the necessary expenses in paying costs of prosecutions before justices of the peace.

Be it further resolved, That six certified copies of this resolution be furnished each municipal secretary; one copy for the municipal president as inspector, the other five copies to be posted in five conspicuous places in the municipality. A certified copy shall be furnished each justice of the peace, a certified copy to the director of education, and a certified copy to the honourable judge of the Court of First Instance of the Sixth Judicial District.

This resolution was passed March 13, 1908, but almost immediately rescinded under orders from Manila. It was re-enacted October 14, and this time followed by a very vigorous campaign of fire, although the season was far from favourable. Three months after this work began a tree showing symptoms of bud rot had become an uncommon sight. In the villages I visited at this time the new cases appearing were certainly not one-tenth as numerous as they had been a year before. I have since made a practice of visiting this district once or twice every year. This year, 1913, for the first time since the vigorous campaign against bud rot, I found half-a-dozen dying trees in the course of a walk of several miles, and these I suppose were burned immediately afterward. The absolute extermination of a pest is usually impossible, and the disease will probably become epidemic again at some future time if given a chance. But for the present it is practically harmless.

The means by which bud rot was reduced to practical harmlessness in La Laguna are the same which should be taken wherever any epidemic must be fought. They are three:

1. Determining the most practical field measures.

2. Securing legislation strong enough to ensure concerted and vigorous action.

3. Educating the people. If any one of these is more important than the others, it is the last. Printed matter ought not to be relied upon to do this anywhere; it is not convincing enough. The most of the villagers of the Laguna coco-nut country cannot read at all, but they would have had to be shown in the same way in any case.

America.—Bud rot is known in the West Indies and on the American continent in various places. The earliest dates which can definitely be placed on its known presence are 1870 in Cuba, 1875–6 in Demerara, 1891 in Jamaica, 1889, with a probable report as early as 1834, in Grand Cayman, and 1893 in Honduras. It received no real study until the last decade, but has recently received more attention here than in any other part of the world.

Cuba.—In Cuba it was considered dangerous enough to demand the appointment of a commission for its study in 1883; in 1901, Busck, an entomologist of the United States Department of Agriculture, was sent to investigate it. He was unable to make more than a guess at the cause of the disease, but, irrespective of the particular organism causing it, soundly advised the destruction of all diseased material. Immediately after this the Jamaican bud rot was reported by Earle as bacterial. In 1904, Dr. Erwin Smith, the foremost authority on bacterial diseases of plants, made a personal visit to the infected districts in Cuba; and other visits were subsequently made under his direction.

The Estación Central Agronomica de Cuba began the investigation of the disease in 1904. The results of this study were published by Horne. John R. Johnston has since published a monograph on the subject. The disease is certainly known from Havana to Artemisa, at Cardenas, Cienfuegos, Manzanillo, Banes, on the coast west of Santiago de Cuba, and practically throughout the Baracoa district. A plantation cannot be established in any part of the island, with any reason to feel safe from the appearance of the disease, before the trees are mature. Horne believes this to be true of all the neighbouring areas, although the disease is unknown and apparently not present in Puerto Rico.

The description of the disease is taken from Horne:

In a bearing tree the first symptom noted is usually that the young nuts drop. The half-grown nuts usually fall a little later, but often a few ripe nuts hang on the tree until it is completely dead. After the dropping of the first small nuts the flowers will be seen to be blackened and, as the disease advances, the flowers and racemes will be blackened when the sheath bursts and allows them to protrude.

As the disease advances still further, younger swords (*tetas*) are affected and their development is stopped. When these affected swords are examined, on the surface of the outer sheath there is a rot which evidently is progressing downwards. In the case of the youngest ones this may penetrate into the cabbage of the trunk, but those nearly ready to burst before being affected have never been found with the rot following down to the trunk. Evidently the tissue of the lower part of the stalk of the opened flower cluster is too hard. Infection of the inner sheath always follows that of the outer, and that of the rachis is still later. Single flower buds are found blackened inside the still unopened sheaths, where apparently there is no chance for the entrance of insects or the introduction of infection.

During these studies no case has been found in which the disease had attacked and destroyed part of the flower clusters and finished its course, leaving the rest of the tree healthy, although in the very severely attacked groves at

Baracoa one very beautiful flower cluster opening on one side of a tree has often been seen and many young nuts still attached on the same side, while on the part of the tree towards the prevailing winds and facing the worst affected portion of the grove, all nuts ~~had~~ were dropped and the young flower clusters seriously affected.

The dropping of part of the nuts of a cluster, or of all the nuts by trees just coming into bearing, cannot be taken as evidence of bud rot.

Fading or turning yellow of the leaves is the symptom by which it is generally possible to recognize the disease in trees of all ages. This is generally first noticed in the case of some of the oldest leaves. . . . The leaves gradually become light yellow, and the leaflets dry from the tips and sides. As the disease progresses the leaves become weak and break with the wind in various ways, the lower ones usually falling off. Examining a mature leaf which is about dead, nothing can be found on the leaflets or outer petioles to account for the trouble, but on the upper surface and at the base there is more or less decay, and this usually reaches a little way into the trunk.

The most characteristic symptom of the disease is the rotting of the youngest undeveloped leaves in the centre of the top. This symptom generally appears after the others have become well developed, but it may be the first one noted. The first stage of this is the appearance of watery decayed spots on the surface of the unopened leaves.

If a very young leaf with only the growing point coming out into the air is affected, it rots rapidly, and, from the base of the tree, nothing is seen to be wrong until the bud is examined. [By analogy with the accounts of the Trinidad bud rot, this is what is to be expected if the disease is caused by bacteria alone, without the presence at first of fungi.]

Once well started the rot moves down along the surfaces of the undeveloped leaves, rapidly penetrating the tender tissues and destroying them completely. . . . The whole central column is converted into a soft stinking mass. When the terminal bud is reached it rots, and the tender upper end of the trunk also.

The tree is usually in the advanced stages within one or two months from the time the first signs of the disease appear. Usually three or four months more elapse before the stump is left bare. . . . So far as our observations go, there is in nature no recovery. Apparently all genuine cases of bud rot prove fatal.

Johnston says that from two months to two years may intervene between infection and death.

Various insects and fungi are found associated with the bud rot; prominent among the latter are *Pestalozzia* and *Diplodia*. The disease spreads chiefly in the direction of the prevailing winds.

Basing his advice apparently on Jamaica experience rather than on his own, Horne recommended two remedial measures:

Flaming, or burning out, the tops of all early cases, or trees suspected to have the disease.

Spraying with Bordeaux mixture in the hope of curing early cases, and for the protection of healthy trees.

With regard to his own experience with burning out the material of the crown, Horne says:

> A trial of flaming to cure sick trees was carried out by the present writer at Baracoa in the summer of 1907. . . . No tree was saved which had a well-developed case of the bud rot, and none was saved in the part of the grove where the disease was in its most destructive form. Some of the flamed trees which had been very carefully observed, and which evidently had the disease when treated, were apparently recovering at the last visit in September. Treatments were made in March, June, August, and September.
>
> The effect of burning a tree depends to a great extent, first, on the weather; second, on the condition of the tree.

Of 144 trees treated in March, June, and August, 1907, 113 were already dead in September. The remaining 31 were said to be apparently recovering.

The use of Bordeaux mixture was not given a good test in Cuba. Five pounds of common salt was scattered into the top of each of five trees supposed to have bud rot; all died with the usual symptoms except one, and it is doubtful if this one ever had the disease.

The chief reliance has certainly to be placed on the careful destruction of the diseased trees, to get rid of the sources of infection. The means of destruction are the same the world over. As another preventive measure, Horne suggests the use of wind-breaks as barriers to the spread of the disease. Strips of natural timber, left when forest land is put into coco-nuts, can be expected to have a limited value in this way against the spread of this and other diseases. Close planting is certainly favourable to the spread of the disease, and is to be condemned for this as well as for other reasons.

The Cuban Government made an appropriation of fourteen thousand dollars to carry further the study of this disease, but without results of value.

Jamaica.—Remedial measures have been better tested in Jamaica than anywhere else. The flaming method originated here. The Director of Agriculture reported in 1905 that "Mr. Cradwick has been engaged at intervals during the last two years in applying various remedies suggested by me. These experiments are still in progress, but I may say that I find the most effectual remedy is to spray with the Bordeaux mixture, at intervals of six to nine months, until there is no trace of the disease."

The mixture used was:—

Copper sulphate . . .	6 pounds.
Lime	4 ,,
Water	50 gallons.

More definite reports showing the value of Bordeaux mixture have since been made, applying, of course, only to cases in the early stages of the disease. Advanced cases are destroyed. The cost of buying chemicals and applying the mixture is estimated at two pence in Jamaica. This is cheaper than it is possible in most countries to do the work well enough to give any chance of success. Mr. Fawcett is quoted by Horne as stating that "a variety known as 'green skin' in Jamaica is to a large degree resistant, and that the San Blas is the worst affected variety."

Trinidad.—In Trinidad it has been established by Fredholm to his own satisfaction that bud rot appears in two forms. One of these is caused, so far as it has been possible to determine, by bacteria alone; the other by bacteria following an initial attack by a fungus, which Fredholm calls *Diplodia*. If one may judge at a distance, from the descriptions of the symptoms, he will conclude that both forms occur throughout the American tropics, and that the complicated form is decidedly the commoner and more dangerous.

Stockdale's report, already quoted for other diseases, takes up also bud rot, and under this head deals almost entirely with the purely bacterial form. Quoting from him:

> The youngest leaves appear to stand upright and do not unfold as they should. Afterward they turn yellow and then brown in colour, and the whole appearance is that of a withering tree with the centre of the cabbage in an unhealthy condition. . . . After a time the terminal bud falls over, frequently leaving a ring of quite healthy-looking leaves at the top of a "headless" trunk. . . . This rot, in a diseased palm that is still standing, is invisible until the harder outer coverings of the bud are removed and it is found to be limited to the softer tissues. . . . A badly diseased bud is generally full of fly larvae, etc., and the smell is awful. . . . Microscopic examination of the roots and stem indicated that they were quite normal, while those portions of the terminal bud, in the advancing margin of the disease, showed in most cases bacteria of different kinds.
>
> The few isolated cases in the Cedros district would indicate that this disease is not of a very infectious character, but large numbers have been killed out in the Siparia district, the spread being very rapid and apparently from the windward. . . . It would appear to be largely due to unfavourable conditions of soil, drainage, etc. . . . With our present knowledge of the nature of the disease, it is impossible to suggest a remedy for trees that are already infected, and therefore steps must be taken for preventing its spread. It is suggested that the top four or five feet should be cut from the diseased trees and buried deeply with lime.

Fredholm also found a few cases of bud rot in which no *Diplodia* could be found with the microscope, and in which the characteristic symptoms of the latter were absent. When the bud rot is purely bacterial, then, the first symptoms are shown by the youngest leaves.

In the complicated bud rot the first attack is made by the *Diplodia*. Quoting Fredholm:

The earliest sign of the disease is retarded growth of the "set" fruit, soon followed by the dropping of immature nuts. At the same time none or very scant new fruit is "set." Next, some of the leaves, generally the lower, begin to droop and turn yellow at the tips, which yellowing progresses until the whole leaf is involved. About the same time that the leaves become discoloured the basal portion of the petioles commences to show a dark-brown discoloration. Shortly the leaves dry and are found hanging down along the trunk, finally falling either as a whole at one time, but not infrequently breaking and coming down piecemeal. Thus leaf after leaf withers, until all are hanging from the "crown." But long before all the leaves have dried, or even become yellow, the last leaf just emerging from the top of the "crown," and as yet unexpanded, will be seen to shrivel and die.

The pustules already described in connection with the *Diplodia* disease can be found on the bases of the petioles. The death of the tree is to be expected three months after the first symptoms are observed.

If the crown of an infected tree is split, the usual decay of the cabbage will be encountered. Unless putrefaction is too advanced, the sides and top of the decaying region will be found bordered with a reddish tissue.

Not seldom similarly discoloured areas will be found at the base of a pedicel or a petiole below and at some distance from the cavity and unconnected with it. Such conditions, when met with, serve to illustrate matters of great importance, as will be perceived when the mode of introduction of the disease is studied. This discoloured material, if examined microscopically, is found to consist of cell-tissues undergoing destruction by the mycelium of a fungus. If the petiole is split open its tissues will also be seen to be discoloured and permeated by strands of mycelium.

The disease is endemic . . . and is not infrequently met with in the high woods. It is highly infectious, and after gaining a foothold in a plantation it speedily becomes epidemic.

Evidences point to the wind as the main factor in the distribution. The disease is seen to progress more rapidly in direction with the prevailing wind, but the spores do not seem to be carried great distances, as it has been observed that patches of open land or low intervening hills can contribute barriers affording protection to a considerable degree.

Although air-currents are the principal agencies of distribution, no doubt exists that the disease can also be conveyed by insects. . . . Instances of infection by means of insects are often found on diseased plantations, and to this agency can be attributed isolated cases of the disease occurring at considerable distances from infection centres. Such isolated cases, if not properly treated, will soon develop into new centres.

The disease is spread by means of the two kinds of spores produced by the fungus. In common with other members of the genus *Diplodia*, it is a wound-parasite, *i.e.* effects its entrance into the host through wounds. When a spore falls on a cut or otherwise ruptured surface, it quickly germinates, producing a mycelium which with great rapidity pushes its way into the tissues of the host, and the first phase of the disease is established. The disintegration and softening of the tissues consequent on the growth of the fungus facilitate the entry of the bacteria, which readily find the way to the interior succulent parts filled with nutriment, wherein they set up their destructive fermentation process.

The most usual point of attack has been found to be the "common pedicels" of the fruit clusters, into which the fungus gains entrance through the wounds made when picking the nuts. It is a well-known fact that this disease rarely attacks palms not arrived at the age of bearing—and the reason is very patent. Carefully conducted inoculation experiments in the laboratory have established the fact of wound infection.

Fredholm holds out no hope of saving any tree known to be infected. Good cultivation is urged as likely to make trees more resistant. The planter's energy should be focussed on sanitation. "Burning by some method or another" is advocated. Fredholm seems to know from experience that burning completely is not too easy. And it must be complete to have any value. The more promptly it is done the better. The trunk should not be split unless necessary, as it burns. The use of lime is also suggested. A vigilant watch for fresh outbreaks is urged, and it is noted that

Diplodia spores can germinate after at least three months.

First and foremost among measures tending to prevent the entrance of the fungus into the palm is the doing away with all unnecessary wounding of the trees, maliciously, thoughtlessly, or otherwise. The cutting down of dead leaves is uncalled for. Nature will bring them down in due time, and no wound will result. Whenever a wound is inflicted it should at once be dressed with tar or some other aseptic preparation, and such dressing should be frequently inspected and renewed when required.

Fredholm advised dressing the wounds made in cutting the nuts. Commenting on this, Mr. W. Greig of the Cedros estate says:

All practical planters, I am sure, will realize the impossibility of having this done thoroughly, and unless it is done thoroughly, it is worse than useless, so I suggest that picking be stopped on estates suffering from this disease, and that the palms be allowed to drop their nuts. This would necessitate a little more expense in keeping undergrowth down, and in collecting nuts, but the nuts would be of better quality than picked nuts.

Where the nuts are used for copra-manufacture or, as is general practice in Trinidad, for oil-making on the plantation, the product is likely to show a very prompt increase in value, as a result of leaving the nuts to fall off themselves.

The full account which has just been given of observations and conclusions of different men at different places in the West Indies is justified by the tremendous importance of the subject, and by the discrepancies between the different accounts. While all of these reports have been made within the last seven years the most comprehensive treatment by Johnston is later than any of those already quoted, and a brief but pithy statement by Rorer has been published since the appearance of Johnston's work. Johnston's most signal contribution to the understanding of the subject is the absolute demonstration that bud rot can be produced by *Bacillus coli*. This has been established by isolation and identification of the germ from diseased trees, and by the inoculation of previously healthy trees with pure cultures of this bacterium, even by cultures of animal origin, and the consequent production of the disease. A few of Johnston's experiments seem to indicate that other similar bacteria may also produce bud rot; but it is certain that in the great majority of cases this organism is present and pathogenic. This fact is completely confirmed by Rorer, who has found, moreover, that, whether or not infection is sometimes or usually at points already injured mechanically or by fungi, a culture of *Bacillus coli* poured into the crown of an apparently perfectly sound tree is able to produce the disease.

Neither Johnston nor Rorer believes that *Diplodia* has anything to do with the bud rot. In this connection Rorer says:

> Although Stockdale has attributed the root disease to a species of *Diplodia,* there is no ground for this assumption. In fact, work which has been carried on here for the past two years points to the conclusion that physiological conditions, rather than any specific organic parasite, are responsible for the trouble.

I take the liberty of saying that Bancroft, whose especially thorough study of *Diplodia* in the Federated Malay States has already been mentioned, expresses the decided opinion that this fungus is not an active parasite, and is accordingly very unlikely to be a precursor of bud rot.

In spite of the joint judgment of these latest writers, I have thought it worth while to give the conclusions of Fredholm and Stockdale with considerable fulness, not merely for the sake of completeness, but also because their work in itself seems at a distance to be entitled to some respect. It is difficult to believe, even from Johnston's own account of the various ways in which the symptoms of bud rot develop, that a single organism is always entirely responsible. When the first symptom is the fall of the older leaves, one who holds to the opinion that the disease is always purely bacterial must suppose that the bacteria either attack the old leaves directly or that the progress of the disease toward the heart of the tree is very slow in such cases, and that recovery in such cases is not rare.

With regard to treatment, Johnston has made a careful test of some of the remedial measures repeatedly suggested in the West Indies. In his experience none of these offers any promise. With regard to chemical treatment, Johnston reports experiments with salt, copper sulphate, and Paris green, without good results in any case. His report on tree No. 286, page 57 of his work, is typical.

March 11: Nine spikes of nuts and good open flower spike.
May 28: Same.
June 6: Practically the same.
June 29: Appeared unhealthy.
July 6: Had dropped 15 immature nuts; 5 spikes of few nuts; and above were 5 or 6 spikes of no nuts; 3 good swords and good middle leaves. Placed 1 kilogram of copper-sulphate crystals at the bases of the leaves. Rains were so frequent that the crystals were soon dissolved.
July 21: Showed one open discoloured flower spike.
August 6: Only 2 nuts and many empty spikes on tree; a dead flower spike, opened some time ago, and one just opening.
October 21: Central leaves bent over dry and dead; swords dead; many empty spikes; all leaves yellow.

Johnston did not try flaming the trees because satisfied in advance it would be useless.

It has been contended by some people applying this treatment to their trees that there was subsequent recovery from the disease, at least to the extent of flower spikes opening out and setting nuts. It should be noted, however, that the tree, while retaining the disease, may send forth new flower-spikes and nuts for a period of at least a year after infection has taken place without any treatment having been applied. The writer possesses records of individual trees which show this. In many trees flamed the disease progressed subsequently, so that it presented to the writer no evidence of the value of this treatment. As a diseased tree is certain to die if not treated, there can be no error in flaming it; but to try this method with healthy trees in the expectation of warding off infection is not advisable, because (1) there is no evidence that the treatment would succeed, and (2) there is the certainty that the tree would be seriously injured in a way that would make it more susceptible to infection.

My own experience with fire in healthy tree makes me very sceptical as to the advisability of attempting to save trees by this method, especially in any place infested by *Rhynchophorus.* The most favourable of all the reports on the result of flaming, showing a possible saving of 31 out of 144 trees, has already been noted. The red beetle is not, indeed, as dangerous a pest as the bud rot; but the difference is not great enough to make it worth while to apparently save less than one-quarter of the trees from the one pest at the cost of making them subject to the other.

Altogether there are two conclusions which can certainly be drawn at this time with confidence that they will permanently hold good:

First: The best way of fighting these diseases is by destroying the sources of infection.

Second: Attempts to save infected trees are at best a waste of time and effort. Even if some trees are saved, it is at a cost for the whole work of more than those saved are worth. When unsuccessful these attempts lose time and preserve sources of infection. If I had stopped to test the efficiency of remedial measures, as I was urged to do by some of the coco-nut planters of La Laguna, I would not merely have delayed checking the bud rot, but at the same time would inevitably have lost the confidence of the people to an extent which would have made such success as was achieved impossible.

INSECT ENEMIES

Oryctes rhinoceros.—This is one of the two decidedly most important insect enemies of the coco-nut. It is most commonly known to the English planters in the Orient as the black beetle.

The Rhinoceros Beetle.—In the French colonies it is usually called "Rhinoceros," and this name is also used in English and German (*Nashornkäfer*). ~~Of these~~, the Tagalog name "Uang" and the Cingalese name "Kurunimiya" have been taken up in literature. This species, *Oryctes rhinoceros*, ranges from India at least to the Dutch East Indies and the Philippines. It is not yet known in Polynesia. *O. rhinoceros* is unknown in Africa and Madagascar, but is represented by a number of related species having the same habits. Prudhomme names *O. anglias*, *O. colonicus*, Coq., *O. insularis*, Coq., *O. pyrrhus*, Burm., *O. ranavalo*, Coq., and *O. sinnar*, Coq., as found in Madagascar. Vosseler has made a study of *O. boas*, F., and *O. monoceros*, Ol., in German East Africa; and Morstatt reports and figures the remarkably large *O. cristatus*, Snell, from the same region. *O. preussi* is reported from New Guinea.

It has no immediate relative dangerous to the coco-nut in the American tropics, although an American species of *Oryctes* does prey on another palm.

O. rhinoceros attacks several other palms as well as the coco-nut; among them are *Elaeis* (oil palm), *Borassus* (Palmyra palm), *Roystonia* (royal palm), *Nipa*, *Corypha*, and perhaps *Areca* (betel palm).

The adult rhinoceros varies from 34 to as much as 60 mm. in length according to sex and the condition under which the larva grew; as a rule the males are between 40 and 50 mm. long, and the females less than 40 mm. Both are very dark and shiny brown or practically black above, and lighter brown beneath. The head is small for so large an insect, but conspicuous, at least in the male, because of the horn. In large males this is often a centimetre or more in length. In females it is smaller, and sometimes hardly evident. The mandibles are stout and strongly toothed, and, as pointed out by Banks, used by the insect in making

THE BLACK OR RHINOCEROS BEETLE, *ORYCTES RHINOCEROS*
ADULTS AND PUPA.

Photograph by Bureau of Science, Manila.

To face page 64.

his hole in the tree. The thorax has a large concave area in the front, and back of this a point which is sometimes quite prominent in males. The hard wings are finely striate lengthwise, and do not quite cover the abdomen. The legs are hairy.

The egg of *Oryctes* is not positively known except from specimens dissected from the females. These specimens are 3·5 mm. long, and 2 mm. in diameter, being a perfect ellipse in outline. The total number of eggs deposited by one female is probably not more than two dozen.

Beginning at the size of the egg, the larva grows until it sometimes reaches a length of considerably more than 1 decimetre and a diameter of usually not more than 1 centimetre. The head of the larva is black, and the body, which is made of thirteen more or less indistinct segments, varies in colour from dull white to brownish yellow. There are no eyes. The front three segments of the body are provided with legs. The entire body is wrinkled, soft and fleshy, smooth in spots, and in spots bearing fine spines. It is ordinarily found bent downward in the same general form as the grub of *Rhynchophorus*. But, unlike the larva of *Rhynchophorus*, it is not greatly thickened posteriorly. There is no satisfactory and definite information as to the length of life of a larva. According to various authorities, it is usually from eighteen to twenty-four months. Vosseler fixes the life of the larva of the species he studied at at least one year.

There is likewise no general agreement as to whether or not this larva is injurious to the coco-nut tree. It lives without question in the decaying wood of the coco-nut; and as young larvae are frequently found in decaying parts of the standing trunks, there is no reasonable doubt that the eggs are laid in these places. I have never seen the larva of the black beetle in any part of a coco-nut trunk which was not considerably decayed, and am therefore inclined to believe that these larvae do not channel the way through the fresh cabbage of the tree. If it is true that they live only in more or less decayed wood, then the larva itself is not to be regarded as directly injurious to the coco-nut, but merely as a thing which should be got rid of because of the damage which it might do in the future in another form or in other generations. The grubs are found in a great variety of decaying substances beside the decaying coco-nut wood or refuse. Favourite places of these grubs are decaying manure and decaying sugar waste, but wherever there is any considerable mass of decaying vegetable material there are likely to be a large number of *Oryctes* larvae growing in it. It is a common thing to find scores of these larvae in a small pile of rotting manure; and the manure dump from a large stable is sometimes found fairly filled with these larvae in all sizes. The following quotation from the *Tropical Agriculturist*, 22 (1902), 258, shows how readily the black beetle will breed in any kind of waste matter:

Mr. E. V. Carey writes from Klang to the *Malay Mail* as follows:

> As instancing the danger of having any sort of rubbish lying about an estate, or in private compounds, the following little anecdote may be of interest. Some four months ago I had to discard a number of old sacks; these were thrown in a heap on the ground, covering a space just six feet square, and left there. Last week I had happened to notice them, and stood by whilst they were being removed. From this one little heap no less than 201 larvae of the rhinoceros beetle were collected. . . . Moral: Let every one keep his grounds scrupulously clean, and have even the insignificant and harmless-looking collections of rubbish promptly burned.

The cocoons are found in any places where the larva can live. In going from the larval to the pupal stage, the insect shrinks greatly in size so that the length of the entire cocoon is likely to be rather less than that of the larva, the pupa itself being not more than half as long as the larva was. The cocoon is made of different substances. The cocoons whose larvae lived in the coco-nut are made of coco-nut fibres, which are usually transversely and quite compactly matted altogether.

As already noted, the adult of *Oryctes* is provided with jaws by means of which it can cut its way through hard wood. Its practice, however, is to go through as little hard wood as possible. We are not concerned here with the method of its entrance into other breeding or feeding places. In entering a coco-nut tree, the rhinoceros lands in the crown and then walks downward until he is out of sight between the leaf sheaths, or often not so far but that the place is visible when it turns and begins to eat its way inward into the tree. As a rule, it eats fairly directly inward. The only certain object of the rhinoceros in visiting coco-nuts is to obtain food. It does not seem, however, that it eats any of the pieces which it chisels or tears from the tree. It squeezes these pieces and consumes the juice which is squeezed from them. The rate at which the beetle can tear its way through such tissues as those of the base of a mature petiole has been measured by Banks and by the students of the Philippine College of Agriculture, and in both cases found to be 1 millimetre a minute.

So large a beetle, of course, makes a very large hole. This would itself be conspicuous enough unless covered by leaf bases outside the point where the hole begins, but is made still more so by a plug or wad of torn-up fibres which the beetle pushes out behind itself as it digs deeper into the tree. If a fair watch be kept over a coco-nut grove, as is done wherever a number of men are steadily employed to kill the beetles, these wads will be readily seen while fresh, and it is then easy to remove them and to remove or kill the beetle by means of a sharp piece of iron, or even of bamboo. In some places the practice is merely to kill the insect by punching a hole through it; in others, a spiral wire, like a flexible cork-screw, is used, by means of which the beetle is removed and killed. The catching and killing of these insects has been done with especial care in the British colonies of the Straits Settlements and Federated Malay States, and Ceylon; but in a smaller way it has been practised in many other countries where these beetles occur.

Experience as to the effectiveness of this warfare has not been uniform. In Ceylon it has not been found that, as beetles are caught year after year, there is any decrease in the number of black beetles which can still be caught. On the other hand, there has been a very great decrease in the number which can be caught in the Malay States and Straits Settlements. The reason for this is without doubt to be found in the warfare of an altogether different kind which has been waged in the Straits Settlements and Federated Malay States at the same time at which the beetles were being collected and killed individually.

This latter warfare is against the larvae of the beetle and consists of the destruction of their breeding-places. The first systematic piece of work in coco-nut sanitation on the part of any Government was the Coco-nut Trees Preservation Ordinance of the Government of the Straits Settlements, passed in 1890. This was amended in 1895, and has since that time been in force.

The terms of this ordinance as amended are as follows:

STRAITS SETTLEMENTS

Ordinance No. IV. of 1890.

An Ordinance for the Protection of Coco-nut Trees from the Ravages of certain Beetles.

6*th March* 1890.

L. S. Cecil C. Smith,
Governor and Commander-in-Chief.

Whereas it is expedient to make provisions for the protection of coco-nut trees from the ravages of certain beetles:

It is hereby enacted by the Governor of the Straits Settlements with the advice and consent of the Legislative Council thereof as follows:

1. This Ordinance may be cited as "The Coco-nut Trees Preservation Ordinance 1890."

2. It shall be the duty of the owner or person in charge of every coco-nut tree which is dead or is attacked by the beetle secondly described in the schedule forthwith to uproot such tree and either to consume it with fire or to bury it in the ground at a depth of not less than three feet, or to keep it completely submerged in water so that the beetle and all eggs and larvae thereof may be totally destroyed and that the tree may not serve as a breeding-place for any or either of the beetles in the schedule mentioned.

3. If any person without reasonable excuse (the burden of proof whereof shall lie on the accused) neglects or refuses to perform the duty imposed upon him by the last preceding section, he shall be liable to a fine not exceeding five dollars for every tree in respect of which such neglect or refusal occurs, and the Director of Gardens and Forests, or the District Officer, or such other Officer as the Governor may appoint in that behalf, may cause to be performed the duty so neglected or refused to be performed, and may recover the cost of such performance from the defaulter in the Court of Requests.

4. (1) If any person keeps on his premises dead coco-nut trees or stumps of coco-nut timber, rubbish heaps or other accumulations of dung, vegetable refuse or other matter which would be likely to harbour or become breeding-places for the said beetles, and neglects or refuses to remove or destroy the same when required so to do by a notice in writing from any of the persons mentioned in the next following sub-section, he shall be liable to a fine not exceeding twenty-five dollars.

(2) A notice in writing under the last preceding sub-section may be given by any of the following persons, namely:

(*a*) The Director of Gardens and Forests.

(*b*) Any District Officer.

(*c*) Any Officer whom the Governor may appoint in that behalf.

(*d*) Any owner or occupier of land planted with coco-nut trees and situated within one mile of the premises on which such dead coco-nut trees, or stumps, or coco-nut timber, or other accumulations of dung, vegetable refuse, or other matter are kept.

(3) Upon the conviction of any person under this section the Magistrate may make an order authorizing:

(*a*) The Director of Gardens and Forests,

(*b*) Any District Officer,

(*c*) Any Officer appointed to give notice under sub-section (2) hereof,

(*d*) Any Police Officer,
to cause such trees, stumps, timber, rubbish heaps, or other accumulations to be removed and destroyed, and any person so authorized may do all acts necessary for the execution of such order and may recover the costs of such removal and destruction from the defaulter in the Court of Requests.

5. All Officers of the Government Gardens and Forest Department, and the District Officer and his assistants, and any such other Officer as aforesaid, shall have access at all reasonable times into and upon any land whereon any coco-nut tree is growing for the purpose of inspecting such tree, and also into and upon any land or premises where there is reason to suppose that there are kept any such things as in the last preceding section are referred to.

