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OF THE TROPICS

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COCOA

IMPERIAL INSTITUTE SERIES OF HAND-BOOKS TO THE COMMERCIAL RESOURCES OF THE TROPICS, WITH SPECIAL REFERENCE TO BRITISH WEST AFRICA

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IMPERIAL INSTITUTE HANDBOOKS

COCOA

ITS CULTIVATION AND PREPARATION

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WITH ILLUSTRATIONS

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CONTENTS

CHAPTER V

LAYING OUT A COCOA PLANTATION

CHAPTER VI

SHADING AND INTER-CROPS FOR COCOA

CHAPTER VII

PROPAGATION

CHAPTER VIII

PLANTING, CULTIVATING, AND PRUNING

CHAPTER IX

MANURING

CHAPTER X

RESULTS OF MANURIAL EXPERIMENTS IN VARIOUS COUNTRIES

CHAPTER XI

DISEASES

CHAPTER XII

VEGETABLE PARASITES AND EPIPHYTES

CHAPTER XIII

HARVESTING AND TRANSPORTING

CHAPTER XIV

COCOA FERMENTATION

CHAPTER XV

METHODS OF FERMENTATION

CHAPTER XVI

WASHING AND SUN-DRYING COCOA

CHAPTER XVII

YIELD AND EXPENDITURE

CHAPTER XVIII

COMMERCIAL COCOA, ITS MANUFACTURE AND USES

LIST OF ILLUSTRATIONS

COCOA

CHAPTER I

HISTORICAL

Early Use of Cocoa in Mexico.—Cocoa or Cacao of commerce is manufactured from the beans of two or three species of small trees indigenous to the forests of tropical Central America. It was cultivated and highly appreciated as a beverage in Mexico and Peru long before Columbus discovered the New World, and he was responsible for bringing the first tidings of the virtues of this important food product to Europe.

Bernando de Castile, who accompanied Cortez when he subjugated Mexico in 1521, describes one of Montezuma's feasts, at which some fifty jars of cocoa were brought in and drunk. The word chocolate is derived from the Mexican *chocolatl*, a sweetmeat, which the Mexicans made from cocoa, flavoured with cayenne pepper, vanilla, etc.

In conjunction with various other Mexican products, samples of cocoa were sent by Cortez to his royal master, Charles V. of Spain, shortly after the conquest of Mexico.

Under the name of *Amygdalæ pecuniaræ*, cocoa beans were used by the Mexicans as money, and in Antonio de Herrera's *History of the West Indies* it is stated that one of Montezuma's store houses contained 40,000 loads of cocoa which had been received as tribute from the provinces subject to him. Prescott's *Conquest of Peru* relates that Pizarro's followers saw, as they sailed along the Pacific coast, "hill-sides covered with the yellow maize and the potato, or checkered in the lower levels with blooming plantations of cocoa."

The Introduction of Cocoa to Europe.—Spain was the first country in Europe to manufacture cocoa, and monopolised this industry for many years. Monks were responsible for the introduction of cocoa into Germany and France. Cardinal Richelieu is reported to have been cured of a dangerous disease by its use, which was undoubtedly a valuable advertisement in its favour in France.

The earliest record of the introduction of cocoa into England is contained in a notice in the *Public Advertiser*, dated June 16, 1657, which stated that an excellent West Indian drink, called chocolate, was on sale at a Frenchman's house in Queen's Head Alley, Bishopsgate Street. Early in the eighteenth century it had become an exceedingly fashionable beverage: about this time the "Cocoa Tree Club" in St. James's Street was a recognised rendezvous of the Tory party. Its relatively high price, compared with that of tea and coffee, limited its use to the wealthy classes for several years.

Growth of Cocoa Consumption.—In 1822 the consumption of cocoa in England only amounted to about 500,000 pounds, of which, strange to say, more than one half was consumed by the Navy, and this curious feature obtained until 1830, when the total consumption was still under a million pounds. The extent to which its use has increased in popularity is well illustrated by the fact that in the United Kingdom the consumption of cocoa increased from 2,500,000 pounds in 1848 to 18,000,000 pounds in 1888, whilst during 1908 it had risen to 46,000,000 pounds. In other words, the rate of consumption in the United Kingdom was during the year 1840 about half an ounce per head of population; in 1888 it rose to half a pound per head; in 1908 it was more than one pound per head.

With the increased demand for cocoa in Europe its cultivation was rapidly extended in Brazil, Ecuador, Santo Domingo, and Venezuela.

From Central America the cultivation of cocoa soon spread to the West Indian islands, and as early as 1671 the cocoa plantations in Jamaica, which had been formed by the Spaniards, were destroyed by a "blast."

The World's Production and Consumption of Cocoa.—The following table extracted from the *Gordian* shows the main sources of supply and the principal countries of consumption in recent years.

SOURCES OF SUPPLY

Countries.	1906.	1907.	1908.
	Kilogs.	Kilogs.	Kilogs.
Brazil	25,135,000	24,528,000	32,956,000
Ecuador	23,426,897	19,670,571	32,119,110
San Thomé	24,619,560	24,193,980	28,560,300
Trinidad	12,983,467	18,611,430	21,737,070
Santo Domingo	14,312,992	10,151,374	19,005,071
Venezuela	12,864,609	13,471,090	16,303,196
British West Africa	9,738,964	10,451,498	14,256,634
Grenada	4,931,530	4,612,100	5,108,245
Hayti	2,107,905	2,350,000	3,150,000
Ceylon	2,509,622	4,699,559	2,836,215
German Colonies	1,367,977	1,966,336	2,737,529
Jamaica	2,505,608	2,218,741	2,694,381
Dutch East Indies	1,849,847	1,800,153	2,538,841
Fernando Po	1,557,864	2,438,856	2,267,159
Surinam	1,480,568	1,625,274	1,699,236
French Colonies	1,262,090	1,387,219	1,500,000
Cuba	3,271,969	1,713,830	862,631
Saint Lucia	716,200	750,000	700,000
Belgian Congo	402,429	548,526	612,000
Dominica	572,948	590,633	498,821
Costa Rica	176,243	277,884	340,375
Other Countries	1,000,000	1,000,000	1,000,000
TOTAL	148,794,289	149,057,054	193,482,814

CONSUMPTION

Countries.	1906.	1907.	1908.
	Kilogs.	Kilogs.	Kilogs.
United States	37,948,575	37,526,505	42,615,293
Germany	35,260,500	34,515,400	34,351,900
United Kingdom	20,132,040	20,159,472	21,054,520
France	23,403,800	23,180,300	20,444,500
Netherlands	11,224,000	12,210,249	15,821,000
Spain	5,636,821	5,628,239	6,580,113
Switzerland	6,466,900	7,124,200	5,820,500
Belgium	3,861,686	3,253,967	4,554,081
Austria-Hungary	3,312,800	3,471,700	3,707,300
Russia	2,670,940	2,473,380	2,588,060
Italy	1,385,000	1,455,500	1,432,600
Denmark	1,190,000	1,225,000	1,200,000
Canada	1,035,182	1,115,957	1,077,034
Sweden	1,057,218	696,455	974,000
Australia	386,497	400,000	500,000
Norway	580,043	524,713	466,959
Portugal	145,604	150,000	171,572
Finland	86,252	103,804	85,504
Other Countries	1,000,000	1,000,000	1,200,000
TOTAL	156,783,858	156,223,841	164,641,936

The stocks of cocoa remaining on hand at the end of the years 1906, 1907, and 1908, were estimated at 52,345,058 kilogs., 45,204,647 kilogs., and 78,488,009 kilogs. respectively. [Kilog. = 2·204 lb.]

During the years 1898 to 1908 the world's consumption of cocoa has risen from 70,000 tons to 164,000 tons, an increase of more than 134 per cent. In the same period the world's production has increased from 80,000 tons to 193,000 tons, or more than 240 per cent.

It is estimated that the area now under cocoa cultivation is more than 2,000,000 acres.

CHAPTER II

BOTANICAL

Origin of Commercial Cocoa.—That Linnæus entertained a very high opinion of cocoa may be concluded from his identifying the genus to which belong the species of trees yielding this product, as *Theobroma,* i.e. θεός (god) and βρῶμα (food). The genus *Theobroma* is included in *BUETTNERIACEÆ*, a tribe of the natural order *STERCULIACEÆ*, comprising some twenty species, all of which occur in the wild state in Central and South America. Many of these produce edible seeds or beans,* but at present only three species are known to yield beans of commercial value: these are *Theobroma cacao*, L., *T. pentagona*, Bern., and *T. sphærocarpa*, Chev.

The world's cocoa supply is chiefly obtained from *T. cacao*, L.; until quite recently, it was considered the only species productive of commercial cocoa. *T. bicolor*, Humb., *T. sylvestris*, Mart., *T. leiocarpa*, Bern., *T. angustifolia* (*T. speciosa*, Willd. ex Spreng.), and *T. ovatifolia* (*T. bicolor*, Humb.) are cultivated in Guatemala and Nicaragua, and their beans are mixed with those of *T. cacao*, L., in the local manufacture of chocolate. *T. cacao*, L., has been cultivated for at least five hundred years, and, like numerous other plants which have been cultivated during long periods, it has developed numerous varieties which show marked difference from the original type. The following is a brief description of *T. cacao*, L., *T. pentagona*, Bern., and *T. sphærocarpa*, Chev.

"DESCRIPTION OF THE GENUS *Theobroma*.

"Calyx 5 partite, coloured. Petals 5; limb cucullate, with a terminal, spathulate appendage. Column 10-fid;

* According to recent botanical nomenclature, "seeds" is a more correct description than "beans." In view of its common employment in commerce the term "beans" is retained in this book.—EDITOR.

fertile lobe bi-antheriferous; anthers bilocular. Style 5-fid. Fruit baccate, 5-celled; cells pulpy, polyspermous. Embryo exalbuminous; cotyledons fleshy, corrugate. Trees; leaves entire; pedicels fascicled or solitary, lateral.

"DESCRIPTION OF THE SPECIES *T. cacao, Linnæus.*

"*T. cacao*, L. Leaves oblong, acuminate, glabrous, quite entire; flowers fascicled; pericarp ovoid, oblong, 10-cosiate. Calyx rose-coloured, segments lanceolate, acuminate, exceeding the yellowish corolla; pericarp yellow or reddish, leathery, 6 to 8 in. long." (Grisebach.)

DESCRIPTION OF *T. pentagona*, Bernoulli.

Habit similar to *T. cacao*, young shoots and petioles very tomantose, hairs white or reddish. Leaves 18 to 25 cm. (7 to 10 in.) long by 7 to 9 cm. (2¾ to 3½ in.) broad, glabrous, of the same shape as *T. cacao* but of a dark green colour, much more papery, convex, at the sides more or less incurved downwards, often crisped and serrulate-dentate at the extremity.

Flowers rarely isolated or in pairs, but generally grouped in bunches of six to fifteen flowers, each borne upon a pedicel inserted directly upon the trunk. Pedicels and flower-buds green, not rosy.

The fruit has distinctly raised, acute-angled ribs on the surface, between which lies a warted surface. The outer coat is soft and easily penetrated, and when ripe is readily broken. Generally yellow in colour, but sometimes tinged with red. Cured beans have a fine flavour, and are generally larger than beans of *T. cacao.*

DESCRIPTION OF *T. sphærocarpa*, A. Chevalier.

Habit more compact than *T. cacao.* Leaves dark green, broad and parchment-like, generally measuring from 20 to 25 cm. (8 to 10 in.) long by 9 to 11 cm. (3½ to 4¼ in.) broad, with a short and broad point. Flowers almost always isolated, produced not only upon the trunk and principal branches, but sometimes also upon the youngest branches. Young fruits of a dark green colour, often tinted with red and almost spherical, rather deeply ribbed. Mature fruits of a clear yellow colour, short, length only from 10 to 12 cm. (4 to 4¾ in.), almost spherical, perfectly round at both extremities, and even sometimes a little depressed at the summit. Surface smooth, showing ten ribs well marked in the upper part, but disappearing towards the centre; the lower half is completely round, without furrows.

Habitat; common in cocoa-plantations in San Thomé.

Distinguishing Features of the Forastero and Criollo Varieties.—For convenience of reference attempts have been made to divide up the varieties of *T. cacao* into three divisions, which have been named respectively Forastero, Criollo, and Calabacillo. The varieties included under the Forastero and Calabacillo divisions are more robust than those belonging to the Criollo division, and are generally more hardy. The several varieties are, however, best differentiated by the characters of their fruits and beans. The different forms which the fruits of the Forastero varieties assume are clearly shown in Plates 1 and 2, which are reproduced from photographs recently taken by the writer in San Thomé. The fruits marked I, II, III, and IV all belong to the Forastero division, and clearly show the extraordinary manner in which they differ in size and form. Fruits marked I, II, and IV are fairly representative of the varieties generally classified as *Liso colorado*, *Liso amarillo*, and *Amelonado*. The fruit marked III is a form of *Amelonado* which the writer proposes to distinguish as *Amelonado pequeno*, and that marked VI is a fruit representative of the Calabacillo division. If each of these varieties constantly produced the form of fruit by which it has been here distinguished, identification would be an easy matter; but this is by no means the case, for the forms of fruit on a single tree frequently show such variation that it is possible to select fruits representative of two or even three of these varieties. Again, the colour of the fruits of a particular variety is also inconstant, as it varies from red to bright yellow, and it is not uncommon to see both red and yellow fruits on the same tree.

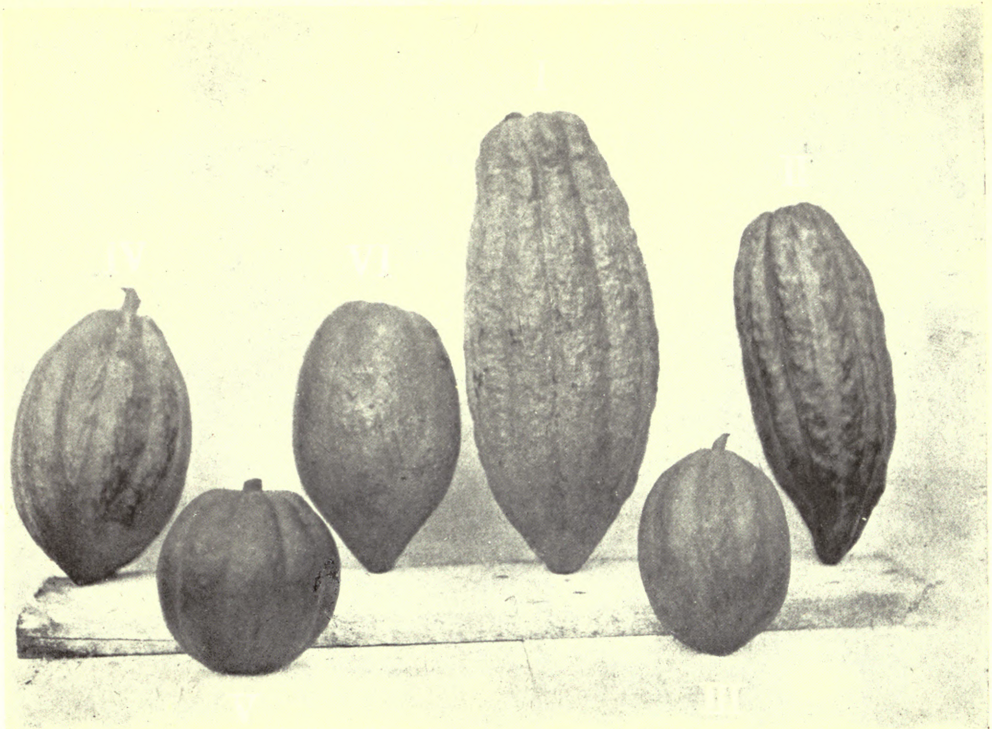
The fruits of the Criollo varieties likewise exhibit similar diversities in form, size, and colour. The differences between the Forastero and Calabacillo varieties are of such little value for purposes of identification that in this work it is not proposed to attempt to distinguish between them. We are thus enabled to class the varieties of *Theobroma cacao*, L., under two divisions, Forastero and Criollo. The main distinguishing characters of these two divisions being that the Criollo varieties generally produce fruits with thinner and softer walls than the Forastero varieties, although even this distinction cannot always be relied upon, as the fruits of *Amelonado* and *Amelonado pequeno* are sometimes as thin and soft as those of some of the Criollo varieties. The beans of the Criollo varieties are almost invariably rounded and plump, whereas the Forastero varieties quite as constantly produce much flatter beans. The most important distinction, however, lies in the Criollo beans possessing pale or white cotyledons, whilst those of the Forastero beans are generally purple. Where Criollo and Forastero varieties are cultivated in close proximity cross-fertilisation takes place between them and the characters of each type may be found merged in the progeny. This is a feature extremely common in Ceylon cocoa plantations, where it is almost impossible to find trees producing white beans only, as the writer has shown elsewhere.*

The cotyledons of the beans of *T. pentagona* are white, while those of the beans of *T. sphærocarpa* are purple. The fruits of these are readily distinguishable from those of *T. cacao*. The fruits of the first-mentioned species are provided with five prominent ridges or wings, between which the surface is covered with pronounced tubercles. The fruits of *T. sphærocarpa* are small and rounded, as shown in Plates 1 and 2 v.

All of the three species of *Theobroma* previously described are evergreen trees, with a short erect trunk; the height of cultivated trees varies from 12 to 40 ft.

The Production of Cocoa Flowers and Fruits.—The greatest number of flowers are produced on the stem and principal branches, and a tree may continue to bear flowers and fruits from the same areas for many consecutive years. Swellings or cushions are eventually formed

* Johnson's *Report on the Cultivation of Rubber, Cocoa, and other Agricultural Products in Ceylon*, 1903.



COCOA FRUITS

I. Forastero : *Liso colorado.*
II. ,, ,, *amarillo.*
III. Forastero : *Amelonado.*
IV. ,, ,,
V. *Theobroma sphærocarpa.*
VI. Calabacillo.

p. 8]

at these points as is shown in Plate 7. Flowers may be found on the trees throughout the year, but the greatest number are usually present about six months antecedent to the principal crop season. As many as 27,000 flowers have been found upon a tree at one time, but the average number produced by a single tree per year is approximately 6,000. The average number of fruits which a healthy cocoa tree matures per year is approximately seventy, so that only about 1 per cent. of the flowers yields mature fruits.

Cocoa flowers are so constructed that outside aid appears to be essential for pollination. Uzel, who investigated this subject in Ceylon, came to the conclusion that they are solely pollinated by thrips, and that these insects occurred more abundantly in sunlight than in shade. Many other insects are doubtlessly instrumental in this connection in other countries where thrips are not plentiful.

Five or six months usually elapse between floration and fruit maturation. The beans are arranged in the fruits in five longitudinal rows; ten beans may be traced in each row, but rarely more than forty-five properly developed beans are found.

Dimensions of the Flowers and Fruits of Different Varieties.—The size, weight, and form of the fruits vary considerably in different varieties. The writer obtained the under-mentioned averages by examining one hundred fruits of each of five of the varieties illustrated in Plates 1 and 2.

Characters of Different Varieties of Cocoa

No.	Variety.	Longitudinal section of fruit.	Transverse section of fruit.	Thickness of pericarp.	Number of beans.	Dimensions of beans. Length.	Breadth.	Thickness.
		cm.	cm.	mm.		mm.	mm.	mm.
I.	Forastero : *Liso colorado*	20·82	9·45	16·2—28·85	41	25·88	15·12	10·83
II.	Forastero : *Liso amarillo*	19·63	8·78	14·3—27·4	44	25·53	14·37	9·98
III.	Forastero : *Amelonado pequeno*	12·59	6·97	8·95—15·55	38	24·78	14·13	8·4
IV.	Forastero : *Amelonado*	14·08	7·66	9·36—18·75	44	25·18	14·82	8·83
V.	*Theobroma sphærocarpa*	8·7	8·31	9·7—13·8	38	21·20	15·02	9·13

No.	Variety.	Weight of 100 fruits.	Weight of fresh beans from 100 fruits.	Weight of cured dry beans from 100 fruits.	Number of fresh beans per kilogramme.	Number of cured dry beans per kilogramme.	Average weight of a fresh bean.	Average weight of a cured dry bean.
		grammes.	grammes.	grammes.			grammes.	grammes.
I.	Forastero : *Liso colorado*	79,579	15,076	6,190	257	626	3·89	1·06
II.	Forastero : *Liso amarillo*	54,856	13,363	5,361	299	745	3·34	1·34
III.	Forastero : *Amelonado pequeno*	26,293	8,321	3,658	474	1,078	2·11	0·93
IV.	Forastero : *Amelonado*	36,495	11,335	5,223	357	775	2·80	1·29
V.	*Theobroma sphærocarpa*	27,610	8,479	4,000	394	912	2·54	1·21

No.	Variety.	Weight per cent. of fresh beans to whole fruits.	Weight per cent. of cured dry beans to whole fruits.	Weight per cent. of cured dry beans to fresh beans.
I.	Forastero : *Liso colorado*	18·94	7·65	41·06
II.	Forastero : *Liso amarillo*	24·36	9·77	40·12
III.	Forastero : *Amelonado pequeno*	31·65	13·92	43·96
IV.	Forastero : *Amelonado*	31·05	14·31	46·08
V.	*Theobroma sphærocarpa*	30·71	14·49	47·18

CHAPTER III

CLIMATIC REQUIREMENTS OF COCOA TREES

A REVIEW of the climatic conditions obtaining in some of the most important cocoa-producing countries will best enable us to understand the cocoa tree's requirements in this respect.

BRAZIL

The largest cocoa-producing country is Brazil, which contributes more than 16 per cent. of the world's cocoa supply ; more than 80 per cent. of Brazilian cocoa being produced in the province of Bahia. San Salvador, the capital of Bahia, is situated in 13° South latitude and 30° 20′ West longitude. The average temperature of Bahia is given as 76° Fahr. In the interior of this province an average annual rainfall of 58 in. is obtained, while that of the district in which the town of Bahia is situated is 80 ins.

ECUADOR

The second largest cocoa-producing country, Ecuador, is traversed by the Equator. Cocoa is principally grown in the lower coast region. In Guayaquil, which is probably the most important cocoa district, the thermometric mean is 83° Fahr.

The rainy season extends from December to May, with a brief period of dry weather shortly after the December solstice ; a little rainy season occurring after the September equinox.

In the cocoa-growing districts the climate is generally hot and moist, and has been described as resembling the "steaming atmosphere of the carboniferous period." At Quito the average annual rainfall is reported to be 40 in., but as much as 78 in. falls in the Amazon valley.

San Thomé

The small Portuguese island of San or Sao Thomé possesses a perfect climate for cocoa cultivation. It is situated in the Gulf of Guinea immediately north of the Equator, about 160 miles distant from the West Coast of Africa. The annual average rainfall at sea-level is given as 40 in., but it is probably more than double this amount in the hilly districts in the interior of the island where most of the cocoa is grown. Except during a short dry season or gravanha, which generally occurs between July and September, rain falls at fairly frequent intervals all through the year, and the climate is exceedingly moist and oppressive. The temperature ranges between 60° and 80° Fahr. in the so-called cool season, and between 70° and 90° Fahr. in the hot season.

Trinidad

This West Indian island lies between 10° 3′ and 10° 50′ North latitude. The meteorological observations registered at the Botanical Gardens during thirty-five years show an annual average rainfall of 65·49 in., but in the wettest districts the rainfall often is as high as 100 in. per annum. The mean annual relative humidity is given as 78, taking saturation at 100. At sea-level the mean temperature is 78·1° Fahr., and ranges from 69° to 89° Fahr. According to Olivieri (*Treatise on Cacao*), the rainy season extends from June to December, the driest months being February, March, and April, and the wettest months July and August.

Santo Domingo

Another West Indian island, Santo Domingo, is situated between 17° 37′ and 20° North latitude. It is essentially mountainous, but there are numerous large fertile plains between the various ranges. In the plains it is generally hot and moist, the temperature often rising to 96° Fahr., and occasionally even to 100° Fahr. There is a well-marked wet and dry season, rains being most frequent and heaviest in May and June; the average annual rainfall is 60 in.

Venezuela

In the South American Republic of Venezuela, which lies between 1° 40′ and 12° 26′ North latitude, cocoa is principally cultivated in the warm, moist, lower lands. At Guayara, which is the principal seat of the cocoa trade, the mean temperature is 85° Fahr. The temperature is, however, considerably moderated by the trade winds, and great extremes of heat are not met with. The rainy season proper at Guayara only lasts about three months, May to August, but is more extended in the hills. In many districts it is thus only possible to cultivate cocoa successfully by the aid of irrigation. The hottest periods are the middle of April and the end of August. The average annual rainfall at Caracas is 31·5 in.; that of Maracaibo, the Caribbean Coast, the Gulf of Paria, and along the Orinoco, is 70, 65, 63 and 60 in. respectively.

West Africa

In West Africa cocoa is more or less cultivated from 8° North latitude to 8° South latitude. It is more extensively planted in the Gold Coast than in any other part of the West African Coast, and more cocoa is exported from that Colony than from all the other West African Colonies.

The principal districts in the Gold Coast where cocoa is cultivated are in the neighbourhood of Aburi, where, at the Botanic Gardens, meteorological observations have been regularly recorded for many years. Below are given the means of ten years' records.