6. The Governor may from time to time, out of moneys to be voted by the Legislative Council, make such compensation as he may think fit to any owner of any coco-nut tree who, being in needy circumstances, is required to destroy such tree: provided always that the compensation shall not exceed five dollars for each tree, and that the compensation given in one year to any one person shall not amount to more than one hundred dollars.

7. A person charged with an offence against this Ordinance may, if he thinks fit, tender himself to be examined on his own behalf and thereupon may give evidence in the same manner and with the like effect and consequences as any other witness.

Passed this 6th day of March 1890.

A. P. Talbot,
Clerk of Councils.

In the Federated Malay States the campaign against beetles is carried on under "An enactment for the protection of coco-nut trees from the ravages of certain beetles" (Enactment IV. of 1898). This is patterned after the enactment of the Straits Settlements, from the amended form of which it differs most essentially in giving no authority to the owners of coco-nut plantations, but in centering the entire responsibility upon the employees of the Government. For this work the Government of the Federated Malay States employs an Inspector, two European Assistant Inspectors, and sixteen Sub-Inspectors, who are mostly Malays. The best endorsement of Acts of this kind is the results which are obtained in their operation. The results have been so conspicuously good that these Acts should stand with the Laguna bud-rot resolution in a class by themselves, as legitimate models.

The methods to be followed then in getting rid of black beetles are:

First.—To get rid of every possible breeding-place for the larvae. This must be done for considerable districts in order to be effective. Any single planter who takes the proper care will naturally fail to obtain the proper immunity for his coco-nuts if the plantations of his neighbours are not kept in equally good condition.

The campaign against the black beetles should be carried out in the way which has already been described in the case of the bud-rot. The individual owners of coco-nut trees and plantations, and other occupants of lands in the neighbourhood of coco-nuts, must be made individually to understand the evils of permitting any breeding-place for the black beetles to exist on their premises. Laws or ordinances, varying more or less in their application as the circumstances may demand, must be passed and must be enforced. The thoroughness of practical enforcement will depend on the thoroughness with which the campaign of education has been carried out. It must be kept constantly in mind that there are many other substances in which these beetles breed just as rapidly as they do in the decaying wood or rubbish of the coco-nut, and that these other substances—manure, cane waste, or of whatever nature—must be got rid of just as carefully as the wood of the coco-nut itself. It should also be understood that *Oryctes*, at least at times, breeds in the ground, where it is in general beyond the reach of effective attack. The destruction of visible or accessible breeding-places, however it may abate the nuisance, can therefore not be expected to get rid of the pest completely.

Second.—When all of the measures provided for in the preceding paragraph have been vigorously executed, then, and then only, it is worth while to undertake a campaign against the individual beetles in the coco-nut trees. The most effective way of fighting these which is known at this time is by killing them with a sharp iron or stick in the holes in the tree, or pulling them out of the holes and then killing them. After this is done, it is a good practice to plug the hole with a piece of clay, or in any other handy way, in order to prevent other beetles from entering easily in the same place. In some places the beetles are said to be driven out by merely pouring water into the holes.

Third.—It has been observed that trees which are tapped for the production of toddy are rarely, if ever, attacked by the black beetles. These beetles are frequently found drowned in the vessels which are used to catch the sap, and it may be that the freedom of the trees from attack is entirely due to the greater attraction for the beetles which is exercised by the sap as it begins to ferment. In groves which are rather severely infested by beetles it is a good practice to use a considerable part of the trees for a few months for the production of toddy in order to get rid of the beetles, even though the toddy is hardly profitable in itself. In neighbourhoods where the beetles are constantly numerous, and where it is impracticable to get rid of the outside sources of infection, it will be found good policy to tap occasional trees, even as many as one tree in every four, for the sake of the protection of the tapped trees and their neighbours. Where there is a demand for the toddy, it is not an unusual condition that the trees which are tapped yield higher returns than those which are used for the production of copra. This method of fighting beetles therefore has a great advantage over all others in that the campaign can itself be made a source of profit instead of expense.

There are other ways of less importance which have been advocated for the suppression of these beetles. Considerable work has been done at the Philippine College of Agriculture in an attempt to poison the beetles without poisoning the trees. It has been found that with sufficient care this can be done by means of carbon bisulphide or hydrocyanic acid. Except in the most expert hands, however, neither of these can be used without some danger to the tree, and both are dangerous in the hands of careless persons. Neither can be advised for general plantation use. The use of salt, and of sand and ashes, or best of all of very finely ground glass, any of them sifted among the leaf-bases of the crown of the tree, has been recommended as a means of keeping the beetles from going into individual trees. The immunity which can be provided in this way probably rests upon the irritation of the beetle by particles which get between the segments of its body and cut into him; but this immunity is at best only partial. Either poison or this method may sometimes be used to good purpose in protecting individual trees which are especially valuable, as, for instance, where they are used for decorations on lawns; but on a plantation scale it has not been shown that the use of the ashes or other fine particles produces a sufficient freedom from attack to make it worth practising.

Since the completion of this manuscript, three papers have arrived, dealing with the presence of *Oryctes rhinoceros* in Samoa. The most comprehensive of these, being in the nature of a review, is in the Gardens' *Bulletin of the Botanic Gardens at Singapore* for December 1913. A very full account of the work is also given by Friederichs in *Der Tropenpflanzer*, 17 (1913), 538. The beetle is supposed to have reached Samoa in 1910, or possibly in 1909, in a shipment of rubber stumps from Ceylon. It was first noticed, November 4, 1910, in coco-nuts near the Customs House at Apia.

Quoting from the Singapore publication, by Burkill:

On the 8th of November 1910, the Government of Samoa issued a proclamation in vernacular to the effect that the beetles and their grubs should be collected, and promising a reward of one mark (36 cents) for every twenty beetles and the same for every fifty grubs. Seventeen days later a law was promulgated stopping coco-nut planting, ordering the cleaning up of all existing plantations, forbidding the using of coco-nut trunks for bridges and pig-styes, and arranging for inspections. About £2000 was the cost of this method of dealing with the pest up to the end of January 1912, and yet no satisfactory impression had been made on its numbers. Therefore on the 1st of February 1912, it was made compulsory to search for and destroy the insect. Following this there was issued on April 19th, 1912, a decree calling into being a commission with powers to inspect and compel owners of coco-nuts to keep their estates clean, and to remove structures made of coco-nut trunks, or standing dead trees, at the owner's expense. Then on the 10th of May 1912 appeared an order requiring all able-bodied persons in the affected districts to turn out at six o'clock on every Wednesday to search for beetles and grubs, which were to be brought to the village headmen, counted and destroyed by fire or hot water. Into this great holocaust passed the grubs of beetles which happen to be similar to those of *Oryctes*. Friederichs names them specifically; but their number is a matter for estimation. From the 1st of April 1912 to the 31st of March 1913, roughly, ten million grubs and a quarter of a million beetles were collected and killed on the island of Upolu; allowing for the grubs of the similar beetles, Friederichs puts down the *Oryctes* larvae destroyed as six million and the beetles as two hundred thousand—a nice little family originating in a few grubs imported in 1910 or possibly 1909.

To this figure has yet to be added the number of the grubs and beetles collected on the European Plantations. On the estate of the Deutsche Handels- und Plantagen-Gesellschaft der Sudsee-Inseln zu Hamburg over the same period were collected and destroyed about 350,000 grubs and 23,200 beetles. Further, the number of insects trapped by the Commission over the same period was 180,000 eggs, 776,000 grubs, 220 pupae, and 11,300 beetles.

A plant pathologist was secured from Germany, particularly to fight this beetle, and a considerable force has been employed in the campaign, both by the Government and the leading plantation company. Almost every method has been employed, and these are fully described and discussed in Friederichs' paper.

The method which has given most satisfaction is trapping the insect in holes.

For the making of a trap a hole is dug in the ground from nine to twelve feet square, and about two and a half feet deep. Rotten coco-nut stumps, plantain stems, and soil are put into it; and over the top large leaves, such as coco-nut leaves, bread-fruit leaves, and plantain leaves, are placed, rising perhaps a foot above the surface of the soil. Into these pits the female beetles penetrate to lay eggs and the male beetles to find the females. What beyond digging the traps is necessary is that they should be opened at regular and at not too distant periods, or that the beetles in them may be in some way killed.

At distances of about one hundred yards along some of the roads in Samoa these traps have been made in series, and on the plantation of the Deutsche Handels- und Plantagen-Gesellschaft there is one trap to every hundred standing trees.

On the latter estate the traps are opened every six weeks or two months.

Burkill's paper contains a considerable amount of information on this beetle in other countries, including a review of a careful study at Pusa in India. He believes that under favourable conditions six to seven months are enough for the insect to pass from the egg to maturity, and with this opinion I am in complete agreement. The paper closes with an account of *Rhynchophorus*, which is short and altogether to the point.

Rhynchophorus ferrugineus.—This pest is most commonly known as the red beetle, the name used by the planters of Ceylon and British Malaya. Banks calls it the Asiatic Palm Weevil. Its native name in Ceylon is "Kandapanuwa." In Annam it is called "Con-Duon." The Tagalog of Luzon do not distinguish it from "Uang," which is usually *Oryctes*. Some Visayans of Samar call it "Dalipos," and those of Negros, "Bagangan," but these names are also applied to *Oryctes*. It is the most deadly insect of the coco-nut, but, since it cannot attack sound trees, not the hardest to combat. Its known range is from India to the

Philippines,[1] and it is almost certain that it reaches to New Guinea. Beside the coco-nut, it attacks some other palms, but no plants of other kinds.

Other species of *Rhynchophorus* having the same habits are *R. phoenicis* in Africa, and *R. palmarum* in the West Indies and on the American continent. And there are other species with *R. ferrugineus* in the Far East. What is said here about its treatment applies equally to its immediate relatives. *R. palmarum* lives also on sugar-cane.

The red beetle belongs to a group of insects, the weevils, practically all of which are destructive to vegetable substances, and among which it is remarkable for its great size. The adult varies from less than 3 to more than 5 centimetres in length. Like other weevils, it has a boat-shaped body narrowing to both ends, and a long, slender snout, the end of which curves downward. The female is said to use the snout to punch holes in the tree, and to lay her eggs in these holes. The short antennae are attached to the snout near its base. The head is very small compared to the thorax. The whole insect is very variable in colour; from reddish-brown to almost black. The thorax often has large dark spots on a lighter background. The median dorsal band is usually darker or lighter than the rest of the body. The elytra, or hard wings, are ribbed lengthwise, and at least their borders are usually nearly black. The egg, as described by Banks, is 2·4 millimetres long, and 0·6 millimetre wide at the middle, slightly more pointed at one end than at the other, and a very light ochre in colour. To the naked eye its shell is smooth and shining, but under the microscope it is finely reticulate. The eggs are deposited in the soft wood.

The destructive stage in the life-history of the red beetle is the larva. Beginning at the size of the egg, this grub grows until it becomes considerably longer than the adult, with a thickness of two-fifths or one-

[1] I follow Banks in calling the Philippine insect *R. ferrugineus*.

THE RED BEETLE, *RHYNCHOPHORUS FERRUGINEUS*, ADULTS AND LARVA.

Photograph by Bureau of Science, Manila.

To face page 76.

half of its length. It eats a channel through the soft wood or the heart of the tree, the channel necessarily widening as the larva grows. The larva begins its life inside the tree, and normally never comes to the surface. Therefore, neither it nor its work is directly to be seen. It can sometimes be heard if the ear is held closely against the outside of an infested trunk. As a rule, the first indication of its presence is the appearance of mutilated leaves or the collapse of young leaves. A tree badly infested by these larvae may be expected to be killed, promptly or slowly, by the destruction of its heart. Young leaves may simply cease to appear, or may be killed one at a time after they appear, or the younger part of the crown may be undermined so that it falls out.

The head of the larva is brown, rather large, and without eyes. Its body is white, and is thickest behind the middle. It has thirteen segments. The surface is velvety in appearance, and much wrinkled. Scattered all over the body are shiny spots, each of which bears one bristle, excepting the spots on the next to the last segment, which bear six bristles each, and four protuberances, each with two longer bristles, on the last segment. The larva is without real legs. As usually found, it is curved strongly downward.

The cocoons of *Rhynchophorus* are made of coarse coco-nut wood fibres, closely woven together. They are elliptical in outline, 5 to 12 centimetres long, and more than half as much in diameter. They are numerous in badly infected trees, sometimes being found in the thick bases of the petioles, whence the adult will be able to escape directly into the air. They have always been described as formed close to the surface, but in decaying crowns are produced at the last points reached by the larvae, where the tissues are just softened, at whatever depth from the surface of the trunk. Within the cocoon is the pupa, showing all the parts of the adult.

There is a wide difference of opinion as to the time required for the life-cycle of *Rhynchophorus*. Mr. E. E. Green, Government Entomologist of Ceylon, says: "I have found nearly fully grown larvae of the beetle in trees under conditions that indicate that they must have developed within a period of six weeks. It seems possible that the insect may reach maturity in from eight to ten weeks' time." Banks estimates the necessary time at eighteen to twenty-four months. I have found numerous cocoons containing larvae, apparently mature, in trees which had been cleaned perfectly and used for bait ten weeks before. Vosseler puts the duration of the life-cycle of *Rhynchophorus phoenicis*, F., at one year; the pupa rests six to eight weeks.

The adult does not fly during the day, and apparently travels, as a rule, but a short distance. All vulnerable trees immediately around a badly infested one are almost sure to be attacked, while those even 50 metres away are comparatively safe. It is moderately attracted to light, but not so strongly that any great numbers can be destroyed by bonfires. It needs no food, and enters a tree only to find a place to lay eggs, or a place of refuge.

The methods to be employed in fighting *Rhynchophorus* follow obviously from the fact that it cannot lay its eggs in sound trees, but only in those where the softer tissues have already been exposed in some way. Coco-nuts usually become susceptible to its attacks in one of the following ways:

1. By mechanical injury done by men.
2. By previous attack by other insects.
3. By injury by violent storms.
4. By being burned.

1. Mechanical injury is done to trees, by those who think they are taking care of them, in several ways, as by cutting notches in the trunk, in cutting down the nuts, and by unduly clearing the crowns. While the general view in English colonies has been that these beetles attack the top of the tree directly, Banks thinks it no less normal for them to enter through lesions in

the base of the tree, or where steps have been cut in the trunk. The latter cases are comparatively rare but certainly happen. If steps are cut deep enough to expose any soft wood, they furnish a possible place for the beetles to lay their eggs; therefore they should be cut as shallowly as will serve the purpose, and should not be made within $1\frac{1}{2}$ metres of the height at which the nuts are borne. The first few crops of nuts from a tree should be harvested without cutting any steps, whatever may be done later. Nuts intended for the manufacture of copra or oil would better always be left on the tree until they fall of their own accord.

The red beetle rarely or never enters a tree through the wounds normally made in cutting down nuts, even if they are cut young for immediate local use. But the careless use of a knife in gathering nuts sometimes results in making wounds in which the eggs can well be laid.

It was formerly generally believed that the careful removal of all dead matter from the crown, and of all hanging leaves, was an important part of good sanitation. Experience has amply shown that such treatment, except in exceptional cases, is a costly blunder. The fibrous leaf-bases, which at first are complete sheaths, are the natural protection of the young, still soft wood, and at first of all the underlying structures which have not yet become woody. Nature is not wasteful. If the fibrous stuff is cut away before it would naturally fall, the tree is deprived of a protection which it needs, and the advantage is given to the beetles.

Two illustrations of the effect of too much injudicious care have appeared in Ferguson's *Coco-nut Planter's Manual*; they are copied here from p. 38 of the fourth edition:

On one property the trimming system had been carried on for years, till, indeed, more than one-third of the original plants perished, before the estate was ten years old, and they were going at the rate of three trees weekly. The work of trimming was stopped for the reasons offered above; the loss of trees continued for some time afterwards, but at the end of six months it had entirely ceased. On another property, beetle-men had been employed for ten years, and trees were being constantly lost; from the day that the "beetlers" were discontinued two trees perished within the month, and not another was lost in the subsequent seven years.

2. In spite of Vosseler's doubt,[1] the general feeling must be taken as correct, that the red beetle commonly makes use of the holes made by the rhinoceros beetle, in securing a proper place to lay eggs. Where both kinds of beetles occur, the adults of both can often be found in the same holes. Even if the red beetles enter these holes for the sake of shelter, it is hard to imagine that, finding themselves in a suitable place for laying eggs, they refuse to deposit them. I have seen groves in which both beetles were too common, but in which practically no trees not attacked by the rhinoceros beetle contained any adults or larvae of the red one. As the rhinoceros beetle can enter a sound tree, but the red one cannot, the conclusion forces itself that injury by the former is a necessary condition for any attack by the latter. *Oryctes*, the rhinoceros beetle, is not itself as dangerous or destructive a pest as is *Rhynchophorus*; but, where both are present, the campaign should be directed first against the former. While it remains common, the *Rhynchophorus* will be beyond our reach, and when it has been disposed of, if other conditions are as they should be, *Rhynchophorus* will disappear.

Small insects, making holes too fine to permit the entrance of the red beetle, might still furnish places for the latter to lay their eggs; but I have not known of a case in which this happened.

3. Storms do not, in themselves, do as much injury to coco-nuts as is often supposed; in fact, it would be very difficult to find another crop as little liable to damage by them. But by breaking the petioles, tearing

[1] *Der Pflanzer*, 3 (1907), 304.

the fibrous bases, and sometimes causing splits in the trunks, very severe storms make it possible for the red beetles to lay their eggs in many trees, and so to multiply rapidly. This is obvious, and the fact and its consequences may not rarely be observed.

Mr. E. E. Green reports a remarkable increase in the number of red beetles after a cyclone which visited the Batticaloa district of Ceylon in March 1907. The beetles had been systematically collected since 1903, the number decreasing steadily; the records for various plantations being complete by months. In one case, where 199 had been caught in May and June of 1906, 1906 were captured in the same months of 1907. In another instance the increase in the same months was from 128 in 1906 to 3889 in 1907. This increase was almost entirely in the number extracted from the standing trees, taking no account of those blown down, in which also the beetles can of course multiply.

The only way in which this kind of damage can be prevented is by having no beetles at hand to take advantage of storms.

4. Burning away the fibrous leaf-bases must be expected to result in the same way as their removal by any other means. In Cuba one of the methods of combating bud rot is by scorching the crown by burning the light and inflammable stuff. Since *Rhynchophorus palmarum* is the chief insect enemy of the tree in that region, such treatment appears decidedly risky. In the Old World I have never heard of such treatment as intentional. If young plantations are uncultivated, they will go into grass for a time, the grass ultimately being supplanted by brush. As long as they are in grass fire is likely to go through them on any dry day. In the land bought by the Philippine College of Agriculture was a small grove which was partly run through by fire in March 1909. The work of red beetles was evident within three months, and in eight months every tree reached by the fire was apparently moribund. Outside of the burnt area there was no

sign of red beetles except in occasional trees where *Oryctes* furnished a place to enter.

Young trees are most liable to damage by fire, both because a grass fire will not reach the inflammable sheaths of tall trees, and because old groves are not likely to be in dry grass.

The most of the means to be employed in preventing damage by *Rhynchophorus* have already been made clear. If the eggs are laid in a tree, the metamorphosis may be complete by the time the presence of the insect becomes evident; and even if the larva chances to gnaw leaves about to grow into sight, and so betrays itself early, it is often impossible to extract it without practically destroying the tree. Every effort must therefore be made to prevent the laying of the eggs, and the measures by which this is to be done follow from a knowledge of the ways in which the tree becomes susceptible.

Trees attacked by *Rhynchophorus* may die as a direct and immediate result if the larvae happen to destroy the growing point. This does not usually occur, the larvae more often missing the embryonic tip, and the tree escaping from the first attack with less than fatal injury. Such trees are unquestionably left more subject to subsequent attacks. They are also obviously rendered less productive; for nuts are made by the use of food manufactured in the leaves, and when the leaf-surface is reduced the number of nuts is necessarily diminished. So the planter who waits to see if trees will recover from an attack by the red beetle can expect them at best to be for some time weakened, and liable to renewed attack.

Worse than this, from such trees a crop of beetles escapes to seek a chance to attack other trees. The attempt to save one tree may thus result in the loss of many. It is better policy to destroy a tree as soon as it is known to be infested by the red beetle, without even waiting for the maturing of nuts already so old that they would surely ripen if given a chance.

If this practice is strictly followed, and a good watch is kept for signs of the beetle, there is a good chance that they can be exterminated in any locality, and this is more than can reasonably be hoped for in the case of most pests. British planters in Ceylon are so convinced of the soundness and necessity of this policy that, besides destroying their own infested trees, the more enterprising also destroy any others in the neighbourhood, if necessary paying damages for them.

As to methods of destruction of trees, my own confidence is all in the prompt and thorough use of fire. Burying, and submerging in water, are sometimes proposed as alternatives to burning. Burning is not easy, and unless there is more rubbish than ought to be at hand, and unless the time is very dry, it usually requires the use of kerosene. All the soft parts of the crown must be burned; the length of this soft part depends upon the age and vigour of the tree. If the rhinoceros beetle also must be reckoned with, the whole trunk must ultimately be destroyed, but this need not be done so promptly. Burying the trunk may be effective when only the red beetle is concerned, but cannot be relied upon in the case of *Oryctes*. Submerging will prevent the use of the dead wood as a place to lay eggs, but cannot be trusted to prevent the escape of beetles already mature or nearly so.

Three other methods of fighting *Rhynchophorus* are in use:

1. Extracting the beetles or larvae from their burrows and from places of concealment on the tree. This method is widely used in combating *Oryctes*, and adult red beetles are sometimes caught with the black ones, both kinds in the same holes. So far as larvae and beetles in the burrows are concerned, it is not as practicable against the red beetle alone as against the black, if used in proper conjunction with other sanitary measures. However, Green says, in commenting on the catches from 1903 to 1907: "It is noticeable that up to the present year the annual total of captures of

Rhynchophorus—not of *Oryctes*—has steadily decreased, a fact which seems to prove conclusively the value of a systematic collection of the insects."

2. The use of bait and traps. This method has found considerable favour in the American tropics, where *R. palmarum*, called the palm weevil, is a dangerous pest. Some palm of less value than the coco-nut, which the weevil is known to attack, is felled and cut into convenient lengths, say 1 metre, and some of these are split. The open pieces are exposed until the soft heart becomes sour, which is likely to be in one day. They are then watched, and beetles are killed as they are attracted by the sour smell. A test of this method is reported in the *Trinidad Bulletin of Miscellaneous Information*, April 1905. The tree was cut February 2, and the first beetles came to it forty-eight hours later. They were collected mornings and evenings, the numbers being:

February 4 . . .	23
" 5 . . .	19
" 6 . . .	6

The trunk was opened February 18 and a number of larvae were found. The pieces of the tree sacrificed for bait should of course be burned before any insects can possibly mature in them.

Mr. J. T. Seay of British Honduras has perfected this method by furnishing a place for the insects to hide after laying their eggs. This can be done by putting a little pile of rubbish close to the bait. But a better way is to use the top of a palm and to have some holes in this in which the insect will hide. Mr. Seay uses the "salt-water pimento," which he cuts off just above the cabbage; he then cuts a hole into the latter. The beetles hide in this hole and in the cavities within the leaf-bases. Such a trap lasts for a week or two and is then destroyed. Mr. Seay states "that 3 or 4 miles is no distance for the insects to fly in search of a sickly tree or one that is beginning to bear fruit, because then the bark is soft, and the sun will make cracks and the sap, which is liked by all of these pests, oozes out in quantities." It also appears that the American palm weevil flies by day as well as by night.

I have repeatedly used the remains of infested coconut trees as bait, removing every trace of insects and leaving the stub to attract others. From the second to the fifth day after the operation there is always a harvest of beetles in the little piles of rubbish deliberately left for them to hide in, when there is not room for all in cracks and holes in the stub itself. Such stubs must not be left, as in a few weeks they are full of larvae and pupae as far down as they have softened enough to be penetrable.

Vosseler recommends, as bait, mangoes crushed in coco-nut milk and water, and exposed in shallow dishes.

3. The use of poison. As the holes by which this insect enters the tree are not necessarily visible, and the channels in the tree become of appreciable size only as the larva grows, it is not usually practicable to kill the weevil in any stage by the use of poison. However, when the holes or channels are open, or opened, carbon bisulphide can be introduced and the hole plugged again; any insects that the vapour can reach will die. This method has been tested, using carbon bisulphide, potassium cyanide, and hydrocyanic acid, against *Rhynchophorus* and *Oryctes*, at the Philippine College of Agriculture, without results of practical value. Vosseler advises the use of carbon tetrachloride.

The larva of *Rhynchophorus* is said to be regarded as an especially choice morsel by various natives in America, where it is known as the gru-gru worm. The oldest report of these insects, dating back to 1726, emphasizes this usefulness. The larvae are eaten in Africa and Malaya also; but, so far as I have personal knowledge, they are by no means esteemed a delicacy.

Rhynchophorus palmarum seems to be a less serious pest than *R. ferrugineus*. Urich states that "young trees up to four and five years of age are those mostly attacked. Full-grown trees are not touched.” “The remedies employed have been preventive, and consist in tarring wounds. . . . As long as the bud is not damaged, the larvae are cut out and the wound dressed with tar.”

R. phoenicis is also a less-known pest because it is prevalent in countries where a great coco-nut industry has not yet been developed.

Minor Beetle Pests, Weevils.—Beside *Rhynchophorus*, of which more than one species is found, Banks has encountered three other weevils in Philippine coco-nut trunks. One of these, *Cyrtotrachelus*, is a common enemy of the betel-nut palm, but sometimes attacks sound, or at any rate apparently healthy, coco-nuts. The trees found attacked have usually been those about to come into bearing. This weevil is much smaller than *Rhynchophorus*, the larva being 20 millimetres, the pupa 13 millimetres, and the cocoon about 35 millimetres, and the adult 17 millimetres in length, snout included. The same measures to be taken in guarding against the two chief beetle pests will probably provide immunity against this one.

The shot-hole coco-nut weevil is about the same size as the preceding, but does not form a cocoon. It is able to penetrate old hard wood, and is not uncommon, locally, in it. It is found in living trees, but rarely, if ever, in sound ones or sound parts of trees, and therefore seems unlikely to do direct injury. The third of these insects, called by Banks the four-spotted coco-nut weevil, is decidedly smaller, the body of the adult being only 5 millimetres long. This also is found only in dead parts of the tree, where other enemies have gone before ; it probably never does direct damage.

Sphenophorus obscurus, Boisd., is a weevil nearly related to *Rhynchophorus*, which is found in Polynesia, reaching as far north as Hawaii, and west to New Guinea. It is better known as a pest of sugar-cane, and is accordingly known as the “sugar-cane weevil.” The insect is about 2 centimetres in length, with black head and snout, and deep reddish-brown body with a black blotch behind the head, the thorax coarsely punctured above, and the hard wings striate. Damage is done by the larva, with regard to which the following quotation is made by Froggatt from Doane:

> The larger larva usually works closer to the base of the leaf, often killing the leaf by burrowing all through it. Sometimes the larva will keep close to the edge of the leaf or go only as far as the centre, boring a tortuous chamber from half to three-quarters of an inch in diameter. The burrow is usually filled with the chaff and castings, and the larva is usually found at the upper end of the burrow. Often from the blackened portion of the infested leaf the resinous exudation will be issuing in several places, making it appear that several larvae are at work in the same leaf. This is sometimes the case, but a single larva may bore along a leaf stem for 12 to 15 inches, causing the exudation to flow in abundance from several openings, and making many large discoloured spots, beneath which the tissue is soft and decayed. The older leaves are usually attacked. After attaining its full growth the larva bores close to the surface, and constructs a rude oval cocoon out of the fibre that it has been eating, and transforms to the pupa stage, from which it later issues as the adult beetle. These cocoons may usually be found quite abundantly in the chaff at the base of old leaves or on the old leaves. In some instances the larva bores into the trunk of the tree for a short distance where the broad leaf-base joins the tree. In one instance I found the beetle quite abundant in and around the growing tip of a young tree that was dying, whether as a result of the work of the beetle or from some other cause I was unable to determine.

The beetles are trapped in some places where they are especially destructive to cane sugar.

American beetles closely related to those mentioned are *Metamasius hemipterus*, L., *M. cinnamominus*, and a species of *Rhabdobaenus*. These attack the trees under the same conditions as *Rhynchophorus palmarum* and can be guarded against in the same manner. Another enemy of coco-nuts and other palms in the same part of the world is the "bearded weevil," *Rhina barbirostris*. This attacks mature trees but not the younger ones.

The larvae bore into the hardest parts of the stem, although scorching is said to make the tree more liable to their attack. Concerning this insect in Trinidad, Urich reports, "The methods of control adapted have been preventive, and consist in tarring the stem of trees that have been scorched. A mixture of white lime, to which is added 5 pounds of arsenate of lead to every 50 gallons of solution is also used." *Calandra taitensis*, Guerin, called by Froggatt "the small palm weevil," is a serious pest, at least in the Society Islands. Comparing it with *Sphenophorus*, Doane says:

> The smaller weevil, *C. taitensis*, seems to be much more abundant, and, on account of its habits, is perhaps more injurious than the larger species. It is found more commonly boring in the edge of the base of the leaf-stem. Its presence is indicated, as with the larger species, by the presence of a gummy exudation mixed with castings. These are often in the shape of long twisted strings $\frac{1}{4}$ to $\frac{1}{2}$ inch long. As the larvae do not work so deep in the tissue of the leaf as do those of the larger species, the damage here is not very great, but when they work further out at the base of the leaflets, many of the leaflets are destroyed. A still more serious damage is done where the larvae attack the spikelets, killing them at the point of attack, and working towards the base.

Preuss mentions still another weevil which, in German East Africa, bores into the young nuts.

A considerable number of beetles related to *Oryctes* are also pests of the coco-nut. *Strategus titanus* is a large beetle found in the inflorescences of coco-nuts in Cuba, and believed locally to be injurious; but Busck, who encountered it during his preliminary study of bud rot, believes it to be practically harmless. *Strategus anachoreta* is an enemy of the coco-nut in Trinidad, and is probably identical with the large beetle which is known in British Guiana as "the cockle." This is known in Trinidad as the "rhinoceros beetle," because of a horn-like projection on the upper part of the thorax of the male. It is 4 to 6 centimetres in length and chestnut-brown in colour. It is a broad, thick-set, powerful-looking beetle with strong front legs with which it burrows into the ground or forces its way through woody tissues. The damage is done by the adult. "A hole is made in the ground near the stem of a young tree: those about two years old are usually selected. Externally this opening looks like a crab-hole—sometimes there is a heap of earth blocking the entrance;—either of these indications is a sure sign that a beetle is at work. Generally one beetle only is found, and it is sufficient to destroy a tree if not removed in time." It may be killed or removed by means of a wire. Lime around the young trees is an effective preventive. It is suggested that some trees be left unprotected as bait and watched. The larvae live in rotten wood; this stage lasts three to four years; the pupal stage lasts four to six weeks.

Xylotrupes gideon, of which *X. nimrod* is sometimes regarded as merely a form, is known well over the whole Malay-Polynesian region, and is reported as a pest in Java, the Philippines, and Solomon Islands. *X. lorquini* is reported from New Guinea. These very large insects, popularly known as "elephant beetles," are readily recognized by the two huge projecting horns, one from the head and one from the thorax, which reach forward like a pair of curved tongs. In its attack on the coconut the elephant beetle works in the same way as the rhinoceros beetle, and is fought in the same manner, by dragging the beetles out of their holes in the tree. Froggatt reports that a related species of the same genus collects on the jacaranda, an ornamental tree common along streets in the tropics, and suggests that this may accordingly be used as bait. There is a statement in circulation to the effect that elephant beetles do to palms more incidental damage with their horns than they do directly in feeding or burrowing. It is not easy to see how such an unwieldy insect does any damage at all.

Another related beetle reported by Froggatt is *Trichogomphus semilinki*, Ritz., which he calls the "Solomon Island rhinoceros beetle." In appearance it is intermediate between *Xylotrupes* and *Oryctes*. It is reported to damage young coco-nut palms in the same manner as *Xylotrupes*. *Chalcosoma atlas*, L., is a huge beetle, in appearance still more remarkable than *Xylotrupes*, which has been alleged to have larvae which attack the trunk of coco-nut in the Philippines. Of this I have no personal knowledge.

Scapanes is another genus of huge beetles, each with three great horns. *S. australis*, Boisd., and *S. grossepunctatus*, Sternb., occur in New Guinea and destroy young trees two or three years old; adult trees are not attacked. Barrett reports a species believed to be *S. australis* in the Philippines.

Other beetles reported as injurious to coco-nut in New Guinea are *Pimelopus* (four species), *Camelonotus quadrituber*, and *Oryctoderes latitarsis*.

Froggatt further reports as a pest which does a great deal of damage to young coco-nuts in the Solomon Islands *Eurytrachelus pilosipes*, Waterhouse, which he calls the "coco-nut stag beetle." The adult bores into the stem under the shelter of the base of the leaf-stalk. Froggatt anticipates that where the land as a whole has been brought into cultivation, and there is no fallen timber for these beetles to breed in, they will cease to be a serious pest. *Eurytrachelus intermedius* has also been mentioned as a pest of coco-nuts. Another stag beetle, *Passalus tridens*, is reported to have done much damage to coco-nuts in Demarara.

Barrett, in a general resumé of insect pests of the coco-nut, writes with especial respect of *Melitomma insularis* of the Seychelles and Madagascar region, which he calls "perhaps the most insidious trunk-infesting coco-nut pest in the world." "This insect enters the stem at the base, among the roots, and, partly by its own voracity, and, it is thought, by reason of 'caustic liquid' excreted by the larva, soon kills the tree."

Ambrosia beetles or Scolytidae are wood-boring beetles. They are found in various places, and in Cuba are common enough in apparently healthy trees to be suspected of doing damage both directly and indirectly, in greater measure, as they furnish places for infection by fungi, or for the laying of the eggs of the palm weevil.

Leaf-eating Insects (*Bronthispa*).—Of the small leaf-eating beetles of the family Hispidae several have been reported as serious local pests of the coco-nut. Among these, Froggatt describes *Bronthispa froggatti* as certainly the worst pest the planters of the Solomon Islands have to fight in their young plantations. This was first reported in 1903 from New Britain, where it was also a serious pest, and fully 50,000 plants were said to be already ravaged by it. Both the adult and the larva feed upon coco-nut leaves.

The beetle measures up to half an inch in length from the tip of the antennae, which stand out in front, to the tip of the body; but they are often much smaller and variable in size, and are very slender, not more than one-tenth of an inch across the broadest part of the back.

The general colour is shining black, with the thorax and fore pair of legs dull yellow, and the second pair marked with yellow. The head is small, the eyes project on the sides, the front is produced into a lance-shaped point standing out between the basal joints of the stout antennae. These antennae consist of eleven small segments, the basal ones irregularly rounded, the apical ones cylindrical and fitting close into each other. The thorax is almost square, slightly hollowed out on the sides, and curved round in front behind the eyes. The long slender body is covered with stout black wing-covers deeply and finely marked with parallel furrows, which are finely and deeply punctured, so that the whole surface is finely but regularly pitted. The tips of the wing-covers are depressed and rounded.

The beetles crawl into the folds of the opening fronds as they are expanding, and under their shelter lay their small horn-coloured eggs, from which the curious flattened larvae hatch and feed upon the surface of the leaf. Both the beetles and larvae damage the leaves, and the whole life-history of the pest can be studied in a single frond. The larva, when full grown, measures just two-fifths of an inch in length; it is slender, cylindrical, and somewhat flattened, with the segments well defined. It varies in colour from dull horn-yellow to dirty white. The head is small, lobed, with short jaws on the under side of the head; the small legs are divided at the extremities, forming two rounded feet. The abdominal segments, eight in number, are furnished on the sides with a slender, rounded, fleshy tubercle; and the anal segment has the tips flattened and produced into a pair of short, incurved, flat, caliper-like processes, which, curving inward, form a perfect crescent between them. They are ornamented with a few warty tubercles and fine hairs.

The result of the attack is that the leaves are reduced to skeletons connected by dead membranes before they are well unfolded. When the attack is serious, the tree is of course weakened until the production of fruit is impossible. On the Solomon Islands, gangs of boys are kept at work killing the insects by shaking tobacco and soap wash into the still folded leaves. Preuss recommends the use of nitrogenous fertilizers to help the trees to resist attack.

Koningsberger reports what may be the same insect and is at any rate nearly related to it as a serious local pest in Eastern Java. It is extremely flat, and therefore able to penetrate between the leaflets, or the halves of a leaflet, even while the leaf is still tightly folded. It eats the epidermis next it and the green tissue, but not the other epidermis; the latter soon dies and remains as a yellowish semi-transparent layer. At the same time the females deposit numerous small yellow eggs, from which equally flat larvae develop. These feed like the adults. They pupate in the same place, and a new generation of beetles flies out in eight to ten days.

A leaf attacked by numerous beetles and larvae is too weakened to unfold; or, if it still unfolds, is valueless to the tree. By the destruction of many successive leaves the tree may be killed. However, the work of the pest is conspicuous, and if the infested young leaves are removed and burned the trees are easily saved. The beetles are about 9 millimetres long and 2 millimetres wide and, as already said, very flat. The head is yellowish-brown, and has a small spine-like prominence between the black antennae. The full-grown larva is 10 to 11 millimetres long and of a yellowish-white colour.

In the related genus *Promecotheca* three species are known as coco-nut pests, *P. cumingii* in the Philippines, *P. antiqua* in New Guinea, and *P. opicicollis* in the New Hebrides. The Philippine species has been studied by Jones,[1] who describes it as follows:

The beetles vary from 7·5 to 10 millimetres in length, exclusive of the antennae, and from 1·6 to 2 millimetres in width. The thorax is much narrower than the slender body. General colour brown ochre, head small, eyes and mandibles black, elytra finely punctate in parallel furrows. Antennae 11-jointed, tarsi broad and flat, one larger spine on inner side of each femur with a corresponding depression on the tibia. The body is pilose.

The beetles are sluggish and do not fly readily upon being disturbed. They rest by clinging lightly to the under side of the leaf with the antennae extended forward close to the leaf. They crawl about promiscuously on the leaves of the young coco-nut and feed extensively upon the tissues between the veins of the leaflets. The injury has the appearance of a slight cut, but does not entirely penetrate the leaf.

The damage done by the larva is greater than that by the adult, as a single larva will excavate a place in the leaf from 12 to 16 millimetres long and 1½ to 3 millimetres wide. The tissue attacked soon dies and becomes brown, and in badly infested areas the numerous dead leaflets give the palm the appearance of being unhealthy or half dead; where the trees are used for decoration this effect is very displeasing. The palm is also injured by the loss of these leaflets.

The eggs are inserted by the female beetles just beneath the epidermis of the leaf. They are deposited singly, and hatch in from 13 to 15 days. The period of incubation varies but little. The larvae upon hatching enter the parenchyma of the leaf and here spend the entire larval period, which is about 32 days. They do not form any pupal cell, but pupate in the middle of the excavated chamber formed by feeding. The average length of the pupal stage is 7·5 days. The adult after emergence remains from 2 to 4 days within the food chamber before it bursts the epidermis of the leaf and escapes.

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[1] *Philippine Agricultural Review*, May 1913.

In the Philippines this pest is largely controlled by its natural enemies. Jones found two hymenopterous parasites, one on the egg and the other on the larva and pupa, which together, in a hundred leaflets examined by Jones, were killing about half of the pests. The infested leaflets are readily recognized, and may be easily removed and burned ; or the adults may be picked off by hand, and the leaflets infested by other forms removed and burned.

P. antiqua is reported as so serious a pest in New Guinea that trees over considerable areas are made entirely unproductive for a year or more. It attacks even the oldest and tallest trees. It has a dark brown head and hard wings (elytra), which are three-fifths orange and two-fifths dark blue. *P. opicicollis* has black elytra each with a yellow spot. In New Guinea trees standing in alang-alang (cogon) grass are especially subject to attack and the beetles seem to disappear when the grass is eradicated.

Oxycephala froggatti, mentioned by Preuss, may be identical with *Bronthispa froggatti*.

Lepidoptera.—A number of moths and butterflies attack the coco-nut, but are up to this time known only as local enemies. Koningsberger has published in the *Bulletin of the Department of Agriculture of the Dutch Indies*, 1908, an account of two of these. *Brachartona catoxantha* is a small moth, measuring only 14 or 15 mm. with its wings expanded. It is uniformly brown above. Beneath, the thorax, abdomen, and legs are yellow; the fore wings brown with yellow patches at base and apex of costa; and hind wings brown, with the costal area yellow and the veins on it black. The caterpillar is about 10 mm. long. The head and thorax are yellowish brown; the body greyish brown with a black dorsal streak bordered by white and finely hairy. The caterpillars are found on the upper side of the leaves. They eat through to the nether epidermis, but leave the latter, thus making brown spots, which are 1 to 2 mm. wide and up to 30 mm. long. When a tree is badly infested, these spots almost cover the leaves. The leaves then curl up, and so furnish the caterpillars a place for pupation.

Brachartona has recently made itself seriously felt in the Federated Malay States. It goes through four generations in eight months, by which time it multiplies enough to become locally epidemic. Then it disappears, having become abundant enough to let its own enemies multiply in excess. When the *Brachartona* is almost exterminated, its parasites die off, and after perhaps two years the *Brachartona* reappears as a pest. If it can be detected as it reappears it can probably be controlled by spraying with kerosene emulsion ; but this will demand careful watching, as its work is not conspicuous until it has multiplied greatly.

The other pest reported by Koningsberger is *Hidari irawa.* The caterpillars of this butterfly are reported as very numerous at Sawah Loenta, on the west coast of Sumatra, feeding upon the leaves of the coco-nut.

From the Philippines likewise two of these insects have been described by Banks. One of these is a skipper butterfly, *Padraona chrysozona*, Plötz. Quoting Banks, *Philippine Journal of Science*, 1906 :

> During the months of September and October many of the leaflets of small coco-nut trees of from 6 to 15 feet in height are partially destroyed. Certain of these leaflets have their outer edges sewn together by means of a pure white silk which is decidedly elastic, so that the leaf may be pulled slightly apart without tearing the fastening. Inside these folds the light yellowish-green caterpillar, having a chitinous head, somewhat darker than the body and boldly marked with a very regular pattern, is encountered.
>
> Toward the latter part of October the semi-active pupae are found in these "cradles," partially covered and surrounded by a snow-white flocculent substance, which has a wax-like feel.

The adult insect is 15 to 16 mm. in length, a bright yellow ochre in colour, with dark-brown markings. The eggs are deposited, usually singly, on the under surface of the leaf; they hatch after seven or eight days. The larva is at first 3·5 mm. in length, and grows to about 45 mm. This insect lives upon the betel-nut palm also. It is preyed upon and held in check by hymenopterous parasites, and Banks does not believe that it is likely to become a dangerous pest.

He holds the same opinion regarding the moth *Thosea cinereomarginata*, the larva of which is a slug-caterpillar, easily recognized by having along each side of the body a row of spinous tubercles. Like the insect just described, this does moderate injury to coco-nut leaves in Manila.

Thosea and *Padraona*, and with them *Erionota thrax*, another of the skippers, are known in the Federated Malay States.

Another butterfly, whose larvae live upon the leaves of the coco-nut in the Philippines, is *Amathusia phidippus*. The same insect is found in British India, where its food-plant is also the coco-nut. It is not a common butterfly here, and is not known anywhere to do very great damage. Jb. Coert, nevertheless, states that in the Dutch East Indies the larvae sometimes become numerous enough to defoliate trees (see Wilborn, in *Bull. Kolon. Museum*, Haarlem 41 (1909), 122).

Very serious local damage is reported by Schultz, the horticulturist of the Canal Zone, as done to the coco-nuts of Panama by *Brassolis isthmia*. In May 1906 the majority of the coco-nut trees in the vicinity of Ancon were defoliated by its caterpillar. Trees which had been prolific for several years were left with their bare petioles and midribs looking like skeletons. Some trees recovered, under special care; others were cut down. In September the caterpillars again appeared in smaller numbers. "All coco-nut trees were, therefore, sprayed with a strong solution of arsenate of lead, a most tedious and troublesome, although very effective, method of fighting these insects, in view of the height of the trees, which were mostly from 30 to 35 feet." Rain washed the poison off within a few weeks, but all the insects on the treated trees had been killed. It has since reappeared.

The larvae feed only at night. At daybreak they retire into a tough nest, shaped like a narrow bag, from 30 to 60 cm. in length, in which 700 or more often crowd together. The nest is made with the help of the pinnae, and where their tips meet, at the lower end, is slightly open. As many as four nests are sometimes found in one tree. The larvae are 5 to 10 cm. long. They can entirely strip a bearing tree of its foliage in a few nights, and give it such a check that under conditions otherwise most favourable two or three crops are lost; "And it is no rare occurrence that a tree dies outright or becomes so weak that it cannot resist fungoid and other diseases, and gradually perishes."

The chrysalis stage lasts twelve to sixteen days. The larva of an apparently dipterous insect is parasitic on the chrysalis, and helps to hold the pest in check. The simplest and easiest way to fight this pest is by cutting down and burning the nests; but watchfulness and diligence are necessary if this method is to be really effective. *Brassolis* has also been found on the royal palm, and some other trees of the same family.

A related species, *Brassolis sophorae*, has been known in Trinidad since 1892. It is scattered over the whole of that island, and while not common, is becoming more so. The adult flies at dusk. The life cycle lasts nine weeks. Like *B. isthmia*, it skeletonizes the leaves, and is therefore conspicuous. On some estates it has been held in check by cutting down the nests and crushing the larvae, at the cost of two cents per nest. In the same island the larvae of *Hyperchiria*, called the "spiny coco-nut caterpillar," skeletonize the leaves. This species is gregarious, but not nest-building. So far it is not a serious pest.

Omiodes blackburni, "the palm-leaf roller," is a Pyralid moth reported on coco-nuts in Hawaii. Preuss reports larvae apparently of the same family, which destroy young nuts in New Guinea. A Tineid moth, large for its group, with light-grey, black-spotted wings, occurs on coco-nut leaves in Ceylon.

Locusts.—Prudhomme states that the most of the coco-nut plantations of North-Western Madagascar have suffered seriously from these insects, being completely defoliated, and made unproductive for at least six months after the flight. I have seen a young grove in Mindanao thoroughly stripped, and so set back that fruiting must have been delayed for two years. Any country subject to visitations of this pest is likely to have similar experience.

However, the coco-nut is no favourite food of the locusts, which will first consume such crops as rice, maize, and cane. Getting rid of locusts is a big general economic problem, likely to be solved in any country only by reforestation, and extending the land in cultivation, until wild grass and brush land, the locusts' breeding-place, disappear. When the scourge is bad enough to involve the coco-nuts, something may be accomplished in a small way by means of fire, noise, and agitation; but the locusts are likely to have their meal.

Busck notes the common occurrence of the egg-holes of a large Cicada on the stalks of the lower leaves of Cuban coco-nuts, but states that the damage is insignificant.

Graeffea cocophaga.—*Graeffea cocophaga*, called by Froggatt "the coco-nut phasma," one of the walking-sticks, is known from New South Wales northward and eastward across Polynesia. It feeds on coco-nuts wherever they are found, and has temporarily done considerable damage in Samoa and on the Hervey island. In spite of its size, fully 20 centimetres in length, the insect is inconspicuous because of its colour. As a rule, it is kept closely in check by its natural enemies; but when these happen to be temporarily wanting, it is capable of rapidly doing great damage. When they become a pest in plantations, Froggatt suggests burning the ground over or cultivating it as a means of destroying the most of the eggs.

Aspidiotus destructor.—Of the various scale insects occasionally found on the coco-nut, this is the only one ever found in large numbers or charged with doing serious damage. In the same genus, *Aspidiotus*, are the San José scale, and a number of other pests of trees of temperate lands. *A. destructor* is probably found in every land where coco-nuts are grown. Beside the coco-nut, it has a considerable number of other common hosts, among them the papaya, annatto, betel-nut, guava, and mango.

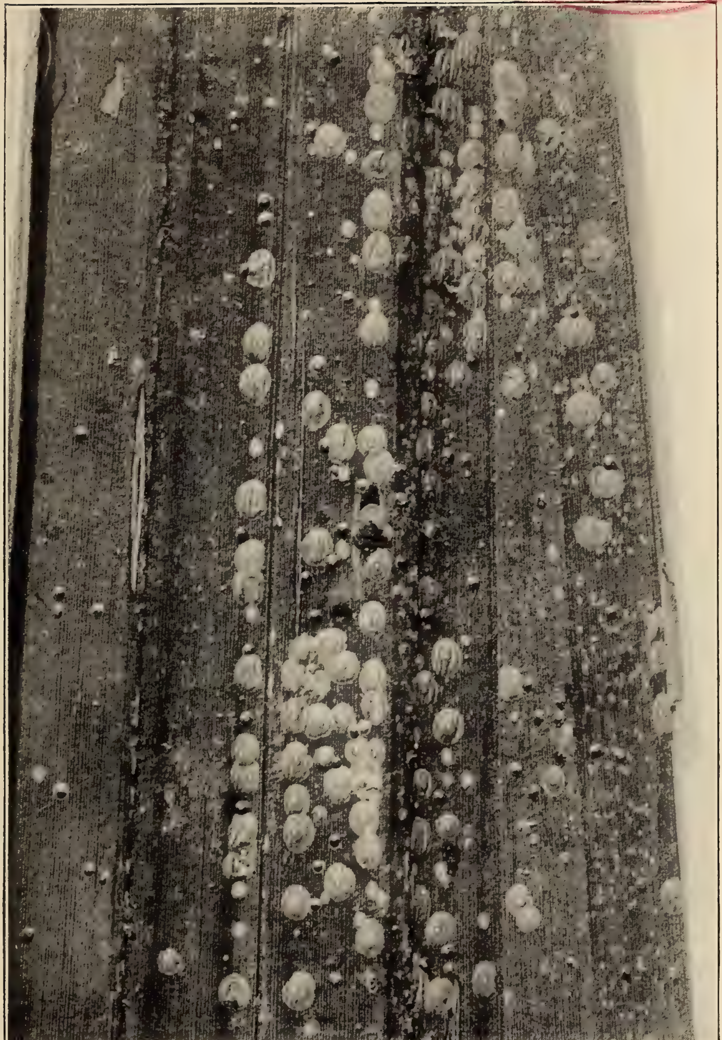
The worst reports concerning this scale have come from the Caroline Islands, the staple crop of which is the coco-nut. The scale is said to have been introduced from the Philippines in 1892, and a few years later to have cut the crop in half. It is especially destructive in dry places and during dry seasons. Dryness favours the insects directly, because they do not endure great humidity well; and indirectly, because drought weakens the host. Trees of all ages are attacked, and those weakened by any kind of unfavourable conditions are sooner or later killed. On arid ground whole groves lose their natural green colour and turn a pale yellow, due to the loss of the green tissues and the layers of scales on the leaves. It is the local practice to sell the whole nuts. No part of the crop is returned to the soil, which grows steadily poorer, so that old groves have not the proper strength to resist any attack. Young trees planted under old ones do not receive light enough to make them vigorous and able to resist. And the native custom of eating the sweet "foot" of their seed-nuts ensures the weakness and susceptibility of the seedlings.

It should by no means be assumed that vigorous trees are less subject than weakly ones to the attacks of all pests; but in the case of the scale this rule would seem to be a good one. Therefore, to guard against injury from it the trees should be amply spaced, provided with plenty of water in the ground, and, if necessary, cultivated and manured. If other pests or diseases are present, it must be remembered that these will help the scale to destroy the trees.

Being a sucking insect, the scale will not eat any poison. If it is deemed necessary and worth while to attack the scale directly, the ordinary kerosene emulsion will in most places be the best weapon. As the emulsion is to be applied to the leaves it must not be too strong. An emulsion of palm oil and soda is safer; it has been used in Togo and found entirely effective, but at an altogether prohibitive cost. This will be found true in general of any direct attack on the scale. It is of course possible to spray a bearing coco-nut tree, or to enclose it in a tent or balloon and disinfect it with hydrocyanic acid—a method gaining in favour in the fight against the San José scale; but such measures are not in general practically worth while. The treatment is very costly in proportion to the value of the tree; if the tree is healthy it is not likely to suffer much from the scale; and if it is susceptible it is not worth much, and is sure to be attacked again.

The chief check on the coco-nut scale is furnished by its natural enemies, foremost of which are lady-birds of the genus *Chilocorus.* In Cuba, in the Philippines, and probably in almost the whole range of the scale, these predaceous little beetles are found with it. If for any reason the scales become numerous, the food of their enemies thereby becomes abundant; and the latter multiply and the scale is suppressed.

Schwartz, writing in *Der Tropenpflanzer*, has urged that the attempt to combat any pest by means of parasites on it is of necessity futile, and that reliance can never be placed on natural enemies to prevent injury from a pest. It is obviously true that its parasites cannot exterminate a pest. They reduce it in number until there is no longer support for the parasite, but the parasite is the one which will usually disappear first. Practically, however, it must be maintained that when a pest has been so reduced that its parasites can no longer maintain themselves upon it, it must itself have ceased to be a pest. It is beyond question that *Aspidiotus destructor* is itself kept in check in this way



THE COCO-NUT SCALE, *ASPIDIOTUS DESTRUCTOR.*

Photograph by the Bureau of Science, Manila.

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in almost or quite all of the lands where it would otherwise be utterly destructive to the coco-nut industry, and that it is only in occasional outbreaks and these of limited duration that its damage is seriously felt. That other insect pests, among them the sister species *Aspidiotus vastatrix*, have also been restricted in the same manner, is abundantly proved by experience, in spite of the fact that no pest has ever been exterminated in this way.

This scale has gradually worked its way eastward over Polynesia, and in some groups of islands as in Tuamotou, has done grave damage. In other islands it is held in check by its natural enemies, and in this way prevented from becoming dangerous. The means of its migration from island to island, as far as is known, are entirely human help. Unhusked coco-nuts, or young seedlings or parts of plants of other hosts of the scale, are carried in boats from island to island, and the living scales are in this way introduced. Under these conditions the obvious method of preventing its spread in this part of the world is by prohibiting the carrying in boats of unhusked coco-nuts or of anything else on which the scale might live. The natives of Takotu and Fakahina have vigorously enforced a quarantine against the introduction of any living plant, even taro, and by such means have kept themselves immune against damage by the scale.

In Trinidad *Aspidiotus destructor* is often protected by the ant *Azteca chartifex*, and in this way is completely guarded against the attacks of its natural enemies. In such cases the scale insect does considerable damage to coco-nuts. To protect the coco-nuts the planters' business is to destroy the ants, and other insects will then destroy the scales.

Not less than thirty other species of scale insects have been reported upon the coco-nut. None of these has ever been known to do it serious damage. Whether or not some of them might develop and become destructive, if not destroyed by other insects, is unknown, and it need not be a cause of surprise if other scales from time to time do sporadic mischief.

Related to the scales is the coco-nut mealy wing, *Aleyrodicus*. *A. cocois* was described long ago in the West Indies, and of late years has been noticed as a parasite of the coco-nut. It feeds on guava and other trees.

A. destructor has recently been reported by Macke in the *Philippine Agricultural Review* for March 1912 as a very serious pest in a limited district in Oriental Negros in the Philippines. It attacks trees six to eight years old. It does not kill them, but weakens them enough to prevent the production of fruit, and so renders them at least for the time being of no value. It is recommended that leaves which are infested be cut off and burned. As this is a sucking insect, kerosene emulsion is recommended if sprays are to be used. As an indication of governmental alertness, it may be noted that the governments of the Straits Settlements and Ceylon have quarantined against the Philippines to prevent the possibility of the introduction of this pest. It shows no present indications of being likely to spread at all, and no measures have been taken to confine it to the limited region where it has so far appeared.

Termites.—As is true of the locusts, the white ants destroy whatever they find, without any predilection for the coco-nut. They therefore demand no discussion here. The nuts when planted are especially likely to be consumed, and their protection, so far as it is practicable, is taken up in the discussion of the seed beds.

Even the lengthy list which has been given does not include all of the insects which have been stated to feed on the coco-nut. There are, for instance, several which are known to feed upon the flowers or pollen. None of these have done evident injury to the industry. As our knowledge concerning a large majority of the pests already mentioned has been obtained during the last decade, it must be expected that the next few years will show great additions to the list.

INSECT PESTS OF THE COCO-NUT.

Name of Pest.	Where found.	Nature of Damage.	Treatment.
Oryctes rhinoceros	Indo-Malayan Region.	Burrow in young tissues and so injure leaves. Less frequently enter the young stem, and rarely kill the tree outright. Their holes admit other enemies. Damage done by adult. Larvae not found in coco-nut except where decay has already begun.	Destroy all possible breeding-places in or near coco-nut plantations. Kill individual beetles in holes, or after pulling them out. Treat holes with tar. Trap beetles by using some trees for toddy. Scatter fine ground glass, or sand or ashes, in crown of tree.
O. anglia	Madagascar.		
O. colonicus	,,		
O. insularis	,,		
O. pyrrhus	,,		
O. ranavalo	,,		
O. sinnar	,,		
O. boas	East Africa.		
O. monoceros	,,		
O. cristatus	,,		
O. preussi	New Guinea.		
Strategus titanus	Cuba.	Injury doubtful.	Scatter lime or arsenical poison around seedling. Kill individual beetles.
S. anachoreta.	Trinidad.	Attacks seedling underground.	
S. aloeus.	Venezuela.	,, ,, ,,	
Pimelopus tenuistriatus	New Guinea.	Destroy heart of seedling, as Strategus.	As Strategus.
P. robustus	,,		
P. preussi	,,		
P. pygmaeus	,,		
Camelonotus quadrituber	,,		,,
Xylotrupes gideon	Malaya, Polynesia.	As Oryctes.	As Oryctes.
X. lorquini	New Guinea.		
Trichogomphus semilinki	Solomon Islands.	As Oryctes, especially attacks young trees.	,,
Chalcosoma atlas	Philippines.	Said to attack trunk.	,,
Scapanes australis	New Guinea, Philippines.	Kills young trees.	,,
S. grossepunctatus	New Guinea.	,,	,,
Oryctoderes latitarsis	,,	Bores in trunk.	,,
Eurytrachelus pilosipes	Solomon Islands.	Bores in top of trunk.	,,
E. intermedius			
Metopodontus bison	Hermit Islands.	Attacks trunk.	
M. cinctus			
Passalus tridens	Demerara.	,,	
Mycterophallus xanthopus		Destroys flowers.	
Melitomma insulare	Seychelles, Madagascar.	Kills trees by attack at base.	As Strategus.
Rhynchophorus ferrugineus	Philippines to India.	Larva lives in soft part of tree. Trees often fatally injured before the pest is detected.	Avoid mechanical injury of tree in any way whatever. If wounds are made, tar them. Avoid fire. Keep Oryctes and similar insects out. Trap with fermenting palm tissue. Kill individual beetles.
R. signaticollis			
R. rajah	Philippines, Malaya.		
R. phoenicis	East Africa.		
R. palmarum	American Tropics.		
Cyrtotrachelus sp.	Philippines.	Larva lives in tree.	As Rhynchophorus.
Shot-hole c. weevil	,,	Breeds in unsound wood.	
4-spotted c. weevil	,,	,,	

INSECT PESTS OF THE COCO-NUT—*Continued.*

Name of Pest.	Where found.	Nature of Damage.	Treatment.
Sphenophorus obscurus	Hawaii to New Guinea.	Larva lives in petiole; rarely enters trunk.	Trap with pieces of decaying sugar cane.
Metamasius hemipterus	American Tropics.	As Rhynchophorus.	As Rhynchophorus.
M. cinnamominus	,, ,,	,,	,,
Rhabdobaenus sp.	,, ,,	,,	,,
Rhina barbirostris	,, ,,	Penetrates even hard wood of adult trees.	Tar injured or scorched trees. Use lime-arsenic spray.
Calandra taitensis	Society Islands.	Bores in young leaves and flower branches.	
Xyleborus perforans	West Indies.	Bores in trunk.	
,, ,, var.	Philippines.	,,	
Bronthispa froggatti	Polynesia, New Guinea.	Attacks young leaves.	Treat crown of tree with tobacco and soap wash. Use nitrogenous fertilizer and cultivate well.
Promecotheca cumingii	Philippines.	Attacks leaves.	Burn infested leaves. Spray with kerosene emulsion or arsenic at first appearance.
P. antiqua	New Guinea.	,,	
P. opacicollis	New Hebrides.	,,	
Brachartona catoxantha	Dutch Indies, Malay States.	Destroys leaves.	
Hidari irawa	Sumatra.	,,	
Padraona chrysozona	Philippines, Malaya.	,,	
Thosea cinereomarginata	,, ,,	,,	
Erionota thrax	Malay States.	,,	
Amathusia phidippus	India, Malaya.	Eats leaves.	
Brassolis isthmia	Panama.	Destroys leaves.	
B. sophorae	Trinidad.	,,	
Omiodes blackburni	Hawaii.	Eats leaves.	Burn nest. Use arsenic spray.
Nephantes serinopa	India.	,,	,, ,,
Graeffea cocophaga	Polynesia.	,,	Burn ground over or turn it to destroy eggs; put barrier on trunk.
Aspidiotus destructor	All coco-nut lands.	Destroys leaves.	Attend to sanitation of trees. Use weak kerosene or palm-oil—soda emulsion if worth while.
31 other scale insects	Various lands.	Attack leaves.	Remove and burn infested leaves. Kerosene emulsion may be used.
Aleyrodicus cocois	West Indies.	Eats leaves.	
A. destructor	Philippines.	,,	
Locusts, various kinds	All coco-nut lands.	Destroy leaves.	
Termites, various kinds	,, ,,	Destroy seed nuts; rarely injure trees.	