Solar maximum Fahr.	Terrestrial minimum. Fahr.	Shade maximum. Fahr.	Shade minimum. Fahr.	Relative humidity, saturation = 100.	Rainfall per annum, inches.	Number of wet days per annum.
136·52	70·22	82·34	70·67	85·20	45·18	100

The most striking feature of these records is the small rainfall as compared with that of most other cocoa-growing countries. In several parts of West Africa the rainfall exceeds 100 in. per annum. At Aburi the low rainfall is no doubt compensated for by the humidity of the atmosphere. In Kandy, one of the principal cocoa-growing districts in Ceylon, the average mean annual relative humidity is given as 78; that of Trinidad is similar, whilst that of Aburi, as shown above, is 85·20. The rainfall at Aburi is exceedingly well distributed, for a reference to the meteorological records shows that rain almost invariably falls during every month of the year. (See also Dudgeon's *Agricultural and Forest Products of West Africa.*)

Ceylon

As representative of the climate of cocoa-growing countries in the East Indies that of Ceylon may be taken. This fertile island lies between 5° 55′ and 9° 51′ North latitude. The rainfall, in the districts where cocoa is principally grown, varies from about 75 to 122 in. per annum; the average mean annual humidity is 78, and the average annual temperature 74·5° Fahr. There are two monsoons in the year, called respectively the south-west and the north-east; the former usually arrives between the 10th and 20th of May, and the latter between the end of October and the middle of November. February and March are the driest months; the two following months are hotter, but the atmosphere is more humid; during the remaining months of the year rainy weather prevails.

Broadly speaking, cocoa cultivation is limited to lands lying between 20° North latitude and 20° South latitude. Even within these limits cocoa cultivation is seldom profitable at a higher elevation than 2,000 ft., nor where a protracted dry season obtains.

The whole of the region lying south of the Equator in South East Africa is unsuited for cocoa cultivation, principally on account of the period of drought, which usually extends from May to September, but there are several suitable localities in the Protectorate of Uganda.

The cocoa tree flourishes best in countries possessing a hot, equable, moist climate and a well-distributed rainfall. The amount of the rainfall is not so important provided it be well distributed throughout the year and there be an abundance of humidity in the atmosphere during the greater part of the year.

Countries where droughts and great extremes of temperature obtain are therefore most unlikely to prove profitable for the cultivation of cocoa.

CHAPTER IV

SOIL REQUIREMENTS OF THE COCOA TREE

The Chemistry of the Cocoa Tree.—As the cocoa tree is mainly dependent on the soil for its nutrition a consideration of its chemical components will afford an indication of its requirements in this respect. The chemistry of the cocoa tree has been investigated by Harrison in British Guiana, Cockrane in Ceylon, Mareano in Venezuela, and Jumelle furnishes valuable data of this nature in his book *Le Cacaoyer*.

Jumelle gives the following ash analyses of a cocoa tree twenty years of age.

Different parts of the tree, air dried.	Ashes.	Potash.	Phosphoric acid.	Lime.	Magnesia.
Trunk . . .	4·53	0·83	0·198	1·56	0·29
Large branches .	33·7	0·64	0·317	0·78	0·24
Medium branches .	4·33	0·77	0·509	0·82	0·26
Small branches .	7·04	0·58	0·566	1·67	0·32
Pruned branches .	8·97	0·71	0·830	1·12	0·34
Leaves . . .	15·06	1·45	0·370	1·60	0·49
Husks of fruit . .	11·90	3·15	0·585	0·87	0·17
Beans . . .	3·58	0·95	1·377	0·22	0·29
Bean-shells . .	4·56	0·80	0·409	0·49	0·16

Cockrane found by his investigations in Ceylon that the trunk and principal branches represent 50·2 per cent., leaves and small branches 36·6 per cent., and the roots 13·2 per cent. respectively of the whole tree. He found the proportion of organic matter to be highest in the beans, trunk, and principal branches, and lowest in the leaves and fruit-shells ; also the highest percentage of nitrogen in the beans and lowest in the stem, and the ash constituents lowest in the beans and highest in the leaves, small branches, and fruit-shells. His analyses of the ash of the cocoa tree are as follows :

COMPOSITION OF THE ASH OF THE COCOA TREE

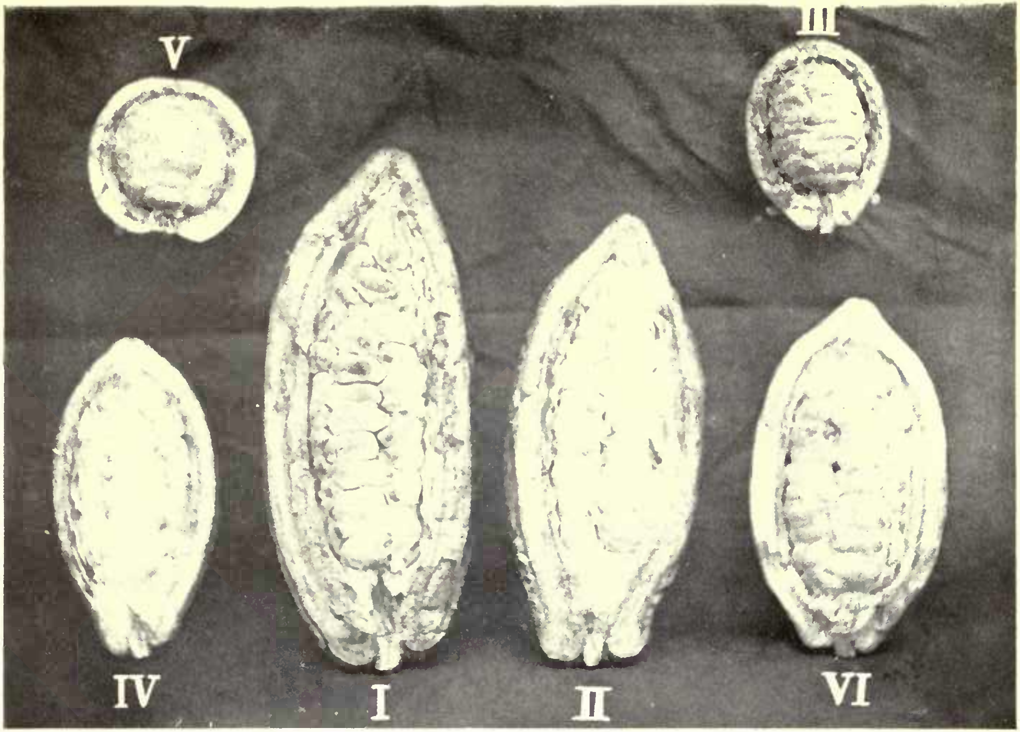
	Root.	Stem and principal branches.	Leaves and small branches.	Beans.	Fruit-shells.
Potash	27·68	29·257	19·15	36·56	49·41
Lime	22,89	29·317	25·62	6·80	8·67
Silica and sand	8·07	0·562	28·29	2·35	2·43
Magnesia	8·83	9·910	5·54	16·77	6·92
Phosphoric acid.	3·01	4·237	3·33	30·80	4·43
Other ingredients	29·52	26·717	18·07	6·72	28·14
TOTAL	100·00	100·000	100·00	100·00	100·00

The Report of the Ceylon Botanical Gardens for 1908 states: "The analysis of the young and old cocoa leaves, to ascertain the storage and transference of inorganic constituents during and after the periods of rapid growth, is interesting as showing the increase of potash and phosphoric acid in the more actively growing parts and their transference to other parts of the trees when the leaves are ready to fall.

"A marked feature is the large proportion of silicates in the older leaves, amounting to from 43 to 54 per cent. of the ash, and apparently chiefly combined with lime and magnesia, while the potash and phosphoric acid in the young red leaves and twigs amount to about 35 per cent. and 10 per cent. respectively; in the older leaves they only amount to 5 per cent. and 2·5 per cent., and fallen leaves have still less. The ratio of lime, magnesia, potash, and phosphoric acid in the ash of the young leaves is as 6 : 4 : 2 : 1, showing the necessity of ample, easily available lime and magnesia in the soil, as well as potash, if the growth of the cocoa is to be luxuriant."

Harrison recorded the constituents in the various parts of the fruit of the Forastero and Calabacillo varieties as follows:

	Kernels of beans.		Cuticles and pulp.		Fruit-husks.	
	Forastero.	Calabacillo.	Forastero.	Calabacillo.	Forastero.	Calabacillo.
Water	36·567	37·637	83·030	87·600	84·538	82·893
Albuminoids	4·826	6·696	1·271	0·918	1·017	0·760
Indeterminate nitrogenous matters	2·725	0·531	nil	traces	0·031	0·169
Fat	30·602	29·256	0·421	0·444	0·142	0·146



SECTIONS OF COCOA-FRUITS WITH BEANS *IN SITU*

I. Forastero: *Liso colorado.*
II. ,, ,, *amarillo.*
III. Forastero: *Amelonado.*
IV. ,, ,,
V. *Theobroma sphærocarpa.*
VI. Calabacillo.

	Kernels of beans.		Cuticles and pulp.		Fruit-husks.	
	Forastero.	Calabacillo.	Forastero.	Calabacillo.	Forastero.	Calabacillo.
Glucose	0·917	0·991	0·091	0·725	nil	0·132
Sucrose	0·165	traces	1·001	0·066	0·969	traces
Starch	6·038	3·764	1·305	0·945	0·445	0·469
Iron peroxide	0·032	0·032	0·010	0·004	0·009	0·005
Magnesia	0·454	0·324	0·073	0·114	0·101	0·099
Lime	0·105	0·054	0·030	0·054	0·037	0·039
Potash	0·635	0·142	0·248	0·190	0·358	0·454
Soda	0·068	0·239	0·015	0·041	0·073	0·041
Silica	0·016	0·016	0·003	0·202	0·008	0·006
Sulphuric anhydride	0·048	0·079	0·031	0·021	0·032	0·042
Phosphoric anhydride	1·045	0·749	0·098	0·115	0·096	0·082
Chlorine	0·032	0·019	0·061	0·018	0·026	0.036
Total nitrogen	1·543	1·603	0·327	0·236	0·198	0.177

Wright, *Theobroma Cacao or Cocoa*, has drawn up the subjoined table from Marcano and Cockrane's investigations, in Venezuela and Ceylon respectively, to show the chemical ingredients in the trees occupying an acre of land :

COMPOSITION OF ONE ACRE OF COCOA TREES

	Marcano. lb.	Cockrane. lb.
Nitrogen	201	123
Lime	400	313
Magnesia	111	86
Potash	251	277
Phosphoric acid	95	42

The quantitative variations in these analyses are no doubt attributable to the different ages of the trees in the two countries, and to the fact that Cockrane's analyses include roots.

The Chemical and Physical Characters of Cocoa Soils.—The relatively high percentages of lime and potash in the foregoing analyses are specially noteworthy as indicative of the cocoa tree's demands in these respects. It is, however, important to bear in mind that a chemical analysis of a soil does not always indicate the amount of plant-food present in a soluble form and available for a plant's immediate use. Still, it is significant that soils which produce good crops of cocoa are generally rich in potash.

Hart (*Cacao*) furnishes the following analyses of good and poor cocoa soils as determined in British Guiana :

Good and Poor Cocoa Soils

	Good Cocoa Soils.				Poor Cocoa Soils.			
	Demerara.	Surinam.	St. Vincent.	Grenada.	Demerara.	Surinam.	St. Vincent.	Grenada.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
(i) Organic matter and combined water	9·031	15·452	3·046	10·442	4·471	18·701	3·029	12·897
Phosphoric anhydride . . .	0·087	0·139	0·114	0·184	0·020	0·157	0·042	0·050
Sulphuric anhydride . . .	0·018	0·047	0·055	traces	0·111	nil	0·045	0·099
Chlorine	traces	traces	traces	nil	nil	trace	trace	trace
Iron peroxide	4·783	5·952	9·574	9·485	4·081	3·874	9·695	22·349
Alumina	9·217	16·076	8·889	10·024	7·214	15·269	7·374	26·925
Manganese oxide	0·347	nil	0·435	0·313	0·005	nil	0·487	0·320
Calcium oxide	0·596	0·495	4·981	2·379	0·225	0·010	4·787	0·210
Calcium carbonate	0·032	nil	nil	0·026	nil	nil	trace	0·264
Magnesium oxide	0·404	1·071	2·418	3·367	0·041	0·661	1·899	0·314
Potassium oxide	0·291	1·072	0·178	0·343	0·051	0·041	0·083	0·056
Sodium oxide	0·208	0·258	0·369	0·574	0·225	0·003	0·704	0·230
Insoluble silica and silicates . .	74·986	59·438	69·941	62·863	83·556	61·284	71·855	36·286
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000
(i) Containing nitrogen . . .	0·262	0·306	0·205	0·271	0·057	0·265	0·075	0·171
Water retained by air-dried soil .	6·500	11·000	8·100	12·400	1·900	7·600	7·600	14·100

For comparison with the preceding the following analyses of Ceylon cocoa soils have been extracted from a circular of the Botanical Department for 1905.

COMPOSITION OF CEYLON COCOA SOILS

	Plot No. 1.	Plot No. 2.	Plot No. 3.	Plot No. 4.
Moisture	3·600	2·600	3·000	3·000
(i) Organic matter and combined water . . .	4·600	4·600	4·000	4·000
Oxide of iron and manganese .	7·200	4·400	4·400	5·600
Oxide of alumina . . .	6·786	4·818	8·147	7·547
Lime	0·160	0·140	0·140	0·140
Magnesia	0·216	0·202	0·202	0·144
(ii) Potash	0·077	0·092	0·077	0·170
(iii) Phosphoric acid . .	0·064	0·089	0·076	0·064
Soda	0·233	0·199	0·296	0·284
Sulphuric acid . . .	0·048	0·048	0·048	0·041
Chlorine	0·016	0·012	0·014	0·010
Sand and silicates . . .	77·000	82·800	79·600	79·000
	100·000	100·000	100·000	100·000
(i) Containing nitrogen . .	0·100	0·112	0·112	0·106
Equal to ammonia . .	0·122	0·136	0·136	0·129
Lower oxide of iron . .	trace	trace	nil	nil
Acidity	fair	faint	fair	fair
(ii) Citric soluble potash . .	0·008	0·008	0·008	0·013
(iii) Citric soluble phosphoric acid	trace	trace	trace	trace

A soil may have all the chemical constituents necessary for plant nutrition, but if it is not in a good physical condition satisfactory results will not be obtained. This is another important reason why a chemical analysis of a soil is often by itself of little value. Heavy clays or water-logged soils are unsuited to cocoa cultivation, as also are briny soils, such as those often found on low-lying lands near the sea-shore.

On new lands the character of the indigenous vegetation frequently furnishes a valuable guide to the prospective planter. Land on which nothing but poor, scrubby vegetation is found is most unlikely to be suitable. When planted in shallow land good returns are sometimes obtained for a few years, but as soon as the tree's roots have traversed the rich layer of surface-soil and encounter a sterile stratum below, the tree is starved, its productive powers are decreased, and death follows, either through lack of nutrition or disease, for if an epidemic be present a tree in a bad state of health is more likely to be seriously affected than a healthy one.

Characteristic Root-system of a Cocoa Tree.—Plate 3 well illustrates the characteristic root-system of a cocoa tree. Although only seven years of age the "tap" root was 8 ft. long, and many of the extremities of the so-called surface-feeding roots were 12 ft. distant from the trunk. The cocoa tree develops an unusually long "tap" root as compared with that of many other species of trees of similar size. This amply demonstrates how very necessary it is for the cocoa planter to investigate the character of the sub-soil before deciding upon a site for his plantation. A water-logged sub-soil is quite as detrimental to the tree's development as a hard, stony one ; stagnant water destroys the hygienic conditions which are so essential for healthy root growth. Roots in such areas are more subject to fungoid attacks, as will be shown in the chapter devoted to pests.

Biological Condition of Soil.—The quantity of plant-food available in a soluble form is largely affected by the number of nitrifying and other bacteria present. Under favourable conditions these micro-organisms act upon the nitrogenous compounds of organic matter which are present in most soils, changing them into ammonia and ultimately to nitrates, in which state they form a soluble plant-food. For the life and multiplication of soil-bacteria, air, moisture, and heat are essential. Water-logged land is invariably sour and inadequately aerated, conditions which are inimical to the life of soil-bacteria. Drainage operations would probably render such lands fertile, but this operation should of course depend upon the necessary expenditure. It will in most instances be found more economical to choose a better site.

Soil Moisture.—Stagnant water must not be confused with soil moisture, for a humid soil is a most valuable auxiliary to successful cocoa cultivation. The soil's power of retaining moisture is largely dependent upon the amount of organic matter which it contains. Light, sandy soils are invariably lacking in this respect, and

PLATE 3

Characteristic Root System of the Cocoa-Tree

p. 20]

their choice for cocoa cultivation is consequently undesirable unless ample means are available for supplying the deficiency by the application of heavy dressings of humus-producing materials, such as animal or vegetable matter.

The most favourable soils for cocoa cultivation are those which have been enriched by the yearly leaf-fall in forest regions, or by alluvial deposits impregnated with various organic matters. The striking development of the San Thomé cocoa industry is a good example of the adaptability of such soils for the growth of cocoa. All the best plantations are situated on land cleared of forests, where the leaves annually shed have been converted by natural agencies into a rich, black, vegetable mould, in many cases more than a foot deep. These lands have been, and are still being, enriched with valuable fertilising materials carried down by the tropical rains from the neighbouring hills. It is mainly from this rich, upper layer of soil that the trees derive their nutrition by means of a veritable network of fibrous roots, for the sub-soil is frequently found to be composed of a sandy clay. Experiments conducted at the Minnesota Agricultural Experiment Station to test the retentive power for moisture of various soils, show that 100 pounds each of sand, clay, and humus are able to retain 25 to 30 pounds, 40 to 50 pounds, and 180 to 190 pounds of water respectively. Humus improves both the physical and biological condition of a soil by rendering it more porous.

CHAPTER V

LAYING OUT A COCOA PLANTATION

Wind-breaks.—Where strong winds are prevalent a sheltered position should be chosen for the plantation, as the foliage of the cocoa tree is peculiarly susceptible to damage from wind when unprotected from them. Trees in exposed situations are at times completely divested of young, tender foliage by their agency; and even the soft wood of new growths becomes dried up and killed through the same cause. Planters frequently attribute to disease the injuries due to wind and lack of shade; this is not altogether surprising, for the curled, shrivelled-up appearance of the young foliage injured by wind is entirely dissimilar to the well-known shredded, ragged aspect which the wind often imparts to larger foliage. Unprotected plantations near the sea-shore appear to be most seriously damaged; this is probably attributable to the salt-laden breezes, which not only destroy all young foliage, but discolour and then shred that which is fully developed. Many trees which afford suitable wind-breaks inland will not thrive near the sea-coast. The Japanese Lilac, *Melia Azedarach*, flourishes near the sea-coast, even in brackish soil, as also does the Coco-nut Palm, *Cocos nucifera*, and the giant Bamboo, *Bambusa arundinacea*. Planted in such situations these three species would form a most efficient wind-break.

When forest land is being cleared, and is plentiful and cheap, belts of indigenous trees may be left to serve as wind-breaks. If forest trees are not available, or should it be considered preferable to plant wind-breaks, trees of economic value should be chosen for this purpose, avoiding those liable to be broken by the wind. Besides sheltering the cocoa they would serve as disease-checking belts, provided that the species chosen are unrelated to cocoa.

Trees suitable for Wind-belts.—There are a variety of trees which commend themselves for obvious reasons, but preference should be given to those requiring similar soil and climatic conditions to those in which the cocoa tree flourishes. The Pará rubber tree, *Hevea brasiliensis*, Mull. Arg., at once suggests itself as a suitable tree to employ for this purpose, since it is not seriously affected by wind when the trees are planted close to each other. The Rambong rubber tree, *Ficus elastica*, Roxb., the Ofruntum rubber tree, *Funtumia elastica*, Stapf, and the West African Memleku rubber tree, *Ficus Vogelii*, are likewise well adapted for wind-breaks, as also are the following fruit trees: Bread Fruit, *Artocarpus incisa*; Avocado Pear, *Persea gratissima*; Sour Sop, *Anona muricata*; Mango, *Mangifera indica*; Guava, *Psidium Guava*; and Mammee Apple, *Mammea americana*.

The Jak Fruit, *Artocarpus integrifolia*, yields both edible seeds and a useful timber. Its large leaves, which are produced in dense masses, admirably adapt it for a wind-shelter, and it is largely employed in San Thomé for this purpose. In the same island several species of Cinchona have been planted as wind-breaks in cocoa plantations situated in the hilly districts. It is, however, doubtful whether these species could be generally employed, as they require a higher elevation than that at which the cocoa tree thrives.

Amongst the timber trees which could be planted with advantage are Red Sandalwood, *Adenanthera pavonina*; Lebbek, *Albizzia Lebbek*; West Indian Cedar, *Cedrela odorata*; *Michelia Champaca*; and various species of Eucalyptus.

Clearing Land for Cocoa Cultivation.—When clearing new land for cocoa plantations some planters prefer to leave a certain number of the indigenous trees to serve as shade for the cocoa. This practice is common in West Africa and in San Thomé. Where steep slopes are to be planted the roots of the trees which are left standing will certainly tend to hold the soil together and prevent heavy rains washing it away. As it is impossible to leave trees standing at uniform distances apart, regular shading by this method is impracticable. They are very subject to be uprooted by the wind when those trees which previously protected them have been removed.

As this frequently occurs several years after the plantation has been established many valuable cocoa trees are destroyed by the fall of the huge, foliage-laden branches. It therefore will be found preferable to clear all vegetation from the land to be planted, and plant the necessary shade trees at regular distances apart. In felling useful timber trees the prudent planter will arrange to preserve a good supply of logs for buildings, drying platforms, fermenting-houses, bridges, and similar purposes.

All brush and wood not required should be burnt. The extraction of large tree stumps is a costly operation, but it can be facilitated considerably by scraping the soil off the large surface-roots, piling on them a large stack of brushwood and firing it. By this means the base of the trunk and the largest stumps of the main roots often may be completely destroyed, or at any rate burnt to such an extent that they can be quickly chopped out. Stump-extractors should be employed to remove all the small tree stumps. If left in the ground, many tree stumps develop new growths which require constant lopping.

The ashes resulting from the burning, if spread over the land, will provide a valuable fertiliser, as they contain rich supplies of potash and phosphoric acid.

Plotting out the Plantation.—If no plan exists of the estate it is advisable to have it surveyed and a plan made. The whole area should then be divided into rectangular—preferably square—blocks to facilitate the keeping of records, inspection, and for reference purposes. Taking as a base-line the longest boundary line, commencing at one end pegs are put in at 10 chains apart. Lines at right angles to the base-line should now be made through these points, then starting from the base-line pegs should be placed 10 chains apart on the lines made at right angles to the base-line. Each peg will mark the corner of a square block, which is approximately 10 acres in area. To fix these points permanently, plant a particular tree or shrub, each with a distinctive mark or number. If each block be numbered in rotation reference may be made to any line of trees in a block, or even to a single tree in a particular block, by mentioning the number of the block and the number of the line and tree counting from a particular direction. The size of the blocks may be varied from 5, 15, to 20 acres by fixing points on the lines running at right angles to the base at 5, 15, or 20 chains apart respectively.

A uniformly laid-out estate will then be obtained, which will considerably facilitate allotting and controlling task-work.

It is advisable to mark the blocks with their respective numbers on the estate plan.

Roads.—A proper system of well-maintained roads is necessary on every cocoa estate. When possible they should be demarcated before planting operations commence. On estates where no steep lands occur the main roads might with advantage form the divisions of the 10-acre blocks, with intermediate paths to serve as feeders. This system of communication is of course not practicable where steep lands are planted, for it is advisable to take roads alongside such slopes, both to prevent excessive washing of the soil by heavy rains and to facilitate transport. As transport on such areas is more difficult than on moderately level lands more roads are desirable, and their distance apart ought not to exceed 5 chains. Light railways could be employed with advantage more generally on cocoa estates. Light four-wheeled trolleys, furnished with safe-brakes, can be run on rails at more than double the speed and with less than half the power required for the haulage of ordinary estate carts or wagons. The necessity for expediting the conveyance of shelled cocoa-beans to the fermenting-house will be dealt with subsequently.

Drainage.—It must not be inferred that drainage is unnecessary because the cocoa tree flourishes in a humid soil, for its roots are quite as susceptible to injury from stagnant water as from drought. Water drains away far more rapidly from a loose soil than from a compact one. Land with a heavy clay sub-soil requires particular care in the matter of drainage, but the surface-soil often exhibits no indication of the stagnant water below. The trees in such situations carry sickly, yellowish foliage, for the air is unable to circulate and promote the hygienic conditions so essential for healthy root development. Tiled or closed drains of any description are impracticable on a cocoa estate, as they rapidly become choked with roots. Full advantage should be taken of natural ravines and water-courses by leading drains into them, following the lie of the road as much as possible. The size of the drains and their distance apart must be governed by the character of the soil and the contour of the land. More drains are necessary on heavy land than on that of an open, porous nature. Generally speaking, drains 18 in. wide by 2 ft. deep and from 45 to 50 ft. apart will be found sufficient. It is erroneous to suppose that drains are unnecessary on hill-slopes, for they are of great value in preventing the washing away of rich surface-soil which otherwise occurs during heavy rains. In such situations a system of smaller and more numerous drains will be found more effective than that described above. In digging them the soil should always be thrown on the lower side of the drain. When completed, the whole drainage system of the estate should be inspected after the first heavy rain, as any necessary alteration can then be noted and rectified when a favourable opportunity presents itself. To ensure the efficient working of the drains it is necessary to keep them clear of the silt and débris which collects in them after heavy rain. As soon as the roads and drains are in satisfactory working order it will be found convenient to mark them on the estate plan for reference purposes.

Distance Apart to plant Cocoa Trees.—It is impossible to lay down any hard and fast rules regarding the distance to plant cocoa trees apart. The different varieties vary considerably in habit, and a variety which in one country develops into a small compact tree may in another develop into a much more vigorous tree, owing to differences of soil and climate. The Criollo varieties, *Theobroma pentagona* and *T. sphærocarpa* grow more slowly and produce smaller trees than the Forastero varieties.

Twelve feet may be considered a fair average distance to plant the first mentioned types apart, and 15 ft. is usually sufficient for the latter. Trees which have been planted too closely should be thinned out immediately crowding is evident. The disastrous effect of too close planting is well demonstrated by the drawn, straggly trees shown in the photograph (Plate 4). It is incorrect to assume that the best crops will be obtained from lands which carry the greatest number of trees. Unless a cocoa tree has sufficient space to develop its foliage properly its fruit-producing capacity must be restricted. On the other hand, if an unnecessarily large space be left between the trees the roots will suffer by the undue exposure of the soil to the sun, and the foliage will be needlessly exposed to both wind and sun. Should the cultivation of catch crops be objected to, the cocoa trees might be planted much closer together than here suggested. This would enable a much larger crop to be gathered during the first few fruiting years of the plantation, and alternate trees could be destroyed as considered necessary. By the adoption of this plan the ground would be well shaded, and the roots of the trees would hold the soil together and prevent the excessive wash-away which sometimes occurs on widely planted estates where no catch crops are planted. In this connection it is, however, important to bear in mind that a cocoa tree often produces lateral roots 12 ft. long; the comparatively young tree shown in Plate 3 had lateral roots 12 ft. long, with a tap-root 8 ft. deep in the ground.

Lining.—If the suggestions offered under the heading "Plotting out the Plantation" have been adopted the work of marking the points where the cocoa and shade trees are to be planted will be a comparatively simple matter. A surveying pole, or any other straight pole about 8 ft. long, is placed at each corner of one of the blocks; then standing at one corner an assistant puts in three or four poles approximately equidistant and in a straight line between the two corner poles on one side of the block. A surveying chain or a rope is used, marked by means of coloured cloth or similar material at every 15 ft.—supposing this to be the distance apart the cocoa trees are to be planted—and, starting from one of the end poles, pegs are put in corresponding with the cloth marks. This operation is repeated at the opposite side of the block. By the same method pegs are placed 15 ft. apart between the first-placed peg on either side of the block, and so on all through the block. If care be taken to plant the cocoa trees as near as possible to the points marked by the pegs they will be at a uniform distance apart. The slightly additional labour which lining involves is more than compensated for by the symmetrical appearance of the estate and the fact that it contains the greatest number of trees which can be profitably grown. Where lining is not practised, a certain number of trees will be always found planted too closely together, while others have an unnecessarily large area allotted to them and ground space is wasted.

Holing.—It will considerably facilitate the growth of the young cocoa plants if the ground be carefully prepared for their reception. A month or two before transplanting takes place holes about 3 ft. square and 2 ft. deep should be dug ; the sub-soil being thrown into a heap alongside the hole. On steep hill-slopes this soil is best placed on the lower side of the hole.

If water stagnates in the holes this indicates that drainage is necessary and must receive attention before planting commences. A few days previous to transplanting the young cocoa plants the holes should be filled with any rich surface-soil in the neighbourhood. Should this not be available it is advisable to place a good layer of animal manure at the bottom of the hole. If it be decided to sow beans " at stake," i.e. at the points allotted to the cocoa trees, three or four beans should be sown at the commencement of the rainy season at each peg and protected by erecting a small framework of palm-leaves or similar material over them. Should more than one bean germinate all except the strongest must be removed when the plants are about a foot high. This method of propagation is impracticable when frequent periods of dry weather occur during the rainy season, as the young cocoa trees demand a moist soil during the first four or five months of their existence.

PLATE 4

DRAWN, STRAGGLY COCOA TREES, TOO CLOSELY PLANTED AND DENSELY SHADED

p. 28]

CHAPTER VI

SHADING AND INTER-CROPS FOR COCOA

It is universally acknowledged that shade is necessary for young cocoa trees; whether it is absolutely essential for mature trees has been the subject of a great deal of controversy. A too dense shade is conducive to the growth of the various fungus diseases to which the cocoa tree is subject and checks the development of flowers and fruits by excluding air and light. Plate 5 shows a too densely shaded cocoa plantation in San Thomé, and Plate 4 the ill effects on the cocoa trees beneath, which have been too closely planted together. The latter are drawn, straggly specimens, and although the photograph was taken during the cropping season scarcely a fruit is to be seen. The species employed for the first mentioned purpose are termed temporary shading agents, and those for the latter permanent shading agents. We will consider the latter first.

Permanent Shade for Cocoa Trees.—In connection with this question it is well to remember that the cocoa tree is a native of forest regions, and in view of its low habit must receive a certain amount of shade from the species of larger trees which inhabit tropical forests. Cocoa has been successfully cultivated without shade in Grenada for many years, and the planters in that island affirm that it is not only unnecessary but injurious to this product. Fawcett considers that shade is not required for mature cocoa trees in Jamaica. On the other hand, Trinidad planters just as emphatically maintain that shade is essential in their cocoa plantations. Cocoa is almost invariably shaded in Surinam, but Dr. Van Hall, who has devoted a great deal of time to the study of the cocoa industry in that country, has stated that although the rainy season is followed by three very dry months, if the shade were properly removed cocoa could be grown there without it. Permanent shade for cocoa is generally considered necessary in Central America, Ceylon, Trinidad, Fiji, Tobago, British Honduras, Samoa, and the whole of West Africa, including San Thomé.

If a planter has doubts as to the beneficial effects of shade it would be most unwise for him to remove it all at once. The shade might be reduced by degrees from a small selected area and the effects noted. His decision should not be made from the results observed during a single year in view of the varying climatic conditions which many countries experience during different years.

In countries where cocoa is grown a planter establishing a new plantation should be guided by the methods adopted on the most promising plantations. The amount of shade required is to a very large extent dependent upon the climatic conditions which obtain. Shade trees, in addition to protecting the cocoa tree from the sun, act as a wind-break and assist in preserving soil-moisture during periods of drought.

Greater shade is therefore required where strong winds prevail and also where dry weather is experienced at certain periods of the year. In choosing shade trees for such regions it is therefore important not to employ those which shed their foliage at the season when their protection is most required.

The trees most largely employed are those which belong to the natural order *LEGUMINOSÆ*, probably because they are considered to be less exhaustive of soil nitrogen as they are enabled to fix atmospheric nitrogen and add it to the soil by the aid of the bacteria associated with the nodules on their roots.

The Merits and Demerits of different Shade-Trees.—The following are common leguminous trees recommended for permanent shade purposes:

Erythrina velutina, *E. umbrosa*, *E. lithosperma*, *E. indica*, *E. ovalifolia*, *Albizzia moluccana*, *A. stipulata*, *Pithecolobium Saman* and *Gliricidia maculata*.

The first two mentioned are largely used in Trinidad and to a less extent in some of the other West Indian islands, Ceylon, and Guam. In Trinidad they are planted at distances varying from 40 to 50 ft. apart. They yield no commercial product; even their wood is of no value. They are objectionable on account of frequently losing their leaves during the dry season. *E. umbrosa* was planted for shading cocoa in the Botanic Gardens, Aburi, Gold Coast, but as it was invariably leafless during the dry, harmattan season it was cut down and *Pithecolobium Saman* (Rain Tree) was substituted.

This tree proved satisfactory for several years. The Acting Director, in a letter to the writer dated October 1909, on this subject remarks: "They have made such rapid growth during the last year that I am afraid they will soon do more harm than good. Still the cocoa is doing remarkably well under them, and in the centre block they look exceptionally healthy."

In St. Lucia *Erythrina indica* is reported to give better results than *E. velutina* and *E. umbrosa*, as its shade can be more easily controlled by pruning.

Albizzia moluccana is an evergreen tree indigenous to the Moluccas and Java. It is a large, rapidly growing tree, with a trunk 3 or 4 ft. in diameter and 70 or 80 ft. high. It produces a dense shade, which is inclined to encourage the spread of fungus diseases. Possibly this might be modified to a certain extent by the systematic pruning of young trees. It is readily propagated by seeds. Its timber is light in weight and of no great value, but might be employed in the manufacture of packing cases.

Ceylon appears to be the only country where it is planted as shade for cocoa.

Pithecolobium Saman.—This is planted as shade for cocoa in Trinidad, Venezuela, and to a small extent in the Gold Coast. Like *Albizzia moluccana* it requires constant attention in regard to pruning to prevent its forming too dense a shade. Such prunings, however, rapidly decompose and provide valuable dressings of humus. Being evergreen it is preferable to *Erythrina* for the reasons already described. The legumes of this tree are sometimes used as cattle food, but otherwise it yields no product of economic importance. The "Medera" (*Gliricidia maculata*) tree of Nicaragua is reported (*Bulletin of Miscellaneous Information*, Botanical Department, Trinidad, September 1903) to be used as shade for cocoa in that country; it is raised from seeds sown in lines 13 ft. apart. About two years after the seeds have been sown the cocoa is planted in alternate lines, and the Medera provides the permanent shade.

The San Thomé planters utilise numerous indigenous trees as shade, these being left standing when the land is first cleared for planting. The commonest of these are the "Odum" timber tree (*Chlorophora excelsa*); West African Oil Palm (*Elaeis Guineensis*, Jacq.); *Musanga Smithii*; West African Bread Fruit (*Treculia africana*); Cola-nut tree (*Cola acuminata*); the Silk-cotton tree (*Eriodendron anfractuosum*). Where extra shade is necessary, various fruit trees are planted, such as Avocado pear (*Persea gratissima*); Mango (*Mangifera indica*); Jak fruit (*Artocarpus integrifolia*); Sour sop (*Anona muricata*); Bread Fruit (*Artocarpus incisa*).

Various rubber trees are employed in some countries for shading cocoa. The Pará rubber tree is probably the most suitable species to adopt where soil and climatic conditions are suitable.

Temporary Shade for Young Cocoa Trees.—Young cocoa trees are usually shaded by cultivating catch crops on the vacant land between the trees. The distance apart at which the cocoa tree is planted in different parts of the world varies from 6 to 25 ft., 15 ft. may, however, be considered a fair average distance. Planted at 15 ft. apart the trees will not meet for from ten to fifteen years. It is advisable to cultivate any vacant land between the trees during this period with catch crops, which, while affording the necessary shade, will protect the soil from adverse climatic conditions and yield a return to the planter until his cocoa comes into bearing. The plants most commonly used for this purpose are bananas or plantains (*Musa spp.*), cassava or manioc (*Manihot utilissima*), coco or tania (*Colocasia antiquorum*).

Assuming that it be decided to plant cocoa at 15 ft. apart, and the permanent shade trees are 45 ft. apart, a banana should be planted in the centre of every four cocoa trees and a tania, cassava, or similar plant intermediate between the other trees. The diagram on page 33 illustrates the position of the various plants at the end of the first year.

When circumstances permit, it is advisable to plant the temporary shade trees two or three months before

PLATE 5

A TOO DENSELY SHADED COCOA PLANTATION

p. 32

the cocoa, so as to have shade ready for the newly transplanted cocoa seedlings.

B	x	B	x	B	x	B	x	B	x	B	x	B	x	B
x	S	x	C	x	C	x	S	x	C	x	C	x	S	x
B	x	B	x	B	x	B	x	B	x	B	x	B	x	B
x	C	x	C	x	C	x	C	x	C	x	C	x	C	x
B	x	B	x	B	x	B	x	B	x	B	x	B	x	B
x	C	x	C	x	C	x	C	x	C	x	C	x	C	x
B	x	B	x	B	x	B	x	B	x	B	x	B	x	B
x	S	x	C	x	C	x	S	x	C	x	C	x	S	x
B	x	B	x	B	x	B	x	B	x	B	x	B	x	B
x	C	x	C	x	C	x	C	x	C	x	C	x	C	x
B	x	B	x	B	x	B	x	B	x	B	x	B	x	B
x	S	x	C	x	C	x	S	x	C	x	C	x	S	x
B	x	B	x	B	x	B	x	B	x	B	x	B	x	B

THE DIAGRAM

shows ¼ of an acre of land planted with Cocoa.

C = Cocoa. B = Bananas. S = Permanent Shade Trees. x = Cassava or Tania at the end of first year.

Bananas or Plantains, *Musa spp.*—In countries where favourable facilities exist for marketing the fruit, the adoption of bananas for shading purposes proves a valuable adjunct to cocoa cultivation, as the profits obtained from the sale of the fruit can be made to cover the cost of up-keep until the cocoa comes into bearing. This plant is very hardy and grows rapidly from the suckers which are produced from the root-stocks of mature trees.

In the East the word plantain is synonymous with banana, but it is here used in reference to the variety of *Musa paradisiaca*, which does not yield sweet fruits; these are generally boiled or baked and eaten as a vegetable.

Cassava or Manioc, *Manihot utilissima.*—The well-known tapioca or manioc flour is obtained from the enlarged root of this plant, and its cultivation, as a catch crop with *Hevea brasiliensis* in Malaya, has been known to pay for the cost of up-keep during the first four years from the establishment of the plantation. It is readily propagated by cutting up the stems in lengths of about a foot and fixing them firmly in the ground where they are intended to grow in the plantation. The roots are ready to harvest in from fifteen to eighteen months from the date the cuttings are planted. The roots form an important article of food for the labourers, and may be served out as rations either in the fresh state or in the form of flour made by grinding up the dried roots.

Coco or Tania, *Colocasia antiquorum.*—This plant is propagated by cutting up its tuberous roots so as to leave two or three buds or "eyes" on each section or "set." The "sets" are planted singly in the plantation about an inch below the surface; the tuberous roots mature within about twelve months from the date the "sets" are planted. These, when cooked, are much relished as food by most estate labourers.

It should, however, be mentioned that the cultivation of both cassava and tania is very exhausting to the soil, and when planted on poor land a good dressing of manure should be applied after the crop is reaped.

Chillies, *Capsicum annuum.* This is a much less exhausting crop than cassava and tania and might be planted with advantage as a catch crop with cocoa.

The tall growing varieties of "bird pepper" are preferable, as they provide a better shade for young cocoa plants.

Seedlings should be raised in prepared nursery beds; when the young seedlings are 2 or 3 in. high, they may be transplanted into rows 3 ft. apart and about 2 ft. apart in the rows. Chillies should be harvested with the stalks attached and carefully dried in the sun; it is necessary to remove the stalks previous to marketing the crop. Fifteen hundred pounds per acre is considered a fair crop, but as much as 2,500 lb. per acre has been obtained. The price of Zanzibar chillies fluctuates between 15*s*. and 25*s*. per cwt.

The species planted for temporary shade must be removed when they show signs of overcrowding the cocoa. It is best to reduce this shade gradually, or the cocoa may suffer by sudden exposure to the sun and wind. Wherever vacancies have occurred in the plantation the temporary shade should not be removed until the refills have become thoroughly established.

CHAPTER VII

PROPAGATION

The cocoa tree may be propagated from beans or by budding or grafting. The first mentioned method is the one most commonly employed.

Bean Selection.—The careful selection of the beans is of the highest importance, for upon this largely depends the quality and often the quantity of the resulting crop. It is of far more consequence than is the case with annual crops, where the sowing of seed of inferior varieties in any one season may be remedied the following season. With cocoa several years must elapse before the results are apparent. The cocoa planter should endeavour to produce a crop of even grade, and to enable this to be done it is necessary to obtain beans from similar trees. In selecting the species or variety to be cultivated he must be guided to a very large extent by the local conditions as regards soil and climate.

The Criollo varieties of *Theobroma cacao*, and *Theobroma pentagona* are less hardy and require a richer soil than *Theobroma sphærocarpa* and the Forastero types. The produce of the first two mentioned is of better quality and of higher market value than that of the last mentioned types. But as *Theobroma sphærocarpa* and the Forastero varieties generally yield larger crops than the others it is probable that the gain in weight compensates for the lower price obtained. The Criollo varieties and *Theobroma pentagona* are more susceptible to disease, and will require much greater care and attention in districts where this is prevalent. As previously stated, the Forastero varieties and *Theobroma sphærocarpa* produce flatter beans than those of the Criollo varieties and *Theobroma pentagona*, but some trees of the former types yield much rounder beans than others, and these should preferably be chosen for propagating purposes.

Round or "bold" beans almost invariably realise higher market prices than flat ones of the same quality. Certain trees are more disease-resistant than others. Beans from trees infected with disease should therefore not be used for propagating. Beans of diseased trees often contain a fungus mycelium, which might be the means of infecting young plants raised from them; other qualities desirable in trees selected for propagating purposes are that they should be of high vitality and heavy, regular fruit bearers.

Beans intended for sowing should only be selected from well-formed mature fruits and be taken from the centre of the fruit, where they are larger and better developed than those found at the ends of the fruit.

Packing and Transport of Cocoa Beans.—Cocoa beans which have been taken from out of the fruit and exposed to atmospheric influences soon lose their vitality. They may be preserved in the fruits for a week or two by completely covering them with a substance, such as paraffin wax, which hermetically seals the contents. Beans for propagation which are to be sent on a two or three weeks' journey may be satisfactorily treated as follows:

Select perfectly ripe beans, thoroughly wash them and carefully wipe off as much of the adherent pulp as possible without injuring the integument. Spread them out thinly in a current of cool air for about twenty-four hours, then dust them with finely powdered charcoal. Prepare a mixture consisting of equal parts vegetable mould and finely powdered charcoal. Slightly moisten the mixture and place alternate layers of the mixture and beans in wooden boxes with a capacity of about a cubic foot. To prevent the fine portions of the mixture filtering through to one side of the box in transit, place sheets of stout paper or some similar material between each layer of beans. About 250 beans can be packed by this method in a box of the dimensions previously stated.

When cocoa beans are to be sent on a journey of more than three weeks' duration they should be packed in Wardian cases. The bottom of the case should be covered to a depth of 3 or 4 in. with a slightly moistened mixture, consisting of three parts of leaf mould and one part of powdered charcoal. This should be firmly pressed down and the cocoa beans, prepared in a similar manner to that previously recommended, spread upon it close together in a single layer. Cover them an inch deep with the leaf mould and powdered charcoal mixture and press it firmly down. Upon the latter spread a thin layer of straw, fine twigs, or similar material and nail this tightly down with thin wooden battens an inch wide and about three-quarters of an inch distant from each other. To keep the straw or twigs in position it is necessary to fix the battens at right angles to the direction in which the former layer is placed. When the case has been properly closed it is ready for despatch.

The beans will germinate in from ten to fifteen days. As provision is made in the Wardian case for the admission of both air and light the cocoa seedlings are enabled to develop unhindered, and upon arrival at their destination should be at once transferred to pots or baskets and placed under nursery shelters.

Nurseries.—If it is not feasible to raise the young cocoa trees in the situations it is intended they shall occupy in the plantation they must first be raised in nurseries and transferred to the plantation when established. Sowing the beans in nursery beds is not recommended, as the young plants develop a substantial tap-root which is frequently injured when they are transplanted, and results in an unnecessarily high mortality in the plantation. The beans should therefore be sown in baskets or pots, from which they may be more readily transplanted and with less damage to the roots. As it generally takes from six to eight months to raise nursery plants large enough for transplanting in the field, to avoid loss of time it is necessary to regulate the date of sowing accordingly.

The site for the nursery should be chosen in a well-sheltered situation adjacent to the plantation. For the protection of the young plants it is advisable to erect temporary nursery shelters, by fixing stout, upright posts about 8 ft. high, in lines 10 ft. apart each way, and then on these cross bars ; the whole being sufficiently strong to support a thin layer of palmleaves, split bamboos, or some similar material. It will be found that under such a shelter the work of irrigating the young plants will be considerably lessened and the young seedlings will be protected from heavy rains and scorching sun.

Most estate labourers are adept at making, from stout palm leaves, split bamboos, young pliable twigs, or strips cut from the outside layer of the petiole of palm leaves, baskets in which to raise young plants. Such baskets vary from 9 in. to a foot in height and in diameter from 4 to 6 in.

Where suitable clay is available, plant pots may be moulded from it and kiln-dried to harden them.

Sections of large, hollow bamboo poles also make excellent pots in which to raise young plants. The poles are sawn up into sections about one foot long. The bottom of the pot is formed by sawing one end off about an inch below an internode or division of the pole, a hole being made in the bottom to permit water to drain away.

Bean Sowing.—A few rough stones should be placed at the bottom of the pot or basket to prevent fine soil filtering through and to facilitate drainage ; then fill to within 2 in. of the top with good, light, friable soil. It is advisable to dry or remove the white, mucilaginous pulp with which the beans are covered previous to sowing them. This may be done by spreading them out in the sun or by rubbing them with wood ashes. Provided that the vitality of the beans is satisfactory, one bean is sufficient to sow in each pot ; this should be placed on the soil in the pots prepared in the manner above described, and then covered with about half an inch of soil. Press the latter closely around the bean, thoroughly saturate the soil with water, and germination will take place in five or six days. In order to provide for failures in the plantation it is desirable to sow about 40 per cent. more beans than the number of trees which it is decided to establish in the plantation.

The germinating properties of cocoa beans are generally excellent, and the proportion of beans which germinate often reaches as high as 98 per cent., but the mortality of young trees in the plantation is relatively great. The number of young plants which fail to grow may be estimated at 25, 10, 5, and 2 per cent. of the total number of trees planted during the first, second, third, and fourth years respectively from the establishment of the plantation.

The young seedlings in the nursery require special care in regard to watering, as dryness at the roots is liable to check their development severely. In from six to eight months the young plants will have grown to about a foot high and may then be transferred to the plantation, provided the weather be suitable.

Budding.—Unless a cocoa flower is protected, cross-fertilisation may occur, and even if protected the characters of any particular variety of cocoa are not necessarily " fixed " in the plants raised from beans collected from it. The best and most certain means of perpetuating the desirable characters of the parent tree in its progeny are by budding, grafting, or by propagating young growths. With this object in view the writer commenced in 1898 a series of experiments with cocoa trees growing in the Botanic Gardens at Aburi, in the Gold Coast.

Only moderately satisfactory results were obtained by budding and the forms of grafting which necessitated the immediate removal of the scion from the parent tree. Attempts to propagate by cuttings furnished negative results, but grafting by approach proved most successful. Fawcett considers that the budding of cocoa is in every way more suitable than in-arching or grafting by approach. In Jamaica, Harris and Cradwick have both obtained excellent results by budding cocoa trees.

Budding or grafting affords an admirable means of combining the commendatory qualities of the Criollo and *T. pentagona* varieties with the high vitality and prolific character of the Forastero types.

It is almost invariably found that budding and grafting induce early bearing and a low spreading habit to the trees. The latter is a valuable attribute, for it facilitates the collection of the crop and renders shading and protection from the wind less difficult. By Cradwick's demonstrations in Jamaica many small settlers, who previously were totally ignorant of the art of budding, have obtained uniformly successful results in budding Criollo on Forastero stocks.

The budding and grafting of cocoa provide the planter with a means of regulating the grade of his crop throughout the whole of his estate.

Budding may be effectively carried out in both old and young plantations. In regard to the former, suckers from the old stocks should be operated upon and the old main stem removed when the buds have become thoroughly established. Young plants may be budded previously to planting them out in the plantation, or young plants established in the plantation may be budded. If a strip of bark be cut from a cocoa tree and then carefully replaced and bound up it will re-unite. In the same way, if a strip of bark be cut off one cocoa tree and a similar piece be cut from another and properly placed and bound up on the wound of the first tree, this will generally unite, and should it contain a healthy bud this will eventually develop into a branch and produce fruits similar to its parent.

The success of the operation depends upon the junction of the cambium tissue of the stock with that of the bark containing the bud which it is desired to propagate. For this to be effected it is obviously necessary to bring these tissues in close proximity to each other.

The cambium is the light-coloured, rapidly-growing tissue situated between the wood and the inner bark, and may be recognised when a cross-section is made of a young, woody stem. When bark is stripped off a stem a portion of the cambium tissue is usually taken away and the other remains adhering to the wood. The best time of the year to conduct budding operations is during the rainy season, when the sap is most active. The variety best adapted for the stock will of necessity vary in different countries, it is therefore advisable to choose for this purpose a locally cultivated variety which is hardy, prolific, and disease resistant ; these qualities are most commonly found in the Forastero varieties. Although the high quality of the beans produced by the Criollo and *T. pentagona* varieties commends them for this method of propagation, discrimination is necessary, as a particular variety will invariably be found to be less subject to disease and more prolific in a specific district than others. Whenever possible, select stocks for budding with a stem of a half to an inch in diameter. The bark containing the bud should be cut off about three inches long, about three-quarters of an inch wide, and rectangular in shape. Place this upon the stock and mark the stock to enable a similar piece of bark to be cut out of it.