MISCELLANEOUS PESTS

The robber crab, *Birgus latro*, is a huge crab, sometimes more than a foot long, living on the coasts of the Islands of the Indian and Pacific Oceans. From Samar across Polynesia it is known as an enemy of the coco-nut. Its claws are so powerful that it can tear the husk from a ripe nut and break the shell, either directly or by beating it on a stone. It then eats the meat. A crab can consume two coco-nuts daily, but it is likely to have time for only one, as it works chiefly during the night. The crab not only destroys fallen nuts, but has been certainly known to climb trees and fell the nuts. The crab itself is a highly prized article of food, and is therefore kept in check where there are enough people to have coco-nut plantations. It has been suggested that with the decrease of the Polynesian population the crab may increase in number, enough to become a dangerous pest; but as men will always live where there are coco-nuts, and there is no interest in coco-nuts where there are no people to care for them, this danger is probably not great.

Snakes are not an enemy of the coco-nut, but are rather serviceable in that they kill rats. Where rats are abundant, snakes are not rarely found in the crowns of the trees, and have been known to kill men gathering nuts or toddy.

Among birds a parrot is said to destroy young nuts in parts of Polynesia. The crow is an enemy of coco-nuts in most parts of the tropics. It picks holes in the young nuts for the sake of the water, and all nuts which have so been opened fall to the ground. In times of drought, when water is hard to find elsewhere, the damage done by crows becomes very serious. The most practical way of getting rid of them is to shoot as many as possible, and hang their carcasses in the trees. The same method will probably serve against the parrot.

The huge fruit bats, sometimes called flying foxes, are found, in different kinds, throughout the range of the coco-nut, and occasionally molest the nuts. In the West Indies, and still more in East Africa, they do appreciable mischief to this crop, but in general they find other fruit more to their taste. Something can be accomplished by shooting in the plantations; but where they are numerous it is necessary to find and break up their roosts.

The rat is an enemy of the coco-nut in scattered localities throughout the tropics. The rat is most dangerous as a bearer of bubonic plague, and in places it has been found worth while to practically exterminate the animal for this reason. When this is done, the coco-nuts are freed from the pest at the same time. To get rid of rats in coco-nuts, the most practicable method is probably surrounding the trunk of each tree with a collar of tin or sheet iron, several inches wide, and attached so that it slants outward and downward from the tree. This treatment of the trees is costly enough, so that it is not worth while except where the damage done by rats is especially serious, or where the rats are being got rid of for sanitary reasons.

The bandicoot, a huge rat reaching a length of as much as 2 feet, native in India and neighbouring regions, kills young trees outright for the sake of the tender internal structures. Trees four to five years of age are not yet free from such attack. A report from Ceylon tells of 150 trees killed in a few weeks, in a grove of $7\frac{1}{2}$ acres.

The porcupine attacks smaller trees and kills them in the same manner. Trees one and a half to two and a half years old are in greatest danger from this enemy.

In the Malay States bears are classed with pigs and rats as dangerous enemies, and the three are said to do more damage than is now done by beetles. In Lower Perak bears recently destroyed more than a thousand trees in one year.

Of the higher animals the most dangerous to the coco-nut is probably the hog. In the coco-nut regions of the old world, the wild hog is almost everywhere present, and may be expected to destroy all young coco-nuts which it can reach. In the Philippines many plantations of young trees have been almost wiped out by these pests. Something can be done in keeping them away by means of dogs, but this kind of protection usually proves ineffectual where wild hogs are numerous. Coco-nuts are not safe unless protected by good fences, and a fence to be reasonably hog-tight must be of barbed wire, with at least six wires, the lower ones not more than four inches apart and close to the ground, and very tightly stretched. If such a fence is built, it should then be patrolled at intervals of not more than one week, to see that hogs do not open holes under it, and use them as runaways. Planters sometimes have the idea that coco-nut seedlings are cheap, while the fence is expensive, and that it is economical to keep hogs away as well as possible with guns and dogs, and to replace such trees as are still destroyed. This policy may be trusted not to succeed. The hog is both wary and venturesome. If seedling coco-nuts can be reached, he is likely to find them, and where there is abundant bait many hogs may be expected. In the Philippines, instead of the effectual barb wire fence a light rope, or a heavy cord, is sometimes soaked in tar or in hog dung, and strung around the field to be protected; for a time this affords reasonably efficient protection and can be renewed without much cost.

In some places appreciable damage is done by monkeys and apes of various kinds. Very moderate use of a gun will usually drive such animals away.

CHAPTER IV

SELECTION AND TREATMENT OF SEED

A. Varieties of Coco-nuts.—There have nowhere been any prolonged experiments in the breeding of coco-nuts; there are no seedsmen who deal in coco-nuts as seedsmen do in the seed of the field and garden crops of temperate countries; and except the French Ministry of the Colonies, no government has carried on any systematic study of the different varieties, races, and strains which may be recognized among the coco-nuts, or made any effort to compare in a single place the races from different countries. There are very numerous names which are given in different parts of the world to more or less distinct varieties. Practically none of these forms are so well characterized and understood that it is possible to say positively whether or not similar varieties found in different parts of the world are identical. This much can be stated positively, that we do not know thoroughly distinct varieties which can be trusted to breed true, as for instance, the different races of horses or of maize will do; but that there are in all countries, where the raising of coco-nuts is an important industry, strains or varieties which are suited to different purposes, or which are of unequal value. With regard to the suitability of different varieties for different climatic or soil conditions, nothing whatever is known.

The best study of the varieties of coco-nuts which has so far been made seems to me to be that undertaken in Madagascar by Prudhomme. The Colonial Government collected, by visiting different lands with well-developed coco-nut industry, the best-known varieties of Ceylon, Indo-China, and the islands of the Indian Ocean. These were grown together, but no publications have so far been made which show how the different varieties have behaved when grown side by side.

As to the number of varieties which may be recognized, Prudhomme presents a plate showing photographs of twenty apparently very distinct forms. These represent the most conspicuously distinct varieties from Ceylon, Nouméa, the Seychelles, and continental India. The list of names for varieties can be carried very much higher. Simmonds lists thirty varieties, and Shortt names thirty for Travancore alone. On the other hand, Watt reduces all the Indian forms to five varieties. Jumelle states that at least twenty-five varieties are known in Java. But both he and Hubert also state that there are more than forty known in the Philippines; and this figure, if it has any basis whatever, can only rest on the number of dialect names which it is possible to distinguish.

The more conspicuously different varieties are for the most part unquestionably duplicated in the different lands where coco-nuts are grown. It is possible to distinguish varieties in various ways. For instance, the colour of coco-nuts varies from green to yellow and brown. The brown nuts and green nuts are very different in appearance; but a careful analytical study made by Walker at San Ramon failed to show any constant differences whatever in size, in yield of copra, or in richness in oil. Different, then, as these nuts appear, there is no practical object whatever in distinguishing between them. There is no reason to suppose that this statement does not apply equally in every part of the world.

So far as any careful observations show, differences in form are likewise unimportant. It is easy in any place with many coco-nuts to find a considerable difference in shape. The extremes are from spherical to a form which is at least twice as long as it is thick. The tip may be indented or beaked. These differences are usually the characteristics of the tree, the nuts on a single tree being alike. They could therefore easily be maintained by selection and developed into race characters. But there is obviously no object in this so long as we do not know that any form is superior to any other.

There are practically to be distinguished in the Philippines the following varieties:

First: What may be called the San Ramon nut, because it is the characteristic tree of the San Ramon district, and because it has received especially careful study there. This is a very large and productive coco-nut. The average production, year after year, from the San Ramon hacienda and the neighbouring plantations, is one picul of copra from every 200 nuts; at this rate, 3270 nuts are needed to produce one ton, or 2240 pounds of copra. Apparently the same nuts are found near Dapitan, on the same island, where they are known as "Romano." They are also in general cultivation in the coast district of the province of Pangasinan in Luzon, and are found occasionally in various parts of the Philippines; and individual nuts, larger than any I have seen at San Ramon, have been exhibited from the islands of Marinduque and Bohol. This nut is found in various coco-nut countries, ranging at least from Ceylon across Malaya and Polynesia, and probably in the West Indies. But there are no records from any other part of the world of *plantation averages* showing such size of nut as those of San Ramon. There was one cutting for the entire plantation at San Ramon in 1905, when the average production was one metric ton of copra from every 2800 nuts. This represents nuts more than twice as large as the average for the whole world. Under reasonably favourable conditions the San Ramon nuts are produced in fairly large numbers—as many as a tree can well carry—of nuts of this size. One tree especially well situated produced during the entire time which I spent at San Ramon at the rate of 220 nuts per year, 55 being the average for three successive cuttings three months apart, and understood to be the usual yield of this tree.

Second: The Laguna nut. This is the ordinary coco-nut of the archipelago as a whole, and represents in creditable form the typical coco-nut of the whole world. Of these nuts the average number required is 5600 for each metric ton of copra. As a basis for comparison with some other countries, it may be said that this would represent very satisfactory nuts in Ceylon; that in Samoa 6000 nuts are in general regarded as necessary for each ton; that weighing of a few African nuts indicates 6450 as needed to make one ton of copra; and that of the usual run of Trinidad nuts 6600 are required. It is to be understood that the dwarf varieties are not included in any of these figures. The Laguna nuts, like the San Ramon nuts, will occasionally produce fruit in five or six years; under altogether favourable conditions a plantation should be in general bearing in eight years, the time under less favourable conditions being from ten years upward. These figures represent in general the time necessary in every country which has a great coco-nut industry.

Third: The coco niño or baby coco-nut. This variety is found in the Zamboanga district accompanying the San Ramon nuts, from which it is locally exceedingly distinct. Seven thousand or more of these are required to produce one ton of copra. This coco-nut produces fruit at the age of four years, when the trunk is so short that the nuts can be collected for several years by persons standing on the ground. This nut has a rather thick and hard copra, and, as far as regards the number of nuts, is exceedingly productive. The tree which has already been mentioned, which in successive cuttings two months apart produced 112 and 106 nuts, was of this variety.

Fourth: The Pugai, a very dwarf nut. The name given here is a Bicol name. Specimens which I have from the province of Camarines have the nut proper, 7 centimetres in diameter, surrounded by a husk not more than 2 centimetres in thickness. Apparently the same nut is known in Pangasinan as "Piligpog," and the same variety is found also in Zambales. These very small nuts are used as curiosities, one of the eyes being punched out to represent a mouth, so that the germinating end looks like the face of a monkey. They are also used as household banks, or they may be stuffed with candy or sweetmeats. The Pugai is likely to fruit in three years. There is also a variety, very likely identical with this, in India, which fruits in this time, and the same is true of a dwarf variety which was introduced from Ceylon to Madagascar.

Forms intermediate between the coco niño and the Pugai are the dwarf nut known in the Visayan islands as "Dahili," and probably a nut known in Laguna as "Mañgipod." The latter is said to produce fruit when the tree is so small that the cluster rests directly upon the ground. The dwarf Jaffna variety of Ceylon and Kalapa Babi of Java are like the Mañgipod or identical with it.

Clear cut and distinct as are the San Ramon nut, the Laguna nut, the coco niño, and the Pugai, when only these four forms are considered, it would probably not be difficult to collect in the Philippines an unbroken series without a break of 1 millimetre in diameter which should connect the largest nut and the smallest nut; and while the extremes in some places are perhaps not so great, it would probably be easy to make an equally perfect series as far as it went in every country where coco-nuts constitute an industry.

Among these varieties, or among the equivalent varieties known in another coco-nut country, choice must be made according to the market on which the product must be placed. As a rule, the product will be marketed in the form of copra or of oil. In this case the first consideration is the total amount of copra or oil which a variety will produce, and next in importance to this is the size of the individual nuts. For between two varieties of approximately equal total productiveness, the one with the larger nut is decidedly the more valuable. This is for the obvious reason that it costs about as much to harvest, to husk, and to open a small nut as it does a large nut, and that therefore any given amount of copra can be manufactured more cheaply from large nuts than it can from small ones. It is further to be observed that the copra of large nuts will sell on a really discriminating market at a higher price than the copra of small nuts, because it can be marketed in larger pieces. The difference in economy in handling large nuts and small nuts is so great that even though one of the dwarf nuts, which in general mature several years sooner than the large nuts do, were approximately equally productive with one of the very large varieties, it would still in the long run not be economical to select the dwarf nut for the manufacture of copra.

If the product of the coco-nut is to be marketed in the form of jaggery (tuba, or coco-nut wine) or used to make alcohol, sugar, or vinegar, then the choice of variety will be entirely different. The value of the product is here independent of the size of the nut, but depends on the total vigour of the tree and on the number of fruit clusters which are formed. The number of these fruiting branches is often greater on the dwarf varieties than it is on the varieties with large nuts. Since the dwarf varieties are also productive at a much earlier age, it is obvious that these are the ones to be chosen. In the Philippines the coco niño is the most valuable nut for this use.

There are also special uses of the coco-nut and special markets for some of the products. To meet these a special selection of the seed nuts or special choice of variety should be made. From various parts of the tropics whole coco-nuts are shipped to the temperate zones, and in different places these are bought on different terms. Where the local custom is to pay a given price per coco-nut, irrespective of the size, the planter who produces large nuts is at an obvious disadvantage, for small-fruit varieties almost always produce most nuts. If the nuts were bought by weight, each variety might be expected to sell according to its actual value; but as a business procedure this is hardly possible, because of the variable amount of water contained inside the nuts. In Trinidad the nuts are sold by number, but only nuts above a certain minimum size will be accepted. For such a market, it is evident that the most desirable variety, from the point of view of the planter, is one which produces a crop which is uniformly just above the minimum marketable size.

If coir is the product which is expected to be of greatest value, the qualities which make a nut good or bad are the amount, quality, and ease of preparation of the fibre. Some but not all of the varieties grown in the Maldive and Laccadive Islands produce a particularly good fibre. As a rule, the market prices are such that coco-nuts are worth more for copra or oil than for coir, and it is therefore not advisable, except under peculiar local conditions, to sacrifice anything in the copra producing power for the sake of superior fibre in the husk.

In the Philippines, in the province of La Laguna and in the coco-nut district immediately around it, and locally elsewhere, there is found a peculiar variety known as "Makapunó," which, instead of having a cavity inside the hard endosperm, has a moderately light but still firm tissue filling the entire interior of the nut. Makapunó nuts themselves will not germinate, but are likely to be produced on trees which grow from ordinary nuts borne on trees part of whose nuts were Makapunó. The Makapunó nut is valued as a delicacy, and the individual nuts sell frequently at a price of

20 centavos or more, on a market where the ordinary nuts cost 3 or 4 centavos only. In such a case it is evidently good business practice to select seed which will be likely to reproduce this peculiar freak.

Other peculiar nuts for which there is a local and limited demand are those known as "Lonó" in Albay, which have a soft endosperm instead of a hard one such as could be used well for the manufacture of copra; and the variety whose husk is sweet so that it may be eaten like sugar-cane. This variety is called "Tabán" in Pangasinan, "Cuyamis" in Northern Mindanao, and "Kalapa Tebu" in Java. Finally, the coco-nut, like other palms, is valuable for decorative purposes. For such use one or other of the dwarf varieties is usually chosen, because these are peculiar and unusual, and because of their early fruiting habit. In the island of Marinduque there is a variety which has the foliage as well as the nuts yellowish in colour. This variety is regarded as inferior for the ordinary uses of the coco-nut, but is valuable as a decorative tree. This is probably the Palamcotta of Simmonds' list.

Still other varieties are recognized in certain limited localities in the Philippines. Thus in La Union, beside the ordinary nuts, large and small and of various colours, and the Tabán already mentioned, there is a variety called "Tataguden," which has a thick husk used by weavers to clean their fibre. "Tutupaen" of the same locality is a small nut with very thick shell. These shells are beaten together and bets are placed on which will break the other. An especially hard-shelled nut of this variety is probably the highest priced of all coco-nuts. "Lupisan" is a large nut with very thin husk in the same province. A notably large number of varieties are distinguished by name in the Visayan island of Leyte. Among these are the Makapunó, already mentioned; "Agtá," characterized by nuts so dark a green that they are almost black; "Bulao," with pale-brown fruit; "Busag," which is a very pale green; "Burawis," which has both fruit and foliage a very shiny yellow; "Lunó," identical with the "Lonó"; "Cayumanis," identical with the "Cuyamis" already mentioned; and "Lincoranay," characterized by its low growth. The Lincoranay includes a number of minor varieties, having fruit red or green and large or small, including also "Dahili," and the still smaller nut called "Inano," which is not as extreme a variety as the "Pugai."

To sum up what we know about the varieties of coco-nut: there are many forms to be found in all the leading coco-nut countries. How distinct these are, or how true they will breed, or how far they are identical in the different countries cannot at present be said. According to the form in which it is expected that the product shall be sold, different varieties may be entitled to first choice. If the product is to be sold in the form of copra or oil, the most desirable variety is one which at the same time has large individual nuts and a large total production. It would obviously be desirable to take the percentage of oil in the endosperm into account in selecting the seed, but this refinement is not at present possible.

B. Selection of the Seed.—Whatever variety of coco-nut may be chosen, the seeds which are to be planted should be selected as the product of *individual trees*, and these trees should be very carefully picked out and should be the ones which most exactly have the qualities which it is desirable to give to the entire plantation. There is no point in the coco-nut business where careful personal attention is more necessary or will prove more profitable than in the selection of the *trees* which are to furnish the seed nuts. Leaving out of account selection for any of the minor uses, and considering only the production of copra or oil, there is one safe and sufficient rule. Select the seed of the TREES which are conspicuously MORE PRODUCTIVE THAN are THEIR NEIGHBOURS which are GROWING UNDER THE SAME CONDITIONS.

If a tree is especially productive because it grows in especially rich soil, or because it is well watered or well fertilized, or because it is freely illuminated on all sides, then no matter how conspicuously productive it may be, there is no sound reason for choosing it as the source of seed. Seeds are chosen for their hereditary qualities, and a good environment cannot be inherited. A tree in the middle of a grove which regularly produces more nuts or larger nuts than its neighbours, and is without any compensating drawback, should be selected as the source of seed, even though a tree at the outside of the same grove which is still more productive be passed over.

The selection of nuts from piles or at any time after they are cut from the tree is not to be recommended. A tree bearing very few nuts is for that reason likely to bear large ones, and it will thus often happen that the selection of large nuts from the nut pile is in effect selection from trees which are not very productive. Moreover, there is a chance that the large nuts in general nut piles are from trees which produce large nuts because they grow under especially favourable conditions, and, as we have just seen, there is no reason whatever why the fruit of such trees, however good it may be, should be selected for propagation.

When the trees which are to be the source of seed nuts have been selected, their nuts should be regarded as having a value which is based on the value of the trees they will produce, and as therefore out of all proportion to the value which they have as mere nuts. It is worth while to harvest these nuts with a care which would be economically impossible for nuts intended for the production of copra. It is well worth while to collect the nuts of a good seed tree by lowering them to the ground by hand in order that there can be no risk of breaking or cracking them. A cracked nut will never germinate.

The nuts are ready to be used for seed at the same time at which they are really ready to be used for copra, that is, when a third or a half of the water in the interior cavity has been used up. This condition can be recognized by the heaviness of the nut and by the noise which it makes when shaken.

C. Germination of the Seed.—Under exceptional circumstances seed may be planted directly in the field before waiting for it to germinate. This could well be practised, for instance, if the land is already in cultivation with a crop which would not be interfered with by the presence of the coco-nuts, or with such a temporary crop that it would be difficult at any later time to stake the ground off and make the holes for planting the coco-nuts. In general practice, however, since some coco-nuts will not germinate and blanks will thus be left in the field, and because the coco-nuts in the field are exposed to the attacks of various enemies which can easily be guarded against while the nuts are kept in small beds, and since it is usually desirable to have the nuts germinating and getting their start at the same time that the land is being prepared to receive them, for all of these reasons the nuts are germinated collectively, and are subsequently transplanted to their permanent places.

The way that the nuts can best be handled while they germinate depends somewhat on the time which is to elapse before they are transplanted, and partly upon local climatic conditions. Leaving out of account the mere piling up of the nuts without order, which is mere shiftlessness, there are several ways which, under different conditions, may be recommended for the treatment of the seed nuts. One of these is to tie them in pairs and hang them over a pole. When this is done, the nuts will obviously receive no water from the soil; it is therefore a method which can be employed only where the climate is exceedingly humid or where it is very easy to sprinkle the nuts at any time. If the nuts are hung where no water will fall upon them except artificially, the rate of germination is entirely subject to control. This method is therefore a good one when it is desired that the germination should be

NUTS HUNG UP IN PAIRS TO GERMINATE.

Photograph, Reimold.

NUTS STACKED ROUND A POLE TO GERMINATE.

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slow. Or if it is known for any reason that transplanting will be long delayed, this method is to be recommended, because the nuts are so placed that the development of the roots is hindered more than the growth of the plumule. Another method essentially like this, which is sometimes practised in the Philippines, consists in putting the nuts up in the form of a hollow cylinder around the posts which support the houses. They are then dependent on an artificial supply of water, so that germination may be hastened or made slow as is wished, and likewise so that the development of the root is relatively checked.

The use of seed beds is far commoner than that of the methods which have just been described. It has the advantage that the nuts require less attention, and the disadvantage that the development is under less perfect control. It is, moreover, obvious that the nuts can be more perfectly protected against hogs, white ants, or any other enemies if they are hung up or tied up under the house than if they are in any other position.

The arrangement and care of the seed beds, and the method of planting the nuts in them, are determined by the length of time that the nuts are expected to remain there. From the standpoint of the nut, it is desirable that it be transplanted to the field and permitted to begin the development of a permanent root system at as early an age as possible. In practice, however, transplanting may have to be delayed while the land can be prepared to receive the nuts, or because of the difficulty of protecting the seedlings after they are transplanted, or for still other reasons. Germination itself requires from three to six months. The most rapid development can be expected if the seedlings are transplanted into the field before the plumule exceeds 15 centimetres in height. If it is to be expected that this practice will be followed, then the seed beds need not be cultivated to a depth of more than 20 centimetres, unless deeper cultivation will result in a better supply of ground water, and therefore in an economy of sprinkling; and the nuts ought not to be buried for more than a third of their own thickness. In such case also the nuts may be placed in contact, side by side. If, on the other hand, it is anticipated that the nuts must remain in the seed bed for a year or more, then the soil in the seed bed ought to be worked fine to a depth of at least 30 centimetres. The nuts may well be buried to about their entire thickness, and there should be left between the neighbouring nuts a space, the width of which must depend upon the size which the seedlings will reach before they are transplanted.

Under all conditions it is desirable to choose for the seed bed a place where water is easily available for sprinkling, where the ground is well drained, and where there is light shade. The nuts should be placed on the side; and it is probably worth while, in order to facilitate germination and to guard against occasional distortion of the young shoots, to slice off a piece the size of the palm from the husk, near the end at which germination occurs, and to place the nuts with this cut surface on the upper side. The cultivation of the seed bed and the ground immediately around it should be thorough enough to protect it from any danger of white ants, and it is usually worth while to enclose the seed bed with a fence to keep off larger enemies.

While it is very strongly to be recommended that the seedlings be transplanted before they have an opportunity to develop a root system in the seed beds, and while there is no necessary reason why any nut so transplanted should not live and thrive, it is still not fairly to be expected that every nut transplanted will ultimately produce a tree. To fill up vacancies which may subsequently occur in the field, a small reserve seed bed should be maintained. It is worth while to space the trees in this reserve bed as far apart as 1 metre by 50 centimetres, and to remove the alternate trees as they are needed in the field. The trees left then will be 1 metre apart, and these can be drawn upon to fill vacancies in the field at any time until the trees are at least four years old. If planting is going on over a term of years, trees used to fill vacancies should be older than the trees among which they are placed, as they will be relatively backward on account of previous crowding and of injury done in transplanting.

In many places, probably in most places, it is customary to postpone transplanting from the seed bed to the field until a year or a year and a half after the nuts are placed in the bed. While no considerable damage is likely to be done by transplanting nuts whose shoot is not more than 15 centimetres in height, without regard to the roots which may be broken, the same thing does not remain true as the seedling becomes more developed; and it is questionable if it is ever economically practicable in the establishment of a plantation to keep dirt about the nuts when they are transplanted into the field.

If the seedlings are left in the bed until the shoots are 50 centimetres high, they are damaged so much by transplanting that they are likely to be overtaken by plants transplanted at the same time, but which have not reached more than one-third of the height. If seedlings are allowed to develop in the seed bed beyond the point where the first leaves begin to expand, care should by all means be taken that transplanting does not happen at or about the time that the last of the reserve food of the nut is consumed. If they are left in the seed bed until most of the food stored is used up, they ought then to be left for a considerably longer time to permit the plants to develop such strength that they can recover from the injury of transplanting without the use of the food in the nut. If the nuts are placed closely side by side or if the seed bed is too densely shaded this will never happen.

The practice of delaying the planting of the nuts in their permanent places reaches its extreme in the northern part of Ceylon. What is known as the Jaffna method, because in use in that district, consists in a double transplanting. The nuts here are placed in seed beds at distances of 30 centimetres apart. After eight to twelve months they become too large to be left so close together. They are then transplanted into larger beds, and spaced in general about 1·5 metres each way. In these they are left for three or four years, and during this time are manured, watered, and given careful cultivation. So much care and attention is not economically possible in most places; but the treatment given the trees in this second bed can well be applied elsewhere to the beds used for reserve nuts, since it is worth while in order to prevent vacancies in the plantation to fill blank spaces at a cost greater than would be reasonable for the average of all the trees. The Jaffna method demands cheap labour; and even with labour cheap in proportion to the value of land, it is only worth while where the soil is light and there are severe dry seasons.

SEED BED WITH YAMS IN BACKGROUND.

This is in a very humid region ; in most places the nuts should be buried deeper if left to this size.

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CHAPTER V

FIELD CULTURE

A. Preparation of Land.—The preparation which land needs to receive in advance of the planting of the coco-nuts in the field depends of course altogether on its previous condition. If it has been already in cultivation in other crops, there is obviously no especial advance cultivation required. If it has been previously in cultivation and is now occupied by grass, the preparation needed before it can be used for coco-nuts offers no particular problems, and may therefore be passed over with a word. For coco-nuts, as for most other crops, this is the worst condition in which land can begin to be used. However, in many parts of the world this grass-land, or land in which grass and brush are mixed, is the only place which is practically available. If possible, such land should be ploughed repeatedly until the wild grass has been practically eradicated, and short-lived catch-crops should be made to pay the cost of this work.

Wherever it is available, the first choice of land will be given to virgin forest, or to second growth forest as old as possible. In many parts of the tropics, notably in Africa, the valley of the Amazon, and some of the large and sparsely populated islands of the Old World, such as Borneo, New Guinea, Celebes, Mindanao, and Sumatra, such land is still to be secured at a very low price. This is true, however, solely because of the absence or scarcity of inhabitants, and this condition creates a labour problem which should be solved by every prospective planter before he tries to establish himself. The problem is a personal one in its nature; the man who is acquainted with local and neighbouring conditions, and who is apt and skilled in handling labour, will solve it with little difficulty. The stranger or the man without the genius for holding and handling his labour will not succeed under such conditions.

Land which is covered by forest will show the measure of its fitness for coco-nut production to the practised eye at the first glance. Both the moisture of the air and the moisture in the soil show themselves in the character of the native vegetation. There are in all lands characteristic trees and other plants which serve the local expert as infallible guides to the local soil and climatic conditions. Only the local expert can read such clues; but it can be taken as a quite safe general proposition that wherever in the tropic lowlands there is a heavy stand of large and evergreen trees the coco-nut with proper treatment can be made very productive. The clearing of this land will have to be done by local labour, and this labour will usually do its work best if permitted to do it in its own way. In the Malayan region the native practice is to cut first the smaller plants, the vines and the younger trees, and to burn these when they become sufficiently dry. The larger trees are usually felled after they die as the result of ringing or of fire, or rarely are left to fall to pieces as they decay. The practice, on any large scale, must be to fell all trees and to burn the waste vegetation as completely as possible. This is most often done by burning three times; what does not burn the first time is gathered into piles for the second, and this operation is repeated with what is left for the third burning.

Whether or not the local vegetation, as it is cleared off, will furnish saleable products which will pay for the work, or yield a profit, is a question depending altogether on local conditions. It ought not to need to be said that where a profit can be obtained as the land is cleared, it should be done; still I have seen more than a few cases where planters were so eager to reach the stage of cultivating the land, and so occupied with this single aim, that they wasted the natural resources and failed to get any return whatever from marketable timber sufficient to have paid the whole cost of establishing the plantation.

As already said, it will be necessary to burn the ground over several times to get rid as completely as possible of branches, trunks, and stumps which would interfere with the use of the land. This burning wastes the nitrogen stored up in the native vegetation, and usually causes the soil to retain its original fertility for a shorter time than it would if the vegetation were permitted to decay in place. Nevertheless, it is often the only possible practice, because in the absence of fire the vegetation which has been removed will be replaced by brush before it is sufficiently out of the way to permit effective cultivation, even by hand.

The removal of stumps is a different question. In temperate countries no good farmer tries to convert woodland into field without removing the stumps of the trees. Rubber planters in the Orient are rather generally agreed that they should do the same when planting rubber on virgin land, and some English coco-nut planters in Ceylon have maintained that the planting of coco-nuts on land from which the stumps have not been removed is a slipshod device which cannot be regarded as decent farming. This probably depends largely upon the relative value of land and labour. Where the land is expensive and labour is cheap, it is good business to invest more money in labour and less in land than it is in places where the conditions are reversed. The former condition is the general one in Ceylon. Where land is as cheap as it is in the Philippines, and where labour is as expensive, I am very sure that any man will in the long run get far greater returns on the capital he invests if he clears and plants as much land as he can expect to care for and invests no part of his resources in pulling or grubbing out stumps. It would cost more to remove the stumps than it usually does in temperate countries; and on the other hand, with the tropical heat and moisture, white ants or other insects, and the fungi will get rid of the stumps far sooner than decay would remove them in the North. The rubber planters' objection to the presence of stumps is chiefly that they serve as breeding-places for white ants, which then attack the living rubber. It will rarely happen that the termites do any damage to coco-nuts planted in the field; and where they are troublesome they can be guarded against by poison or by cultivation far more cheaply and effectively than can be done by grubbing out the stumps.

Assuming that the land is cleared, by labour and by fire, as completely as is feasible, it should then be brought into immediate use, both by coco-nuts and by catch-crops for the coco-nuts. The first thing to be done is to line off the ground, marking accurately the spot for each tree. The regular arrangement of trees in the field is a matter of very considerable permanent importance. Cultivation is obviously made much easier by it, and this applies not only to the coco-nuts but to any other crop which may be interplanted. More important than this, however, is ease in supervision. Whether or not the management and care of the farm be handled by contract, it is very desirable that it be easy to check at all times the work which is done on the field. This will of course be very much easier if the trees are regularly arranged so that the grove can easily be divided up into units. Before the ground can be lined off, a decision must be made as to the distance between trees, a point on which practice in different places varies very widely.

Those who have written about the coco-nut have, without exception, recommended wider spacing than is often to be found in practice. One factor which has contributed considerably to close planting is the fact that a coco-nut plantation is usually valued by the tree instead of by its area or even by its production. In the principal coco-nut region of the Philippines the younger groves are usually planted more closely than those twenty years or more old. Filipino planters have themselves told me that they do not get a greater yield by the closer planting; and as a matter of fact I am satisfied that the yield of the newer groves, even after they come into full production, is quite appreciably less. But, as business is done in these islands, if a man desires to sell his grove, he is likely to receive from three to eight pesos a tree, the price depending upon the location and upon the current market price of copra, but not upon the closeness of the planting nor upon the actual number of nuts which the trees produce.

It is said that natives in Ceylon, Indo-China, and some other parts of the Old World, plant their coco-nuts as close together as 4 metres when they are not mixed with trees of other kinds. According to Watt's Dictionary, the Indians of Bombay plant their trees about $4·5 \times 5·5$ metres, and in Mysore 6×6 metres. The customary distance in Zanzibar is given as $4·5 \times 6$ metres. Prudhomme regards 7·5 metres as the least proper distance in poor soil. It is my opinion that where this distance is the greatest which the coco-nuts can use to good purpose the conditions are so unfavourable that coco-nuts should not be planted. The usual distance on larger plantations in Trinidad is from 7·3 to 8 metres (26 feet); 7·3 metres (24 feet) is the commonest distance between them. Coert, in a carefully worked out prospectus for coco-nut plantations in Java, assumes the distance between trees as 8·4 metres.

Semler regards 10 metres between trees as in general the best distance, and cites as evidence the experience of the Alma estate in Penang. A part of this estate, planted with 100 trees to a hectare (that is, 10 metres apart), yielded an average of 60 nuts per tree, or a total of 6000 nuts; while another part having the trees 8 metres apart yielded 30 to 35 nuts a tree, or a total of about 5000 nuts. In Polynesia there are various European plantations on which the trees are spaced 10 metres, and some on which an even wider spacing is in use. So far as the nature of the ground permits regular planting, 10 metres has also been found a proper distance in the Seychelles. Van Oijen, in the *Bulletin of the Colonial Museum* at Haarlem 41 (1909) 30, states that on the plantation of Tjikeumeuh, in Java, the trees are set about 13 metres apart; and summing up all the information and experience at his disposal gives 12 metres as in general the distance which can be most confidently recommended.

The effect of sunlight on the productiveness of coco-nuts is illustrated by records made by myself at San Ramon in Mindanao. There are coco-nuts in double rows, one on each side of each narrow road, on this plantation. In such a row, which contained no non-bearing trees, I found the yield at one cutting to average 22 nuts to the tree. It is customary here to cut the nuts four times a year. A single row of trees along the well-drained bank of a slough yielded an average of 27 nuts, all trees producing. A single tree standing by itself in the open yielded 55 nuts, which was the average of this tree for several successive cuttings. In the centre of an old grove the average for the *producing trees* was about 11; and in the same situation in a large grove on the neighbouring hacienda of Talisayan the average yield of bearing trees was only 8 nuts; the individual trees in the area in which this count was made were less than 6 metres apart, their crowns interlacing freely and producing a rather dense shade; and many trees were without ripe nuts.

In determining the distance to be adopted, the favourableness of local conditions, both climatic and of the soil, and also the treatment which the grove is likely to receive, should be taken into account. If the conditions are unfavourable, the trees may well be planted somewhat closer together. However, I do not believe that a less distance than 8 metres is ever to be recommended; where the trees cannot make good use of all the space when they are this far apart, it is not worth while to go into the business of raising coco-nuts. If the trees are planted 10 metres apart they will fruit well enough so that under any conditions, excepting at any rate those which are very exceptionally favourable, they will give a larger return per hectare than if they are placed much farther apart. It must be observed, however, that the total returns from the land do not have to depend upon the coco-nut alone, and that if a wide spacing is adopted, the opportunity for catch-crops, or for the use of the same land as pasture, may make the total and the net returns greater than if attention is given entirely to the coco-nuts. This consideration will presently be discussed at more length.

The given distance between trees having been decided upon, it should be observed that the common method of planting in squares, so that the rows run regularly in two directions which are at right angles to one another, does not make as complete and perfect a use of the land as can be done by having the trees alternate in the alternate rows. The latter method is commonly known as planting in quincunx, or may be described as planting in diamond or triangle. Adopting this method and assuming a distance of 10 metres between trees, the stakes for the first row made will be this distance apart in a straight line. Returning then to the beginning of the second row, describe an arc of a circle with a radius of 10 metres from each of the first two trees in the first row. The point of intersection of these two lines is the location of the first tree of the second row. The second tree is located likewise by arcs described from the second and third trees of the first row, etc. The distance between the first row and the second row is about $8\frac{2}{3}$ metres. The other rows are located in the same manner and of course fall the same distance apart. But while these rows are approximately $8\frac{2}{3}$ metres apart, there is no tree which is placed less than 10 metres from any other tree, and the distance between the trees is the thing which is important. Planted in this way, and maintaining the distance of 10 metres between trees, each hectare of ground, instead of 100 trees, will support 115·47 trees. To find the number of trees on one hectare with any given spacing, if the trees are planted "in square," divide 10,000 by the square of the distance between trees expressed in metres; if the trees are in quincunx, divide 11,547 by the same figure. Whatever the spacing, any given area has room for 15·47 per cent more trees in quincunx than in square. The advantage of this method of planting, provided the distance between trees is not altogether too short, is too obvious to need further argument.

B. Transplanting.—The preparation which it is worth while to give to the spots where the nuts are to be planted depends on the nature of the ground and the price of labour, and on the age at which the seedlings are transplanted. An ideal method under all conditions would be to prepare a very large hole and to fill this, around the nut, with very rich and well prepared soil. It is especially important in an altogether practical sense that the coco-nut should grow rapidly from the very start. It is obliged to compete for light with other plants unless it receives really good cultivation. Competitors for light are not dangerous unless they are nearly as tall as the coco-nut, or taller. By the time the coco-nut is three or four years old, it is a very simple matter to protect it against this kind of competition, and the sooner the leaves can be made to grow up to the point where they overtop the neighbouring vegetation, the cheaper will be the cultivation which is necessary to bring a grove into profitable bearing. It is therefore a general principle that the smaller the tree is, the more need it has for cultivation and the better return it will pay for even a small amount of fertilizing; and the easiest and best time at which to provide it with soft and rich soil is when it is being transplanted.

But, while the ideal treatment would be the digging of a very large hole, there are practical limits, fixed chiefly by the price of labour; and it therefore rarely happens that a planter digs holes of such size as most writers recommend. It is also evident that in soft and rich ground, the coco-nut can take care of itself with comparatively little help. In actual practice, it is probable that most coco-nuts when transplanted are set into holes just large enough to receive them. Such extreme economy of labour certainly does not pay. There are probably no economic conditions in any place such that it would not be worth while to open a hole at least 35 centimetres wide and deep, even though the cost of preparing these holes limits the number of trees which can be planted. In soil which is light and rich, it is probably not worth while to make the holes much larger than this, and this is especially true if the space between the coco-nuts is going to be used for catch-crops which will keep the land in a state of tilth, but will not rob the coco-nut of light. On heavy land, the holes can profitably be made considerably larger, and the same is true of sandy but poor soil, where a larger hole should be prepared and filled with earth better than the most of the surrounding or underlying soil. The figure as recommended for practice in Ceylon is 90 centimetres (3 feet) in each direction. Watt recommends that on poor or heavy soil a hole should be 90 to 180 centimetres in diameter, and 70 centimetres deep. Simmonds goes to the extreme, recommending that on level ground the holes should be 135 centimetres in each diameter, and that on slopes they be made from 180 to 225 centimetres across.[1]

Unless there are conditions such as the necessity of transplanting seedlings before they become too large, or of getting the coco-nuts into place before brush can grow up, or before the presence of catch-crops would

[1] *Tropical Agriculture*, p. 224: "In a level, loose soil, the hole should be a cube, of a yard and a half, on hill-sides 2 to 2½ yards, but in low grounds half or three-quarters of a yard deep with one yard square is sufficient."

interfere with easy transplanting, the holes should be dug from one to three months before they are to be filled. This will permit the exposed soil to weather, and will often make soil which, when first dug, would not be fit to pack around the nuts, serve very well for this purpose; and where it will serve well, it is naturally most convenient to use this soil. It is, however, good general practice to rake or hoe a thin layer of the surrounding surface soil into the hole when the nut is transplanted, and to pack this around the nut.

Regarding the cost of digging the holes, Prudhomme quotes Keating as stating that at Tamatave a labourer under good management can dig in a day eight or nine holes of a cubic metre, or twelve to fifteen holes 80 centimetres wide and deep. The filling of the holes is said to take about the same time. In most tropical countries it certainly will take good management to make labour show this measure of efficiency. In Trinidad, using light soil, the nuts are buried a depth of 8 or 10 centimetres, and the holes are dug just big enough to permit this. Three or four handfuls of lime are thrown into the hole; the nut is put in, covered, and tamped in; and some dry straw is thrown over it. One labourer can transplant one hundred trees in this way in a day.

When the time comes for actual transplanting, the hole should be filled with weathered soil in the way that has just been mentioned, up to such a depth that, when the seedling is put in, the level of the nut will fall at or just below the level of the ground. The nut should then be placed in the middle of the hole, and the space around it filled up in the same way, and the soil around the nut should be placed firmly enough to ensure that it will be sure to keep its place and hold the nut securely. If it is practicable to apply manure or fertilizer of any kind, this should be mixed with the soil which is placed under and around the nut. The soil should be made to cover the nut with a thin layer, but not to cover the short plumule. In places which are naturally wet, or if transplanting is done in especially wet weather, the nut should be planted a little more shallowly so that when the soil is packed around it, it will stand somewhat above the general level of the surrounding ground.

On good and even ground, coco-nuts planted according to the directions just given will develop a large bole, a sufficient part of which will be below the general level of the ground to ensure the perfect anchorage of the tree. There is therefore no necessity for planting at a greater depth, and if the nuts are planted more deeply, their subsequent growth for a considerable time is likely to be retarded. In wet situations this danger is especially great. As an illustration of this danger, I have experience at San Ramon, where the manager of the government plantation undertook to put the seedling nuts out of the reach of wild hogs by digging deep holes and then planting the nuts so far down that the upper side was 30 to 50 centimetres below the surface of the ground. The soil where this was done was well drained and reasonably light, and as the holes were left open above the nuts, it could be seen that in this place the deep planting did not result in the presence of stagnant water about the nuts. Nevertheless, the growth of these seedlings was so slow that when they were eighteen months old they were hardly as large as properly planted seedlings would have been at the age of six months.

On the other hand, if the nuts are not planted sufficiently deep in the ground, there will be danger in many places that the roots as they begin to grow will find themselves in too dry soil; and in all places too shallow planting results in the production of a bole which is not buried to the extent that it should be, so that a large part of the roots come out of it above the surface of the ground. These aërial roots grow exceedingly slowly, and so impede the development of the tree, and such trees are not as perfectly anchored as they should be. I have seen small plantations deliberately planted in this way because they were on wet land, and it was desired to put the younger trees where they would not be injured by the rise of the ground water. With proper handling such trees can be made to develop rapidly and produce reasonably well. But such a situation is not one to be recommended where the planter has freedom of choice.

Reference has already been made to the desirability of filling vacancies, which are bound to occur from one cause or another in every growing grove. The Ceylon planters of highest repute are said to make it their regular practice to fill all vacancies which occur in groves up to eight or even ten years old. It is very important that trees which are transplanted to fill these vacancies should be at least as advanced in their development as the general stand of trees in the grove. The care which can well be taken in transplanting trees which have already reached a considerable size is again a business question which must be settled after a consideration of the local cost of labour and of the distance which the trees must be moved, and the probable necessity and ease of watering them after transplanting.

Under all conditions, there should be transplanted with such a tree a ball of earth so large that no roots need be cut so as to leave them less than 30 centimetres long. If it can practically be done, they should be left longer than this, but by the time the coco-nut becomes four years old it is a good load if accompanied by even a small ball of earth. The most of the leaves should be cut off, leaving not more than the two or three youngest ones. If a larger mass of earth can be transplanted, it will be safe to let more leaves remain on the tree; and recovery from transplanting will of course be quicker in this case. The hole to receive the tree should be made considerably bigger than the ball of earth, which is transplanted and the extra space should be filled with fine, well-weathered and very rich ground which must be packed firmly into place. Care must be taken that there is no opportunity for the roots of such a tree to become dry; for at least two months after transplanting the tree will have to be well watered unless this is made unnecessary by rain.

C. Cultivation of Young Groves.—The treatment to be given the young grove is primarily a business question, the first question to be decided being whether or not catch-crops shall be grown. It is evident that no crop can be grown between the coco-nuts and harvested without removing something from the fertility of the soil, and that this taken by itself is bad for the coco-nuts. The growing of coco-nuts, however, is a business, and the planter will usually not be particular where he gets his returns. If the land can be made to yield a greater profit by growing more than one crop on it at a time, and there are not too great difficulties in the way of doing this, the planter will naturally prefer not to use it for the coco-nuts alone. If labour conditions permit, that is, if the supply of labour is so ample that its use in the cultivation of catch-crops will not interfere with the extension of the coco-nut plantation, it will be found then, under any reasonably good market conditions, that there are various crops which can be taken from the ground and made to pay some profit, above the cost of raising them and purchasing fertilizers more than sufficient to replace what they have taken from the soil; and that their culture will keep the coco-nut plantation in better condition than can be expected if attention is devoted to the coco-nuts alone.

On the other hand, the use of catch-crops is very likely to prove unprofitable in the long run, even though it may yield some immediate returns, unless some fertilizers are returned to the coco-nuts to make up for what the temporary crop has taken from the soil. If such a return is made, and in full measure, the coco-nuts will fare better for the operation; because the food of the catch-crop is taken from the area between the coco-nuts, and the fertilizers can be applied more immediately to the neighbourhood of the young trees. And this is bound to result in their growing more rapidly than they would if they had all the ground to themselves, but were not helped to reach their food.

The labour problem will often make the use of catch-crops on plantations of any size impossible. Where the supply of labour is too limited—and it is more or less limited in all places—the attention put upon the catch-crops must result in interference with the extension of the planting of coco-nuts. For there is no catch-crop, even among those which demand the least care, which can be handled without the use of considerably more labour than is needed to keep the coco-nuts themselves in such conditions that their growth will be satisfactory. Catch-crops will also require the care of the manager, and on plantations of any considerable size, the attention of the manager can usually be better devoted to the promotion of the coco-nut culture alone.

Assuming, then, first, that catch-crops will not be used, the thing to be done for the coco-nuts is merely to see that they have a decent chance to grow, both in the air and in the ground. Coco-nuts themselves do not demand much cultivation of the ground, and except in places where there are decidedly dry seasons what cultivation there is must be quite superficial. On light soil it is the general practice, and probably good practice, to be contented with merely keeping the surface clean. On soil which is very heavy or which is inclined to crack, a little surface cultivation should be given if labour is cheap enough to make it practicable.

Concerning the cleaning of the soil, it is necessary to see that other plants do not interfere with the supply of light for the coco-nuts, and that the other vegetation around the trees is not thick or close enough for its roots to interfere with the roots of the coco-nuts. For some time after transplanting, a space of at least 50 centimetres around the nuts should be kept so short as not to shade the coco-nuts at all. The best plan is that for a metre or more around each tree, the vegetation should be cut as near the ground as is most convenient, and that immediately around the tree the ground be hoed often enough to keep it thoroughly clean. The rest of the space between the rows of trees can be left to itself so long as trees do not manage to grow in it. After six months it is desirable to extend the circle which is hoed or thoroughly cleaned to at least a metre. This, however, is not so necessary that it is recommended in places where labour is especially expensive, or so scarce that its use for this purpose would interfere with the extension of the planting.

Such attention as has just been recommended is all that under favourable conditions needs to be given until the trees come into bearing. It is not only useless, but is distinctly undesirable to clean and keep clean the entire space between the trees, unless it is also kept in cultivation. If the ground in the tropics is kept clean and is not in use, it is sure to deteriorate both by washing and by baking.

As deviations from the procedure which has just been recommended, some writers have advised moderate cultivation for the coco-nuts at all times; and it is said that at least in Ceylon there are some planters who make this their practice. Mr. Orville Wood, an American planter on the gulf of Davao, in Mindanao, states that as an experiment he cultivated a part of a small grove of young trees back of his beach, keeping the rest of the grove clean but without working the ground; and that at the end of six years the cultivated trees averaged four inches more in diameter than the others. This is indeed a very striking result, and it may prove, as the trees produce, that the money spent in cultivation pays better returns than it would have done if used in planting and giving the merely necessary attention to a larger number of trees. It is my personal opinion that under most labour conditions, such care cannot profitably be given to coco-nuts, and I am sure that where it is practicable to cultivate to this extent, it is advisable to raise catch-crops.

On the other hand, there are many planters in most or all tropical countries who give their trees less attention than is here advised. It is even stated that once the coco-nut has been planted and been given a chance to begin its growth, it can take care of itself without any further attention. The fact is that in most places a large part of the trees will survive if left to themselves; but no good planter will be contented with merely seeing his trees survive. What the planter wants is not coco-nut trees for themselves, but the profit which they can be made to yield, and merely surviving does not yield returns. I have seen prospectuses and estimates which provide practically nothing for labour on plantations from the first year up to the time that the trees come into bearing, and which provide for a full crop in ten years, with the further statement that at least a fair crop should be expected earlier than this. So far as I know, there is no country where coco-nuts left to themselves in this way can be expected to come into general bearing in ten years. They do better than can be expected with any confidence if they come into what is called full bearing in fifteen years, and full bearing for such plantations never means what it does for those which are decently cared for. I have seen various plantations, for the most part small ones, which received practically no care while young. In every case, there were a considerable number of vacancies; the trees always spindling, with a smaller crown than coco-nuts ought to carry; and as a rule, such groves as a whole do not bear a decent crop of nuts when they are fifteen years old. In spite of the fact that a great many people treat their coco-nuts in this way, I do not believe that anybody who has observed the matter carefully enough to frame a sound opinion will hold that the money invested in such plantations has been used to the best purpose.

Taking up now the other assumption, that a catch-crop is to be cultivated, choice must be made among the various crops which in different places are used for this purpose. The catch-crop must be one

YOUNG TREE.

Beginning to bear heavily at about seven years. Each bunch is supported by a pole.

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which does not need to keep the land for a long enough time to interfere with the development of the coco-nuts, or to have to be sacrificed when the coco-nuts need the whole of the ground. This is equivalent to saying that it must be a crop which can either be removed at the end of not more than three years, or which can endure being shaded after that time, by the coco-nuts. In spite of the fact that it has already been advised that if any catch-crop be grown a return of fertilizers be made to the soil to balance what the catch-crop removes from it, it is advisable in choosing the catch-crop to give the preference to one which is known not to make too heavy demands on the soil's fertility. For instance, tobacco if at all intensively grown, makes very heavy demands on the fertility of the soil. In other respects, it would be a valuable catch-crop, but for this one reason, it is not in general to be recommended. So far as possible, it is advisable to give the preference to a catch-crop which will be consumed on the ground, rather than to one which provides an article of commerce which contains in considerable quantity any mineral food; and a crop whose seed or grain only is sold from the plantation is better than one of which the whole plant is sold.

Taking up now a few individual crops which might be used in this way, the commonest choice is rice or some other grain. Rice used in this way must be upland rice. Except during the first year of use of land previously in forest, upland rice requires a great deal of weeding, and this work takes so much time that where it must be done by hired day labour, this labour must be exceedingly cheap or the crop can not be made to pay a profit. Owners of small groves, whose children or whose dependants can do this weeding, and who therefore do not have to take its cost into account, can raise it as a catch-crop among coco-nuts better probably than any other crop. If nothing but the grain is taken away from the soil, the latter is impoverished in but a very slight degree, and the expense for fertilizers to prevent this impoverishment is therefore very little. Practically the same considerations apply to other grains as do to rice. Maize is everywhere easy to raise. Its use therefore makes less demand upon labour. In most places it too is a profitable crop, though the gross returns are not likely to be comparable to those from rice. Because of its height, maize must not be planted too close to young coco-nuts.

In recently established coco-nut plantations in the Philippines, it has been a very common practice to mix coco-nuts and abacá. With a reasonable measure of neglect, rather than of attention, the abacá is expected to begin to yield returns during the third year, and to continue to do so up to the tenth year. The theory is that, in about ten years, the coco-nuts will come into full bearing and the abacá will be worn out. This combination of crops has little indeed to recommend it. The abacá shades practically all of the ground by the time that it comes into bearing. If an attempt is made to plant it so far from the coco-nuts that the latter are not shaded, there is practically no place left to be occupied by the abacá (*Musa textilis*).

Whenever I have seen the combination in practice, the coco-nut is shaded, except for the tips of a few leaves which grow straight up and close together, before the end of the first year. The coco-nut, therefore, during the first years, when the bole is first getting established and the tree is fixing its habits of growth, receives so little light that it forms fewer leaves than it should, and these of slow growth, and starts life with a slender stem which never afterwards becomes as stout as it should be. From the standpoint of the coco-nuts, the interplanting with abacá is therefore a thoroughly bad practice. The mixture of the two crops might still be a good business practice if it yielded very large returns during the years that the abacá is in production. But this is not the case. While the abacá at first shades the coco-nuts, and hinders its development and does it permanent injury, the situation will be reversed after three or four years, that is, almost immediately after the abacá begins to yield good crops. From this time on, the abacá is shaded by coco-nuts. Shaded abacá will never yield as good returns as abacá which receives the whole of the sunshine, and uses the whole of the sunshine in the building up of its fibres. Moreover, abacá is a crop of uncertain value. There are years when its price is so low that it hardly pays to harvest the fibre, and there is no return for the work which it has taken to bring it to maturity. There are other times when it pays handsome returns, and if one is counting on his returns at this time of high prices, he can certainly not afford to cut them in two by shading his abacá with coco-nuts. Finally, both the abacá and the coco-nuts are surface feeders. Before either one has yielded any crops, their roots will be in active competition and doing each other mutual harm.

In spite of all these considerations, some abacá planters maintain that their abacá cannot be expected to return crops of fibre for more than ten or twelve years, and that unless they have interplanted the coco-nuts they will then have nothing of value on the land, and that even rather inferior coco-nut trees are much more valuable than nothing whatever. The latter contention must be granted, but the former is not true. Abacá which is given proper cultural treatment will certainly continue to give big crops for at least twenty-five years; this I know from actual observation, and there was no reason to suspect that the plantation which had given good returns for twenty-five years might not continue to do so for as much longer.

My own preference in the choice of a catch-crop, if it is possible to utilize it, is manioc. Manioc is an exceedingly heavy producer and can be made to pay a very large return for the use of the land. This can be done either by feeding the roots to stock, which however can be recommended only with certain qualifications, and often only with certain treatment, or by using the roots for the manufacture of starch or alcohol. This is not the place to discuss these industries. They are distinct and separate from coco-nut culture, and must be understood both in their industrial and their market relations before they can safely be undertaken. Where market conditions are satisfactory, it is practically certain that the production of manioc starch or alcohol can be made in two crops to pay for the necessary manufacturing equipment, for the clearing of the land, planting of both crops, and the cultivation needed by the land, and the return of fertilizers, and still leave a good profit from the operation of establishing the plantation.

There are various crops, of the garden rather than of the field, with which this can be done on a small scale, but there is no other which makes such slight demands upon labour, nor which can safely be undertaken on so large a scale, the reason for the last statement being that the manufactured products from the manioc are not perishable, and are marketable on the world's markets.

There is a superstition, or it might be more respectful to say belief, that manioc is an exceedingly hard crop on the soil. This is caused by the practice formerly common in the Malay Peninsula, of clearing land for manioc, and abandoning it, to return to grass or brush, after harvesting two or three crops. There is no doubt that land treated in this way deteriorates very rapidly. In the Philippines land is very commonly treated in exactly the same way, except that the crop temporarily raised on it is usually rice. Still nobody believes that rice is distinctly a hard crop on the soil; and neither, as a matter of fact, is the manioc. The soil would deteriorate almost as rapidly if the rice or manioc were ploughed under and nothing at all taken away from the ground. Observation has given me considerable confidence in the opinion that the soil does not deteriorate as rapidly in manioc as it does in rice.

This has little to do with the relative rate of removal of mineral food, but is simply because the manioc keeps the soil more nearly in what may be called its virgin condition.

All that has been said so far presumes that the catch-crop will be grown by the coco-nut planter himself or under his direct supervision. If catch-crops are to be grown, this is the most desirable way of handling them. Frequently, however, it is not the most practicable. All reasonably populous coco-nut countries have also what may be called a tenant system, known in different countries by different names, the most familiar word adopted into English for this use being "Guioa," the native Singalese name of a tenant. In most parts of the world, this business is conducted on the same general terms. The tenant has the use of a young plantation during three years, more or less. In return for the use of the land, he keeps, or is supposed to keep, the coco-nuts in proper condition. In some places he is required to plant them; in others he enters on the use of the land after the coco-nuts are planted. In some places he pays some rent, in others he does not. These conditions depend primarily upon the relative value of labour and land. This arrangement spares the coco-nut planter the necessity either of looking after the condition of his coco-nuts or having his time taken up with their care. The latter consideration is a valid argument for the tenant system; but the former, so far as the planter takes advantage of it, is almost sure to work to his disinterest. Where no rent is paid for the land and the tenant is not required to plant the coco-nuts, the arrangement is in effect that the planter pays, for such attention as his young trees receive, a certain share of the freshness and fertility of his soil.

The attention which the trees receive in this way is usually not worth the price. There are, of course, conditions possible, and sometimes realized, under which this tenant system is the best way in which the young trees can receive any attention, or even the only way.

Except where such exceptional conditions make its adoption necessary, it is not to be recommended. It will in general be more satisfactory, if tenants must be employed at all, to shorten the time that they are promised the use of the land, and to use the necessity of renewing the contract as a means of insuring proper attention to the coco-nuts.

CARE OF ADULT GROVES

From the standpoint of the care which it should receive, a grove may be considered to be adult from the time that it ceases to be possible to raise in it catch-crops which require a considerable amount of light. Except where the harvest is concerned, there is no reason for treating differently a grove which has come into bearing, and a grove in which the trees occupy all of the space, but have not quite yet begun to bear. Leaving neglect out of consideration, there are three ways of handling groves whose trees have reached practical maturity. The ground may merely be kept decently clean, or it may be put into pasture, or catch-crops may still be grown. If no attempt is made to get returns from the ground except from the coco-nuts themselves, it must still be given such attention that no weeds can grow up to dispute the space with the coco-nuts, or develop strong root systems. The demands would be satisfied in practice by going over the ground with scythes or knives not oftener than twice a year, and cutting off the vegetation at whatever height is most convenient. In too many places the trees do not receive even this attention.

The principal reason for taking greater care to keep the grove really clean is one which will be emphasized in discussing the methods of harvest. Where it is customary to cut the nuts from the trees before they become ripe enough to fall off themselves, it is not very difficult to find the nuts after they are on the ground, even though there be considerable vegetation to cover

AN ILL-KEPT GROVE.

Twelve to fifteen years old, beginning to bear.

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them up. Some nuts are, of course, lost, but not many. It will be shown, however, that for various reasons it is a better practice to permit the nuts to ripen on the tree, and to fall when fully matured. When this is done, it is necessary to keep the vegetation between the trees cut very close to the ground, as otherwise many of the nuts will never be collected.

If the grove is kept in such condition that all nuts on the ground can easily be found at any time, there is no reason, from the standpoint of the coco-nuts, nor any general reason on grounds of good farm practice, why it should not serve at the same time as pasture. In almost any part of the world, if the vegetation is steadily kept cut so close to the ground that a coco-nut could not be hidden, in time the weeds and woody plants, and even the coarser grasses, will gradually be killed off, and their places will be taken by more succulent grasses; and these can be kept cut close to the ground much more cheaply by the use of cattle than by the use of knives. Kept on the plantation in such numbers as the rate of growth of the pasturage will justify, cattle therefore will perform a useful service in keeping the plantation in neat condition.

In young groves the use of such catch-crops as have already been discussed becomes impossible after three or four years, the time depending on the growth of the coco-nuts. From this time on, if the trees are all equally advanced, cattle may with advantage be turned into the coco-nut groves for pasture. It is not, however, practicable to use them to keep the grove in good condition while the trees are younger than this, because, however well fed the cattle may be, they are sure to tear the coco-nut's leaves if the latter are within their reach.

A great deal has been written regarding the fertilizing value of the manure of the animals turned into the coco-nut groves. Some of the most involved and prolonged discussions come to the conclusion that at the best cattle cannot be made to pay a profit in this way. This is self-evident without any discussion. Unless feed is purchased for cattle, or secured elsewhere than from the coco-nut plantation, they can return nothing to the soil which did not come from it. There is therefore no opportunity for profit here; and supposing that their food does come in part from elsewhere, and that therefore they add something to the richness of the soil, it is hardly conceivable that this outside food is obtained for less than its value as fertilizer. In a small and not very important way the fertility of coco-nut groves may be influenced by the use of cattle. They may be kept in corrals or stables, all the time or at night, and in this way their manure may be concentrated, and then applied to single parts of the grove where it seems to be especially needed. Or the cattle may be tied at night in places where their manure is in demand, or may be tied for days or weeks at a time in certain parts of the grove, and fed there with materials from other parts of the grove or elsewhere. Where the cattle are tied, the ground is fertilized and also cropped closely. It is also likely to be tramped hard, and under some conditions this tramping may seriously injure the soil. As is true of most practices, any attempt to influence the distribution of the manure or the fertilizers in this way must be done with judgment, or it will do more harm than good. In the use of stables, special care must be taken that manure is not allowed to remain in piles for long periods, else it will become a breeding-place for the larvae of the rhinoceros beetles. One large crop of this pest turned loose from the manure heap can do more damage than can be compensated for by the value of the manure.