The bud-bark should then be fixed in position and carefully bound up with waxed tape.

Waxed tape can be made by dipping ordinary broad tape into melted paraffin wax.

Provided that the work has been properly done junction of the scion with the stock should be effected in from two to three weeks. When the bud has developed a growth about six inches long it is necessary to remove all growths of the stock above it. The scion may be expected to produce fruit when from one and a half to two years of age.

Grafting.—Excellent results have been obtained by approach-grafting improved varieties of cocoa on Forastero stocks by Jones at the Botanic Gardens, Dominica (*vide* pamphlet, Series No. 6, issued by the Imperial Department of Agriculture for the West Indies). He obtained 175 fruits from seven grafted trees, viz. *Theobroma pentagona* on Forastero stocks, within three years of planting the grafted plants; and fourteen grafted trees, selected Forastero on Calabacillo stocks, yielded an average of eighteen fruits per tree within three years from date of planting.

Successfully to carry out the operation of approach-grafting, or in-arching as it is sometimes termed, it is necessary to convey the stocks to the plant or plants which it is desirable to propagate or bring the latter in close proximity to the former. The first mentioned plan is the more practicable, since it is advisable, before deciding upon taking grafts from any particular tree, that it should have been under observation for several years and proved its prolificacy.

The stocks on the other hand may be raised in baskets or pots, in the manner recommended under the heading "Nurseries." Seedling plants grown under these conditions will be large enough to use as stocks when they are eight or nine months old. The best time for grafting is during the rainy season, so the beans should be sown about eight months previously.

As the cocoa tree carries its lateral branches several feet from the ground, it is necessary to support the pots or baskets which contain the stocks on a stage or platform, so as to bring the branches to be used as scions and the stocks contiguous to each other. From the preceding remarks it will be seen that a low-branched "scion" tree is preferable, to facilitate both the grafting operations and any subsequent attention required by the grafted plants. As with budding, the object to aim at in grafting is to bring the cambium of the scion and that of the stock in conjunction. The scion should therefore have a stem diameter similar to the stock. Carefully slice away a strip of bark and wood about two or three inches long from one side of the stock; this strip should not exceed a third of the thickness of the stem. Then carefully slice a similar strip from the growth selected as a scion, so that when the cut portions of the stock and scion are brought together the cambium tissues meet. Any leaves found on the section of the stock or the scion which has been sliced may be removed; the two cut surfaces should then be bound carefully but firmly together with waxed-tape. The roots of the stocks must be kept constantly moist. During dry, windy weather the soil in the pots will evaporate rapidly, and it will be found necessary to water them at least once a day.

If there be any danger of the pots being blown down by the wind they should be firmly fastened to the staging. To prevent undue movement of the grafts it may also be necessary to tie the branches supporting the scions to stout stakes fixed firmly in the ground.

Union of the cambium tissues is usually apparent in five or six weeks. The scion should then be partially severed from its parent stem; this is best done by cutting off a strip of bark about half way round the stem of the scion immediately below its junction with the stock.

If on examining the scion a fortnight later it shows satisfactory progress it may be completely severed from the parent tree. The upper part of the stock should, at the same time, be carefully cut back to the point where it joins the scion.

The grafted stock should now be placed in a shady position and well protected from both wind and sun. It sometimes happens that the leaves of the scion flag when it is first removed from the parent tree; this is due to the fact that water is being more quickly transpired by the leaves than it can pass from the roots through the newly formed tissues. The check in growth associated with the flagging of the leaves may be remedied by placing the plants for a few days in a darkened place, which retards transpiration, or by cutting off some of the leaves and thus reducing the transpiring area.

After about a month has elapsed since the severance of the scion from the parent tree, the new growth which has formed should be slowly accustomed to the hot sun by gradually diminishing the shade until it will stand unshaded without flagging; the grafted plant is then ready for planting out in the open field.

The forms of grafting which necessitate the removal of the scion from the parent tree, previous to its being bound to the stock, do not usually give such satisfactory results as the method of grafting by approach. Since these methods of grafting permit of scions being applied to stocks under nursery shelters, it follows that the grafts can be better protected from adverse climatic agencies, such as scorching sun and winds, than those in the open field. As in the approach method of grafting, it is advisable to raise stocks in pots or baskets. Until the operator has become expert it is not advisable for him to attempt the more complicated operations which "tongue" or "splice" grafting involves.

What is known as "saddle" grafting is easily accomplished. Having obtained a stock and scion whose stems are similar in diameter, slice off a thin strip of bark and wood from two opposite sides of the stem of the stock so as to leave a wedge-shaped strip of bark, about half an inch to three-quarters of an inch long; trim all leaves off the scion and cut the base of the stem so that it will exactly fit over the wedge-shaped portion of the stock. As before, it is necessary to bring the cut cambium surface of the scion and stock in contact. Now bind the cut surfaces of the scion and stock firmly together with waxed tape and cover the latter with grafting wax to exclude air from the cut areas.

Grafting wax may be manufactured by weighing four parts of resin, two parts of beeswax, and one part of tallow, placing them in a pot and melting them over a fire and mixing them thoroughly together. The mixture is ready for use when cool.

As soon as a complete junction between the scion and the stock has taken place the wax and tape may be removed.

After the grafts have developed into good sturdy plants they should be hardened off by the removal of all shade preparatory to transplanting them in the open field. Whichever method of budding or grafting be adopted, it is important to prune away any growths which form below the bud or graft.

CHAPTER VIII

PLANTING, CULTIVATING, AND PRUNING

Planting.—The best time for planting cocoa is at the commencement of the rainy season, as this gives the young plants sufficient time to become thoroughly established before the dry weather appears. Having partly accustomed the young nursery plants to the conditions which obtain in the open field, by removing all shade from them, transplanting may commence during a spell of wet or cloudy weather. The soil is first thoroughly saturated in the baskets or pots with water, to facilitate the subsequent removal of the plants. The roots should be disturbed as little as possible, and if the tap-root is broken or split it should be pruned back with a sharp knife above the injured area. The plants should not be buried too deeply in the ground; it is quite sufficient if the surface-soil is on a level with the top of the ball of earth taken from the pot or basket. Should this ball be broken the roots in the ground should be buried so that the surface-soil just reaches the point where the stem issues from the soil in the pot. These elementary matters are of primary importance, as large numbers of young cocoa plants fail to grow satisfactorily if they have been planted too deeply or too far out of the ground. The soil should be firmly pressed around the ball of earth enclosing the roots. It is almost impossible to carry out transplanting without slightly disturbing the roots. It is therefore advisable to protect the foliage from the hot sun; leafy twigs, palm leaves, or bracken bent over in the form of a cage will provide the necessary shade until the young plants start into growth. If a spell of dry weather sets in before they become established in their new quarters it will be necessary to water them daily until rain falls.

The mortality amongst newly planted cocoa is often very great, and sometimes as many as 30 per cent. of the plants perish during the first year following the establishment of the plantation. To obtain a uniform plantation it is essential to fill up these vacancies as rapidly as possible after they occur.

Cultivating.—We have already seen that the cocoa tree thrives in a moist soil rich in organic matter and that soils containing an abundance of humus are more retentive of soil-moisture than those in which it is lacking. The greatest percentage of organic matter is almost invariably found in the uppermost layers of a soil. Unless this surface-soil is protected it is liable to be washed away by heavy rains. There is, however, less likelihood of losses of this nature occurring on an estate where the soil is held together by a mass of fibrous roots. This state of affairs obtains in old cocoa plantations, and to a less extent in young cocoa plantations where all the vacant spaces between the trees are occupied by catch crops.

Some planters affirm that the soil is best protected by allowing weeds to grow and by cutting them down at intervals. There is much to be said in favour of this practice, especially on hilly lands, for the surface-soil is prevented from being washed away by the network of fibrous roots formed by grasses and similar weeds. When they are cut down the plant-foods which they have extracted from the soil are in a measure returned as soon as decomposition sets in. The biological condition of the soil is likewise improved by the protection afforded by the weeds, as soil-bacteria, which act upon the nitrogenous compounds of organic matter in the soil and convert them into soluble plant-food, cannot thrive unless protected from strong, direct sunlight.

Manurial Value of Weeds.—According to the *West Indian Bulletin*, the weeds normally growing on 225 sq. ft. of land, under a young cocoa plantation, in Dominica, were collected and weighed; then allowed to dry and weighed again, when it was found that they had lost 33·6 per cent. of their original weight. An analysis of the air-dried material gave the following results :

Constituent	Percentage	Weight per acre, lb.
Moisture	10·83	
Nitrogen	0·74	70·8
Phosphoric acid (P_2O_5) . .	0·22	21·1
Potash (K_2O) . . .	0·99	94·8
Total ash	10·33	

The figures in the third column give the weight of the chief manurial constituents in the weeds contained in an acre of ground, or in other words the quantity of weeds growing on an acre would contain as much nitrogen, potash, and phosphoric acid as there are in about 334 lb. of sulphate of ammonia, 171 lb. of sulphate of potash, and 1 cwt. of basic slag respectively.

The disadvantages associated with allowing weeds to grow in young cocoa plantations may now be considered. Unless the weeds are constantly cleared away from the cocoa trees they will interfere with and check the development of the young lateral roots of the cocoa trees and rob them of a certain amount of available plant-food. Shade trees and plants used as temporary shading agents will be similarly affected.

Many noxious perennial weeds found on cocoa plantations are exceedingly difficult to eradicate if allowed to grow unchecked, and rapidly spread in all directions. The most pernicious are those which develop tuberous or stoloniferous roots. Such plants cannot be destroyed by cutting down the foliage-bearing portions. A striking example of this category is the common nut-grass, *Cyperus bulbosus* (*rotundus*). It is useless to cut down this plant before it seeds to check its spreading, as its roots frequently descend 3 or 4 ft. below the surface of the ground and bear numerous "nuts" or bulbs, any one of which is capable of producing a new plant. This plant also develops lateral, nut-bearing roots which frequently extend a foot or more from the parent plant. A dense growth of this Cyperus, in the neighbourhood of the roots of a cocoa tree, would be exceedingly difficult to eradicate without seriously damaging the cocoa roots. It would be almost impossible to extract all the Cyperus bulbs from the ground at one time. By the time the bulbs which had been left in the ground had produced foliage their roots would have again become entangled with those of the cocoa tree, and the latter would be redisturbed when the Cyperus roots were extracted.

Cyperus bulbosus (*rotundus*) is a serious pest in Gold Coast cocoa plantations, and the writer has seen it growing profusely in cocoa plantations in San Thomé.

Several other weeds found in cocoa plantations develop long, underground, jointed stems, capable of producing new plants from the buds formed at each joint. If the foliage of the parent plant is cut down, encouragement is given to these buds to form new plants, which rapidly take possession of the ground. When colonies of such weeds occur in the neighbourhood of a cocoa tree there is a struggle between its roots and the roots of the weeds. The tender roots of the cocoa tree are rapidly smothered and its growth is severely checked. Fortunately it is possible to cover the vacant ground between cocoa trees with leguminous plants, the growth of which can be so controlled that they do not interfere with the development of either the permanent or the catch crops.

Leguminous Cover-Plants.—When the commonest weeds found on cocoa plantations are cut down they only return to the soil the plant-foods which they have extracted from it. Leguminous plants, when cut down, return to the soil not only the plant-foods they have taken up from it but, in addition, the atmospheric nitrogen which they are able to fix. It will therefore be apparent that a green covering of leguminous weeds is likely to prove more beneficial than a covering of ordinary weeds. The arborescent types of *Leguminosæ* are not recommended for this purpose. When frequently pruned they develop large root-stocks; these are difficult to eradicate without damaging the roots of the cocoa trees, when the time arrives to remove them in order to provide additional space for the latter. Various herbaceous *Leguminosæ*, such as Crotalarias, Cassias, and Cajanus, are much better adapted for ground-covering purposes. All of these are, however, more difficult to eradicate than the prostrate and creeping leguminous types, such as the Vignas, Phaseolus, Arachis, and Mucunas. The latter may be rooted up by hand whenever they show signs of encroaching upon the cocoa trees.

The treatment of leguminous cover-plants and catch crops will be more fully dealt with in a subsequent chapter on manuring. Where leguminous cover-plants are grown weeds must be kept in check ; those cut down should be spread beneath the cocoa trees to serve as a mulch, and when they decay valuable organic plant-foods will be added to the soil.

The ground should not be allowed to become caked on the surface. A loose soil absorbs more water than a compact soil, and surplus water drains away far more rapidly from the former than from the latter. Loose soil is far better aerated than compact soil. Air is not only essential for the proper development of the roots of plants, but also for that of the nitrifying bacteria, which are generally most abundant in the first 6 in. of surface-soil. Forking should therefore be practised wherever there is no danger of injury to the tender rootlets of the cocoa tree, but a network of these is frequently found quite near the surface, and it is only possible to adopt an exceedingly superficial system of forking to avoid damage in these areas.

Pruning.—The main objects of pruning are :—the production of symmetrical trees, with a maximum quantity of fruiting branches ; to facilitate the admission of air and light to all parts of the tree ; to encourage a spreading habit, which enables the fruit to be more easily harvested ; and to remove gormandising suckers which rise from the main stem. Cultivated cocoa trees usually commence to branch when about 3 ft. high. In the case of trees which produce branches when lower than this, it is usual to prune off all but one of these secondary branches. The advantage of this practice is open to doubt, and there seems to be no reasonable explanation why a tree, branching at a foot from the ground, should not give as good results as one which branches at three or more feet from the ground.

The primary branches are generally restricted to three, but there appears to be no reason why, when four or even five appear, they should not be allowed to remain. The primary branches are the principal fruiting branches, so that if thinning be necessary this can be sufficiently practised on the secondary or tertiary branches.

It is obvious that a tree branching near the ground is most likely to develop a low spreading habit, and fruits are more readily gathered from such types. When young trees show no signs of branching when they are 4 ft. high the terminal bud should be removed; this induces the buds in the axils of the leaves to develop into lateral branches. Young trees which are too densely shaded often grow 5 or 6 ft. high before commencing to branch.

Light pruning at frequent intervals is far better than the destruction of large branches which later pruning involves.

The growth of the parts of the tree above ground is in direct ratio to that of those below the ground. It consequently follows that when the branches of a tree are severely pruned the growth of the roots is likewise arrested. The leaves may be regarded as the laboratory where plants elaborate sap which is subsequently employed in building up new tissues for the roots, stem, and branches, and a reduction of the foliage-area of a tree must of necessity restrict this operation.

On many cocoa estates, where trees have been too closely planted together, the young branches are frequently pruned back with a view to limiting the foliage-area of each tree to the space allotted to it in the plantation. This system of pruning may yield satisfactory results for a short time, but it is biologically unsound, as the constant restriction of the tree's development must in time reduce its cropping capacity.

Pruning operations should not be conducted with a view to restricting the foliage-area of a given tree, but to facilitate the development of the fruit-producing parts of the tree and improving the conditions for fruitproduction in their neighbourhood. It would be far better policy to prune back alternate trees, thus allowing the others to spread naturally, and subsequently eradicate the trees which were pruned back when the unpruned trees had grown sufficiently large to cover the ground occupied by them. Pruning operations are of most importance during the first eight or nine years of the tree's life. They should be conducted with a view to obtaining well-balanced trees. Any growths which tend to cross others should be removed. If the branches are too thick to allow of air and light penetrating to the trunk and main branches, where the greatest number of flowers and fruits are produced, the more weakly ones should be removed. Shoots growing in an upward or outward direction from the centre of the tree should be retained in preference to those which grow with a tendency in a contrary direction. It is impossible to state definitely how many branches should be pruned or how many should be left. The art of pruning must be learnt by experience, but it is a good rule not to cut out a healthy branch. The same branch can be pruned off later if necessary, but it cannot be replaced when cut off.

Where a paucity of branches occurs the branch system may be increased by pinching out the terminal buds of the principal branches.

Trees are often robbed of valuable branches when this could be avoided by a little forethought. It frequently happens that a branch hanging across another may be saved from the pruning-knife by propping it up with a stout stake.

Before cutting off a branch which bends downward and drags on the ground an endeavour should be made to put it into place by means of a stout prop.

In an estate where pruning has been neglected all undesirable branches should not be thinned out at one operation, or the growth of the trees will be severely checked for the reasons already explained. A properly executed, annual pruning is sufficient. The best season to prune is when the sap is least active, and this frequently coincides with the end of the principal crop season. Most cocoa trees carry more or less fruit all through the year, but they invariably produce more fruit during a particular period—usually towards the end of the rainy season. The removal of large branches is very rarely necessary from cocoa trees which have been always properly pruned; indeed, the best pruned trees are those from which all undesirable growths have been removed with a pocket pruning-knife. In the case of old trees which have been neglected in the matter of pruning a large and a small saw and pruning shears must be brought into requisition. These are also necessary for the removal of dead branches.

In cutting out large branches the weight of the foliage often causes the branch to split near where the incision is being made, resulting in an ugly, splintered wound.

This generally may be avoided by first making a cut on the underside of the branch and then completing the severance immediately above this cut.

It is necessary to keep all implements used for pruning operations properly sharpened, and with a view to encouraging pruners to maintain their instruments in good working order, each should be provided with, and carry with him, the necessary articles for sharpening his tools.

Cuts should be made in a slanting direction and close to the stems from which the condemned growth issues.

When this is not practised the short butts often decay and offer a convenient ingress to the trees of parasitic fungi and various insect pests. Wounds made in the removal of young growths with a sharp pruning-knife rapidly form a callus and do not need to be antisepticised as a protection against disease. Those made by the removal of larger branches should be first pruned smooth with a sharp pruning-knife and then painted with an antiseptic. Where branches have been broken off by the wind or other agencies the splintered end should be treated in a similar manner. Four parts of resin oil mixed with one part of tar forms an excellent antiseptic dressing for wounds. The application of undiluted tar to wounds is not recommended, as it is liable to burn the green bark at the edge of the wound.

One of the strong, gormandising suckers, which frequently spring from the base of the trunk of the cocoa tree, may be left growing with advantage on a tree in a poor state of health, with a view to cutting down the old stem to the point where the gormandiser issues and of allowing the latter to take its place. The writer has observed excellent fruiting trees obtained from gormandisers both in Ceylon, West Africa, and San Thomé. When the canker disease was rampant in Ceylon cocoa plantations, numerous affected trees were cut down and gormandisers were encouraged to develop in their stead. The same method is adopted in San Thomé with trees which are seriously attacked by termites.

All young growth pruned off should be buried, to increase the organic matter in the soil, and thick branches should be burned to prevent their affording a medium for the propagation of diseases.

CHAPTER IX

MANURING

THE word manure formerly only applied to animal excreta, but it has to-day a far wider meaning, for any substance added to the soil to increase its fertility is considered as manure.

It may be applied either with a view to increasing the productiveness of soils or to renovate and restore the fertility of soils worn out by repeated cropping. We know that plants derive their nourishment from the soil and the atmosphere, and also the particular nutritive elements which are respectively furnished by these two sources. Provided that the cocoa planter establishes his plantation on land adapted to the cultivation of cocoa, it may be premised that if he annually returns to the land manure containing equal quantities of the elements which are removed by his crop, his debit and credit account in regard to the soil should balance.

This reasoning is sound from a purely theoretical point of view, but unfortunately it is not applicable in practice. For the planter has no means of ascertaining the amount of plant-foods lost by drainage nor the changes brought about in the soil by climatic and bacterial agencies.

Reasons for Manuring.—Experiments conducted at Rothamsted have shown that 7·21 lb. of nitrogen per acre were deposited by rain, snow, and dew from the atmosphere, but the loss of nitrogen by drainage, in the form of nitric acid, was much greater than that deposited from the atmosphere. Further, irrespective of the excellent results obtained by nitrogenous manuring, when ammonia salts were applied to wheat in the autumn two-thirds of the nitrogen supplied was unrecovered in the increase of the crops. From the application of nitrate of soda in the spring more than one half of the quantity supplied was unrecovered. By far the greater proportion of the unrecovered nitrogen was lost in the drainage water. This indicates that much more nitrogenous manures must be added than are actually required by the crop.

Plants take up from the soil: nitrogen, phosphoric acid, potash, lime, magnesia, soda, oxide of iron, sulphuric acid, chlorine, and silica. Many virgin, tropical soils contain these constituents in adequate quantity and in a sufficiently available condition for the remunerative cultivation of cocoa; in others there is a deficiency of one or more of these elements; so that after a few years' cropping the soil becomes impoverished and consequently remains unproductive until the missing elements are restored.

The value of the soil, therefore, may be estimated by the amount it contains of the ingredient or ingredients which are most lacking in an available condition. A chemical analysis of the soil may demonstrate that all the food elements necessary for plant nutrition are present, but unless they are in such a form as to be soluble in the sap of the root-cells they are of no immediate value to the plant.

The Economical Application of Manures.—The chemical analysis of the soil and of the crop to be cultivated undoubtedly furnishes useful hints in regard to the soil's manurial requirements, but there are other important factors to be taken into consideration, such as the physical and hygienic condition of the soil.

Not until the cocoa planter has satisfied himself that his soil is satisfactory in these latter respects should he attempt to deal with the manurial problem.

The economical application of manures is dependent upon a due consideration of the requirements of the cocoa trees, the composition of the soil, the physical condition of the soil, and the composition of the manures applied.

The plant-food ingredients in which soils are most generally lacking are: nitrogen, phosphoric acid, potash, and less frequently lime.

Chemical analyses of different parts of the cocoa tree have already been given (chapter iv.). The ingredients used up in the formation of the leaves are in a great measure returned to the soil by the annual leaf-fall; if the shells of cocoa fruits be also returned, the ingredients actually taken from the soil are those used up in the formation of roots, branches, and the beans.

Harrison estimated that the annual production of leaves, young shoots and fruits per acre on a cocoa estate demands from the soil, amongst other ingredients, 138 lb. nitrogen, 104 lb. lime, 94 lb. potash, 64 lb. phosphoric acid, and 31 lb. magnesia. This estimate includes leaves and fruit shells which are on most estates re-incorporated in the soil.

Cockrane estimated that in Ceylon, an acre of cocoa trees, planted at the rate of 302 trees to the acre, and yielding 1 lb. of cured cocoa per tree per annum, would require for the annual incremental growth of the trees and the bean crop: 63·4 lb. lime, 59·3 lb. potash, 31·5 lb. nitrogen, 19 lb. magnesia, and 11·7 lb. phosphoric acid.

On the basis of an annual average yield of 250 lb. and 150 lb. of cured cocoa per acre from Calabacillo and Forastero varieties respectively, the under-mentioned quantities of plant constituents are annually removed from the soil by the beans in British Guiana (*Proceedings of the Agricultural Society—British Guiana*).

Variety of Cocoa.	Calabacillo. Weight per acre.	Forastero. Weight per acre.
	lb.	lb.
Nitrogen	11·30	7·26
Phosphoric anhydride	5·32	4·19
Potash	6·31	3·20
Lime	0·65	0·47
Magnesia	2·69	1·95

Manurial Experiments.—In order to ascertain the plant constituents which the soil lacks, a different manure should be applied to various parts of the plantation and the effects watched. By this means the expense will be saved of purchasing manures containing constituents which are already abundant. For a fair comparison to be drawn from the results obtained it is most essential that the plots selected for experiment should be as like as possible in every factor which would affect the experiment. The land should be flat and the soil similar in each experimental plot. The plots should have been similarly treated in regard to previous cultivation and manuring.

The cocoa trees should be of the same variety in each plot, of like age, and be planted at a uniform distance apart. It is also of importance that the same system of pruning should have been applied to the trees in each plot. The plots should be uniform in area and each should contain the same number of trees. Nitrogen, phosphoric acid, and potash are the constituents in which the soil is most likely to be lacking. It may be deficient in one or even two, but most unlikely in all of these ingredients. To test for one constituent four plots will be necessary, including the control plot. The results in this case would not, however, be satisfactory if more than one constituent were lacking in the soil. It is therefore advisable to have eight experimental plots. Each should be at least one-fifth of an acre in area. Strips of land 88 yds. long by 11 yds. wide would be suitable, and, if the trees were planted at 15 ft. apart, each plot would contain 34 trees. At least two rows of trees should be left unmanured between each plot. In the subjoined table are given the weights of the various manures which it is suggested should be applied to each plot.

No. of Plot.	Name and Weight of Manure to apply per Plot.
1. (Control plot) .	No manure
2.	40 lb. Sulphate of potash
3.	80 ,, Basic phosphate
4.	40 ,, Nitrate of soda
5.	40 ,, Sulphate of potash and 80 ,, Basic phosphate
6.	40 ,, Sulphate of potash and 40 ,, Nitrate of soda
7.	80 ,, Basic phosphate and 40 ,, Nitrate of soda
8.	40 ,, Sulphate of potash, 80 ,, Basic phosphate, and 40 ,, Nitrate of soda.

The fertilisers should be mixed with dry soil and spread broad-cast as evenly as possible and then lightly forked in; and as all the manures recommended for the experiment are of a more or less soluble nature they should be applied towards the end of the rainy season. If applied earlier there would be danger of a great part of the fertilising constituents being washed away by the constant heavy rains. It is necessary to apply the fertilisers annually for at least three consecutive years. During this period each of the plots must be treated similarly in regard to pruning and cultivation. At the end of three years, if careful records have been kept of the condition of the trees and the crops yielded by each plot, the planter ought to be in a position to decide whether his soil is poor in one or more plant-food constituents, and which they are.