The general subject of fertilizers is still to be taken up. With regard to the value of cattle manure, it can be confidently said that it is a good fertilizer; that under exceptional conditions it is possible to distribute it artificially or by control, and to apply it to points where it is most needed, but that in general such attempts are practicable only on a small scale, and that no important results can be expected from them; and that at the best the cattle only return to the soil what they take from it, somewhat improved in availability but decreased rather than increased in amount.

From the standpoint of the coco-nut, the use of the land as pasture is, on the whole, rather an advantage. Such use takes practically nothing from the coco-nuts, and saves expense in the care of the grove. The question, then, which the planter has to decide is, whether or not he is sure of a satisfactory profit from the cattle. In using coco-nut groves for pastures he has land which practically costs less than nothing for this purpose, and which for other reasons should be kept in good condition for pasture. With free land already in good pasture grass, it might seem most extraordinary if it were not possible to raise cattle at a good profit. Nevertheless, there certainly are places in the tropics where the growing of cattle in large numbers, even with these advantages, would be a doubtful undertaking. Whether or not the individual coco-nut planter lives in such a place is a question which he must settle for himself.

We have so far spoken only of cattle in connection with the use of the grove for pasture. There is nowhere in the tropics any great industry in horses, nor are there any data by which one might decide that a coco-nut grove might possibly be used for horse pasture. It will generally happen, however, because of the differences in the feeding habits of the beasts, that horse pasture has more need than cattle pasture of exposure to the light, and that therefore the coco-nut grove is more likely to be well used for cattle. There are also in the tropics extensive industries in pigs and in goats. The goat business is one which does not thrive on a large scale, there being no extensive commerce in goats or any of their products. This is not the case, of course, for the products of hogs, and there is no apparent reason why the tropics should not develop a business in pork, lard, etc., the importance of which will be in some proportion to the ease with which the feed of the hogs can be raised. I am satisfied that it is possible to raise hogs more cheaply in the tropics than in any temperate country, and therefore expect to see the day when such products as pork, as articles of commerce, shall reverse their present direction of movement. But hogs in large numbers are not desirable tenants of coco-nut groves. They do not keep the groves as uniformly clean as cattle would do, and their rooting is not good for the roots of the coco-nuts. Where, however, the utilization of the product of the coco-nut on the plantation is carried to the point of the extraction of oil, oil-cake is produced as a by-product; and if this is done, it is almost certain to be the best economic practice to use the oil-cake on the ground. Although the oil-cake is an article of commerce as a fertilizer, a greater profit can be obtained from its use by feeding it to cattle, chickens, or hogs, and getting their excreta for use as fertilizers, and getting the animals for sale.

We have discussed already catch-crops for use in young plantations. These were by-crops, of kinds which do not endure heavy shade. There are other catch-crops which can be grown in old groves, and which, at any rate on a small scale, it is good practice to grow under old coco-nuts, unless the land is fully used for pasture. I do not speak here of such trees as the jack-fruit, tamarind, nor of any of the various others which are occasionally found interplanted with the coco-nuts, but which are more or less equal to the coco-nuts in height, and which, therefore, are to be regarded as taking the place of a part of the coco-nuts in the field. A catch-crop in adult coco-nuts must be a plant which endures the shade of the coco-nuts, instead of disputing the use of the sunlight with the latter.

Among possible catch-crops in coco-nut groves are certain fruit-trees such as the lanson (*Lansium*) and pili nut (*Canarium*). Either of these trees will thrive reasonably in the shade of the coco-nut, and will pay a bigger profit for the use of the land than will the coco-nut itself, provided it grows close to a good market. Neither,

MINOR PRODUCTS IN THE PHILIPPINES.

Photograph, Reimold.

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however, produces products which can at present be put on to a general world's market in large quantities. The practicability of raising them is therefore a local question, and is usually quite limited. There are certain garden crops, such as ginger, which are frequently grown in shade; so far as these have to be of local consumption, the same conditions apply to them as to the lanson and similar fruits. Pine-apples are often grown under coco-nuts, but, so far as I know, this is never done on so large a scale that it is possible to dispense with the demands of the local market and can the fruit. Among crops which are able to reach wider markets, and therefore to be raised on a large scale, are cacao, coffee, and, on a smaller scale, black pepper. As a general proposition, both coffee and pepper are crops into whose production large quantities of labour must enter. It would therefore seem that they might be very desirable accessory crops for one which like coco-nut requires very little labour. As a matter of general economic propriety this is no doubt the case; but in practice at the present time any district or country with an extensive coco-nut industry is sure to be prosperous; and with prosperity the price of labour usually rises to a point where it is economically impossible to devote it to the production of either coffee or pepper. The situation with cacao is somewhat different. Labour for the production of cacao does not have to be quite so cheap as is demanded for the crops just considered, neither does it have to be so abundant.

Markets for different crops change their relative positions from year to year, and what could best be raised last year may be produced at a loss by the next. Just at this time it would appear that in places with extensive coco-nut interests, but with population so dense that, in spite of the high profit to be derived from the coco-nuts, the value of labour remains reasonably low, the best crop to be grown on a large scale on the same land which is occupied by the coco-nuts is probably cacao. Where coco-nuts are the principal crop, and the population is not very dense, it will usually be found impracticable to raise any other crop on a large scale between the coco-nuts; and the best practice in such cases will be to cut down all vegetation between the coco-nuts and to put the grove into pasture.

FERTILIZERS

More attention has been given to the effect of different fertilizers than to any other phase of the study of the crops of temperate regions. It is a widespread feeling that the same attention would be equally profitable in the case of the coco-nut. In appreciation of the importance of the subject, rather than in the expression of our knowledge on it, Prudhomme devotes nearly one hundred and fifty pages to the discussion of the need of fertilizers under various conditions, of the fertilizers to be employed, and of the method and time of application. There are other treatises on the coco-nut which dismiss this subject with a page or so, and even then omit very little definite information. There is no cultivated crop which cannot be made more productive by the application of fertilizers. If a crop is harvested year after year from the same ground, as is done with the coco-nut, there is a steady removal of food material. It is perfectly obvious that, assuming that this material comes from the soil about the roots, there must be a steady depletion of the stock of available food. This food store is always a limited one. Moreover, it is almost always less, even when the crop is planted, than would produce the most thrifty development and yield. Fertilizers are needed, then: first, to cause a production more ample than the natural store of food suffices for; and second, to replace what is taken away or tied up in the growth of the plant.

Remembering as always that agriculture is a business, we must consider, as each farmer must do for himself, not merely what application of fertilizers would produce an increased yield, but the profit which this increase of yield can with reasonable confidence be expected to pay, over the cost of the fertilizers and of their application. At the present time we have no sufficient knowledge as to the effect of any fertilizer upon the coco-nut. If we had this, it would still be necessary to take into account, from the standpoint of the coconut, the different conditions in different localities, and, from the standpoint of the planter, the relative value of money invested in fertilizers, and of the same money applied in other ways. The effect of fertilizers is to produce greater crops on a given area of land with a given application of labour. If both land and labour are expensive, the use of fertilizers will be relatively profitable. Their cost varies comparatively little from place to place throughout the world. They have a fixed or but moderately varying value in the main centres of distribution. Their value elsewhere is this primary cost plus the expense of transportation; and the cost of transportation, even though in some places considerable, still results in a local value or cost of fertilizers very much less fluctuating, from place to place through the tropics, than are the values of land and labour.

There are also available in every place fertilizing materials of local origin, which in most places are neglected even though their cost would be very slight. There are places in the tropics where both land and labour are cheap, but such places are usually at decided disadvantages in other respects. There are places, such as the Philippines, where land remains cheap but labour is becoming rather expensive; and others, such as Ceylon, where land is expensive and labour remains cheap. Where the combined cost of land and labour is such that the establishment and maintenance in decent condition of a plantation is relatively inexpensive, money is likely to bring a better return if invested in the extension of a plantation than it is if devoted to securing the highest returns from a given area.

Aside from these purely business considerations, and from the actual richness of the soil as indicated by analysis, it has also been made as clear as possible in these pages, that the utility of fertilizers depends upon various factors which influence the physiological behaviour of the trees, and upon soil conditions which are not revealed by chemical analysis. The mineral food of the soil is taken up by the plants in solution. What they do not take up is at the best without value to the trees, no matter how rich analysis may show the soil to be. The conditions which cause active transpiration will increase the mineral food at the disposal of the plant, and will produce the same results as would the application of fertilizers to the soil at the expense of the planter. The same results can be achieved again by such cultural methods as result in an ample development of a root system free from competition with the roots of other plants.

It is a foolish practice, indeed, to apply money to the purchase and application of fertilizers, and then allow these to be absorbed by weeds, or to be lost because the root system of the coco-nut is not what it should be, or to prevent the most complete possible absorption of them by planting the coco-nuts so close together that a proper rate and amount of transpiration is impossible. Under proper conditions, the artificial application of fertilizers will certainly be profitable. But before recourse is had to this expensive method of increasing the yield, intelligent care should be taken that none of the cheaper methods of accomplishing the same result have been overlooked, and that the cultural treatment is such as will insure the most complete possible utilization of the fertilizers applied.

Turning to the soil conditions, it has been emphasized over and over that the typical habitat of the coco-nut is one in which it draws its food not merely from the soil about its roots, but also from a moving body of water continually coming to this soil from land located above it. Soils which, if judged by chemical analysis, would have to be regarded as hopelessly poor, are often seen to produce coco-nuts with all the luxuriance which could be desired. This is the condition along the seashore at San Ramon. In such a location the application of fertilizers will indeed produce some improvement in the crop, but is likely to result in very little profit, or even in a loss of money. The current of water in the soil which brings other food to these coco-nuts is usually taken up in very small part by the roots of the trees. The rest moves onward, and if fertilizers are applied to such trees in such quantities as would produce the best results with crops differently situated, the current of soil water must be expected to carry a large part of them away with it. In the case of trees planted along the beach, artificial fertilizers will therefore be carried into the sea and absolutely lost. The propriety of using fertilizers, therefore, depends upon soil conditions which can be recognized by analysis, and upon other conditions which elude analysis.

It also depends directly upon the available supply of water for the use of the plant. In localities which have pronounced dry and wet seasons, fertilizers, to be profitable, must be applied with especial care. Unless water is artificially supplied, there will be parts of the year in which the material in the soil is at least in considerable part unavailable, because not dissolved in water which the roots could absorb, and other parts of the year when it is likely to be washed or leached away by excessive water. The propriety of applying fertilizers depends also upon the method of handling the grove, whether or not catch-crops are grown, what these crops are, and what they remove from the soil or contribute to it. Sufficient details on this phase of the question have already been presented.

Aside from our general knowledge of the demand of plants for their mineral and nitrogenous food, and of the conditions under which they will absorb and use such food, there are two general methods of investigating the need of particular crops for particular foods, and of the utility and profit of applying particular fertilizers to particular plants. The first of these is chemical analysis. This is the quicker method. But in inexpert hands even a good chemical analysis is not a safe guide to practise, and even in the most competent hands it is most valuable as a guide to experimentation. A number of analyses of the parts of the coco-nut tree or of whole trees, and of the products, have been made in different parts of the tropics. Some of these analyses are on their face not reliable, because the total of constituents falls too far short of one hundred per cent. Others seem to be good analyses, but are based on so little material that they cannot be assumed to indicate general conditions even for the locality where made. And the remaining published analyses, which come down to not more than three sets of figures made in different countries, constitute together too small an amount of information to be more than a general indication of the demands which the coco-nuts make upon the food in the soil. There are many crops of temperate countries concerning which we have such complete information as to the chemical composition and the demands upon the soil, that it is possible from the analysis of the produce of a given piece of land to state almost positively that the crop in question has, or has not had, a proper supply of each of the most essential elements. In the case of the coco-nut, the information is so meagre that it would be ridiculous to draw such a conclusion from any analysis.

Our knowledge of the chemical composition of coco-nuts, and of the products which are usually marketed, is summed up in essential in the following tables. The first table gives the weight of each part of a nut and the per cent of the whole nut. The figures are averages, based on the number of nuts indicated at the head of each column.

[TABLE

ANALYSES OF SAN RAMON NUTS, BY WALKER

	Sea-shore, 1000.		Inland, 1000.		From one tree.					
					Hardly ripe, 10.		Fairly ripe, 9.		Dead ripe, 10.	
	grams.	per cent.	grams.	per cent.	grams.	per cent.	grams.	per cent.	grams.	per cent.
Husk . .	897	38·0	703	30·8	2779	70·0	1268	51·1	520	33·4
Shell . .	282	11·9	291	12·7	227	5·8	214	9·4	201	12·9
Meat . .	647	27·4	688	30·1	405	10·3	465	20·6	453	29·1
Water . .	537	22·7	603	26·4	547	13·9	437	18·9	384	24·6
Total .	2363	100·0	2285	100·0	3958	100·0	2384	100·0	1558	100·0

ASH ANALYSES

Grams, average, in one nut at San Ramon.

	N.	K_2O.	P_2O_5.
Husk . . .	1·609	3·915	0·017
Shell . . .	0·660	0·947	0·459
Meat . . .	4·683	2·475	1·740
Water . . .	1·542	1·313	0·171

Figuring on 173 to the hectare—the actual number on a part of the San Ramon farm—and allowing for an annual production by each tree of 40 nuts, or a round total of 7000, the annual loss is:

	In nuts.	In leaves.	Total.
	kg.	kg.	kg.
N	59·43	31·69	91·12
K_2O	60·55	74·82	135·37
P_2O_5	16·73	24·65	41·38

The following analyses by Lepine and Bachoffen differ from Walker's in being based on single nuts instead of large numbers. Bachoffen's nut cannot have been thoroughly ripe.

[TABLE.

	By Lepine.			By Bachoffen.		
	Total ash, per cent of total weight.	Per cent of total ash.		Total ash.	Per cent of total ash.	
		Salts of K.	Calcium Phosphate.		Potash (K_2O).	Phosphoric acid.
Husk . .	6·08	73·69	0·98	1·63	30·71	1·92
Shell . . .	1·41	86·94	2·18	0·29	45·01	4·64
Meat . . .	1·10	61·81	24·54	0·79	58·23	20·33
Water . .	0·27	46·15	19·22	0·38	47·66	5·68

Coco-nut Cake, by Sanson (Compilation)

Total ash . . .	4·46
Potash . . .	40·57
Soda . . .	2·30
Lime . . .	4·71
Magnesia . . .	2·95
Iron oxide . .	3·56
Phosphoric acid .	26·98

There is also about 3 per cent of nitrogen.

ry dry ~~Ordinary~~ copra contains about 6 per cent of water, 2·5 per cent of ash, and 1 per cent of nitrogen.

From these analyses it is safe to conclude that the coco-nut uses both in its products and in its body a conspicuously large amount of potash. The amount of potash in ordinary soils is small enough, so that it is a safe general conclusion that coco-nuts dependent upon the local soil supply, without the continual addition of fresh quantities brought by the soil water, will respond to a profitable extent to the artificial application of additional potash. Experiments here and elsewhere indicate that this is the case.

To a less conspicuous degree as compared with crops in general, the coco-nut ties up in its own substances and in its products an appreciable amount of nitrogen. To a still less extent, as compared again with crops in general, it removes the phosphorus of the soil. It may be accordingly stated as a probably correct conclusion that of these three most important fertilizing substances the coco-nut in general demands potash first, nitrogen next or with it, and then phosphorus. Even this much of a conclusion must be regarded as tentative and of by no means universal application. As evidence against this order of importance, it should be remarked that fish refuse, which is a fertilizer conspicuously rich in phosphorus, seems always to produce a conspicuously more thrifty development of the coco-nut.

The second method of investigating the need of fertilizers and their effectiveness is experimentation in their application and observation of the results. This is the only method which gives absolutely reliable evidence from the scientific point of view, or which can give evidence which is certainly applicable to any particular coco-nut grove. The information available as a result of work of this kind is astonishingly meagre. The German Potash Syndicate has published a few results indicating the profitableness of applying potash alone and in combination. From personal knowledge of the methods employed by the Potash Syndicate in securing such information, I can say that no suspicion attaches to the validity of these statements because of their origin. It has been clearly shown here, and on private plantations in Ceylon, that the application of potash has resulted in sufficiently more thrifty development to make the treatment decidedly profitable. In the experiments made, the application of phosphorus in the form of basic slag has been likewise profitable.

There are also in the literature a considerable number of notes by individuals, which purport to show that by the application of fertilizers of one kind or another excellent results have been produced. Such statements are usually of questionable general value, because experimentation of this kind by individual planters is usually inexpert. The experiments are likely to be undertaken without the necessary precautions to exclude interference by other factors, and notes on the previous condition of the trees are very often kept with too little care.

It is no unusual thing for a planter to apply a fertilizer to a grove, and to report the immediate increase in the yield as a result, and then to consider that the experiment has been closed. An increase in the yield during the six months following the application is indeed not impossibly a result of it; but if a very marked increase is observed during that time, it is more likely to be due to something else than to the fertilizer. From what has been stated in the earlier pages, and from the observations which are made by each class in this college, it is perfectly evident that the principal effects of such treatment will make themselves felt from a year to two and a half or three years after the application.

The most considerable result must be very indirect, by an increase in the general vital activity of the tree. In its application to the nuts, this may show, first, in the production of larger nuts, which may be manifest within six months but surely not much sooner than this; or second, in the production and ripening of more nuts on each bunch, which can hardly be evident within nine months of the application, and is never likely to be the chief factor in the increase; or third, in the production of a greater number of bunches of nuts, or, in other words, in the more rapid succession of bunches. The same factors which will so influence the thriftiness of the tree as to cause the more rapid production of new bunches can also be expected to produce larger nuts, and are likely to cause rather more nuts to mature on a bunch. The rate at which the bunches of nuts follow one another depends upon their rate of development, and on the rate at which they begin to be formed. So far as we know, fertilizers have little or no influence upon the rate of development. This is certainly controlled by the supply of water in much more conspicuous degree. The number of bunches cannot be greater than the number of leaves produced in any given time, and this is determined by the rate at which the leaf primordia are developed around the growing point of the trunk. Dissections of coco-nut trees show from 17 to 23 or 25 distinct leaves which are not yet visible without dissection. Microscopical study would of course increase this number.

Assuming that there are 24 such leaves, and that the rate of appearance is 16 a year, the youngest of these will require a year and a half before the tip can be detected in the crown of the tree. After a leaf becomes visible, it requires at least six months for the production of flowers in the axil and still another nine months for the production of the fruit. Under the conditions which have been assumed, which are approximately those occurring in nature, it will therefore be two years and nine months before an improvement in the cultural conditions can, by increasing the rate at which the new leaves are formed, increase the production of a marketable crop.

It follows most obviously that data as to the effectiveness of the application of any fertilizer are incomplete unless carried on for more than three years after the application. The fertilizer has no direct effect on the size of the nuts, or the tree's ability to mature all which set, or even the rate at which new clusters of nuts are produced. Its first visible effect may be upon the growth of roots or of leaves, both directly and indirectly. Chiefly through its effect upon growth, a fertilizer is expected to increase the rate of formation of organic material by the leaves. And it is only after it begins to make itself felt by an increase in the assimilative activity of the leaves that it can begin to have any influence upon the production of a crop. If the time necessary for this effect upon the general vegetative activity of the tree be added to the two years and nine months,—which is probably already below the time in which the rate at which the new leaves are laid down can begin to influence the production,—it is obvious that rather more than three years must pass before the principal effect of fertilizing should be realized. The effect of the best application of fertilizers is by no means exhausted even during this long interval. By improving the general vegetative activity of a tree, the planter does not merely produce an increase in the marketable crop in the ways which have just been suggested; but beside this the supply of organic food which the leaves produce makes possible the development of larger leaves and so compounds the advantage. The better supply of organic food tends to produce greater activity in the growth of the roots, and thus greater ability to absorb water and the food about the base of the tree. There is then a greater area and bulk of soil upon which the tree can draw for its water and mineral food; and this in its turn tends to insure a still greater production, even aside from the greater richness of any given cubic foot of soil, resulting directly from the application of the fertilizer. In these ways the effect of a fertilizer may be felt over an indefinite number of years.

On the other hand, the advantage which ought to be secured from the use of fertilizers may be entirely lost by failure to follow up the application by continued proper treatment. The failure of the water-supply may undo the profits which should be expected after two or three years, by making it impossible for the tree to properly develop the additional leaves and fruit clusters which have been formed in embryo as a result of temporary good treatment. If the tree is stimulated to the production of more and larger leaves, which should promise a continued increase in the crop, a failure of water may still make this greater leaf expansion a reason for fear; for the greater the need of water, the greater the injury which will follow if the supply is very inadequate. Again, the expansion of the root system, which should follow the use of fertilizers, will have no result except to bring the trees in keener competition with each other, if they are planted so close together that the available soil of a grove is already fully occupied.

Good treatment of the coco-nut is a full system of procedure, not a single act, nor a spasmodic burst of attention. In order that any detail of the treatment of a grove, however strongly to be recommended in itself, may have the results which in a business sense should be expected from it, it must be co-ordinated with all of the other treatment which the plantation has received and will receive in the future. The propriety of using fertilizers depends not merely upon the amount and upon their cost, and the cost of possible extension of the grove, but also upon every detail of the treatment which the grove receives in other respects, and upon the attention which is given to all of the other needs of the trees.

It is presumably because of the complexity of the problem and of the difficulty in the interpretation of results, and still more because of the long time which must intervene between the application of fertilizers and the drawing of even approximately final conclusions, that reports from the various governmental stations which have undertaken such work with coco-nuts are still wanting. At least four such stations in the tropics have published accounts of the undertaking of systematic work of this kind, but none of them have as yet made the results public.

We turn now to a brief discussion of the fertilizers which are to be recommended, although on other grounds than a sufficient knowledge of the results of their application. The first and greatest need of the tree seems to be that for potash. This can be furnished in the form of ashes or manure, or as a commercial fertilizer. The second need, for nitrogen, will in most cases be most economically supplied by the use of green manures. The necessity of furnishing nitrogen depends upon the method in which the grove is handled. If it is kept clean by the burning of the fallen leaves more nitrogen will be lost by the soil than if these leaves are permitted to decay. If the grove is used for pasture this may consist in considerable part of leguminous plants which, with the excreta of the stock, will maintain or even increase the soil's natural wealth of nitrogen. Either as pasture or as a crop to be turned under there are various legumes which will accomplish this end. Even the sensitive plant which, as a weed, is widespread in coco-nut plantations is eaten by cattle, and contributes very materially to the stock of soil nitrogen. There are other legumes which in young groves will return a direct profit, but these have already been mentioned under the head of catch-crops. The third need of the plant for a mineral food is for phosphorus. There are various commercial sources of which the most common is perhaps basic slag.

The coco-nut removes, as compared with other crops, but little of these elements from the soil. Aside from the fertilizers which provide single food constituents there are in general available for use on coco-nut plantations the manure of live stock, and, if oil is manufactured, the oil-cake of the coco-nut. The manure of different animals varies in composition. That of cattle contains in general terms 0·3 per cent to 0·5 per cent of nitrogen, 0·1 per cent to 0·2 per cent of phosphorus pentoxide (commonly, but inaccurately called phosphoric acid), and 0·01 per cent to 0·2 per cent of potash. Cattle manure is a weaker fertilizer than many people realize, and accordingly must be applied in large quantities to produce conspicuous results. It may then well be supplemented by the application of ashes, or of a commercial fertilizer rich in potash. Applied in sufficient quantities, it will produce results that are conspicuous indeed, as is evidenced by one of our groves, a part of which has been used as a corral.

The oil-cake contains materials which ought never to leave the farm unless at a profit which will permit the purchase of fertilizers to replace the material lost. The composition of the oil-cake of course varies from place to place according to the way in which it is secured. Its ash, as a general proposition, amount~~s~~ to

and nitrogen

about 8 per cent of the total weight. The composition of this ash can be seen from the table of analyses already given.

The need of fertilizers on the plantation obviously depends in a very high degree upon the use to which the trees are put; that is, upon the commercial product which is sold from the plantation. If, for instance, oil is sold and the oil-cake is kept on the place, and either applied directly as a fertilizer or fed to animals whose manure is returned to the soil, the theoretical loss of food material is reduced to zero. There is of course a slight actual loss, as nothing can be taken from the soil and kept upon its surface without some being washed away, and as decay is inevitably accompanied by a loss of more or less nitrogen; but such losses are inconspicuous. If the trees are used for the production of toddy the loss of mineral food is again very slight. Fresh toddy contains about 0·02 per cent of nitrogen, and the total ash amounts to about one-fourth of 1 per cent. If from the toddy, sugar or alcohol is produced, a considerable part of the fertilizing materials in the sap will be separated as waste products and can be returned to the soil.

If copra is produced and sold, the amount of material lost from the soil can be calculated from the analyses already given. In making such a calculation it is merely necessary to assume a reasonable number of trees per hectare and a reasonable yield per tree. To make calculations for a given plantation the number of trees actually present and the actual yield of nuts will furnish a basis for the calculation. As a general proposition copra contains from 1 per cent to 3·65 per cent of ash; a convenient approximate figure is 2·5 per cent. The larger part of this is potash, which is 1·35 per cent, more or less. Phosphoric acid amounts to about one-half of 1 per cent. If the product marketed is desiccated coco-nut, the loss of food from the soil is the same as when copra is sold. If coir is sold, or if for any reason the husks of the coco-nut leave the plantation, there is of course a very great additional loss of fertilizing materials. If the husks themselves are sold, the loss is materially greater than when the coir is sold after its extraction from the husks. The greatest loss of all is of course by the sale of the whole nuts. Yet this is the common form in which to market the produce in some parts of the world, and the chief form wherever transportation facilities are such that nuts can be laid down at reasonable cost at the centres of commerce in temperate countries.

In the past the manuring value of the constituents of the coco-nut has been better understood, or at least better appreciated in practice, in various temperate countries than it has where the coco-nuts are produced. It is evidently in the permanent interest of the planter to produce oil on the ground rather than to sell copra. But the oil-cake made in many tropical countries is without local cash value, while it has sufficient value in other places, so that copra-buyers can, if necessary, bid up to the full oil value of the copra, and make the profits and the cost of transportation and manufacture out of the sale of the oil-cake.

THE HARVEST

The proper time for the harvest of the nuts depends somewhat on the use to be made of the crop. In the rare cases in which the production of coir is the chief end the nuts are not allowed to become very nearly mature. But in most cases the making of coir is not a consideration at all, and only copra is directly produced. The copra in its turn is sooner or later used for the manufacture of oil, and its value depends entirely on the quantity and quality of the oil which can be made from it. To produce the greatest quantity and best quality of oil, and to produce it most easily and cheaply, the nuts must be entirely ripe. A nut is ready for the seed-bed when it is really ready for copra-manufacture. By that time the husk has become shrunken, the meat thoroughly hard, and the hollow inside it about one-third empty, so that when it is shaken the water will make a sharp splash against the meat. The nut loses in weight and size for more than two months before it is ripe, but throughout this shrinkage there is a material increase in the content of oil.

This change in weight as the nut ripens is shown by the following analyses of San Ramon nuts, by Walker.

	Hardly ripe. Average of 10 nuts.	Fairly ripe. Average of 9 nuts.	Dead ripe. Average of 10 nuts.
Husk . . .	2779 g.	1268 g.	520 g.
Shell . . .	227	214	201
Meat . . .	405	465	453
Water . . .	547	437	384
Total . .	3958	2384	1558

These nuts were all taken at one time from one tree.

As the husk grows tougher and the shell harder, at the same time that the nut becomes much lighter in ripening, dead ripe nuts are very much less likely to be broken by falling from high trees than are nuts which are not fully ripe. If nuts are harvested by cutting, it is impossible in practice to wait until each bunch is fully ripe, and in old groves there is always an appreciable loss, from the breaking of some of the nuts not yet ready to fall. Moreover, if the nuts are cut it is not economically possible to separate the dead ripe nuts from those nearly ripe, even though they can be distinguished. They are all opened together, and in this way some oil is lost, and the copra produced is not uniform. In a business sense the most inexcusable of all losses on a coco-nut plantation is that resulting from the production of any but the highest possible grade of copra. This is equally true, whether the copra is sold, or whether the oil is extracted on the place.

For a number of reasons, then, it is clear that the best way to harvest the nuts is to permit them to ripen fully on the tree until they fall.

In spite of the strong reasons for this conclusion most coco-nut planters, the world over, cut the nuts down. The chief reason for this is that they do not understand that incompletely ripe nuts produce less copra and poorer copra, and that it is harder to dry. And it is a fact that the individual planter must usually sell his copra on a market where he gets a price fixed by the general quality of the product of his region. There will be more to say on this point in connection with the manufacture of copra. Another reason why nuts are cut is the force of custom. Men with few trees have everywhere preceded plantations. It is convenient for them to harvest a crop and use it, and be done with it for some months. The same is true of plantations just coming into bearing. The first crops are too small to justify frequent search for fallen nuts, or the constant or very frequent drying of copra, and immature nuts are not likely to break when they fall from young trees. As plantations develop the custom of cutting down the nuts is kept up, after the real reason for it ceases to exist.

There are of course reasons to be found for cutting down the nuts. It is sometimes found that nuts germinate without falling. This is a bad characteristic of rare trees; their nuts should be rigorously excluded from seed-beds. Excessive dampness can also, rarely, cause germination on the trees; coco-nuts will not thrive where the air is so damp that this is common.

It is objected that some nuts are lost if they drop as they ripen. If the place is decently clean, even though it be on a steep hillside—at least as steep as coco-nuts will thrive on—less nuts need be lost than would be broken if prematurely cut. There are sufficient reasons, altogether aside from the ease of finding the fallen nuts, why the grove should be kept in such condition that very few nuts need be lost. It is said that the collection of fallen nuts is expensive, because of the necessity of frequent search for them; but search as frequent as is necessary does not cost as much as cutting down the nuts. And finally, there are many energetic planters who think their trees are not well cared for unless the crowns are cleared of the dead bases of leaves and fruiting branches, and who find it most convenient to have this work and the cutting down of the nuts done together. If this cleaning is to be done it is true that cutting down the nuts costs practically nothing in addition. But the cleaning out of the crowns is itself, more often than not, a misguided effort. There are cases in which it is necessary; for instance, when there are rats' nests to be removed. But in general it is not necessary, and unless very carefully and moderately done it is dangerous. Any carelessness in such work may make the tree a victim of red beetles, or of certain fungi, or possibly of bud rot. And it is no rare occurrence for cleaning to be so excessive that the lower, heavy bunches of nuts are left without sufficient support. Even if a knife does no more than cut off the green stem of a cluster of nuts it leaves a possible point of infection by some of the enemies of the tree.

And still most planters have the nuts cut down. This is done in various ways, each land having its local method, in the practice of which the men concerned become very skilful. In the upper part of the great coco-nut forest encircling Mount Banajao, in Luzon, the trees are not climbed, but the clusters of nuts are cut off by men who remain on the ground, using the "halabas." A short, sharp knife is firmly fastened to the end of a slender bamboo, so that the blade points obliquely downward, toward the lower end. A good pull severs the stalk of the nut cluster. For work in groves of much age additional pieces of bamboo are slid into the lower end of the first one and firmly tied;

several of these extra joints have to be used in old groves. When the nuts are cut in this way the crowns are not cleaned, and the trees thrive on this kind of neglect. Another advantage is that the trees are not notched. And this is the most expeditious way in which nuts can be cut down. There would seem to be somewhat more danger of cutting greener nuts than are wanted than there is when the tree is climbed; but the gatherers are so well acquainted with their business that they usually know exactly what they are getting.

When the trees are to be climbed the commonest practice is to cut notches at convenient intervals on the alternate sides of the tree, so that the climber holds the tree with his hands and walks up it. If the notches are not cut in too young wood, and are not made too deep, they do not seem to injure the tree; but these conditions cannot be guaranteed. In groves of notched trees there are always many individuals showing deep decayed spots, starting from the notches. The notches must also permit occasional attack by red beetles and fungi. The safest practice is certainly never to touch a healthy tree with a knife.

In the extreme west of Africa the natives stick pegs in the side of the tree and use these as steps.

It is possible to climb the trunk and cut down the nuts without any special arrangements whatever. This seems from Prudhomme's account to be the practice in a large part of Madagascar, where the native climbers are said to become so expert that any special devices would seem superfluous.

In many places, for instance in Ceylon and India, it is common practice to facilitate the climbing by passing the feet through a loop just long enough to hold them where they will hold the trunk most tightly. The loop is most effective if twisted once between the feet. Holding the trunk with the feet and the hands the climber goes up it like a measuring worm. A longer rope or band passing around the trunk of the tree and the hips or waist of the climber is sometimes used as a help in climbing, and is very useful when the top is reached. The climber leans back, pulling it tight, and then has both hands free for his work. This arrangement is used by the toddy-gatherers of Ceylon and India, and in collecting the nuts by the Bicols of southern Luzon. It may be regarded as the most refined method of cutting down the nuts.

In spots in the Dutch Indies and in Sarawak monkeys are sometimes trained to climb trees and throw nuts down. Regarding Sarawak, this statement is made on the personal observation of Dr. Foxworthy. Most of the monkeys are held and controlled by a cord while they work, but some of them become expert and reliable enough so that they are let loose and will collect only ripe nuts. A few of these trained monkeys are exported from Sarawak to the Malay States.

CHAPTER VI

COCO-NUT PRODUCTS

Todday.—If you cut or break the skin and continue to irritate the spot, there will be produced a sore from which a fluid which is not blood will be excreted. This flow of fluid is not due to pressure from the inside, but is excreted by the activity of the sore itself. The same treatment will produce a similar result from a mass of active vegetable tissue, and this fact is taken advantage of to secure a flow of juice from various palms. The juice obtained in this way from the palms is always rich in cane sugar (sucrose), and may therefore be used as a beverage, or for the manufacture of an alcoholic beverage, or of sugar, or of vinegar. Where palm saps are the base of any considerable commerce, they are usually obtained from the Palmyra or Nipa palm or from a species of Phoenix, rather than from the coco-nut, which furnishes other products which are better adapted to taking a place on the world's markets.

The general practice in producing a palm wine from the coco-nut is to use for the purpose such coco-nuts as are already at hand; these are usually trees which have been planted for the production of nuts. It has already been pointed out, in the discussion of varieties, that the dwarf varieties which come into bearing after about four years, which ought never to be planted for copra production, have great and evident advantages as sources of toddy, and should always be planted when this is expected to be the chief source of revenue.

COCO-NUT TAPPED FOR TODDY.

Photograph by Bureau of Science, Manila.

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The method of obtaining the sap differs with the different palms. In the case of the coco-nut the sap is obtained from the unopened inflorescence. The first step in securing it is to bend the inflorescence down so that the sap will drip freely from the cut end. This bending must be done slowly and carefully in order that the stem of the inflorescence may not be broken. The operation begins when the inflorescence is 45 to 75 centimetres long, in general when its length is about 60 centimetres. The toddy-collector recognizes as a mere matter of general judgment the proper condition for the beginning of this work. If a rule is called for in the Philippines, that given is that an inflorescence is ready for the bending to begin when the next younger inflorescence has about reached the length of 10 centimetres. The bending is done two or three times a day, the tip being drawn downward a very little each time, and the whole operation requiring one or two weeks. When the bending down is more than half done the tip of the inflorescence is removed with a sharp knife, enough being cut off so that the upper ends of the younger branches of the panicle are also cut.

In Java it is customary to remove at the same time the entire bract (the spathe) which enclosed the panicle, but this is not done in the Philippines, Ceylon, or India. If this is done, it is obviously necessary to tie the branches of the panicle very firmly, so that they may not spread out at all. In Ceylon and India it is customary to bind the bract very firmly by taking a thong and winding it around the inflorescence, working from the base upward, and putting in a knot each time that the thong goes around the spathe. This is sometimes done in the Philippines, but is not a general practice, to prevent such a growth of the inflorescence as would burst the spathe. It is also the practice in Ceylon and India to pound the cut end and the outside of the bract with a bone or piece of hard wood. The beating bruises the cut surface and contributes to the production of the condition of the wound which will result in the flow of sap; and also by slightly bruising the unexpanded inflorescence inside the bract, contributes to preventing such a growth as would burst the latter.

In the Philippines and Java the usual practice is to rely on the cutting alone to produce the flow of sap. After the tip of the spathe has been removed the cut is renewed morning and night, and sometimes a third time daily, a very thin slice being removed each time, with as sharp a knife as possible. The length of time that this treatment must continue before the sap begins to flow depends upon the expertness of the worker, and probably upon the condition of the tree as well. A good worker will get a flow of sap after three days; but the time said to be usually necessary in some countries is four or five days, or sometimes even longer. When the sap begins to flow, a vessel is tied under the tip of the inflorescence to receive it as it drops. For this purpose a joint of bamboo is always used in the Philippines and Malaya, while in India and Ceylon an earthenware jar is employed. An explanation of this difference may be that in the Philippines the sap is used only as a beverage or for production of liquor, while in India the toddy is often used to make sugar. The top of the bamboo is sometimes screened in Java. In the Philippines there is not only no care taken to keep this bamboo jar clean, but a clean joint of bamboo is regarded as unsuitable; the reason for this being that bamboo tubes which have been used contain ferments which hasten the production of alcohol in the toddy. To prevent attack by insects, or fermentation in the cut tip, a Philippine practice is to put the juice of red pepper on it daily.

In Ceylon and India the practice is for the toddy-collector to climb each tree. These men are known in Ceylon as "sanars," and naturally become exceedingly expert climbers. They climb the trees by the aid of a rope which fastens the ankles together, and at the top of the tree pass another rope around the tree and their own bodies, so that both hands are left free for work.

GROVE DEVOTED TO TODDY, LA LAGUNA.

Photograph, Reimold.

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The usual work of one sanar is to care for thirty or forty trees. In the Philippines it is customary to devote a solid grove to toddy production, and to connect the trees of this grove by bamboos, which are tied from tree to tree just far enough below the crown so as to provide a convenient stand for the toddy-collector's work. Each of these bridges is made of two bamboos, one to walk on and one to hold to. The toddy-collector always carries a vessel, whether a bamboo or not, into which he pours the sap which has flowed from each inflorescence, leaving in its old place the vessel into which the sap has dropped. By the method in use in the Philippines it is common for one collector to take care of as many as a hundred trees. Each time that the tree is visited another thin slice is removed from the cut surface. Expertness in this work consists very largely in the removal of the thinnest possible slice by a single clean stroke of the knife. If the cut is not a clean one the flow of toddy is interfered with, and the thinner the slice the longer the flow of toddy can be kept up from each inflorescence.

The business is so highly developed in the Philippines that one special form of knife is made for the cleaning of the inflorescence which goes with the bending, and another special form of knife for the slicing of the cut end. These knives are not articles of commerce but are made locally for the purpose. Failure to remove the slice when the toddy is collected results promptly in a decreased flow. If a slice is removed three times daily instead of in the morning and at night only, a greater flow can be obtained for the twenty-four hours. But this increase is not proportional to the number of slices removed, and therefore results in a decrease in the total yield of an inflorescence.

If the work is expertly done, each inflorescence will continue to give a good flow until the remaining stub becomes so short that it is not practicable to collect the juice, or until only the stem of the inflorescence remains. In Ceylon a single inflorescence flows for thirty or forty days, or less. The result is that the usual number of inflorescences producing toddy at one time is the most of the time only one on a tree. In the Philippines there are usually two inflorescences being tapped on a tree, and it is not rare to find three. If a tree is used exclusively for toddy production it becomes weakened after a time, the flow of sap decreases, and the tree may be permanently injured. To prevent this the Ceylon practice is said to be to permit about one inflorescence in three to produce nuts. In the Philippines every inflorescence of the tree is used for some months, and the tree is then given a rest and allowed to produce nuts only for some time.

With regard to the yield of sap there is a wide divergence in the figures given. The yield obtained depends very largely upon the expertness of the collector and also on the condition of the tree, which in turn is much influenced by the weather. In periods of drought the yield is much less than when the tree is well supplied with water. There is one statement quoted from Watt's *Dictionary of Economic Products of India* after Cleghorn, that forty trees yield about 12 Madras measures daily, seven in the morning and five in the evening; this indicates a production by each tree of about 200 cc. a day. Another statement by Watt after Shortt is that the average quantity obtained is three or four quarts daily for two or three weeks from each spathe. Watt further states that in Ratnágire the yield is 35 to 64 imperial gallons a year; and in Kolaba, 2·2 litres a day or 47·7 litres a month, the latter rate being equivalent to 1·56 litres a day. The most careful measurements from Java are those of Molisch, who obtained 0·57 of a litre a day for fourteen days, 0·54 of a litre for nine days, and 0·3 to 0·4 of a litre, daily for fourteen days, from three different inflorescences. Molisch found at one time a flow of more than a litre a day from a single spathe.

Gibbs has recently made careful observations, on a large scale, of the yield in the Philippines. For one

INTERIOR OF DISTILLERY.

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year, from April 1909 to April 1910, the average daily yield of 5785 trees, which furnish toddy for seven distilleries in Tayabas, was 0·65 of a litre. The averages for the different distilleries varied from 0·36 of a litre daily for 700 trees up to 1·03 litres daily for 1052 trees. These differences could not be explained by Gibbs except on the supposition that in many cases, or in all, the want of expert treatment resulted in a much smaller yield than might have been obtained. Accordingly, he had measurements made on 100 supposedly average trees in the groves whose product was brought to one of the distilleries. These measurements continued over 33 days, and the average yield was 1·435 litres per day for each tree. Two of the days were rainy, and leaving these out of account the average for 31 clear days was 1·38 litres. Since the average yield for all the trees under observation for the year was 0·65 of a litre, while 1·38 litres were obtained by especially expert collecting, Gibbs concludes that intelligent management will increase the production per tree by more than 112 per cent. There is no doubt that this high rate of production would exhaust the tree rather rapidly. Nevertheless, the principal item in the cost of toddy is the collecting, and it would therefore be a very great improvement in the business if the collectors were all expert, and the trees given correspondingly longer resting periods.

There are Philippine data available on a still larger scale. For the calendar year 1909 there were tapped for toddy in the province of La Laguna 10,109 trees, and the total yield was 2,103,286 litres, or an average for the year of 208 litres per tree.

Composition of the Sap.—Gibbs's analysis of the composition of sap in which fermentation had been prevented as completely as possible shows the following results:

[TABLE

Sample No.	Flow from one flower-stalk during the night.	Density $\frac{-15^\circ}{15^\circ}$	Total solids.	Ash.	Polarization at 30°.	Sucrose in 100 cu. cm.	Invert sugar.	Preservative employed.
	cc.							
1	665	1·0675	17·75	0·38	15·02	15·66	0·87	1 cc. formalin
2	635	1·0686	18·08	0·40	14·28	14·99	1·78	,,
3	575	1·0670	17·25	0·34	14·92	15·55	0·39	1 g. $HgCl_2$
4	470	1·0683	17·97	0·36	15·23	15·89	...	,,
5	360	1·0670	17·95	0·39	10·75	12·95	7·13	1 cc. formalin
6	360	1·0670	17·95	0·32	14·12	14·42	1·53	,,
7	440	1·0720	19·13	0·39	15·31	16·02	0·71	1 g. $HgCl_2$
8	440	1·0680	18·32	0·47	14·99	16·49	0·71	,,

The first four trees in this table were forty years old, and the last four twenty to twenty-five years. Each tree had two flower clusters giving sap at the time the sample was collected. Five of the samples showed no acidity, two contained 0·03 of 1 per cent figured as acetic acid, and one contained 0·08 of 1 per cent. Only one of the samples showed a trace of alcohol.

From this table, and from some other analyses, Gibbs concludes that perfectly fresh sap may be expected to have about the following composition, stated in grams per 100 cc.

Density	1·07
Total solids	17·5
Acidity	Trace
Ash	0·40
Sucrose	16·5
Invert sugar	Trace
Undetermined nitrogenous compounds, etc.	0·60

Reducing sugars are nearly or quite absent in the perfectly fresh sap.

This sap no sooner falls from the tree than its composition begins to change; and if the fermentations in it are not interfered with, they go through a series of which the first is under the influence of an unorganized ferment or enzyme, called invertase. This is formed in the sap in the presence of oxygen, and acts with remarkable speed, so that by the time the toddy is collected from the trees but little sucrose remains, and the sap is rich in reducing sugars unless these in their turn have been fermented. The reducing sugars are fermented, with alcohol as a main product, by means of yeast. As the alcohol accumulates, it, in turn, is acted upon by still a third ferment, in this case a bacterium, and this time the principal product is acetic acid. How rapidly this series of fermentations goes on is illustrated by one of Gibbs's analyses of a sample preserved at 10 o'clock in the morning, the sap being that which flowed during the preceding night. The analysis is given in grammes per 100 cu. cm.

Density	1·01
Total solids	3·72
Acidity as acetic	0·68
Alcohol	6·00
Ash	0·41
Sucrose	0·29
Invert sugar	1·95

How far these fermentations should be allowed to proceed and what efforts should be taken to prevent them depend of course upon the use which is to be made of the toddy.

The principal uses of the toddy are:

First: As a fresh beverage.

Second: For the production of alcoholic beverages.

Third: For the production of sugar.

Fourth: For the production of vinegar.

The last of these is of comparatively little importance. Another minor use is as a source of yeast for making bread. Throughout the East, toddy is the usual source of yeast, both for indigenous people and for Europeans.

Fresh toddy will usually have about the alcohol content indicated in the above analysis, that is, 6 per cent, unless pains have been taken to prevent the alcoholic fermentation. In some parts of the East it is usually used with about this amount of alcohol, while in others the preference is for a sweeter and fresher drink. Where the demand is for a moderately alcoholic beverage, no attempt is made to keep the vessels in which the toddy is collected clean. In Java the more general demand is for a sweet drink, and to secure this the bamboo vessels used are changed each time the toddy is collected, and a new one, or one which has been carefully cleaned, is used for each collection. Where earthenware vessels are used, the same pains are taken for the same purpose.

The value of the toddy depends altogether on the local demand for it and on the supply. Its taste is somewhat different from that of toddies obtained from other palms, so that its price is not fixed by the latter. It sells at a higher price than some of the other palms' saps. In the Philippines, the commonest price is one centavo a glass. Where the sap is scarce for any reason the price is high, and where there is a large distilling business the price is low because this is above the price paid by the distillers.

The toddy remains a desirable drink for a very short time, and therefore is never an object of other than local business. In the neighbourhood of cities, large numbers of coco-nut trees can be used for its production, but on plantations, or where there is an extensive coco-nut industry, only a very small fraction of the trees can be tapped with profit. So far as the market exists, this use of the tree is a very profitable one. Welborn figures that at two cents for each collection from a tree and collecting the sap twice daily, the total yield of a tree will be 14·60 fl. per annum, while the usual rental value of a coco-nut tree is only two guilders. The fresh toddy has a peculiar taste which is not usually found agreeable at the first taste, but for which an appetite is easily acquired.

Sugar.—The use of coco-nut toddy as a source of sugar is very old throughout the Far East. The business, however, is everywhere a purely local one. The sugar content of the sap as it flows from the tree is high enough for the sap to be figured as a cheap source of cane sugar, but the fermentation is so rapid that the sugar which can be made from it is decidedly high-priced. Where there is a considerable commerce in palm sugar in southern India, the coco-nut is not its source. For personal use, many of the peoples of Malaya and Polynesia prefer coco-nut sugar to cane sugar because of its flavour, and in certain parts of Java, especially in Bagalen and Kedoe, there is a sufficient manufacture of it to amount to a local industry of some importance. The same is true on the west coast of Sumatra. For the manufacture of sugar, it is necessary to inhibit the fermentation of the sap as completely as possible. The commonest way of doing this in Malaya and Ceylon is to put into the vessels which collect the sap a little of some finely powdered bark which is rich in tannin. The sugar which is produced in this way is called "jaggery." From good sap, $\frac{1}{12}$ the weight of jaggery can be produced. The quality of the jaggery depends altogether upon the care with which it is prepared. It can be refined and made into a clean, white sugar, but this is rarely done, and probably does not increase its commercial value.

Arrack.—Arrack is the Malay name of strong liquor, and has been taken up by Europeans for the liquor distilled from palm saps. In the Philippines this name is found in the form "alak," but the product is now generally known by the Spanish word "vino" ("Bino"), although strictly speaking it is a brandy rather than a wine. The manufacture of arrack, whether as a local industry or on a reasonably extensive scale, is widespread in the East and in most places under strict governmental supervision. In Ceylon the revenues reach two million pesos a year. In the Philippines the direct tax on the manufacture of coco-nut arrack in 1910 was P698,823, and the business is increasing from year to year. From taxes on the traffic in alcoholic liquors, the government derives considerable additional revenue.

The amount of yield of arrack and its value can best be shown by reproducing Gibbs's tables.

[TABLE

THE COST OF PRODUCTION AND THE SELLING PRICE OF COCO DISTILLATES, TOGETHER WITH THE AVAILABLE DATA FOR THE PRODUCTION FROM A FEW DISTILLERIES AND PROVINCES DURING THE CALENDAR YEAR 1909.

The prices in this table are expressed in Philippine currency. One peso is equivalent to $0·50 of United States currency. Proof alcohol is 50 per cent.

Province.	Distillery No.	Tubá distilled during 1909.	Total for province.	Litres of tubá required to produce 1 proof litre of alcohol.	Per cent of alcohol obtained from the tubá.	Average proof of spirits sold.	Cost of producing 1 proof litre exclusive of tax.	Average price per proof litre.
		litres.	litres.					
Tayabas . .	1	162,355	1,273,396	7·40	6·76	90·50	0·19	0·50
,, . .	2	261,193	...	8·23	6·07	82·00	0·20	0·52
,, . .	3	280,899	...	8·43	5·93	86·50	..	0·52
,, . .	4	93,096	...	7·52	6·65	90·50	...	0·49
,, . .	5	89,698	...	8·18	6·11	...	0·21	0·54
,, . .	6	148,204	...	7·85	6·37	...	0·22	0·54
,, . .	7	215,751	...	7·89	6·33	...	...	0·55
Laguna . .	All	2,103,286	2,103,286	7·84	6·38	78·00	...	0·425
Albay . . .	1	633,719	1,145,119	8·35	5·99	57·00	...	0·466
,, . . .	2	511,400	...	10·30	4·85	58·50	...	0·41
A. Camarines.	1	337,820	1,257,163	7·60	6·58	55·00	...	0·39
,,	2	478,760	...	8·65	5·78	60·00	...	0·407
,,	3	386,400	...	7·84	6·38	60·00	...	0·40
,,	4	554,183	...	8·88	5·63	55·00	...	0·39

RECORD OF THIRTY DAYS' RUN OF SEVEN DISTILLERIES IN THE PROVINCE OF TAYABAS.

Distillery No.	Number of trees in use.	Number of days of production during the period.	Sap handled during this period in litres.	Litres of sap handled in the stills on working days.	Daily production from each tree.	Number of proof litres of alcohol produced.		Average proof of the alcohol.		Percentage yield of alcohol from the sap.
						High grade.	Low grade.	High grade.	Low grade.	
126	697	15	12,117	807	0·60	438	968	96	87	5·4
325	1,050	17	36,480	2,146	1·16	1,249	3,306	92	72	6·2
329	1,086	20	21,060	1,053	0·64	1,872	769	94	83	6·3
372	400	7	5,062	723	0·42	460	193	95	86	6·1
532	700	6	7,427	1,238	0·35	973	None	96	...	6·6
533	1,000	14	18,106	1,293	0·60	2,172	None	97	...	6·0
604	850	13	24,240	1,865	0·95	2,817	...	94	...	5·8

It appears from this table that the average yield of alcohol from the toddy is 6·1 per cent by volume, equivalent to an original sucrose content of 9·5 per cent. Since the sugar in the fresh sap is from 3 to 7 per cent above this, there has evidently been a very high loss. This is in part due to fermentations which are unavoidable, but in large part to careless handling. Along with the inversion of the sugar, and the alcoholic and acetic fermentations, there is always more or less activity of putrefactive organisms. This can largely be prevented by cleanliness. An analysis of the figures given in the last table for distillery No. 325 shows that the daily production of proof spirits by the distillery was 268 litres, or 0·255 litres of proof spirits per day for each tree. Now, if the profit of the proof spirits be figured, for the distillers in the Philippines, from the data in the preceding tables, the profit per day per tree would seem to be 3·8 centavos, or a total profit for the year for each tree of P15·96.

Vinegar.—It is generally stated by writers on coco-nut and its product from various countries that a superior vinegar can be made from the coco-nut toddy, and for local use such vinegar is made in various places. This vinegar is usually regarded as having a superior flavour, and it keeps well. The only reason that it is not made on a large scale and has never become an article of commerce is probably the high price of the toddy as compared with other sources of vinegar of good quality. For the manufacture of vinegar, care must be taken to prevent any putrefaction in the sap. This is done by the use of bark rich in tannin or by coating the vessels with lime. The tannin will precipitate a large part of the nitrogenous material in the sap, and it is this material which is the essential subject of putrefactive fermentation.

The advisability of using trees for the production of toddy is a purely local business question. So far as there is a local demand for the toddy, a tree will always yield a greater gross revenue if tapped than if used for the production of copra; but local demands are limited and this business can therefore not assume a great scale in the sense in which the copra market or oil market is great.

COIR

Coir is the commercial name of the fibre prepared from the husk of the coco-nut. The word is Malay or Indian in origin, but has been adopted into European languages. In countries where coco-nut culture is very old, the use of this fibre likewise dates further back than our knowledge reaches. In Polynesia and extending as far west as the Marianne and Caroline islands, this is the main material used for cordage. It was in use as far west as Ceylon before the discovery of this part of the world by Europeans. In these parts of the world it served not merely for rope, and for string to make fish nets, or to tie the parts of houses together, but to caulk boats, and in various other ways. For caulking boats it is better than most other durable fibres because it will swell more when put into water, and will therefore make a tighter plug.

The chief peculiarity of coir rope is its elasticity. The coco-nut fibre will stretch fully 25 per cent without breaking. The amount which ropes made of it will stretch depends upon the method of manufacture, but in all cases they will stretch more than ropes made of any other of the commercial fibres. This makes coir rope especially desirable where it is subject to jerks. As used for fish nets, and in other ways which demand exposure to water, coir has the advantage that it is more durable than most other fibres; that is, it is less subject to decay. Its tensile strength and its resistance to decay are illustrated by the following table:

[Table

COCO-NUT RAFTS AT PAGSANJAN.

Photograph by Bureau of Science, Manila.

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Name of Fibre.	Breaking strength when fresh.	Breaking strength after 116 days in water.
	kg.	kg.
Arenga saccharifera .	43	42
Coir	39	24
Jute	30–31	18–22
Sanseviera zeylanica .	54	13
Crotalaria juncea . .	31	decayed
English hemp . .	47	„
Calcutta hemp . .	34	„
Agave americana . .	50	„

Of the fibres represented in this table then, the most resistant to decay are Arenga (the sugar-palm, Cabo Negro) and after it coir. Arenga is the best of them where it can be obtained, and is accordingly first choice in all such places, but it is not an article of general commerce.

In the comparison of fibres it is a matter of interest to know the relative measurements of the cells which make up the strand of fibre, and the word fibre is sometimes applied not to a whole strand but to one of these individual cells. When these cells are very long they are accordingly fastened firmly together. Other things being equal, the longer the cell the stronger the strand of texture. The following table, taken from Lecomte's *Textiles Végétaux*, gives these data for a few of the important commercial fibres :

Name of Fibre.	Average length in mm.	Average diameter in microns.
Boehmeria nivea—Ramie . .	150	40
Cannabis sativa—Hemp . .	28	20
Linum usitatissimum—Flax .	20	25
Musa textilis—Abaca . .	6	24
Agave americana—Hennequin .	2·5	24
Corchorus—Jute . . .	1·9	17·5
Cocos nucifera—Coir . .	0·7	20

Of the fibres which have been incorporated in the table—and it represents the most of the important commercial fibres which are extracted from the tissues of plants—the coir has the shortest individual cells.

The strands which are extracted from the husk of the coco-nuts and which are referred to in common speech as the fibres are 30 cm. more or less in length, depending of course on the size of the nut from which they are taken. The diameter is about 0·3 mm. In cross section, they are roundish or somewhat heart-shaped, the concavity or groove along one side being the place where the vessels were located. The strands are harsh and more or less dark in colour according to the nuts from which they were secured and the method by which the fibre was extracted. The fibre is strongly lignified, and to this is due its colour and harshness, and its relative brittleness as compared with pure cellulose fibres.

From what has been said as to the qualities of the coir, it follows that for ropes it is to be recommended where elasticity or resistance to decay are especially desired; but for general use it is an inferior cordage material because the brittleness of the strand makes it wear out more rapidly than many other kinds of rope, and because it is weaker than the best rope material. As a textile fibre it is of very little general value because of its coarseness, harshness, brittleness and colour. The colour can be removed, at least in very large part, by chemical bleaching, but this treatment leaves it too weak for practical use. On the other hand, the qualities of harshness and stiffness and dark colour all make it an especially good material for door-mats and hall-mats and for various kinds of brushes. It is for these uses that the coir has its chief market value. This combination of stiffness and elasticity also gives it a certain value as a stuffing fibre, and the poorer qualities of coir are marketed, under the name of mattress fibre, for such use.

The market value of coir, as compared with other vegetable fibres, is indicated by the following table, showing quotations at Havre, September 19, 1913. The prices are stated in francs per hundred kilogrammes.

		Francs.
Sisal . . .	Good Mexican	74–77
	Good superior Javan	87–88
Abacá . . .	Superior	168–178
	Good current	145–149
	Fair current	76–78
Mauritius . .	Superior	72–73·50
	Good	66–68
Maguey . . .	Manila No. 1	48–50
	Cebu No. 1	65–70
Jute . . .	Calcutta superior	85–86
	Best native	75–77
Ramie . . .	Fine	120–125
	Good	100–115
Coir . . .	Superior	54–59
	Good	44–46
Kapok . . .	Java extra	155–185
	Calcutta	114–130
Cotton . . .	Sea Island extra fine	380
	Upland middling	178
	Bengal fine	120

There has never been as careful a study of the source of coir and of the natural qualities of the husk of the coco-nuts under different conditions as the importance of the product would justify. While there are no definite statistics on the subject, there is still no doubt that certain varieties of coco-nut are more valuable than others for the manufacture of fibre, and that there is a proper time for the harvesting of the crop for this purpose, before which and after which the coir is less in quantity, and less valuable weight for weight. What this time is cannot be stated definitely, but may roughly be said to be the beginning of the maturing of the nut. It may be the time at which the nut as a whole is largest, or may be a little later than this, but is certainly considerably before the time when the nut should be harvested to get the greatest and best yield of copra. As the ripening of the nut goes on, the coir becomes exceedingly lignified, and so dark, harsh, and brittle that its value decreases very materially.

With regard to the variety of nuts, some of those found in the Laccadive and Maldive islands have the best reputation in this respect. There are also some ill-defined varieties in Ceylon and southern India which are preferred for this use. These districts furnish almost all of the coir which is an article of European commerce. Ceylon has first place in this respect, but the product of Cochin has been regarded as the best in quality, with the result that the term "Cochin coir" has come to mean not merely that which originates in Cochin but the finest quality whatever its source. The condition here is exactly the same which obtains with the oil of the coco-nut.

From what has been said with regard to the variety and the nuts, it is evident that the same trees cannot be made to produce coir to the best purpose, and oil to the best purpose, but that one or the other product must be in a measure sacrificed. The planter must decide according to market and local conditions which he best can treat as a by-product. As a general condition, the copra or oil is certainly the more valuable, and any planter who selected varieties primarily for their yield of fibre, or who harvested his nuts before full maturity for the sake of the coir, would fail under present general conditions—and these conditions are likely to be quite permanent—to get the greatest possible returns.

It is not many years in an industrial sense since the extraction of the coco-nut fibre was carried on altogether by hand. The first step is obviously the removal of the husk from the nuts and is therefore the same as the first step in copra manufacture, except where, as in Samoa, it is customary to split the entire nut, husk and all. The husks are then macerated by soaking in water,

RECEIVING YARD AT MAGDALENA, AND IRON USED FOR HUSKING NUTS.

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whether fresh, stagnant, or salt, until the fibres can be freed easily from the waste matter in which they are imbedded. How long this takes depends on how the maceration is performed and on what means are used to clean the fibre after it is completed. When the fibre is to be cleaned by hand, and the retting is done in clean, fresh water, the husks are said to be left in it for at least several months, and sometimes for as much as a year and a half. In salt water maceration is more rapid, and in stagnant water still more so. Further the maceration may be hastened by boiling or by skinning the husk, and it is a common practice to hasten the decay by opening the husks before the soaking begins, so that the water may immediately penetrate the interior. If the soaking stops soon enough, the fibre is hard and clean; but if it continues too long, the fibre becomes dark enough to lower its value, and loses its strength by decay. It should therefore be allowed to go on as short a time as will make it economically possible to clean the fibre. When the cleaning is done by hand, the husks, after soaking, are beaten thoroughly and then scraped and combed. The more thoroughly this is done, the better price the product will bring.