Animal Manures.—Although artificial manures have the advantage over animal and vegetable manures in supplying in a compact form the requisite nitrogen, potash, and phosphoric acid, they have not the same beneficial effect on the physical condition of the soil. The natural manures are relatively poor in plant-food, as compared with chemical manures, and their application entails a far greater expenditure on transport and labour. Nitrogen is invariably present in them in far greater relative quantities than potash and phosphoric acid. The nitrogen encourages the growth of leaves and stems, but the potash and phosphoric acid are more helpful in promoting fruit production. Where the latter are deficient in cocoa soils it is advisable to apply them in conjunction with animal manures.

Animal manures are especially valuable in cocoa plantations on account of the beneficial effects they have upon the texture of the soil. It has already been pointed out that the lateral roots of the cocoa tree rapidly take possession of the surface-soil, thus rendering proper tillage impracticable without injuring them. The organic matter which animal manures supply imparts to the soil that sponginess so important in a cocoa plantation for the retention of soil moisture.

Animal manures also improve the sanitary condition of the soil by facilitating drainage and aeration, thus improving the conditions for the development of nitrifying bacteria, and in addition aid in rendering mineral elements already in the soil available for plant-food. They encourage earth-worms, which bring up to the surface a certain amount of sub-soil. This becomes weathered and converted into a state more suitable for plant nourishment.

It is unfortunately comparatively rare to find a sufficient number of cattle maintained on a cocoa plantation to supply an adequate quantity of manure for the whole estate. It appears to the writer that considerable advantage would be gained by increasing the number of live stock on many cocoa estates, even if this necessitated the allocation of a portion of the estate to the cultivation of food crops for them.

The importance attaching to the conservation of the fertilising elements of cattle manure is often not sufficiently appreciated. When exposed to atmospheric influences valuable manurial elements are washed out by heavy rains. The heating or fermentation caused by the growth of bacteria rapidly converts its nitrogen into ammonia, which escapes into the atmosphere unless the manure be properly covered. If when cleaning out the stock-yard it is not convenient to apply the manure direct to the plantation, it should be stored under cover—a thatched roof is well adapted for this purpose—and soil should be thrown over the manure heap. Experiments have shown that two-thirds of the fertilising properties of farm-yard manure are lost by twelve months' exposure to the atmosphere, including nearly all the soluble nitrogen and 78 per cent. of the soluble mineral ingredients.

The liquid excrements of animals, being rich in potash salts, etc., are of considerable value for fertilising purposes, and provision should be made to prevent their leaching away from the stock-yard. Drains can be made at comparatively little cost leading from the stock-yard to the manure heap, over which the liquid should be thrown.

To this heap should also be added all decomposable refuse from the estate kitchens and labourers' quarters.

The following table shows the relative value of various natural manures for fertilising purposes :

	Nitrogen.	Phosphoric acid.	Potash.
	per cent.	per cent.	per cent.
Horse	6	3	5
Cow	4	2	5
Sheep	8	2	7
Pig	4	2	5
Poultry	12	9	6

These figures obviously do not take into consideration the litter commonly applied with these manures.

Kelway Bamber found the under-mentioned constituents in Ceylon cattle and pig manure :

Moisture lost at 212° Fahr. 57·90 per cent.
Composition of sample dried at 212° Fahr.:

	Per cent.
Organic matter . . .	34·20
Phosphoric acid . . .	1·84
Potash	1·60
Iron, lime, etc. . . .	10·65
Insoluble matter . . .	51·71
	100·00

	Per cent.
Nitrogen	1·3
Equal to ammonia . .	1·69

The results of Boname's analysis of pen manure in Mauritius are as follows :

	Per cent.
Nitrogen	4·00
Phosphoric acid	1·90
Potash	2·30
Mineral substances	4·42
Lime	3·90
Soda	0·66
Organic substances	14·22

The amount of animal manure to apply must depend upon the quality of the manure and the condition of the soil, but 1½ tons per acre may be considered a fair average application. When sufficient animal manure is not available to provide a dressing for the whole plantation, it would be advisable to treat different portions in rotation. Animal manure, being less readily soluble than many chemical manures, may be applied at the commencement of the rainy season.

Whenever the root-system of the cocoa trees permits of it, manure should be lightly forked in. It is advisable for drain and road cleaning to be coincident with the application of manure, so that the débris taken from these places could be spread over the manured area to assist in checking the escape of ammonia.

Artificial Manures.—Many fertilisers, such as guano and nitrate of soda, are, strictly speaking, natural manures, but it is usual to consider all manures not produced on the farm as artificial manures. The latter may be divided into four main divisions, i.e. nitrogenous, phosphatic, potassic, and special or compound manures. The basis of the last mentioned is usually super-phosphate, which is mixed with various other manurial ingredients to meet the specific demands of particular crops and soils. It is found more economical to mix dry, fine earth with artificial manures previous to broad-casting them in the plantation, and to fork them into the ground as much as possible without disturbing the roots. The principal nitrogenous artificial manures are: ammonium salts, guano nitrate of soda, dried blood, and oil cake.

Vegetable Manures.—The texture of soils deficient in organic matter may be considerably improved by the incorporation of vegetable matter. It is also found that artificial manures give far better results when a wornout soil's condition has been improved by this means.

Experiments conducted at the Minnesota Agricultural Experiment Station have shown that by increasing the organic matter in the soil 0·5 per cent. the amount of nitrogen was raised by 245 lb. per acre. Vegetable matter is beneficial to both heavy and light soils; in the case of the former it separates the soil particles and renders the soil more permeable to air and moisture; in the latter case the moisture-holding capacity of the soil is increased.

The most practical means of vegetable manuring is by cultivating various quick-growing plants and burying them in the ground. When they decay acids are formed which aid in the dissolution of some of the unavailable plant-foods in the soil. Leguminous plants are most largely used for this purpose in view of the property which many of them possess of absorbing free nitrogen from the atmosphere. The creeping, or low-growing forms of *Leguminosæ* are preferable to the shrubs and tree forms, as the latter are often difficult to eradicate without injuring the roots of the cocoa tree. Some of the former varieties yield commercial products, such as the ground-nut (*Arachis hypogea*) and the cow-pea (*Vigna catiang*). When these are grown with the intention of obtaining a crop before turning the plants into the soil, their value as manurial agents is obviously depreciated. In order to obtain seeds for future sowing it is advisable to allow a certain number of the plants to produce seeds before digging them in.

The cultivation and burying of leguminous plants cannot be expected to renovate completely exhausted soils, as although these plants contribute more nitrogen than they extract they only return the phosphoric acid and potash which they obtained from the soil.

In young cocoa plantations it is possible to bury the plants grown for green manuring. A circular trench should be dug around each tree, but sufficiently distant from its roots to avoid injuring them. In this the green plants should be placed, sprinkled with air-slaked lime, gypsum, or wood ashes, and covered up with soil.

Lime assists the decomposition of the green material and thus renders its constituents more quickly available as food. Wood ashes are rich in lime, and frequently contain from 6 to 9 per cent. of potash and about 2 per cent. of phosphoric acid. Under old cocoa trees which densely shade the ground green-manuring plants cannot be profitably grown, but it is generally found that they will thrive between the trees, provided that the latter have not been too closely planted together. The advantages accruing from protecting the soil in cocoa plantations with a cover of leguminous plants has already been dealt with.

In old cocoa plantations it is generally found that the roots have taken possession of the soil to such a degree that it is impossible to bury the plants grown for green-manuring without injuring the roots of the cocoa trees. In such cases it would be advisable to pile the plants in heaps until they decayed, and then to apply the decomposed matter as a top dressing.

With regard to the cultivation of leguminous plants with the primary object of increasing the quantity of nitrogen in the soil, it is well to point out that plants, growing in a soil which does not contain nitrogen-fixing bacteria, are not enriched by atmospheric nitrogen. There are numerous kinds of these bacteria, and it does not necessarily follow because, say, cow-peas produced abundant nitrogenous nodules on their roots in a particular soil, that an Albizzia would be equally effective in this respect. This particular soil, however, could be inoculated with the form of bacteria associated with, say, the Albizzia root nodules by broad-casting soil brought from land in which Albizzias produced numerous nitrogenous nodules on their roots.

It sometimes happens that where a particular species of *Leguminosæ* has not been previously cultivated comparatively few nodules are found on its roots the first time it is cultivated, but the next time it is planted it is generally found that the nodules will be produced in much greater abundance, provided that the hygienic condition of the soil is satisfactory.

In 1900 the writer introduced the American cow-pea as a green-cover crop in the cocoa plantation at the Botanic Gardens, Gold Coast. When it was first sown comparatively few nitrogenous nodules were produced on the roots of the plants, but succeeding sowings gave excellent results. After the cow-pea had been planted for two or three years, by which time it had become thoroughly acclimatised, it was found possible to grow it all through the year, and from three to four crops were annually turned into the ground. Trenches were dug between the rows of trees, and the cow-pea plants were buried in these after being sprinkled with lime or wood-ashes. Pithecolobium trees were planted as shade for the cocoa trees, and the prunings from these were also buried in the trenches.

The natural soil in these gardens is distinctly poor in quality and much inferior to that found in the principal cocoa-growing districts of the Gold Coast. There is very little doubt that the frequent application of vegetable matter has materially ameliorated the soil conditions in the cocoa plantation, owing to the fact that the foliage contains a high percentage of valuable manurial matters, i.e. 0·27 per cent. nitrogen, 0·10 per cent. phosphoric acid, and 0·31 per cent. potassium oxide. In 1904, when the cocoa trees were thirteen years of age, they yielded at the rate of 7 cwt. of cured cocoa per acre.

In the report of the Gold Coast Agricultural Department for 1908, it is stated with reference to these trees "from a small area of 1$\frac{2}{5}$ acres and from 259 trees planted at 15 × 15 ft., a yield of 18,200 pods, equivalent to 15 cwt. of cured cocoa, was produced between October 23 and December 31 of this year. . . . A considerable crop was also taken in the earlier part of this year of which no record was kept; and the trees are now giving promise of an early crop in 1909." Mr. Evans, the Travelling Instructor, Gold Coast, has recently informed the writer that one block of these trees yielded, in 1909, at the rate of 11 lb. per tree, and two other blocks yielded at the rate of 6 and 8 lb. per tree respectively. The weight of organic matter added to the soil by various leguminous plants is exemplified by the under-mentioned results of green-manuring experiments conducted by the Botanic Department, Antigua:

	lb. per acre.
Barbados bean	20,000
Woolly pyrol (*Phaseolus Mungo*) . .	9,440
Cow-peas (*Vigna catiang*):	
White	10,570
Black	9,440
Clay	8,440
Red	8,250
Pigeon pea (*Cajanus indicus*) . .	4,950
Babricon bean (*Canavalia sp.*) . .	3,520

Wright, *Para Rubber*, gives the following particulars as to the various leguminous plants grown for green-manurial purposes in Ceylon:

Name of plant.	Weight of organic matter per acre.	Time between sowing and up-rooting.
	lb.	
Crotalaria striata . . .	20,244	ten months
Vigna	12,092	four months
Pondicherry ground-nut .	4,692	five months

COMPOSITION OF VARIOUS GREEN PLANTS IN THE FRESH STATE

Name of Plant.	Nitrogen.	Potash.	Phosphoric acid.	Lime.
	Per cent.	Per cent.	Per cent.	Per cent.
Crotalaria striata .	0·7 to 1·0	0·47	0·154	0·210
Vigna . . .	0·6	0·738	0·177	0·727
Pondicherry ground-nut .	0·914	0·493	0·155	0·242

The velvet bean (*Mucuna utilis*) is also well adapted for cultivating as a green-cover crop in cocoa plantations. Experiments conducted by the Barbados Botanic Department show that in from two to three months a crop of vines was produced equal to 12,343 lb. per acre.

The 1908–9 Report from the Grenada Botanical Department states: "The subject of mulching cocoa has attracted considerable attention during the year, and with the object of growing suitable material for a mulch, experiments were conducted with cow-peas in conjunction with bacterial inoculation. No conclusive results were obtained, but the advantage of growing a leguminous crop in the open spaces among cocoa instead of weeds, and bedding this in to supply humus, while the root nodules add nitrogen to the soil, is becoming universally recognised."

Lime.—For the production of good crops it is essential that lime should be present in the soil. Applications of animal manure, guano, and similar manures are of little avail if the soil is deficient in lime. One of the main functions of lime is to combine with the acids of the potash and the ammoniacal salts of guano and of farmyard and similar manures, and to liberate potash and ammonia. The latter are retained in the soil, but the less expensive lime salts largely run away in the drainage water. In addition to supplying a necessary plant constituent, lime prevents the loss by drainage of the three principal fertilising matters, phosphoric acid, potash, and ammonia. Lime actually adds none of these three elements to the soil, so that its repeated application tends to impoverish the soil. Lime should never be mixed with or applied at the same time as manure containing a salt of ammonia, as it acts at once on the salt and liberates the ammonia too quickly.

Applications of lime are particularly beneficial for neutralising the acidity present in sour soils, and for this purpose it should be broad-casted as powdered slaked-lime, at the rate of 2,000 lb. per acre. Sea sand, rich in shells, often contains as much as 30 per cent. of lime ; wood ashes contain from 30 to 35 per cent. of lime, and either of these materials could be advantageously substituted for lime where the latter is expensive. The lime in these materials is, however, not free, but exists as carbonate, which is usually as effective as lime itself.

CHAPTER X

RESULTS OF MANURIAL EXPERIMENTS IN VARIOUS COUNTRIES

CONSIDERABLE research has been undertaken during recent years by the various Botanical and Agricultural establishments in several cocoa-growing countries with the view to ascertaining the kind of manure best adapted for fertilising cocoa in particular districts. The Imperial Department of Agriculture for the West Indies has been particularly energetic in this respect, and the following details in regard to the cocoa-manuring experiments conducted in the various West Indian islands have been extracted, for the most part, from the publications of this Department.

DOMINICA

The table on page 67 shows the excellent results which have attended the cocoa-manuring experiments conducted at the Botanic Station, Dominica. The experiments were initiated in the year 1900, but results were not recorded until 1902–3. Five plots were selected for the experiments, comprising a total area of 1½ acres containing cocoa trees ten years of age.

The manures and the mulch were applied once a year; the former were distributed and slightly stirred into the soil and the latter was simply spread over the ground. The weights of manure applied per acre were as follows:

Plot.

No. 2. 4 cwt. basic phosphate and 1½ cwt. sulphate of potash.

,, 3. 4 cwt. dried blood.

,, 4. 4 cwt. dried blood, 4 cwt. basic phosphate, and 1½ cwt. sulphate of potash.

The mulch consisted of grass and leaves, and the leaves and fruits of the Samaan, Rain or Guango tree (*Pithecolobium Saman*), and was applied at the rate of 80 lb. per tree.

Yield of Cured Cocoa in lb. per acre from 1902 to 1908

The weight of cured cocoa was arrived at by estimating it at 42 per cent. of the weight of the wet product.

	Plot No. 1.	Plot No. 2.	Plot No. 3.	Plot No. 4.	Plot No. 5.
Manures applied.	No manure.	Phosphate and potash.	Driedblood.	Driedblood, phosphate and potash.	Mulched with grass and weeds.
Year.	lb.	lb.	lb.	lb.	lb.
1902–3 . . .	1,138	1,540	1,491	1,599	1,300
1903–4 . . .	822	1,170	1,132	1,069	1,092
1904–5 . . .	1,009	1,179	1,132	1,418	1,338
1905–6 . . .	1,122	1,105	1,231	1,506	1,724
1906–7 . . .	1,095	1,285	1,134	1,461	1,743
1907–8 . . .	1,354	1,680	1,611	1,709	2,012
Total yield during the 6 years . .	6,540	7,950	7,732	8,762	9,709
Average yield of 6 years . . .	1,090	1,326	1,289	1,460	1,555
Percentage of increase over control-plot during 6 years .		21·56	16·67	33·98	40·81

The most striking feature of these experiments is the exceptional yield obtained in the mulched plot. It is reported that the soil in this plot was in excellent physical condition and was well covered by trees planted at the rate of 108 trees per acre, whereas the control-plot requires 178 trees to cover the ground.

The cocoa yielded by this plot in six years has exceeded that of the control-plot by over 40 per cent. It is, however, important to notice that plot No. 4, which was manured with dried blood, phosphate, and potash, shows an increased yield of 33·98 per cent. over that of the control-plot, but plots Nos. 2 and 3, the first of which was manured with phosphate and potash, and the second with dried blood, show together an increased yield of 38·23 per cent. over that of the control-plot.

Grenada

The Botanical Department in Grenada has conducted experiments on several cocoa estates situated in different parts of that island with a view to demonstrating the advantages accruing from good cultivation in conjunction with manurial applications. The subjoined tables indicate the excellent results obtained :

Plots ¼-acre in area.	Manures applied.	Yield of cured cocoa in lb. per annum.			
		1905–6	1906–7	1907–8	1908–9
1. A	1906, 1907, 1908 No manure . .	132	256	360	296
1. B	1906, 1907, 1908 1 cwt. basic slag each year . . .	40	282	692	680
1. C	1906 1 cwt. basic slag, 42 lb. sulphate of ammonia; 1907 7 barrels lime; 1908 15 cwt. pen manure	32	248	1,044	916
1. D	1906, 1907, 1908 8 cwt. pen manure each year. . . .	24	572	526	448
2. A	1906–8 No manure; 1909 Mulched with bush, etc.	496	1,104	1,036	1,024
2. B	1906 1 cwt. basic slag, 42 lb. nitrate of soda; 1907 1 cwt. basic slag, 42 lb. nitrate of soda; 1908 42 lb. nitrate of soda, 8 cwt. sheep manure	462	866	1,144	1,080
2. C	1906 ½ cwt. Ohlendorff's cocoa manure; 1908 ½ cwt. Hughes' packard manure	656	1,088	1,296	1,254
2. D	1906 1 cwt. basic slag, 42 lb. sulphate of ammonia; 1907 1 hogshead of lime; 1908 8 cwt. pen manure	656	692	1,192	1,102
3. A	1906–8 No manure; 1909 Mulched with bush	542	856	870	890
3. B	1906, 1907, 1908 1 cwt. basic slag each year . . .	316	618	694	576
3. C	1906 1 cwt. basic slag and 28 lb. sulphate of potash; 1907 8 barrels of lime	268	1,000	694	866
3. D	1906 8 cwt. sheep manure; 1907 8 cwt. sheep manure	352	548	780	862

1. Mountain Road, St. David's Parish: Elevation 1,900 ft. Rainfall 111·11 in.

2. Chantimelle, St. Patrick's Parish: Elevation 400 ft. Rainfall 60·89 in.

3. Grand Roy, St. John's Parish: Elevation 500 ft. Rainfall 105·66 in.

According to the *Journal of the Jamaica Agricultural Society*, vol. xii., a planter in Grenada has during three years increased his yield of cocoa by over 100 per cent. through applying a fertiliser comprised of 8 cwt. basic slag and 1 cwt. sulphate of ammonia per acre.

Trinidad

The under-mentioned columns show the results of cocoa manurial experiments conducted in Trinidad (*Trinidad Bulletin*, No. 48, 1905).

La Vega Estate

July 1904 *to June* 30, 1905

Number of trees in full bearing. Area approximately one acre.		Manure applied.		Expenses.		Total.	Wet cocoa harvested lb.	
		Per plot.	Per tree lb.	Cost of manure.	Cost of cultivation.		Per plot.	Per tree.
				$. c.	$. c.	$. c.		
235	A	nil . . .	—	—	11·59	11·59	1860	7·91
215	B	400 lb. sulphate of ammonia . 4 cwt. basic slag	1·86 2.08	18·72	15·64	34·96	1896	8·82
224	C	10 tons pen manure . .	1·00	4·80	18·88	23·68	1990	8·88
216	D	4 cwt. basic slag 1 cwt. sulphate of potash .	2·07 0·51	8·08	15·64	23·72	2332	10·79

Dollar = 4*s.* 2*d.*

St. Lucia

Hudson (*Agricultural News*, West Indies, October 1901) considers that an application of basic slag at the rate of 5 to 10 cwt. per acre, applied in December or January, and followed by 1 cwt. of sulphate of ammonia in the following August or September, has given the best results as a cocoa manure in St. Lucia.

The subjoined table gives particulars regarding the results obtained from manuring cocoa with various fertilisers in that island :

Soufrière Plot, La Panta Estate

Area = 1 acre

Year.	Yield of cured cocoa.	Manures applied.
	lb.	
1901–2 . .	217	1 ton sheep manure.
1902–3 . .	236	1½ cwt. sulphate of ammonia, 2 cwt. sulphate of potash.
1903–4 . .	343	10 cwt. basic slag, 1 cwt. sulphate of ammonia, 3 tons stable manure.
1904–5 . .	717	4 cwt. basic slag, 1 cwt. sulphate of ammonia, 10 tons village street refuse.
1905–6 . .	1,081	4 cwt. basic slag, 1 cwt. sulphate of ammonia.

Errard Estate

Plantation No.	Area.	Unmanured 6 years (1897–8 to 1902–3), average yield of cured cocoa per acre.	Manure applied 1903–4 per acre.	Cured crop 1903–4 per acre.	Manure applied 1904–5 per acre.	Cured crop 1904–5 (9 months only) per acre.
	Acres.	lb.		lb.		lb.
1	2	476	7 cwt. crushed bones, 5 tons stable manure	1,316	4 cwt. basic slag, 3 tons stable manure, 1 cwt. sulphate of ammonia	1,412
3	10	460	8 cwt. basic slag, 1 cwt. sulphate of ammonia	711	4 cwt. basic slag, 1 cwt. sulphate of ammonia	847
13	5	381	8 cwt. basic slag 1 cwt. sulphate of ammonia	752	4 cwt. basic slag, 1 cwt. sulphate of ammonia	825
14	1	333	6 cwt. Arnott's cocoa manure	794	nil	650
15	20	244	nil (pruned and drained only)	296	8 cwt. basic slag, 1 cwt. sulphate of ammonia	396

Roseau Plot, Bellair Estate

Area = 1 acre

Year.	Yield of cured cocoa.	Manures applied.
	lb.	
1901–2 . .	360	8 cwt. basic slag, 1 cwt. sulphate of ammonia
1902–3 . .	650	2 cwt. sulphate of potash
1903–4 . .	765	8 cwt. basic slag, 1 cwt. sulphate of ammonia
1904–5 . .	580	4 cwt. basic slag, 1 cwt. sulphate of ammonia
1905–6 . .	450	2 cwt. sulphate of potash

Ceylon

Cocoa manuring experiments were commenced at the Experiment Station, Peradeniya, Ceylon, in the year 1903. The following account of the various manures tested and the crops yielded up to the end of the year 1907 has been extracted from the report of the Ceylon Botanical Department :

Acreage.	Plot No.	Manure applied annually except where otherwise stated.	Number of fruits per 300 trees.				No. of fruits yielded per acre.
			1903.	1904.	1905.	1906.	1907.
		Phosphoric acid and potash					
1	101	250 lb. basic slag and 100 lb. potassium sulphate . . .	3,248	5,423	8,221	6,194	4,382
		Phosphoric acid and nitrogen					
1	7	5 cwt. basic slag and 200 lb. ammonium sulphate . . .	3,323	6,877	11,340	6,241	5,999
¾	Tu.*a*	188 lb. basic slag and 300 lb. blood meal .	4,955	8,112	7,196	8,251	5,038
		Nitrogen and potash					
1	109	114 lb. of nitrate of potash	4,038	3,251	7,865	5,166	5,732
1	108	714 lb. of ground-nut cake and 100 lb. potassium sulphate . . .	4,038	4,987	8,324	4,964	7,285
		Nitrogen, potash, and phosphoric acid					
1	107	250 lb. basic slag, 833 lb. castor cake and potassium sulphate . .	4,038	4,028	8,654	4,989	8,631

Acreage.	Plot No.	Manure applied annually except where otherwise stated.	Number of fruits per 300 trees.				No. of fruits yielded per acre.
			1903.	1904.	1905.	1906.	1907.
		Nitrogen only					
½	95*a*	Sodium nitrate (to determine the effect of excess of soluble nitrogen) 400 lb. per half-acre .	3,448	9,727	10,973	6,713	2,839
½	95*b*	Ground-nut cake (to determine the effect of relatively insoluble nitrogen) 896 lb. per half-acre	3,445	7,929	8,335	4,475	2,804
1	99	Blood meal 400 lb. per acre	1,018	3,300	8,666	4,810	5,888
1	100	Castor cake 833 lb. per acre	1,356	3,860	6,774	4,763	4,567
1	111	Ammonium sulphate 250 lb. per acre . .	4,038	6,595	10,474	7,789	10,085
		Potash alone					
½	94*a*	Potassium chloride (to determine the effect of excess) 107 lb. . .	3,143	8,221	10,754	5,995	3,689
½	94*b*	Potassium sulphate (to determine the effect of excess) 125 lb. . .	3,174	7,513	9,307	5,386	4,168
		Phosphoric acid alone					
½	96*a*	Concentrated superphosphate (to determine the effect of excess) 141 lb.	3,575	7,538	10,955	5,893	2,978
½	96*b*	Precipitated phosphate (to determine the effect of excess) 163 lb. .	3,454	8,312	7,893	5,668	3,462
		General manures					
1	8	6 cwt. of Kainit . .	3,733	5,768	9,645	5,045	4,530
1	9	5 cwt. of bone dust .	3,572	6,064	8,924	5,104	6,937
1	98	5 cwt. fish	1,156	3,211	6,746	3,726	5,764
1	110	250 lb. basic slag, buried with leaves and twigs	4,038	3,227	11,109	7,780	4,987
1	6	Trenched and buried débris with 10 cwt. of lime ; ground not forked	3,266	6,740	9,129	5,587	4,925
1	5	Trenched and buried débris with 10 cwt. of lime, and forked all over the ground .	4,794	8,070	8,072	3,690	4,702
1	4	10 tons of cattle manure forked in around the trees in 1904 . .	6,475	9,326	9,853	3,161	5,077
1	3	1903, two tons of lime ; 1905, Crotolaria sown, pruned and forked in .	8,684	10,222	9,994	4,243	5,106
1	93	Control-plot . . .	2,523	4,271	5,976	3,828	5,140