The larger part of the fibre put on the market, and the fibre of best quality, is now the product of factories where the work is done by machinery. In the best equipped of these factories, the husks are soaked in concrete tanks in fresh water and for only two or three days. They are then taken out and subjected to a mechanical combing by a device which holds them against a revolving cylinder set with long sharp teeth. This combing is repeated perhaps four times. After this, the fibre is washed by brushing in fresh water, and this is continued until the fibre is practically clean. It is then dried in the sun, either in open yards, or, in the best establishments, on concrete courts. When well dried it is again combed by hand and at the same time sorted into different qualities. This combing and sorting may be repeated two or three times, and finally the product is put up according to grades. The better part of it is put up in small packages of about 7 kilogrammes, and is known as bristle fibre; the bristle fibre in turn may be in several grades according to length and other qualities. From the fibre which is not fit for bristle fibre, chiefly, that is, from the residue from the hand combing, the dust is beaten and shaken out, and the resulting irregular fibre is put up in bales and goes on to the market as the better quality of mattress fibre. A poorer quality, containing the fibres made from the waste of the mechanical combing, or these mixed with inferior waste from the hand combing as well, is known as baled fibre, and marketed in that form. Still another factory product, which is made by twisting into cord the fibre which is a waste product from the sorting of the bristle fibre, is known as coir yarn.

In this factory work there is a man in charge of each of the mechanical combs, and these men have the help of boys in keeping the pieces of husk constantly applied to the cylinders. This work is paid by the task. For four combings, the factory price in Ceylon is P10·00 a cwt. The washing and drying are done by women, who receive about 8 centavos a cwt. of coir. A good day's work is the washing and cleaning of 200–250 kilogrammes of fibre, in which case the wage is about one peseta. The workers around the establishment are paid in general not more than 30 centavos a day. A coir industry in places where labour is better paid must work at a considerable industrial disadvantage as compared with a similar establishment in Ceylon. With regard to the yield, a thousand husks, that is, the husk of a thousand nuts, will yield 68 to 79 kilogrammes of coir if the manufacture is by hand, or about 89 kilogrammes of coir in well regulated factories; and this 89 kilogrammes is made up of 66·75 of bristle, and 22·25 kilogrammes of mattress fibre. Where the manufacture of coir is performed on the plantation, or in connection with oil or copra making, the price of the husks does not appear by itself; but where coir manufacture is a separate business, the husks are bought from the surrounding coco-nut planters, and the usual price is P2·00 a thousand.

It has already been stated that coir has not become a factory product nor an article of commerce except in and near Ceylon. In the Philippines, the Government at one time assembled a quantity of husks, locally called "binuti," at its San Ramon farm, but did nothing with them. The best natural location in the Islands for such an industry would be Pagsanjan, where twenty-five to fifty thousand nuts a day can be secured steadily; but the price of labour is higher than coir manufacture can stand.

In Java a company was organized not long ago at Koetoardjó, Residency Kadoe,[1] for the manufacture of coir and coir products for the European market. Opinions as to its chance of success differed. Hoyer, a Government expert sent to British India to investigate the business, recommended the use of locally-made machines modelled after a successful Singalese type, and had two of these made; but at the same time that he reports the successful working of the machines he says the fibre is inferior to that of Ceylon, and the cost of production greater. Vlaanderen[2] states that Javan husks may be expected to produce 80 to 115 g. of textile fibre, and 30 to 40 g. of brush fibre each; but to allow for the inferior quality charged by Hoyer, these figures are cut down to Ceylon standard estimates of 60 g.± textile and 12 g.± bristle fibre per nut, and 100 nuts a year from a tree. Taking as normal London prices crude fibre £6 per metric ton, coir yarn, etc., £15 per metric ton, bristle fibre fl.25 per metric ton, the gross returns figure out, per tree and per annum, fl.0·79 if sold as fibre, or fl.1·44 if all the inferior fibre is made into coir yarn. The chief fault of estimates is that one cannot know how much they

[1] *Bull. Kolon. Mus. Harlem*, 48 (1909) 15.
[2] *Ibid.* p. 47.

should be discounted. A study of the coir possibilities in Indo-China led to the conclusion that the husks are most valuable there as fuel. They serve this use well throughout the tropics.

COPRA

Copra is the most important, in a plantation sense, of the products of the coco-nut. It is not itself an article of ultimate consumption, but has its place on the world's markets because of the oil it contains. In most coco-nut countries, or, at any rate, on most plantations, it is not practicable to make and ship oil, but it is everywhere economically possible to prepare and market copra. Where conditions are all favourable, it is good business to manufacture oil on the plantation. This demands apparatus of some kind for the extraction of the oil, and containers for shipment. But it has the advantages that transportation on everything except the oil is saved for the planter, and that the oil-cake is available for local use. However useful the oil-cake may be on the plantation, whether to feed, to stock, or for direct use as a fertilizer, its money value is, as a rule, so much greater in Europe than it is in coco-nut-growing countries as to pay for the cost of its transportation. In fact, oil mills in the Philippines have been driven out of business because the copra buyers were able, at least for a time, to bid for the local copra the whole of its oil value, paying the cost of transportation and the profit on the business from the oil-cake which could be put on the French market.

The importance of proper methods in harvesting nuts to be used for the manufacture of copra or oil has already been emphasized. Walker's table on the copra and oil content of nuts of different degrees of maturity shows the great importance of never using any except perfectly ripe nuts for this purpose. If immature nuts are used in copra making, the chief loss is not so much because less copra or poor copra is obtained from these nuts, but because poor copra mixed with good copra lowers the market value of the latter, and so keeps the planter from getting its real value even for the good copra which he may produce. Another of Walker's tables shows that nuts cut from the trees increase in yield of copra and oil if allowed to stand in piles for some weeks before they are opened. This is naturally not to be expected if the nuts are allowed to fall from the trees when ripe, and are then collected from the ground. In this case they should be used without delay. The practice of letting the nuts lie in stacks after they are fully ripe is one of the reasons given for the lower quality of much Ceylon oil, as compared with that from Cochin. At San Ramon, where Walker's study was made, the nuts are collected regularly once in three months. The nut-gatherers have no other profession and are regularly employed on this plantation. They must be regarded as expert in this business, and they have no inducement to cut young nuts. It should therefore be safe to conclude that wherever nuts are cut regularly, once in three months, the copra will be improved in quantity and quality if the nuts are left to ripen or seasoned for a time before they are opened. There must be a time when each nut is at its best for copra manufacture. This time is not sharply marked. At least in dry weather, the improvement up to this time is more rapid than the deterioration immediately after it, because the first changes which take place in germination go on very slowly. The best yield from a large pile of nuts will therefore be obtained when the majority of the nuts are slightly beyond their prime.

In most countries the first step in copra manufacture is the removal of the husks, whether the husk itself has any use or not. The only general exception to this rule is in the islands of the Pacific, where the commoner practice is to split the entire nut, husk and all, with a heavy axe. Andes (*Kokosbut~~rer~~ter*, p. 38) describes and figures a machine which splits the entire nut into three parts, and with which "bei einiger Ubung" two men can open 6000 nuts a day. The recent journals mention another machine with which a man can husk one hundred nuts an hour; but this is no more than an efficient labourer does without any machine. Various methods of removing the husks have been in use. But the use of a sharp iron bar set firmly in the ground or in a block, so that it stands with its point aimed directly upward a little higher than the worker's knee, has now come in fairly general use throughout the tropics. Husking a thousand nuts a day may be regarded as satisfactory work, and for this a little more than the common daily wage is sometimes paid. After the removal of the husks, the next step is breaking the nut open. The usual and best practice is to do this with a sharp blow of a heavy knife so that the two halves are as equal as possible. The water inside is spilled as the nuts break. Good vinegar can be made from the water if a little sugar is added, but the market in coco-nut countries does not make this worth while. Care should be taken that the water is thoroughly drained out, because if any remains it will add to the difficulty of drying the copra and will materially injure its quality.

The methods of drying copra may be classed under three heads: sun-drying, grill-drying or smoking, and kiln-drying. The first of these is obviously the most primitive and the least subject to control. To dry copra in the sun requires from four to seven days of favourable weather. If there is no rain and the treatment of the copra is not inexcusably careless, this method produces an article of very high quality. It is therefore a proper method in places where the planter may be sure that there will be no rain during the dry seasons. This condition is a rather rare one in the tropics. If rain falls while the copra is drying, the latter must be protected against it either by bringing it within doors or by placing a shelter over it. Either of these necessitates having considerable labour available for prompt use, and available labour is an expensive

TAPAHAN, OR COPRA-DRYING HOUSE, PHILIPPINES.

Photograph by Bureau of Science, Manila.

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luxury. If such care be not taken, or if the rain be too sudden to be guarded against, the copra on which it falls is permanently damaged.

The best copra can only be produced by uninterrupted drying from the time the nuts are opened until desiccation is complete. It is especially important that the copra become surface-dry as promptly as possible. For this reason, where the sun is relied upon, it is good practice to open no nuts as late as the middle of the day. However dry and regular the climate may be, it is usually necessary to shelter the drying copra at night, either by bringing it under a roof or by putting one over it. If the copra is brought in, its position will incidentally be changed as the drying proceeds. When the copra has dried sufficiently so that it begins to shrink from the shell, it is easy to remove it, and this should be done. Even though the work of removing it were no consideration, it should not be taken from the shell until it is ready to come out easily and whole, because good copra is more valuable if marketed in large pieces than if broken up. In many places the sun is relied upon for the preliminary drying up to the time of removal from shell, where the subsequent drying is performed on grills or in kilns. In Tahiti, where the whole nuts are split, strips are then torn from the husk, and by means of these the half-nuts are then hung up, face downward, in the sun. In three or four days the meat contracts from the shell and falls. It is then dried for several days more. Good copra is produced in this way; but the labour required to hang up the half-nuts makes the method impracticable on large plantations.

If split nuts are laid out on ordinary ground to dry, they are almost certain to get dirty, either in handling or from dust blown over them; if half-dried copra without the shell is so treated, there is no chance of its drying clean. Specially prepared areas, smooth and hard, whether of cement or not, are used where sun-drying is intelligently practised; these are commonest in lands where such places were first used for coffee or cacao. In Cochin the copra is spread on mats to dry, and the mats are brought in before showers and at night. Care in drying the copra is the chief explanation of the high quality of Cochin oil.

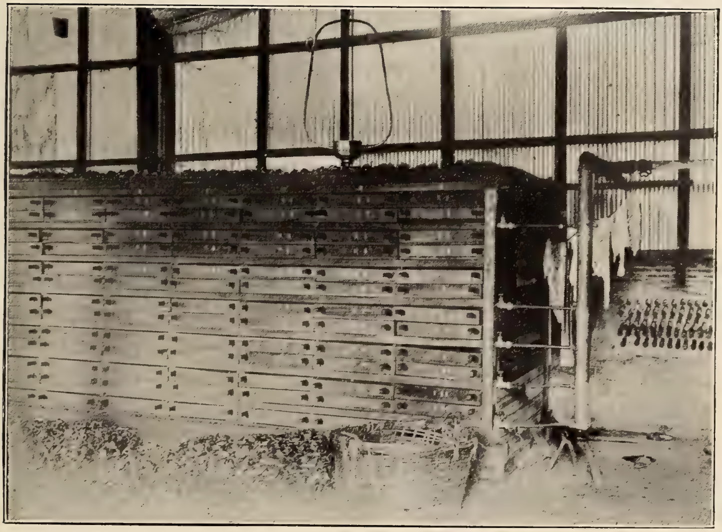
From start to finish sun-drying may take from five to nine days. If more time is needed, it takes too much work, and the resulting copra is inferior.

In almost every country which produces copra more or less of it is dried over free fires, from which it receives the smoke and soot as well as the heat. The fuel is almost always the dry part of the nut—husk and shell or one alone. The hottest and cleanest fire is made by the shells, but these alone are not sufficient except when most of the drying is done by the sun. Except for the small part marketed as "Cebu sun-dried," practically all Philippine copra is dried in this way. The drying houses are mere shacks, as cheap as possible. Roof and sides are usually made of coco-nut or nipa leaves, or the roof may be of bamboo; corrugated iron is unusual, though the owners are seldom too poor to afford it. The shacks are usually a scant 2 metres high, and just big enough to each handle the nuts from a small grove. The fire may be on the ground, but is more often in a hole 30 to 60 cm. deep. Over it is a grating, usually of coco-nut wood, on which the drying is done. Iron in contact with drying copra discolours it; but as smoked copra is never white anyway, the use of wood in the grills is a mere matter of local convenience. Larger and better smoke houses are sometimes built.

The procedure in drying varies in different lands, and even in different provinces in the Philippines. Exceptionally, the drying is uninterrupted. As a rule, the half-nuts are first heated until the meat will come out of the shell; this takes two or three hours. The meat is then put back on the grill and heated either until dry, or on two successive evenings for about two hours each, which dries it. The total time of firing is then only about six hours. To dry it so rapidly the

INTERIOR OF TAPAHAN.

Photograph by Bureau of Science, Manila.



MAGDALENA COPRA DRIER.

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heat must be sufficient to discolour it, but smoked copra is not subject to injury in this way. No effort is made to get it drier than is necessary to make it soluble. No man who takes pride in his copra, or who sells it on its quality, smokes it; and the man who sells it as mere copra, regardless of quality, naturally wants to sell as much water as possible.

While good copra cannot be made by smoking, it is the best method of making poor copra. It is cheap, simple, and practically independent of the weather. From the smoke the copra absorbs creosote or similar substances, which act as antiseptics, and tend to prevent its decay. Copra made in part of unripe nuts is rarely well dried and will not remain so. A variety of fermentation takes place in it, making it mouldy and rancid. As a result of these changes some of the Philippine copra loses as much as one-eighth of its oil before it is laid down in Marseilles, and if it were not for the sterilizing substances taken up from the smoke this loss would be much greater. Smoked copra is the most cheaply sacked and shipped, because not injured by breaking into small pieces. It is used for candles, cheap soaps, etc., but not for food products nor the finer toilet articles. The larger part of the world's copra is at present smoked.

The most uniformly good copra is produced in drying houses. This method of preparing it is in comparatively recent use, but the product which may be grouped as kiln-dried is bound in the near future to increase rapidly in amount, and may be expected ultimately to become the standard. Kiln-dried copra is at present marketed chiefly from Trinidad, the South Seas, and Ceylon. Driers built on models developed for other products can be and are used for copra. Beside these, a variety of houses have been designed especially for this use. Any clean method of heating the house is effective. But the coco-nut husks must in most places serve as fuel, and these produce so much soot that they are not suitable for hot-water or steam heating.

A steam-heated desiccator, notably compact and efficient, was exhibited by the Bureau of Agriculture at the Philippine Exposition of 1912. It was made of two coats of sheet-iron with a middle layer of asbestos. Inside are lateral iron rails running at an incline from one end to the other, and far enough apart for convenience; down these the trays are slid. A system of steam pipes covers the bottom and ventilation is at the bottom and top. The whole structure is about 6 metres long, 3 metres high, and $1\frac{1}{2}$ metres wide. Aside from the heating apparatus, it cost about six hundred dollars. The copra is first dried in the shell, until it will separate from it. The copra from several trays is then put on to one, without the shells, and dried for a longer time. The capacity is about 1600 lbs. a day. The fuel used was coal. In demonstration the drier was altogether satisfactory, the only adverse criticism being that the planter using it would lose money by selling too little water in his copra.

A tunnel drier devised by a German engineer, but not yet tested in practice, is described in a recent number of *Der Tropenpflanzer*. In principle it is not very different from that of the Philippine Bureau of Agriculture, which has just been described.

Three driers, built according to a plan devised by Pedro Bonito, have been built in the Province of La Laguna to dry copra by means of steam heat. One of these, at the town of Magdalena, is illustrated by the accompanying photographs. This machine uses a boiler said to be of six English horse-power. For fuel the husks and shells of the coco-nuts are used, but only husks enough are used to supplement the shells. The copra is dried in cases, of which there are three. Each of them consists of nine vertical tiers of trays with thirteen trays in each tier. Through these cases run horizontal pipes, containing steam, under a pressure in ordinary practice of 60 lbs. or at a temperature of 130° C. Both the inventor and the manager state that the pressure can be raised to 120 lbs. without risk of injuring the quality of the copra. In drying, the husks are first removed and the nuts opened, and the half-nuts then placed on the trays and placed in the drier for a period of two to four hours. They are then removed and the half-dried copra is broken into pieces and dried again. The total time of drying is usually about six hours. It is practicable to run three charges through the apparatus during each twenty-four hours.

The company which owns the drier owns no coco-nut trees, but buys the nuts from the neighbouring planters. The nuts are bought by the thousand, and the price depends on the price of copra and on the size of the nuts. With regard to the size of the nut, no discrimination is made between the nuts of different planters, but from season to season the copra-producing value of nuts varies in response to the climate. Ordinarily one thousand nuts yield about three piculs of copra. After a sequence of favourable seasons, more than three piculs are produced; but as a result of drought the nuts become much smaller. As a result of the drought which ended in June 1912, the nuts decreased very much in size during the following months, until in January 1913 scarcely more than two piculs were produced from one thousand. After this there was a gradual recovery. At the time of lowest yield copra was high, and seventeen pesos to twenty pesos was paid for a thousand nuts, depending on fluctuations in the market price of the copra.

The copra produced by this drier usually sold slightly below the price of Cebu sun-dried. For this the drying was not responsible, the product being as good as drying could make it. The copra lacked something of being first class because the nuts were not all properly ripened. Mr. Bonito understood what was needed to produce good copra, and let all nuts bought remain in piles for two weeks before opening, it being his judgment that, as they had been harvested, this was the period which would produce the best result from the local harvest as a whole. The factory is able to produce sixty to seventy piculs of copra a day. It employs fourteen persons at a total wage of about twelve pesos a day. Husks are removed for sixty centavos a thousand. The removal of the meat from the shells and breaking up the meat is paid for at the rate of fifty centavos a thousand nuts. The factory cost P4000, and when running full blast pays a profit of about P100 a day, from which the cost of management must be deducted.

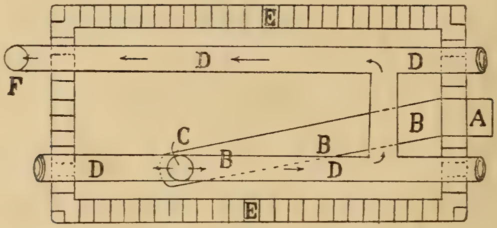
The husks which are not used for fuel are hammered by means of a machine operated by the same boiler, and the half-cleaned fibre is sold in Manila for use as caulking material. Mr. Bonito's statement is that from one hundred husks an "aroba" of coir is produced, and that this sells in Manila at three pesos an aroba. If this statement is correct, the receipts for the fibre are in excess of the price paid for the nuts.

The largest copra drier ever built is probably that of Antonio Navarro of Pagsanjan, in the Philippine province of La Laguna. The kiln is in effect the basement of a one-story building. The excavation is approximately 2 metres deep, 5 metres wide, and 15 metres long, and has floor and walls of cemented masonry. At one end is a very ample fireplace, sunk a little deeper still into the ground. The rest of the excavation is covered with heavy sheet-iron and serves as a great flue; a pipe leading to the high chimney leaves the end opposite the fireplace. The cover of the flue is the floor of the drying chamber, which is less than 150 cm. high, neatly made of sheet-iron, and with trap-doors in the sides and top. The top of the drying chamber is less than a metre above the floor of the building, this floor being hardly more than a hall-way around the drying chamber. The drying chamber is ventilated by means of pipes or by the trap-doors. Coco-nut husks and shells are used as fuel. According to Mr. Navarro's statements, the temperature of the kiln is controlled without difficulty, and kept at about ~~3~~ 6 5° C.; the capacity is then about fifty piculs (roughly three tons) of copra a day; and the cost of drying is rather less in operation than that of smoke drying. The copra is clean, clear, and dry, without the least rancidity after six months in the store-house. As the shells are left in the kiln until the drying is complete, the copra is all in half-nut pieces up to the time they are broken in packing. Except for occasional pieces made from unripe nuts—and far fewer of these than are usually found in the Laguna product—this copra was in a business sense perfect.

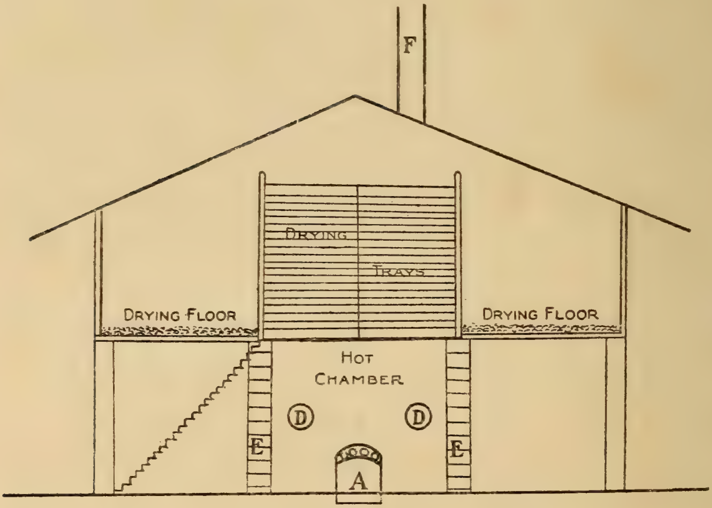
Nevertheless Mr. Navarro has not found it possible to operate his drier the most of the time at a profit. Because of a practical corner on the local marketing facilities held by a leading exporting company, or because of his ignorance of the real market, or lack of capital, he has been forced to sell his product at the price locally paid for the best smoke-cured copra. As most planters make their own, and pay practically no attention to the cost of drying it, their nuts cannot be bought and handled at a profit unless the copra can be marketed at a higher price than they could get. Pagsanjan is so situated, at the junction of two rivers flowing through a great coco-nut forest, that nuts enough to keep this drier busy, seventeen or eighteen thousand a day, are easily delivered. Except in such a place, the operation of a drier of this size would be impracticable for reasons other than inability to sell the product for its real value.

The type of drying house in use by the Deutsche Handels- und Plantagen-Gesellschaft in Samoa has been described twice in the *Beihefte zum Tropenpflanzer*, first by Preuss in March 1907. For the sake of clearness Preuss's figures are copied here.

The house, the outer walls of which are supported by wooden posts set in cement, is set over a smaller room of masonry, in which the air is heated. This hot room is, in one of the driers described as typical, 5 m. long, 2·3 m. wide, and 2·3 m. high. Set into the wall at the middle of one end is the fireplace. A flue of stone runs from the fireplace obliquely well toward the other end of the room. It is there connected by a vertical piece of tubing with a horizontal system of sheet-iron flues, consisting of two or three lengthwise sections (two in the figure) and the necessary crosswise connections. The iron flues are 30 cm. in diameter, made locally from



Ground Plan.



Section.

A, Fireplace. B, Masonry flue. C, Connection of masonry and iron flues. D, Iron flue. E, Wall of stone. F, Smoke stack.

sheets. The ends project beyond the walls, and can be opened when the pipes need cleaning. The last flue ends in a chimney 12 m. high. The course of the smoke is indicated by arrows.

The drying-room proper is directly over the heating room and very little larger, and the floor between them is merely a grating. In operation the drying-room is filled with trays of copra, each holding about 6 lbs. Different driers have a capacity of 200 to 394 trays. The local custom is said to be to remove the copra from the shell without any preliminary drying, which is laborious and inevitably involves breaking it into small pieces. Assuming a yield of two tons a year per hectare, a drier then will take care of the yield of 150 hectares. How large an area can well be made tributary to one drier depends of course on the means and cost of transporting the nuts, as well as on other local conditions. In German New Guinea and the Bismarck Archipelago a drier is built for each 100 hectares. Preuss states that one of them will dry 1700 lbs. of copra in twenty-four hours or about 300 tons a year. The temperature is kept near 50° C. When the copra is taken from the drying chamber, it is spread over the floor of the building to cool and to dry a little more perfectly. Unless the drying is finished in this way, the copra is said to mould; but with proper treatment the product is of excellent quality. One of these drying houses costs 1500 to 1750 dollars.

COCO-NUT OIL

The manufacture of coco-nut oil as an article of world commerce is not a plantation business. The copra of commerce is the raw material for this business, and the extraction of the oil is carried on very largely in temperate countries, especially in France. For a considerable time there have been a few well-equipped factories at work in Ceylon, and individual establishments have been set up in other tropical countries. Oil, as an article of home consumption or of local commerce, is extracted in all coco-nut countries, and may or may not be a plantation product. It is only as it may be a plantation industry that the extraction of the oil requires explanation here.

The methods by which the oil of the coco-nut is extracted fall conveniently under three heads: First, methods involving no special apparatus, but consisting in the mere maceration of the endosperm and squeezing out as much of the oil as can conveniently be expressed; second, more complicated methods characteristic of single regions where they have been locally developed; and third, factory production by modern methods.

By the first of these general methods oil is practically produced only for purely local consumption and in very small quantities. In such cases the oil may be produced without heating, or its separation may be facilitated by heating; and the same is true of its separation from the liquid mass squeezed out of the pulp. A very high quality of oil is likely to be secured in this manner, and it is not unusual in coco-nut countries, at least throughout the Orient, for people to prepare oil in this way for their own use and to prepare other oil for sale.

Of the second general method or group of methods, there are three modifications in wide enough use to merit mention. In Java the coco-nut oil is extracted by the same apparatus used for extracting the oil of pea-nuts. This is not as good a method in any respect as that used in the Philippines or Ceylon. It consists in placing two heavy planks in a framework which holds their lower edges together but lets the upper edges spread apart so as to form a trough. This trough is lined with carabao hides, and inside these are placed strong bags or sacks containing the pulp made by grinding or scraping the coco-nut meat. Wooden wedges are then driven between the outer parts of the planks forming the trough and a rigid structure outside them. As the wedges are driven deeper the trough is narrowed, and the sacks are squeezed, with the result that the oil is forced out of them. The pulp is afterward heated again with additional water and the squeezing is repeated.

In Ceylon and in the neighbouring parts of India a

IPITAN OR OIL PRESS.

Photograph by Bureau of Science, Manila.

ILOHAN, OR ROCKING CRUSHER, LA LAGUNA.

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peculiar form of oil mill, known as the "chekku," is in general use; and in these countries, especially in Ceylon, the manufacture of oil by this method has grown into an industry of such importance that the produce is an important article of export. The chekku is a mortar of stone or very hard wood which is anchored with all possible firmness in its place. It stands above the ground to a height of about a metre. The upper end is hollowed out in such a way that the hollow has the shape of an hour-glass, the lower enlargement being about half as long as the upper. In this mortar is a pestle, usually of hard wood, sometimes of iron, about 140 cm. in length. This mortar fits at the top into the upper end of a piece of wood which is connected with a long tongue, one end of which is fitted to a groove in the bottom of the mortar on the outside near the ground, and the other end is turned by cattle, round and round. The weight of the tongue and of a driver who sits on it is accordingly drawn with the action of a lever, pulling down the upper end of the pestle. At each revolution the pestle goes around in the mortar and at the same time rotates on its own axis.

The chekku takes a load of about 16 or 17 kilograms of copra. It will take six charges a day, using a total of 100 kilograms of copra; from this 60 kilograms of oil are produced, leaving 40 kilograms of oil cake. The most of the oil produced in this way is of poor quality; but there is no reason why, if sufficient care were taken to keep the copra, apparatus, and oil free from dust, the oil should not be of very high grade. These chekkus are used singly or in groups, sometimes of as many as twenty in a single factory. The number in use in Ceylon in 1897 was said to be more than 2800. With the increase in number of modern factories the number of chekkus has since decreased greatly.

In the Philippines there are a number of methods of extracting oil, of which only the commonest is in wide enough use to merit description. The first steps are the removal of the husk and the breaking of the nut into two halves. The meat is then immediately rasped out of the half-nuts. This is done by means of an instrument known as "kabyawan." This kabyawan is a convex iron burr mounted on the end of an axis around which a cord is wound several times and runs down at each end to a pedal. The burr bears teeth all over its surface. The operator sits in such a position that his feet will conveniently work the pedals, pushing them down alternately and so whirling the axis and burr. The burr is pointed away from him so that when he takes a half-nut in his hands and draws it against the burr he can watch the removal of the meat. The apparatus makes an exceedingly effective rasp for the use of human power. In ordinary practice the meat is removed from a nut in about thirty seconds. Rasping a thousand nuts is regarded as more than a day's work except when the work is paid by the unit instead of by time. The grated meat falls into a receptacle under the burr, and is then put into a cauldron, such as is used locally for boiling sugar, and heated to the boiling point of water.

The pulp is then placed in sacks made of rattan, and compressed between two heavy planks. The sacks are usually about 45 cm. wide and 60 cm. long. The plank press is called an "ipitan." The tightening is by one or two screws about 10 cm. in diameter which are set into the back plank, pass through the front plank in an open hole, and outside it bears a very heavy block of wood which runs on the thread of the screw. By means of this block great pressure can be applied to the front plank. Although made entirely of wood, the press is quite durable and capable of exerting very great pressure. The sap squeezed out usually falls directly into a large wooden bowl placed underneath, or may be collected by a trough. At the first pressing from one-fourth to one-third of the oil is obtained. This oil is of superior quality and finds use as a cosmetic or food. The cake then stands until fermentation begins, and is then ground with stone or wooden grinders and repressed from three to six times. The grinding and pressing are often done at once by a very heavy rocking crib called an "ilohan." The oil obtained after fermentation is inferior, and is used for illumination or to make soap.

The figures given by the men running these oil mills vary too widely to be worth publishing, and no careful study of the business has ever been made. The same men who have oil mills practically always have also grills for drying copra, and the amount of each product which they prepare varies with the fluctuations in the market. As a general rule, most of the produce of plantations having access to cheap transportation is sold as copra, while a comparatively large amount of oil is produced on plantations remote from railroads or good roads.

Not much of this oil is exported, but as an article of domestic commerce it is decidedly important. The town of Nagkarlan is crossed by the railroad in its lower part, but the upper and larger part of the municipality can market its produce only over poor trails. The municipal statistics for the three months ending in September 1912 show 505,381 trees in this town. The reported harvest was 6,272,453 nuts for the three months. From this there were made 404,600 kilos of copra and 499,302 litres of oil. The copra was valued at 13 centavos a kilo, and the oil at 35 centavos a litre. The oil produce of the town was therefore worth more than £6000 a month. Practically all of this has to be packed to the railroad on the backs of horses.

In the modern oil factories the extraction of the oil involves two essential phases: first, the maceration of the copra, and second, the separation of the oil. The maceration is very perfect, consisting of grating or scraping and then of very thorough grinding. The oil is extracted by means of large and powerful hydraulic press~~ures~~es. In some cases there is first a cold pressure to produce oil of the best quality, and afterward a pressure after treatment with hot water or steam; or the pulp may be squeezed both times after a preliminary heating to facilitate the removal of the oil. Oil expressed cold is as a rule of better quality, and oil destined for use as food is usually secured in this manner. After the oil is expressed it is permitted to separate by standing. The upper layers, usually cold enough to be solid in consistency, are then removed, and the residue is again treated to secure the remaining oil of poorer quality. The best mills in Europe sometimes succeed in extracting more than 70 per cent of oil from the copra used. This demands not merely very complete extraction but also that the copra used should have contained very little water. With most of the copra marketed it is impossible by the most perfect treatment to secure more than 65 to 67 per cent of oil.

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