The following table gives a comparison of yield during 1907 of the various plots at the Ceylon Experiment Station :

Plot.	Amount of manure applied per acre.	No. of trees.	No. of fruits at 300 trees per acre.	Increase or decrease over unmanured plots.	Relative position of manured plots.
3	Excess of lime . .	271	5,235	− 1,500	—
4	10 tons cattle manure .	239	5,034	− 1,701	—
5	10 cwt. lime, forked . .	202	4,905	− 1,830	—
6	10 cwt. lime, forked .	207	1,630	− 105	—
7	200 lb. sulphate of ammonia and 556 lb. basic slag	270	7,320	+ 585	10
8	6 cwt. Kainit . .	267	7,146	+ 411	—
9	5 cwt. bone dust . .	242	7,710	+ 975	7
10	Unmanured . .	272	6,735	—	—
94*a*	107 lb. muriate of potash	326	7,510	+ 1,210	6
94*b*	125 lb. sulphate of potash	400	6,890	+ 590	9
95*a*	425 lb. nitrate of soda .	250	9,020	+ 2,720	2
95*b*	896 lb. ground-nut cake	398	6,357	− 57	—
96*a*	141 lb. concentrated superphosphate . .	374	7,101	+ 801	8
96*b*	163 lb. precipitated phosphate . . .	274	7,968	+ 1,668	5
98	5 cwt. crushed fish .	375	4,764	+ 1,536	—
99	400 lb. blood meal . .	394	4,269	− 2,031	—
100	833 lb. castor cake .	247	6,204	−96	—
101	250 lb. basic slag and 100 lb. sulphate of potash	215	8,829	+ 2,529	3
107	833 lb. castor cake, 250 lb. basic slag and 100 lb. sulphate of ammonia . . .				
	714 lb. ground-nut cake	376	5,451	− 849	—
108	and 100 lb. sulphate of potash . . .	315	6,075	− 225	—
109	114 lb. nitrate of potash	342	6,336	+ 36	—
110	250 lb. basic slag and buried leaves . .	337	8,115	+ 1,815	4
111	250 lb. sulphate of ammonia . . .	337	8,115	+ 1,815	—
111	250 lb. sulphate of ammonia . . .	295	11,070	+ 4,770	1
112–16 and 119	Unmanured, 6 acres .	334	6,300	—	—

The same report gives the under-mentioned information relative to the number of fruits per bushel, the average weight per bushel of fruits and cocoa during various stages of preparation of three different varieties of cocoa :

TABLE No. 1

Variety.	No. of fruits per bushel.	Average weight per bushel (fruits).	Average weight per bushel (fresh beans).	Average weight per bushel (cured beans).	No. of cured beans per bushel.
	lb.	lb.	lb.	lb.	
Caracas . .	41	47	77	41	14,800
Forastero .	33	46	77	44·5	14,900
Amelonado .	41	44·5	77	46·5	20,400
Average . .	38·3	45·8	77	44	16,700

TABLE No. 2

WEIGHT OF 500 FRUITS, AND BEANS FROM THESE AT VARIOUS STAGES

Variety.	Weight of 500 fruits.	Weight of fresh beans from 500 fruits.	Weight of beans after 40 hours' fermentation.	Weight of beans after curing.	Weight of cured beans from 100 fruits.	No. of fruits to yield 100 lb. cured beans.
	lb.	lb.	lb.	lb.	lb.	
Caracas .	573	103	88·5	37·5	7·5	1,333
Forastero .	706	130	106·5	49·38	9·88	1,012
Amelonado .	533	106	87·5	39·88	7·98	1,253
Average .	606	113	94	42·25	8·45	1,200

From Table No. 2 it will be seen that the weight of cured beans from 100 fruits varies from 7·5 lb. with Caracas to 9·8 lb. from Forastero, the average from the three kinds which are present in varying numbers on all the plots being 8·45lb.

Taking the sulphate of ammonia, Plot No. 111, with a yield of 11,070 fruits, the weight of dry cocoa per acre would be 8¼ cwt., which is very high, whilst the cost of the manure is only 23·12 Rs. (£1 10*s.* 10*d.*) per acre per annum.

The yield from the unmanured plots is equivalent to 4¾ cwt. of dry cocoa per acre.

It is difficult to understand the extraordinary manner in which the yields of specific plots have fluctuated from year to year. In drawing comparisons between the yields of different plots the reader is recommended to bear in mind that the 1907 annual report on these experiments states : "Although the results of the manure experiments are recognised to have amply justified their existence in every case, yet at the same time it is felt that the plots are not of a representative and uniform character, because the trees were originally planted irrespective of distance; they are therefore to be thinned out and left at as much as possible a uniform distance of about 12 ft., and wider if possible"; and "a careful examination of all the plots at the present time, however, shows that unless the greatest care is exercised the figures of yields are rather misleading owing to several reasons, the chief being the irregularity of the bearing trees in each plot and the irregular cutting out of diseased trees, and supplying of new ones during the last few years." Also, "The manuring and improvement of old cocoa is the chief object of the experiments; but as it is almost impossible to obtain identical conditions on each plot, under those prevailing at Gangaruwa when the estate was first taken over, it is better to look at the matter from a general point of view, rather than to base calculations of profit or loss on erroneous or misleading figures." It is further pointed out that the manures containing much nitrogen had a marked effect on increasing the growth of foliage, and in the case of sulphate of ammonia on the crop likewise. Even when certain nitrogenous manures, such as blood meal, crushed fish, castor and ground-nut cake were applied in conjunction with basic slag and sulphate of potash, no marked beneficial effect was observable in the yield. It is, however, evident that sulphate of ammonia and a mixture of sulphate of ammonia and basic slag are among the best manures for cocoa. Good returns were obtained the season following the forking-in of leaves with an excess of lime, but subsequently the yield deteriorated, and the trees developed too much leaf growth. As the soil is rich in lime applications of this material did not have a beneficial effect upon the yield.

The soil is poor in potash, but the results obtained from the plots treated with potash manures are of rather an uncertain nature. It is pointed out that there was a tendency for manures to encourage a maximum yield in December instead of November, maintaining the increase until January; thus indicating that a plentiful supply of plant-food at the flowering and fruit-setting period checked the dropping of immature fruits, and points to the advisability of applying soluble manures immediately previous to the principal flowering periods.

CHAPTER XI

DISEASES

For the cocoa planter to adopt preventive or combative measures in an intelligent manner against the various pests to which cocoa is subject, it is necessary that he should acquire a knowledge of the principles of phytopathology, which involves an understanding of the symptoms, causes, and the life history of plant diseases.

In attempting a diagnosis of plant diseases it is important that he should be able to differentiate between symptoms due to the action of organisms and those due to environment. For example, a discoloration of the foliage may have been caused either by fungus mycelium present in the internal structure of the leaf or by excessive moisture at the roots of the tree. The therapeutic measures to apply to the former ailment would obviously have to differ widely from those applicable to the latter.

The etiology or causes of plant disease may be included in two main groups; the first is associated with its inanimate environment, such as soil, light, atmosphere, or temperature, while the second is connected with the work of living organisms, such as plants and animals. It is necessary to point out, however, that the effects of the work of the living organisms are influenced by the inanimate environment as well as by the host plant. A plant growing under satisfactory conditions as regards soil and climate is better equipped to withstand disease than one growing in a sour or water-logged soil, or one growing in an unsuitable temperature.

In the case of the cocoa tree too dense shade predisposes it to fungus disease. A lack of nutriment in the soil, constricted root or foliage space, may likewise be placed in this category. A definition of disease as affecting the cocoa tree, for the purpose of this work, may be considered as the variation from the normal of functions which threaten the life of the tree, and this implies danger of premature death.

In maintaining the plant in a good state of health by a careful observance of its requirements in regard to soil, light, and air, the planter is adopting the best preventive measures against disease.

Serious epidemics of disease rarely occur amongst plants growing in a wild state. This is mainly due to the fact that a specific disease almost invariably confines its attacks to nearly allied species. Under natural conditions, large numbers of unrelated plants grow intermixed, and it very rarely happens that a single species of plant monopolises a large area of land. Any particular diseased plant is more or less isolated and the spread of the disease to plants of a similar species is thus checked, as the plants in the immediate vicinity are unrelated and are consequently more or less immune from this particular disease.

The practice of cultivating large areas of land with a single species of plant is therefore most conducive to the diffusion of the various diseases to which the plant is subject. In the wild state there is a constant struggle for existence, the plants least adapted to grow in any particular situation are crowded out by those better adapted, which results in the survival of the fittest. The very fact of a plant thriving in any particular district in a wild state indicates that the natural conditions are favourable for its development.

When this plant is introduced to a new country and is grown under the conditions which cultivation involves, some of the factors which might be inimical to its growth in a natural state are obviously removed, but it is introduced to others to which it was not previously subjected. In all probability it will be still affected by the various diseases which it encountered in its native habitat, but many of the factors which previously kept these in check will be absent, and an endemic disease may then develop into an epidemic. For example, the depredations of an insect, which fed upon its tissues, may have been held in check by being preyed upon by another in its native home, but the former may be present and the latter absent in its new home. Again, the hygienic conditions may be more favourable to the development of various fungus parasites; its vitality may be weakened by soil or climatic agencies or by methods of cultivation.

It is universally acknowledged that plants like the cocoa tree, whose habits have been altered, or "improved" from the planter's point of view, by long periods of cultivation, are more subject to disease than the wild types of the same species. That the constitution of the cocoa tree has been altered by introduction to, and cultivation in, new countries, is amply exemplified by the numerous varieties and forms now extant.

It will therefore be apparent that it is incumbent on the cocoa planter to adopt every possible means in his power to prevent the introduction of disease into his plantation, and when it does appear, to take immediate steps to eradicate it.

The difficulties attending the prevention and extermination of disease from a permanent crop, such as cocoa, are far greater than in the case of an annual crop, for with the latter a change of crop will invariably produce the desired results. The cultivation of certain inter-crops and catch-crops with cocoa might tend to check disease diffusion; and belts of trees, planted at suitable distances apart throughout the plantation, would serve both to protect the cocoa trees from wind and deter the spread of disease.

For the reasons already mentioned the species chosen for the inter-crops, catch-crops, or wind-shelter-belts should be selected from those belonging to different natural orders of plants from those to which the cocoa tree belongs, viz. *Sterculiaceæ*.

The living organisms associated with the diseases of the cocoa tree may be divided into two groups, i.e. animals and plants.

Of the vertebrata which are inimical may be mentioned man, monkeys, deer, squirrels, and rats.

It is, however, among the invertebrata that we find the most pernicious pests of the cocoa tree, such as beetles, the larvæ of beetles and moths, thrips, aphis, etc.

Plants as factors of disease in cocoa trees can be separated into two series, the flowering plants, Phanerogams, and Cryptogams. The former are represented by such well-known types as dodder (*Cuscuta spp.*) and *Loranthus leptolobus*, which is nearly related to mistletoe; and the latter by fungi.

Animal Pests

Man.—The injuries inadvertently caused to cocoa trees by man, although perhaps seldom directly responsible for the death of the tree, nevertheless often facilitate the attacks of insects and parasitic fungi. Wounds carelessly made on the stem and main branches during cultural and pruning operations offer a convenient infection spot for the spores of various species of wound fungi, and such wounds are frequently selected by certain beetles to lay their eggs, as affording the larvæ which hatch therefrom a ready means of entrance to the internal tissues of the tree. Wounds made on the roots, in a similar manner, render the tree more liable to infection by the parasitic fungi which attack these organs.

Deer occasionally feed on the young growths and gnaw the bark from the stem of the cocoa tree, thus lowering its vitality and preventing the proper circulation of sap, and in addition, as mentioned above, affording various insects and fungi an opening for attack.

The only practical methods of checking the attacks of these marauders would appear to be by shooting them, or by erecting a suitable fence around the plantation.

Monkeys, Squirrels, and Rats.—These three animals frequently cause great losses to the cocoa planter by their ravages upon the cocoa fruit. They are all extremely fond of the sweet mucilaginous pulp in which cocoa beans are enveloped. They wantonly destroy large numbers of fruits. After gnawing a hole in the shell they extract a few beans and leave the remainder to decay. The beans extracted are rarely eaten, but are thrown down upon the ground, after the mucilaginous envelope has been consumed. Such beans germinate or decay unless collected shortly after they fall to the ground, and even then they only yield an inferior product.

When the attacked fruits are left upon the trees the unprotected tissues afford excellent infection areas for the various fungi diseases which affect cocoa fruits, as also do the shells and beans left lying about in the plantation.

The writer has noticed, both in West Africa and in San Thomé, frequent instances of cocoa fruits having been torn from the trees and carried completely away by monkeys. Squirrels are also troublesome in these two districts, as well as in Trinidad and Ceylon. Considerable damage is caused by squirrels in Ceylon ; the 1907 annual report upon the Experiment Station shows that more than 60,000 cocoa fruits were damaged during that year in the experiment plots.

Methods of Destroying Rats.—The ravages caused by rats are, however, far greater than those due to both monkeys and squirrels.

The losses which San Thomé planters annually sustain from the depredations of rats must be enormous. One authority has estimated it at 10,000,000 francs. This is probably an exaggeration. Some idea of the number of rats which infest the San Thomé cocoa estates may be gathered from the fact that, the manager of one of these estates assured the writer, 16,000 rats were annually destroyed on the property. Other countries where rats are destructive to the cocoa crop are: Trinidad, Martinique, and Samoa.

The most destructive species in San Thomé are *Mus ratus* and *M. decumanus* ; the former is common in Trinidad, as well as the "pouched rat," *Heteromys anomalus*, Thompson, and the "spiny rat," *Loncheres guianæ*, Thos.

It is thus apparent that the planter must look upon the rat as a formidable deterrent to profitable cocoa cultivation, and when it appears in his plantation it must be energetically combated.

Monkeys, squirrels, and rats may all be caught in traps ; poisoned bait can also be effectively used. In San Thomé large numbers of dogs are trained to hunt the rats.

Farmer's Bulletin, No. 297 of the United States Department of Agriculture, suggests the following poisoned baits for the destruction of rats : One part barium carbonate, or barytes, mixed with four parts of meal into the form of dough ; or one part barytes mixed with seven parts of oatmeal and made into a stiff paste. This mixture is tasteless and odourless. When used in small quantities sufficient to kill rats it is not injurious to larger animals. Its action on rodents is slow but fairly sure, and possesses advantages over many similar poisons in that the rats, dying from its effects, almost invariably leave buildings in search of water.

Strychnine is also recommended as a rat poison. Half an ounce of strychnine sulphate should be dissolved in a pint of boiling water, to which should be added and mixed a pint of thick sugary syrup. Owing to its virulence as a poison to man and all animals its employment involves considerable risks. Oatmeal dough should be thoroughly moistened with this mixture, or wheat should be soaked in it to form a bait.

When a bait likely to be injurious to dogs, cats, or poultry is employed it should be placed in a section of bamboo pole, open at each end but with a joint in the centre.

Phosphorus preparations should be avoided, as they may be carried by rats near inflammable materials and cause fire.

The under-mentioned poisoned baits for the destruction of rats are recommended in the *Philippine Agricultural Review*, September 1908:

		lb.
I.	Arsenic	2½
	Cooked rice	6
	Powdered glass	2
	Toasted cocoa-nut	2
II.	Arsenic	2½
	Cooked rice	6
	Brown sugar	2
	Powdered glass	2
	Toasted cocoa-nut	2

The mongoose was introduced with a view to destroying rats in Martinique, but this animal has now increased to such an extent that a destroyer of the mongoose is required.

Rats cause serious damage in maize farms in Mozambique, where they attack the seed sown in the field, the "cobs" in the field previous to harvesting, and also the stored cobs and grain. Experiments instituted by the writer with the object of discovering an inexpensive and effective means of exterminating them resulted in the adoption of the "Universal Ant Destroying Apparatus," in preference to all other methods tested. This method of exterminating rats might be applied with advantage in cocoa plantations. The apparatus consists of an air-pump connected by a length of rubber hose with a small furnace. Glowing charcoal is placed in the latter, and a spoonful or so of a mixture, comprising 85 per cent. of white arsenic and 15 per cent. sulphur, is thrown on the charcoal. When the pump is worked a current of air is forced into the furnace. The air enters the lower part of the furnace and drives out the poisonous fumes, produced by the combustion of the powder, through a hole near the top of the furnace, with which is connected a second flexible tube. In practice the nose of the latter is placed in the largest hole leading to the rat burrow and the pump is started. As it is essential to restrict the fumes to the burrow as much as possible it is necessary before commencing operations to close up all other holes leading to the burrow. Sometimes only one other is found, but there may be as many as five. The amount of fumes required for each burrow depends upon its size, but sufficiency is indicated when they commence to issue from the hole into which they were originally injected. The pump should then be stopped and the hole plugged up. Twenty-four hours later the burrow should be inspected, and if any openings are found the burrow should be treated again. Failure to destroy the rats in the burrow by one application is usually due to the insecure closing of the various bolt-holes. Should no exits from the burrow have been made no further application is necessary.

Insect Pests

The comparatively recent researches of the Entomologists attached to the West Indian and Ceylon Botanical Departments have furnished much valuable data in regard to the insects destructive to cocoa in those countries, and the writer is indebted to their reports for a great deal of the following information on the subject.

Many of the insects recorded do very little damage in plantations; principally because they occur in extremely limited numbers; still, the fact must not be lost sight of, that however small the injury caused by a particular insect may be, it in all probability would be augmented in direct ratio to its multiplication.

Many insects pass through three stages of existence. From eggs are hatched caterpillars or grubs. These subsequently change to a pupal or resting stage, i.e. chrysalis, from which the "perfect insect" (butterfly, moth, or beetle) emerges. It is frequently in the "larval or caterpillar stage" that a particular insect is most destructive. Whenever a butterfly, moth, or beetle is known to be the parent of a troublesome grub, every possible means should be employed to destroy it. By studying the life history of a destructive insect it is sometimes possible to check its ravages by destroying its eggs.

Mosquito Blight, *Helopeltis Antonii.* This insect was originally reported to destroy the young twigs and leaves of the cocoa trees, but at the present time it appears to be more destructive to the fruits. In a report upon "Rubber, Cocoa, etc., in Ceylon, 1903," the writer has given the following particulars regarding this pest. "The Helopeltis insect was described from Ceylon by a French entomologist as far back as 1858, but it was not until 1880 that it was reported as being destructive to cocoa trees. The insect lays its eggs in the rind of the cocoa fruit, where their presence is only evident by the long white hairs which protrude from the end of each egg in single pairs. In about nine or ten days the eggs hatch out into small wingless insects, which grow rapidly and eventually produce wings. These insects feed upon the sap of the cocoa tree. At the point where the insect punctures the fruit the tissues die, and where a large number of these punctures occur close together on the same fruit the diseased portions unite and the fruit dies. In order to check this pest coolies are sent among the cocoa trees armed with sticks smeared with the viscid sap of the Jak tree, *Artocarpus integrifolia*; on this the wingless insects are caught, and so expert do the coolies become at the work that one will catch as many as 1,500 insects per day. At one estate that I visited, over £200 had been spent in the current year on their extermination."

The eggs of Helopeltis hatch out on the tenth day, the young insects are reddish in colour, and resemble small ants. Both the young and the mature insects are easily recognisable by the "drumstick," or erect knobbed horn, which projects from the middle of the back. The insect appears to be most active in the early morning, and combative measures would therefore appear to be most successful if employed at this time.

Attempts to destroy this insect at the Experiment Station, Peradeniya, Ceylon, by spraying with insecticides, gave negative results so far as it was possible to judge.

Steirastoma depressum, L. This pest has been recorded as injurious to cocoa trees in the following countries: Surinam, Venezuela, British Guiana, and several of the West Indian islands. It belongs to the *Longicorn* family of boring beetles, and is about an inch long by half an inch broad, black with whitish-grey markings, and has jointed antennæ longer than the body. The adult insect feeds upon young bark, small plants, or twigs of mature trees.

The female, which is slightly larger than the male, lays its eggs in crevices of the bark of the cocoa tree or in the angle formed by two large branches. Trees in a poor state of health are more commonly attacked than healthy trees. The eggs hatch out into grubs, which at once commence boring, with their powerful mandibles, into the stem tissues. The grubs grow 1½ in. long by ¾ in. broad, and eventually pass into a resting stage, in the form of a chrysalis or pupa. The presence of the grub is usually evidenced by the fine sawdust made by its boring operations which it ejects from the beginning of its tunnel. When the grub is close to the surface it may be cut out, but if it is too far away for this to be practicable it may be destroyed by inserting a pliable wire into its tunnel. The wounds made by the grub, or in cutting it out of the tree, should be painted over with the mixture of tar and resin oil already referred to in this work.

The adult beetles are active by night, but they often may be found resting upon the trunk and large branches of the cocoa tree in the early morning. At this time of day they are easily caught and can be killed by throwing them into a vessel containing a mixture of water and kerosene.

Surinam cocoa planters trap these beetles by tying large pieces of the bark of the silk cotton tree to the trunks of the cocoa trees, to provide a hiding-place for them.

These traps are examined during the day-time, and large numbers of beetles are caught by this means.

Branches cut from the trees are left on the ground in Grenada for two or three weeks. The adult beetles lay their eggs in these branches, but these are destroyed as the branches are burned. Although it is comparatively rare to find a tree which has been killed outright by this beetle, its attacks seriously interfere with the health of the tree.

In Grenada it is reported (*Journal Royal Society of Arts*, August 13, 1909) that on one cocoa estate, 200 acres in area, 120,000 beetles, larvæ, and pupæ have been killed in a year at a cost of £50; and on a neighbouring estate 200,000 were accounted for.

Another beetle (*Adoretus umbrosus*) is reported to feed upon the leaves of the cocoa trees in Fiji, but is not very destructive.

Preuss reports that the larvæ of a *Longicorn* boring beetle (*Tragocephala senatoria*) is destructive to cocca trees in Kamerun.

Thrips.—These minute insects are destructive to cocoa trees in most countries where it is grown, and especially when the trees are suffering from drought, lack of proper plant-food, or other causes. Ballou describes a species of thrips, *Physopus rubrocincta*, common in West Indian cocoa plantations, as follows: "The adult insect is from $\frac{1}{25}$ to $\frac{1}{18}$ in. in length; it is dark brown or black, with delicate wings, which are fringed with fine hairs. The young, which have no wings, are pale green or yellowish green, generally with a bright red band extending across the abdomen." These insects attack the foliage and fruit; they are usually found on the under surface of the leaves in small colonies. An affected leaf is discoloured even on the upper surface, and if the thrips be numerous it is killed. In the case of fruits, the attacks of thrips also cause discoloration, which is often mistaken for that associated with ripeness and sometimes results in the harvesting of immature fruits.

This discoloration of the leaves and fruits is mainly caused by the thrips biting and feeding upon the plant tissues, but in a less degree damage is due to the incisions made by the females in which to lay their eggs.

As trees in an unsatisfactory state of health are most subject to thrips attacks it follows that the best means of combating them is to remedy this by better attention to the trees' requirements.

Affected fruit shells should be buried with lime, and the trees should be sprayed with the resin wash, whale-oil soap solution, or kerosene emulsion described at the end of this section.

Aphis.—Aphides, or plant lice, are frequently found attacking the young foliage, flowers, and fruit of cocoa trees, and their presence is often indicated by the ants which follow them for the honey-dew, or sweet fluid, which they exude and upon which the ants feed. The distorted appearance of mature foliage is often due to aphis attacks upon the young growths, and the development of young flower-buds is sometimes prevented by similar attacks. Spraying the trees with kerosene emulsion or whale-oil soap will generally rid them of these pests.

Twig Girdlers.—Various forms of twig-girdling insects have been found attacking cocoa trees in the West Indies. In Trinidad, *Ecthoea quadricornis*, Oliver, and *Tomicus sp.* have been observed cutting off small cocoa twigs. Another twig girdler, *Oncideres amputator*, sometimes attacks cocoa trees in St. Vincent and St. Lucia. The female of the species gnaws the wood of a twig, and before the twig falls lays an egg in the partially severed portion. The larva, which hatches from the egg, is thus supplied with the dead or decaying material necessary for its food. The only practicable means of checking the attacks of these pests appears to be in catching and destroying the mature insects and in burning the twigs on which the eggs have been deposited.

Mealy Bugs, *Dactylopius spp.*, are another pest of cocoa trees, but are only of minor importance. Like aphides they frequently attack young leaves and flower buds; unless they occur in very large numbers they do not cause serious damage to more mature parts of the tree. Combative measures should be adopted similar to those recommended in regard to thrips.

Ceratitis punctata, Wied, attacks cocoa fruits in Ashanti, Gold Coast, and also in Uganda. According to Gowdey (*Government Gazette*, Uganda, October 1909) this insect belongs to the *Trypetidæ*, a dipterous or two-winged family of vegetable-eating insects.

The female lays its eggs under the peel of the cocoa fruit. Larvæ hatch out from these in from twelve to fifteen days, and at once commence feeding upon the interior tissues of the fruit and interfere with the development of the seeds.

These larvæ measure about half an inch long when fully grown, and are then fifty-five or sixty days of age.

They are footless, colourless, twelve-segmented grubs, with prominent dark-coloured mandibles. They pupate in the soil at a depth of 2 in. near the stem of the tree. The puparium varies in colour from white to pale brown; it is barrel-shaped and segmented. The pupal stage lasts from fifteen to seventeen days.

The ground colour of the adult insect is yellowish white; it has eyes red or purplish, thorax beautifully striped and spotted, abdomen, except basal segment, spotted and with black bristles at apex, wings with fuscous bands and dark spots.

They appear to feed upon any sweet substance. There seems to be no sharply defined season between the broods, and breeding is continuous as long as food is available.

The microscopical examination of several females disclosed the presence of an average of fifty eggs each. As it is considered there are four broods a year it will be observed that if every egg resulted in an adult the descendants from a pair of flies at the end of the year would number 390,625. This number is only based on theory, and would of course never be actually attained. Fruits other than cocoa in which the females lay their eggs are: mango, melon, guava, and passion-fruits.

As the adult insects are attracted by sweet substances, control measures should take the form of poisoned baits of sweet liquids. Gowdey recommends a mixture consisting of: 3 lb. sugar, ¼ lb. arsenate of lead, and 5 gallons of water, being sprayed so as to form a thin film on the trees. Infected fruits should be burned or buried.

Scale, *Asterolecanium spp.*—These insects sometimes occur in considerable numbers on cocoa trees. Several trees in Grenada were completely covered with them, and it was found necessary to cut down the trees and burn them. What is known as "Black blight" is generally due to the presence of a fungus, *Capnodium sp.*, which obtains its nutrition from the excreta of scale insects. Trees badly attacked with scale should be cut down and burnt. Mild attacks may be effectively treated with the remedies advised for the extermination of aphis and mealy bug.

The Lac Insect, *Tachardia Albizziæ*, Green. — The branches of the cocoa tree are occasionally attacked in Ceylon by the Lac insect. Green (*Tropical Agriculturist*, October 1905) does not consider it does much damage, although young growths are occasionally killed by its work.

Deimatostages contumax is the name given by Kuhlgatz to a bug which affects cocoa trees in Kamerun. Strunk (*Der Tropenpflanzer*, November 1906) tested various insecticides with a view to deciding upon an effective remedy for this pest. He found arsenical compounds gave very satisfactory results. Tobacco juice and soap solutions also proved effective when applied at the commencement of the dry season before the insects became abundant.

Parasol Ants, *Atta cepalotes* and *A. octospinosa*, destroy cocoa leaves in Trinidad. Parasol ants are so called from their habit of cutting up leaves and flowers and carrying them away on their heads to their nests. It is stated that they seldom leave their nests during stormy or heavy rainy weather, or while the sun is exceptionally hot, so this should be the best time to attack them to ensure the destruction of the whole nest. Hart recommends the application of coal tar; he states that it effectively destroys the nest, and the ants never return to a nest which has been treated in this manner. The "Universal Ant Destroyer," previously described, doubtlessly could be employed with advantage for the destruction of these pests, or carbon bisulphide might be applied to the nests with equally good results. This liquid is exceedingly volatile, and the fumes which it gives off are of a highly inflammable nature. Many shipping companies object to carry it, and it is consequently expensive.

About $\frac{1}{7}$ drachm, or $\frac{1}{2}$ cubic cc., of the liquid should be poured on a small handful of cotton wool and plunged into the nest. If all holes in the nest are closed up with moist clay, the fumes, being heavier than air, will descend and destroy the ants.

Termites, or what are erroneously termed white-ants, cause serious damage to cocoa trees in San Thomé, and are responsible for minor injuries to these trees in several other countries. In San Thomé they indiscriminately attack both healthy and unhealthy trees, and at least two distinct species occur. Desneux has identified one of these as *Termes Theobromæ*; the other is probably a *Calotermes*, and Plate 6 illustrates the manner in which it attacks the trees. Part of the trunk has been cut away to show the extent of the injury, and on the left-hand side of the plate is seen a gormandising sucker which the tree has produced from the least affected side of its trunk. The insects build their nests at the base of the cocoa trees and attack the roots. Later, and probably after growth has been thus checked, they obtain an entrance to the trunk through the tap-root.

From the trunk their operations are extended to the main branches. In its attempts to recover from the injuries caused by the insects the tree frequently produces one or more gormandising suckers from the base of the stem.

The planter, with a view to encouraging these to take the place of the injured portion, frequently cuts the latter down. Unless the nest at the base of the tree is destroyed the suckers are very soon attacked and the tree is eventually killed.

The nests should be treated by the methods recommended for Parasol ants.

An insect has been recently reported as destructive to cocoa trees in the Gold Coast.

When young it resembles a tick or spider and is reddish in colour. Mature insects are brown or black, and although they generally have wings they can only fly for short distances. Both young and old insects have a trunk which, when not feeding, is folded back along its under-side. Applications of kerosene emulsion have been recommended as a combative measure. It is suggested that seriously attacked trees, which appear to be dying, should be cut off 18 in. from the ground and the top of the stumps coated with tar.

Insecticides

Many of the insect pests previously described cause very little damage to cocoa trees, but others, like thrips and the Steirastoma larvæ, have caused serious damage where no attempts were made to exterminate them.

The fact that a particular insect pest has hitherto not proved troublesome affords no criterion of its capabilities in this respect should conditions more favourable for its multiplication occur. The planter should be constantly on the look-out for possible pests, and when found prompt measures should be taken to exterminate them. In order to be in a position to adopt rational remedial methods it is necessary that the planter should be equipped with the various insecticides which have proved beneficial in checking cocoa pests and also with suitable apparatus with which to apply them. Different insects injure the trees in different ways, and a method of attack which would be attended with excellent results when applied to check the ravages of one insect might be futile against those of another.

The principal insect pests of cocoa may be classed into three main divisions: Boring insects, sucking insects, and leaf-eating insects.

Boring Insects.—Under this division may be included the various larvæ of *Longicorn* beetles and termites; the means of combating both these pests have already been dealt with.

Sucking Insects.—These suck the plant juices by means of a slender tube which they insert into the tissues of the plant. Plant lice (*Aphides*), mealy bugs, scale insects, etc., are comprised in this division. To exterminate these, insecticides known as "contact poisons" are generally applied, which kill the insects when the poisons come in contact with their bodies. The following are some of the mixtures most generally employed for this purpose:

Resin Wash.—Thoroughly pulverise 4 lb. of resin and

PLATE 6

A Cocoa Tree attacked by Termites

p. 90]

1 lb. of caustic soda, and then add to these ¾ pint of fish oil. Cover these with about 2 in. of water and boil until the solids have dissolved. Slowly add water, keeping the mixture up to boiling point, until the whole is made up to 3 gallons. This constitutes the stock solution. Before application dilute at the rate of 6 gallons of water to 1 gallon of the stock solution ; rain-water is preferable, as this is not impregnated with lime or other minerals.

The diluted mixture should be sprayed on insect-infected trees ; 100 gallons is sufficient to treat an acre of cocoa trees, and one man should deal with half an acre in a day.

Resin Compound.—Pound 4 lb. of resin and 3 lb. of common washing soda in a mortar and mix them with 1 gallon of water. Boil until the solids have completely dissolved, then slowly make up the mixture to 5 gallons by the addition of water. Thoroughly boil until a clear brown colour is obtained. This is the stock solution, and should be diluted with 25 gallons of soft water previous to application.

Kerosene Emulsion.—To prepare this dissolve hard soap in the proportion of 1 lb. to every 2 gallons of boiling water. When these have been thoroughly mixed, and while the water is hot, slowly add 4 gallons of kerosene and well churn with a syringe or force-pump until a cream is formed and the oil has become completely incorporated in the soap solution. This forms the stock solution, and if it has been properly mixed, no trace of oil will be apparent on the surface even after it has been standing several days. Before application this should be made up to 66 gallons with rain-water or soft water.

Whale-oil Soap Solution.—This is made by mixing whale-oil soap at the rate of ½ lb. to every gallon of boiling water.

Tobacco Solution is prepared as follows : Steep tobacco-leaf, in the proportion of 1 lb. to every gallon of water, for 24 hours, and afterwards strain the resulting liquid through a cloth. Dissolve 1 lb. of hard soap to every 10 gallons of water. Mix the tobacco water and the soap solution at the rate of 1 gallon of the former to 10 gallons of the latter, and it is ready for use.

Resin and Whale-oil Soap Mixture.—Take 4 lb. resin, 3 lb. common washing soda, and 10 lb. whale-oil soap; make the resin and soda into 4 gallons of resin compound stock solution as previously suggested. Mix the whale-oil soap with 5 gallons of boiling water, and while this mixture is still hot add the resin-compound stock solution. Previous to application add 4 gallons of soft water to every gallon of the mixture of whale-oil soap and resin.

Leaf-eating Insects.—Applications of the "contact poisons" will often destroy many leaf-eating insects, but better results are obtained by poisoning their food.

This can be done by spraying affected plants with arsenical and other solutions, which may be termed "stomach poisons." Since sucking insects obtain their food from the interior tissues these will be unaffected by such insecticides.

The following "stomach poisons" will be generally found to give satisfactory results:

Paris Green.—This may be effectively applied either in powder form or in solution. When it is applied in the dry state it should be first mixed with about twice its weight of starch, flour, or lime.

To make Paris Green solution, mix at the rate of ½ lb. Paris Green and 1 lb. powdered lime to every 100 gallons of water.

London Purple.—This likewise may be applied dry or in solution. It should be prepared with lime, flour, or starch, in a similar manner and in the same proportions as suggested for Paris Green.

CHAPTER XII

VEGETABLE PARASITES AND EPIPHYTES

THE dodder, *Cuscuta spp.*, and *Loranthus leptolobus* are, strictly speaking, only partially parasitic on the cocoa tree, as they derive a certain amount of nourishment from the atmosphere. The latter is usually propagated on the cocoa tree by means of its seeds, which are carried on to the branches by birds. The seed germinates and its radicle penetrates the interior tissues of the branch, where it obtains nourishment, and a sucking organ develops at the expense of the cocoa tree. Unless checked, *Loranthus leptolobus* forms dense masses, often more than a foot in diameter, which must considerably deplete the vitality of its host. This parasite, therefore, should be cut out, and the wounds thus made should be painted with the tar and resin mixture. Epiphytes, such as mosses, lichens, and small orchids, often interfere with the development of young cocoa buds, and should be carefully removed from the tree. Many of the cocoa trees in the hilly districts of San Thomé are badly infected with various forms of epiphytes. The Orchella Weed is very common, and often hangs down from the branches in masses a foot long. Hariot identified two epiphytes common on cocoa leaves in that island as *Cephaleuros virescens*, Kunze, and *Phycopeltis flabelligera*, Hans. Lichens, common on Ceylon cocoa trees, are: *Physcia speciosa* and species of *Lecani* and *Ramelinia*.

Fungus Diseases of Cocoa.—A large number of fungus pests attack the cocoa tree; some of these are purely local, whilst others, such as the "Brown-pod" disease of the fruit, *Thyridaria tarda*, are almost ubiquitous in every country where the tree is cultivated.

It is not proposed to follow the practice adopted by some writers of describing these various diseases under sub-heads in accordance with the particular portion of the tree which they generally affect, as some of the pests attack indiscriminately several portions of the tree above ground.

Losses sustained through Fungus Diseases.—The tremendous losses which agriculturists in different parts of the world have suffered from the ravages of parasitic fungi should be sufficient to convince the cocoa planter of the advisability of adopting suitable prophylactic measures with a view to protecting his trees from similar epidemics.

Rust in Australian wheat, during the season 1890–1, is estimated to have robbed the farmer of £2,500,000 sterling. During the latter year the ravages of parasitic fungi in Prussian cereal crops are estimated to have entailed a loss amounting to £20,500,000 sterling. The Ceylon coffee-leaf disease is reported to have resulted in a loss of nearly £15,000,000 sterling in ten years.

The cocoa planter should make himself acquainted with the general habit and the name of the commonest groups of the fungus parasites of plants, their means of attack, and the conditions which best favour their development. He should also bear in mind that many of the fungi are facultative. The saprophytes, which generally live on dead organic matter, may assume a parasitic habit, and parasitic fungi may in turn adopt saprophytic habits. Mycelium, or hypha, which constitutes the vegetative form of a fungus, performs similar functions in the way of assimilating nourishment for the fungus plant as roots and leaves perform for flowering plants.

The mycelium of parasitic fungi, with comparatively few exceptions, remains within the tissues of its host. The casual observer therefore only sees the fruiting or reproductive stage when that particular fungus plant may have completed its destructive work. Consequently it does not follow that because the reproductive form of a fungus has been discovered on dead tissues, it is a saprophyte, as it may have been the cause of their death. In the same way a particular fungus must not be considered responsible for the death of plant tissues because it is found growing on them, as it may be a saprophyte.

The difficulties associated with the attempts to exterminate epidemic fungus diseases are amply demonstrated by those adopted with regard to "Vine mildew," *Plasmopara viticola*, De Bary, "Wheat rust," *Puccinia graminis*, Pers., and "Coffee-leaf disease," *Hemileia vastatrix*, Berk. The necessity for adopting preventive measures by maintaining sanitary conditions in the plantation cannot be too strongly urged. Proper cultivation, selecting beans from disease-resistant plants, and the burning of diseased tissues are all prophylactic measures which also merit general adoption.

A stock of reliable fungicides, such as those recommended towards the end of this chapter, should always be kept, as well as suitable apparatus, such as sprayers, to apply them. A disease treated in its early stages usually may be checked and even extirpated, whereas this may be impossible if it be allowed to become rampant.

Vegetative and Reproductive Organs of Fungus Parasites.—Fungus diseases are most largely disseminated by means of spores; these for all practical reproductive purposes may be considered to take the place which seeds occupy in regard to flowering plants. Some forms of parasitic fungi, however, rarely produce spores, and perpetuate themselves by hibernating mycelium.

Spores are minute bodies, many thousands of which are required to cover a threepenny bit. They vary greatly in size and colour, and are produced in enormous quantities, which are readily distributed by wind, rain, insects, animals, man, and numerous other agencies. Any which happen to alight on a suitable host germinate, and, if the conditions favourable to their development be present, spread disease. The most propitious conditions for the development of parasitic fungi are heat and moisture. Sunlight generally acts as a deterrent, so that closely planted cocoa trees afford more encouragement to disease diffusion than those planted wider apart.

The *blights* mentioned in old writings referring to cocoa, were doubtlessly mainly due to fungus diseases.

De Verteuil, in his book on *Trinidad*, writes: "But in the year 1727, according to Gumilla, not a disease of the trees, but a *blight*, attacking the pods (fruits) under certain atmospheric influences, destroyed the crops."

It is, however, only within the last thirteen or fourteen years that specific cocoa diseases have been systematically studied.

It is probable, therefore, that the majority of the recently discovered diseases have been present in cocoa plantations for many years.

In conjunction with the study of the life-histories of the fungus parasites responsible for these diseases, considerable information has been acquired in regard to remedial treatment, which has satisfactorily demonstrated that practically the whole of them are amenable to treatment. Many diseases which had become rampant were rapidly reduced to a minimum by careful, systematic treatment. It is considered that the additional expenditure which the remedial measures involved was more than compensated for by the increased crops produced as a result of the improved sanitary condition of the trees.

Canker Disease, Nectria sp., in Ceylon.—A parasitic fungus disease, termed canker, was observed in Ceylon cocoa plantations in 1889, and Carruthers subsequently investigated the life-history of this pest and suggested remedial measures (*Circular*, Royal Botanic Gardens, Ceylon, No. 23, 1901). The fungus was referred to the genus *Nectria*, and on estates where the suggested remedies were adopted the spread of the disease was appreciably checked. This is still the most serious disease which affects cocoa in Ceylon. The mycelium of the fungus is rapidly diffused through the stem and branch tissues, but infected trees may live for months, and even years.

The symptoms associated with this disease are: a reduction of the crop, dying-back of branches, and a general lack of vigour in the tree.

Affected parts of the stem and main branches are often indicated by moist, dark patches on the bark. If such areas be excised the interior tissues of the bark will be found discoloured brown or reddish, in marked contrast to the much paler colour of healthy bark.

If the disease be allowed to develop, a gummy matter frequently exudes through the bark of the affected parts. Pustules of white or pinkish spores eventually appear on the bark, which are carried about by wind, insects, and other agencies, and further disseminate the disease.

Dense shade and excessive moisture encourage both the development of the disease in infected trees and also the propagation of the disease.

The excision of diseased areas and reduction of shade were attended with satisfactory results.

The dry season, when the trees carry a minimum quantity of flowers and fruits, is considered the best time to carry out the work of excising cankered tissues. At least a $\frac{1}{2}$ in. of the healthy bark surrounding the diseased portion should be cut away, in addition to the latter. A sharp pruning-knife should be employed for this operation. Where the cankered tissues extend more or less round the stem it would be advisable to remove them gradually, so as to avoid "ring-barking" and thus killing the tree.

Trees which have been excised should be examined periodically with a view to discovering whether the previous operation was effective and if new areas of infection have developed.

All excised tissues should be carefully collected and burned, as any left lying about the plantation may be the means of infecting healthy trees. It is advisable to antisepticise all wounds made in cutting out the diseased tissues by painting them with tar and resin oil. All wounds found on the trees should be similarly treated, as these afford convenient infection areas for the spores of the canker fungus. Badly infected trees which are producing healthy suckers from the base of the stem should be cut down just above them, as this will encourage the suckers to grow rapidly and to take the place of the parent tree. Branches or trees killed by canker should be pruned down and burned.

The advisability of reducing the shade to let in more sunlight to the cocoa trees should also receive due consideration. Where trees are densely shaded the excision of cankered tissues will not be attended with satisfactory results. Wright (*loc. cit.*) states: "On one area where the excising, collecting, and burning of cankered tissue was subsequent to the thinning out of the shade, the yield of the cocoa has been increased from 1 cwt. to approximately 5 cwt. per year. On an adjacent area where the shade was allowed to remain dense, but the other curative methods adopted, the yield remained almost stationary, the increase being only in this case from $\frac{3}{5}$ to 1 cwt. per acre per year.

The table given below shows the cost of canker excision and burning of diseased tissues at the Experiment Station, Peradeniya, Ceylon, during the year 1907 (*Annual Report*, Botanical Department, Ceylon, 1907).

Month.	No. of days.	No. of coolies employed.	Total cost.	Cost per acre.
			Rs. c.	Rs. c.
January	8	141	47 94	0 47
February	5	106	36 4	0 39
March	4	86	29 24	0 31
April	3	48	16 32	0 18
May	—	—	—	—
June	4	48	16 57	0 17
July	—	—	—	—
August	4	82	27 88	0 29
September	—	—	—	—
October	—	—	—	—
November	—	—	—	—
December	21	360	122 40	1 28

From the above-mentioned figures it is seen that the total cost per year of excising and burning diseased tissues on a cocoa estate affected with canker only amounted to 3 rupees 9 cents (4*s.* 1½*d.*) per acre.

This expenditure cannot be considered excessive when the gradual depletion of the crop is at stake. It should, however, be pointed out that the excising of cankered tissues commenced on the plantation in 1902, at which time nearly every tree was affected by the disease. The first year's operations are reported to have cost 17 rupees (£1 2*s.* 8*d.*) per acre, and that of the several following years cost from 8 to 12 rupees (10*s.* 8*d.* to 16*s.*) per acre. During this period diseased trees were reduced from 96 to 6 per cent.

Canker in the West Indies.—The principal fungus parasites responsible for cankered cocoa trees in the West Indies are *Nectria Theobromæ*, Massee, and *Calonectria flavida*, Massee. Both of these parasites are sometimes found in the same diseased area, and at other times they occur alone.

The symptoms of the West Indian canker diseases differ slightly from those of Ceylon canker. In the former, the bark of diseased areas presents a peculiar dry, greyish-brown aspect. The diseased bark is most evident during the dry season immediately after a shower of rain, as it does not dry so rapidly as healthy bark. During the early stages of the attack the bark, when cut, shows only a slight discoloration, but when the disease is more advanced a cut reveals a deep claret coloration. In the latter condition the bark is soft and moist, and the exterior, woody tissue is usually affected and assumes a dark brown colour. A brownish-red, gummy fluid subsequently oozes out of cracks which form in these areas; this is known as the bleeding stage. The dried, gummy exudations impart a rusty appearance to the bark.

Branches are frequently killed by becoming "ringed" with the canker, and even whole trees are destroyed when the disease affects the trunk near the ground.

One of the effects of canker on cocoa trees in Dominica is the production of an abnormal number of flowers which do not mature fruit. Cocoa trees which annually produce a phenomenally large number of flowers, and have never been known to produce mature fruits, have been observed by the writer both in the Gold Coast and in San Thomé; in these instances this was purely a teratological character, as the trees exhibited not the slightest trace of being diseased.

The fructifications of both *Nectria Theobromæ* and *Calonectria flavida* usually may be found on diseased bark during the rainy season.

Two forms of spores are produced, viz. conidiospores and ascospores. The former appear first in the form of white pustular-like mould through cracks in the diseased bark. Later in the same places, colonies of perithecia appear. A single perithecium is about the size of a grain of red pepper and contains numerous asci in which the ascospores are placed. The perithecia of *Nectria Theobromæ* are red, while those of *Calonectria flavida* are yellow.

The preventive and remedial measures to apply to these parasites are similar to those suggested with reference to the canker disease of cocoa in Ceylon.

Die-back and Brown-Pod Disease, *Thyridaria tarda*.—For the following remarks on this ubiquitous cocoa pest, the writer is indebted to Mr. H. Bancroft, of the Jodrell Laboratory, Royal Botanic Gardens, Kew:

"*Diplodia cacaoicola* (*Thyridaria tarda*) was described by Hennings in 1896 on the wood of the cacao plant from Kamerun. It has since then been shown to occur in Tropical America (including the West Indies), Java, Samoa, Ceylon, the Philippines, and San Thomé. It ranks among the most injurious of the pests of cacao and also possesses the widest area of geographical distribution.

"The fungus attacks the stem and fruits of the cacao plant. On the stem the disease is popularly known as 'die-back.' The young shoots first show symptoms of disease; they commence to die at their tips and proceed to die back toward their bases; if the disease is allowed to proceed unchecked the older branches and finally the trunk usually become affected. In some cases the growth of the fungus has been known to be limited to a definite area on the trunk or on a branch; it then produces a canker-like spot on this area.

"On the fruits the disease is known as 'brown-pod'; it makes its appearance in the form of a discoloration at one or other end of the fruit. The discoloured area extends until the whole, or nearly the whole surface of the pod becomes dark brown in colour. The fungus spreads through the tissues of the 'shell' to the mucilaginous coat surrounding the beans and finally attacks the beans themselves.

"The fungus can only effect an entrance into the stem through a wound; in the case of the fruit, however, it appears to be capable of entering through the unwounded basal or stigmatic ends. All wounds made on the stem by pruning, or such as have arisen from other causes, should be sealed with coal-tar or with a mixture of coal-tar and clay. Care should be taken not to confuse the disease caused by *Diplodia* (*Thyridaria*) with the dying off of the tips of young shoots which commonly occurs on cacao plantations from drought, want of shade, etc. Diseased shoots should be cut off at a distance of 6 in. to 1 ft. from the nearest dead end; diseased fruits should be removed from the tree. All diseased material should be buried in pits with lime. A vigorous growth of the plant induced by good sub-soil drainage, green manuring, and careful pruning has been shown to render it less liable to attack. Spraying of the fruits with 'Bordeaux Mixture' has yielded good results in some countries. Spraying should commence when the fruits are just 'set,' and should be repeated at intervals of two or three weeks.

" The fungus is known to occur on other hosts ; in the West Indies it occurs on the sugar cane, on *Castilloa*, and has recently been reported to cause a root-disease of the Coco-nut Palm ; in Ceylon it is said to cause the later stages of a 'die-back' disease of *Hevea brasiliensis*, and also to occur on tea and on *Albizzia moluccana*."

In addition to the countries quoted by Bancroft, *Thyridaria tarda* occurs in cocoa plantations in the Gold Coast and Fernando Po.

The life-history of this parasite was worked out by Howard. The spores are produced just beneath the epidermis in Pycnidia. They are first expelled in the form of white powdery dust, which later turns black, and consists of elliptical, uniseptate, brown-black spores. He conducted experiments which indicated that the fungus is a wound parasite and capable of readily infecting trees in which wounds are present or those not in a vigorous state of health.

The fungus is facultative and able to live on both dead and living fruits and branches. It is therefore obvious that when the disease is prevalent, dead tissues should be buried as a preventive measure.

An experiment conducted on the La Perle estate, St. Lucia, has shown that this disease may be defeated by high cultivation, manuring, and attention to careful pruning. It has been almost exterminated on this estate, and the yield of cocoa is reported to have been increased from almost nil to over 1,000 lb. of cured cocoa per acre in six years.

Thyridaria tarda causes serious losses to San Thomé cocoa planters. Its attacks are, however, mainly restricted to the fruits, which it attacks in all stages. It is most prevalent during the rainy season, in densely shaded areas and in hilly districts where the atmosphere is frequently saturated with mist.

On one large estate which the writer visited the disease was almost absent from those portions which were situated at from 1 to 400 ft. above sea level, but gradually increased in virulence from the latter elevation up to 2,000 ft.

On some of the trees growing at the last-mentioned elevation as many as 95 per cent. of the fruits were attacked. When the young fruits are infected their growth is arrested as the disease develops and the beans are not matured. The fruit turns brown, the tissues decompose, and they may fall to the ground or remain on the tree and infect healthy fruits. When the disease attacks a fruit at a later stage it may grow to its normal size and be harvested with properly matured fruits; it differs from them, however, as both the enveloping mucilage and the integuments are usually dried up and sour smelling. Once a fruit has been infected with the disease there appears to be no means of checking its spread. The importance of burying diseased fruit shells and fruits which have been destroyed by the fungus previous to maturation cannot be too much insisted on.

When the shade is too dense this should likewise receive attention.

Good results are reported to have attended the spraying experiments carried out at the Experiment Station, Peradeniya, Ceylon, to check a *fungus* disease of cocoa fruits. The following table, taken from the 1907 *Report of the Ceylon Botanical Department*, demonstrates the reduction in the number of diseased fruits harvested.

Month.	1907.	1906.	1905.	1904.	1903.	1902.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
January .	1·4	1·8	1·1	1·3	2·2	
February .	1·2	5·3	1·3	1·3	2·4	
March .	·3	2·6	1·7	1·1	2·6	
April . .	·3	2·9	1·2	0·5	0·9	
May . .	·8	4·6	1·5	0·6	1·7	24·0
June . .	2·3	3·4	1·1	7·5	2·9	13·0
July . .	3·1	9·3	4·2	21·0	4·0	25·0
August .	28·5	5·9	12·3	27·4	3·2	60·0
September .	22·4	18·8	6·7	7·7	13·5	62·0
October .	10·9	13·3	4·5	4·5	22·8	60·0
November .	12·2	2·7	1·3	7·2	9·3	34·0
December .	4·3	2·0	2·4	3·5	4·5	28·0

Bordeaux Mixture was the fungicide employed, and the same report shows that the fruits on 196 acres of cocoa trees were sprayed at a total cost for labour of 82·6 Rs. (£5 10*s.* 1½*d.*), or an average cost of 6¾*d.* per acre.

Witch-Broom Disease, *Colletrotrichum luxiferum.*—This disease is also due to a fungus parasite; it has caused serious damage in Surinam cocoa plantations, and has also been found on cultivated cocoa trees in British Guiana and Trinidad. The extent of the losses sustained by the ravages of this pest in Surinam may be estimated by the falling off of the cocoa crop from 1,290 tons in 1895 to 464 tons in 1899. The popular name of this disease is due to the hypertrophied growths that it induces; which in conjunction with the numerous lateral branches, formed in clusters, resemble small brooms. Fruits are also affected by it; these do not develop to a normal size, but become indurated. The parasite responsible for this disease was originally described as *Exoascus Theobromæ*, Ritz Bos, but the more recent and extensive researches of Van Hall and Drost in Surinam have proved that it is due to an entirely different fungus, i.e. *Colletrotrichum luxiferum.* The following information on this subject has been extracted from Fredholm's translation (*Proceedings of the Agricultural Society, Trinidad*) of the report of these two investigators.

The first symptoms of the disease are usually the abnormal development of shoots, which are generally from two to six times as thick as healthy ones, in conjunction with a strong tendency to produce side shoots and leaves which remain soft and flimsy. On diseased twigs the buds begin to grow before they have matured; they seldom bear leaves themselves, but are supported at the base by an abnormal leaf. Some trees have been observed which did not carry a single healthy twig.

The texture of the "witches'-brooms" is herbaceous and fleshy, and they never become woody. The growths develop quickly, but their life is short, drying from the base upwards and dying in about two weeks. Severely attacked trees are covered with "witches'-brooms"; when these latter die, infection of the tree by wound parasites is facilitated, and *Thyridaria tarda*, the "die-back" disease previously described, is commonly met with on such trees.

In addition to the induration of the fruits which the disease occasions, the fruit-stalks and even the fruits themselves may be hypertrophied. In the latter case one or more "humps" are formed which, when cut in section, show brown streaks in the affected tissues. Such fruits never ripen, but fall before they are half grown. Other disease-infected fruits show one or two black blotches, the tissues of the shell are stone hard, changing first to a brown and later to a black colour, and eventually die. These fruits may contain beans which are apparently sound, together with several mucilaginous beans.

Another symptom of the disease is that of "Star blooms," which consists in the production of a large number of flowers crowded together, vegetative shoots developed into small "witches'-brooms" being frequently found among the flowers. The "cushions" from which the flowers arise may be hypertrophied, from which spring side shoots that branch and give rise to fascicles of flowers. Fully developed fruits are rarely produced from "Star blooms," but irregularly shaped fruits are sometimes formed, which on being cut in section are found to consist of a thick rind with five small cavities devoid of beans.

It is considered that infection of both twigs and flowers takes place only at very early stages of their development, and that this is effected by spores which fall on vegetative buds or on the cushions from which flower-buds issue.

The productive capacity of certain trees is diminished, while others die from the effects of this disease.

Before the outbreak of the disease in Surinam the average yield of cured cocoa was estimated at 440 lb. per acre; in 1904 the yield had fallen to 72½ lb. per acre. The area under cocoa cultivation had decreased from 15,828 acres in 1903 to 13,481 in 1908 as a result of the abandonment of diseased plantations.

Owing to the decreased vitality of affected trees they are rendered more susceptible to the attacks of the "cocoa beetle" (*Steirastoma depressum*).

With regard to trees dying, it seems possible that in most cases *Thyridaria tarda* is eventually responsible for death, as it enters the dead "brooms" and then penetrates into the living tissues.

Young plants, placed out in the vacancies caused by the death of trees from disease, are generally attacked, so that only a few survive. Not infrequently whole nurseries of young plants are destroyed.

It has not been noticed that any particular variety of cocoa is less susceptible to the disease than others.

The quantity of shade appears to have no influence on it, but humidity is favourable to its development.

The remedial measures suggested consist of the lopping and burning of all leaf-bearing branches, tarring the ends of the stumps, and spraying the pruned trees with a 3 per cent. solution of sulphate of copper. This solution not only destroys the fungus spores, but moss and similar small epiphytes on the trees as well. The "Deming Success" pump-sprayer was employed to apply the spray, and is reported to have given satisfaction.

Trees which were treated in this manner produced new crowns in a surprisingly short time, and comparatively few "witches'-brooms" appeared during the first year following the pruning operation.

The principal dry season, when growth is least active, is considered the best time to carry out the work of pruning and spraying.

Subsequent pruning operations recommended entail the removal of undesirable growths which form on the trunk and main branches, and also of any "witches'-brooms" which appear, together with a small portion of the growth below the diseased area.

Trees which had been lopped commenced to produce new foliage in from fourteen to twenty-one days. A few of these trees yielded fruit the first year after being lopped. Two years after lopping a moderate crop was obtained, but it is anticipated that a normal crop would not be yielded until the third season. A plantation of cocoa trees which had been treated in the manner described above yielded 5, 2½, and 2½ per cent. of indurated fruits during the first, second, and third years respectively following the lopping.

The rate at which the yielding capacity of lopped trees increases is well demonstrated by the results of the experiments described below:

Experiment field No. 1.; 5 acres in area, containing 900 trees, forty years of age, which were lopped in November 1904:

Date.	Yield of cocoa.		
	Total.	Per acre.	Per tree.
	Kilos.	Kilos.	Kilos.
1905 (no crop) . .			
1906	516	103	0·573
1907	510	102	0·566
1908	1,207	241	1·341

Experiment field No. 2: 15 acres in area, containing 2,320 trees, forty years of age, which were lopped in November 1905:

Date.	Yield of cocoa.		
	Total.	Per acre.	Per tree.
	Kilos.	Kilos.	Kilos.
1906 (no crop)			
1907	810	54	0·349
1908	3,216	214	1·386

On the same estate as Experiment fields Nos. 1 and 2 were 187½ acres which contained 34,496 fruiting trees. These were not lopped, and the crops which they yielded during the same years are given below for comparison with those of the experiment fields.

Year.	Yield of cocoa.		
	Total.	Per acre.	Per tree.
	Kilos.	Kilos.	Kilos.
1905	6,000	32	0·174
1906	4,600	2·45	0·133
1907	11,200	59·6	0·325
1908	7,799	41·5	0·225

The crop from the pruned trees was doubled in the first three years, while that of the first four years was nearly three times as great as that from the untreated trees, although no crop was obtained from the pruned trees during the first year following the pruning.

The indurated fruits produced in the experiment fields was 5 per cent. and 2½ per cent. in 1906 and 1907 respectively, while those produced by the untreated trees amounted to 50 per cent. of the ripe fruits harvested in April and May.

At another estate where lopping experiments were carried out in 1905 an average yield of 1·32 kilos. of cocoa per tree was obtained in 1908. From another block of trees which were lopped in 1905, an average yield of 1·347 kilos. of cocoa per tree was harvested in 1908.

The expenditure incurred by lopping and spraying is estimated at 1*s.* 8*d.* per acre, which was compensated for by the increased yield obtained within two years.

Lasiodiplodia.—The complete life-history of this fungus parasite of the cocoa tree has not been fully investigated. It occurs in cocoa plantations in San Domingo, Brazil, and several of the West Indian islands. Barrett, who spent several months in 1907 studying the various fungus diseases attacking cocoa trees in Trinidad, estimated that between 50 and 75 per cent. of the young cocoa fruits are destroyed by fungus parasites in that island. Of the total losses suffered from these pests he considered 90 per cent. were due to a species of the genus *Lasiodiplodia.* It infects the fruits, stems, and branches, and it is considered possible that the roots are also infected by it.

Infection experiments carried out at Dominica tended to prove that this fungus is only weakly parasitic in habit, and it was therefore supposed that infection might take place through wounds. In Dominica the growth of the fungus is said to be slow and trees may be infected for a considerable time before they are killed.

According to Barrett the disease known as "brown rot" in Trinidad is due to *Lasiodiplodia.* The invasion of the skin of the fruit, especially in its earlier stages, occurs either at the tip or at the base. Spores lodging in the sinus, at the junction of the pedicel and the fruit, where moisture is more constantly present than on any other portion of the fruit surface, may germinate and effect an entrance through the cuticle into the tissues of the fruit-wall. As rain and dew also collect at the opposite or stigmatic end of the fruit it is considered possible that germinating spores may less frequently inoculate the fruit at this point.

The mycelium of the fungus spreads through the tissues of the fruit-wall and then attacks the mucilaginous envelope of the beans and eventually the beans themselves. Infected fruits in Dominica and Grenada present a scabby appearance; small, blackish, corky patches being produced on the surface. Such fruits do not properly develop, and they do not usually decay, but the beans are frequently smaller than those of healthy fruits. Specimens of diseased roots and stems of cocoa were examined by the Mycologist of the West Indian Department of Agriculture. Large numbers of septate, dark-coloured mycelial threads were found in the vessels of the roots, as well as in the vessels, medullary rays, and other cells of the stems.

Trees affected with this disease in Dominica lack vigour, present a dwarfed appearance, and the branches die back. Blackish fructifications have been noticed pushing through the bark. Cankered trees have been observed in Grenada, where *Lasiodiplodia* appeared to be following the old canker-affected areas. Canker is, however, attributed to this disease in Trinidad.

Manuring and high cultivation have been attended with good results in regard to cocoa trees affected with this disease in Dominica. It is generally found in districts where the soil is not well suited for the cultivation of cocoa. Where the fungus causes canker it should be attacked by the measures already suggested with reference to cankered trees. If it attacks the fruits and causes the branches to die back the remedies recommended in regard to *Thyridaria tarda* might be applied.

Black Rot of Fruits, *Phytophthora omnivora*, De Bary.—This disease is ubiquitous in cocoa plantations in both Trinidad and San Thomé, and has also been found attacking cocoa in St. Lucia, St. Vincent, British Guiana, and Surinam. Affected fruits are turned black and become covered with the mycelium of the fungus. The ovate conidia borne upon the mycelium are carried about by the usual agencies, and disseminate the disease. Conidia which fall on fruits germinate, and if the conditions be favourable, penetrate the fruit-wall. The fungus mycelium then rapidly spreads through the tissues and frequently destroys the fruit. The latter becomes black and hard; it may hang on the tree for a considerable time and is eventually enveloped in white mycelium and conidia.

Resting spores (oospores) are formed by a sexual process within the fruit, and these are liberated when the latter decays and still further aid in spreading the disease.

Dense shade and excessive moisture favour the development of the parasite, so that when these conditions obtain they should be remedied. All affected fruits should be collected and buried with lime, which destroys the disease producing organisms. Where the disease is prevalent it would be also advisable to treat in a similar manner the shells of ripe fruits from which the beans have been extracted. Should the disease show signs of developing into an epidemic spraying the trees with Bordeaux Mixture must be resorted to.

Another species of *Phytophthora*, viz. *P. Faberi*, Maublanc, is responsible for cocoa fruit disease in Ceylon, and it has already been shown that spraying with Bordeaux Mixture was attended with satisfactory results.

Root Disease.—The roots of cocoa trees have been frequently found attacked by fungus mycelium, the parasite being unidentifiable as no reproductive bodies were discovered. Barber investigated such a disease in Dominica in 1892–3, as also did Howard in Grenada some nine years later. A similar disease has been reported from Jamaica and St. Lucia, and the writer has recently observed the roots of cocoa trees affected in a like manner in San Thomé.

Although no reproductive bodies were found in the latter case the general habit and effects closely resemble those of *Armillaria mellea*. An affected tree presents an unhealthy appearance. The foliage is under-sized and of a yellowish hue. Gradually the young branches die and eventually the whole tree may be destroyed. It is not infrequent to find several contiguous trees affected in this manner.

Diseased roots turn black and eventually decay. Upon careful examination white mycelial threads are observed. These frequently form a web between the bark and the woody tissues of the root. The interior tissues are also permeated by the mycelium, and when all the principal roots have been attacked the tree dies. Although the young mycelium is white it later becomes grey and eventually may assume a pale brown tint.

The underground mycelium passes from the roots of one cocoa tree to those of another providing they be adjacent, or it may in the same way pass from a cocoa tree to a shade tree. Its origin in some instances has been traced to the roots of shade trees.

Stockdale, who has investigated a fungus root-disease affecting cocoa trees in the West Indies, remarks (***Fungus Diseases of Cocoa, etc.***, Pamphlet Series, No. 54, 1908, Imperial Department of Agriculture for the West Indies): "Trees are rarely killed off singly, but usually in patches. These patches of dead trees, unless something is done, increase in size; and it has been observed in Dominica, when the disease has been neglected, that areas of nearly an acre in extent have been destroyed. It has been frequently noticed—though this is not always the case—that these patches, when they are quite small, are circumscribed by the spread of roots from trees that have been used for shade. Pois-doux, bread-fruit, bread-nut, mango, pomme-rose, and avocado pear, which are dead or dying, have been commonly observed in the centre of a diseased area of cocoa, and it has been suggested that the fungus attacks the dead or dying roots of these trees and then affects the young roots of the cocoa. . . . In Dominica it has been found that cocoa has become affected where none of the above-mentioned trees were present, and it was difficult, owing to the length of time that elapsed since the disease first appeared and when investigations were made, to establish clearly at what spot the disease commenced."

The same writer suspects that more than one species of fungus may be associated with the malady, and that the disease may originate from the fungi found on the decaying logs lying about the plantation. If the latter surmise be correct it is obviously necessary for the cocoa planter to destroy by fire all such logs as well as any dying trees in the plantation.

Trees affected with the disease should be isolated by digging a trench at least 2 ft. deep and 1 ft. wide around them. The soil taken from the trench should be thrown within the disease-infected area. Trees adjacent to the diseased area should be frequently examined and any which show signs of disease infection should be isolated in a similar manner. Stockdale (*loc. cit.*) recommends that the whole of the trees in the isolated area should be examined and those most badly diseased extracted and burned. Trees less seriously affected should have the soil removed from their principal roots and the diseased portions removed and burned. The holes made around the trees by the removal of soil should be given a dressing of about 5 lb. of lime, and the soil should then be replaced. Where the root area has been considerably reduced the branches should be heavily pruned to prevent the tree suffering from excessive transpiration.

He further advises that the whole of the isolated area should then be properly forked and a dressing of quicklime broad-casted at the rate of about 10 lb. per tree. Later, applications of pen manure and mulchings should be given, and in the succeeding year a dressing of lime at the rate of 3 or 4 lb. per tree should be given. It is reported that in Dominica and St. Lucia, where planters have adopted remedial measures similar to those previously described, considerable numbers of trees have been saved. It has been amply demonstrated that when such measures have been adopted during the early stages of the attack the disease may be successfully treated.

Pink Disease, *Corticium lilaco-fuscum*.—Cocoa trees attacked by this disease have been observed in Dominica and St. Lucia, but up to the present no serious damage has been attributed to it.

Young branches frequently become incrusted with the pink fungal threads of this parasite ; these force their way into the bark tissues and may even penetrate the wood of young growths. As a result the bark cracks and peels off, but branches are rarely completely killed by the disease.

It is, however, necessary to keep the disease in check, as the fissures which it causes in the bark afford convenient infection areas for the spores of the various wound fungi. Badly infected branches, or any which may be killed by the disease, should be pruned off and burned. Stockdale is of opinion that the fungus may be destroyed by washing affected branches with a lime-sulphur wash. The latter may be made by mixing 7½ lb. of slaked lime with 2½ lb. of flowers of sulphur in 10 gallons of water, and boiling this mixture until it turns an orange colour.

Affected branches should be well rubbed with the mixture when it has become cold.

Thread Blights.—The branches and leaves of cocoa trees in several of the West Indian islands have been found affected with strands or threads of sterile mycelium. Microscopical examination of these threads by the Mycologist of the West Indian Department of Agriculture showed that they are composed of parallel-running, fungal hyphæ closely woven together. When the hyphæ penetrate through the cortex to the deeper tissues of a growth the latter is frequently destroyed. Leaves and young buds may be killed in a similar way.

Thread blights are spread by the mycelium on dead twigs and leaves which are carried by the wind to healthy trees.

A disease of a somewhat similar nature was observed by Hart on cocoa trees in Trinidad. The threads closely resemble a tuft of horse-hair caught in the twigs, and the name "horse-hair" blight has been given to this disease. In this case some of the threads were closely attached to the bark from which hyphæ were given off and penetrated to the deeper tissues of the branches. The fungus responsible for this disease was determined at Kew as *Marasmius equicrinus*, Mull.

These diseases are not of a serious nature, and may be readily checked by pruning off and burning the affected portions of the trees.

Similar diseases have been recorded in Ceylon, India, and Java, where they affect tea and nutmeg, tea, and coffee respectively.

Fungus Diseases of Minor Importance.—*Nectria Bainii*, Massee, is the name given by the Kew authorities to a disease which attacks cocoa fruits in Trinidad. It causes semicircular dark blotches to appear on the fruit-walls, and the affected portions become soft and watery. Eventually these become covered with a yellow or orange-coloured mycelium, from which small, red perithecia are produced.

At present the distribution of this pest is somewhat restricted. Probably the methods suggested for the control of "brown rot" of the fruits would be effective in checking the spread of *Nectria Bainii*.

Taphrina Bussei, Faber, or "Balais de Sorciére," is said to attack the branches of cocoa trees in Kamerun. The remedy suggested is the cutting out and burning of affected parts, in conjunction with the heavy pruning of the trees, to facilitate the admittance of sun and air.

Fungicides.—These are plant poisons diluted to such an extent that they are inimical to the thick-walled tissues of the host-plants, but are nevertheless sufficiently strong to destroy the tender fungus-tissues. It is therefore apparent that their application can have no effect upon the mycelium within the tissues of the host-plant.

It has been already pointed out that several of the most pernicious fungus parasites of cocoa can be held in check by spraying the tree with suitable fungicides.

The following have been therefore selected from those which have given the best results in the treatment of these pests.

Bordeaux Mixture.—This is one of the most efficient fungicides, and is probably more largely employed than any other. It may be prepared in the following manner:

Weigh 20 lb. of copper sulphate, and immerse this, tied up in a piece of sacking, in 80 gallons of water. Slake 15 lb. lime; add water in small quantities and stir until a perfectly smooth paste is obtained; then add sufficient water to make 80 gallons of lime water. Thoroughly stir this, and when it is cool slowly mix it with the water in which the copper sulphate was dissolved. It is advisable to prepare the mixture on the same day it is required and not to use iron or tin vessels, as the copper sulphate corrodes these metals. The mixture, after being carefully strained, is ready for use.

Ammonia and Copper Carbonate Mixture.—Take 1 lb. of carbonate of copper and mix this with 5 lb. of carbonate of ammonia, and thoroughly dissolve the mixture in hot water. This forms the stock solution, which, previous to application, should be diluted by adding sufficient cold water to make 256 gallons.

Potassium Sulphide Solution.—Mix potassium sulphide, i.e. "liver of sulphur," in the proportion of 1 lb. to every 4 gallons of hot water to form the stock solution. This must be made up to 36 gallons, by adding cold water, before being applied.

Each of these three mixtures should be applied with sprays fitted with nozzles which distribute the solution in the form of a fine mist.

CHAPTER XIII

HARVESTING AND TRANSPORTING

Fruiting Age.—The age at which cocoa trees commence to bear fruit varies in different countries. In the Gold Coast and San Thomé fruit usually is produced when the trees are from three to four years of age. Dodd informs the writer that cocoa trees in Southern Nigeria also commence to bear fruit at this age. According to a report by the Governor of Fernando Po, fruit is not produced in that island until the trees are four or five years of age. Trees three and a half years of age produce fruit in Samoa and also in Trinidad and Ceylon.

In Ecuador, cocoa trees do not bear fruit until the sixth year, while in Grenada the trees do not commence to bear a great crop of fruit until the fifth year.

Preuss mentions that the Nicaraguan-criollo cocoa tree does not commence bearing in Nicaragua until it is six years of age, but the same variety produces fruit in Ceylon at least two years earlier.

It is most essential to harvest the fruit at the proper time to ensure the beans being correctly fermented and cured, and placed on the market in good condition. The beans of immature fruits are not properly developed, and after being fermented and cured become shrivelled and unsightly. Undeveloped beans do not ferment readily when placed in the fermenting receptacles, and when mixed with well-ripened beans the cured product will contain a number of imperfectly fermented, shrivelled beans.

On the other hand, when ripe fruits are allowed to hang for too long a time upon the trees fermentation often commences in the fruit and the beans germinate. When mixed in the fermenting receptacles with beans of a proper degree of ripeness, those which have already been submitted to a certain amount of fermentation will obviously require a shorter further period of fermentation than the properly ripened beans. Consequently an uneven sample is obtained, and unless very careful grading is practised the commercial value of the product will be depreciated.

Characters of Ripe Fruit.—Unless very great care is exercised by the pickers a certain amount of both over-ripe and under-ripe fruits will be harvested. These should be sorted out from the bulk and the beans taken from them should be fermented separately.

The external appearance of a properly ripened fruit varies considerably in different varieties. In all varieties, however, when the fruit is ripe the beans detach themselves in a mass from the fruit-wall, and when the latter is rapped smartly a hollow sound is heard; if immature fruits are similarly treated only a dull sound is heard.

The colour of the ripe fruits of different varieties varies from a pale canary-yellow to a dark chocolate-red.

The six varieties of fruits illustrated in Plates 1 and 2 vary in this manner. Nos. II, III, IV, and V are of different shades of yellow, while Nos. I and VI are different shades of red.

When cross-fertilisation has taken place, a tree which usually produces fruits of a yellow colour when ripe may have some fruits tinged with red. This is another important reason why different varieties should be separated in the plantation. For example, when several varieties which produce fruits all of different shades of yellow when ripe are mixed together in the plantation, it is inconceivable that the average estate labourer will be able to discriminate between them and decide what shade of yellow indicates ripeness of the fruit of each variety.

Nor is the method of tapping fruits to ascertain their degree of ripeness always practicable or even possible. Far too much time would be lost if the pickers were sent into the plantations with instructions not to harvest fruits which did not give, when tapped, the characteristic sound which is indicative of maturity.

Collection.—It is preferable to collect frequently, especially during the biggest crop season. This will tend to obviate the danger of fruits becoming over-ripe on the trees, and fruits which have not assumed the characteristic hue associated with ripeness may with less likelihood of deterioration be left on the trees.

Extreme care should be exercised in severing the fruits from the trees. The cocoa tree produces the greater part of its fruits on the trunk and main branches, and flowers and fruits may be produced from the same region for many consecutive years.

The first flowers are produced in the neighbourhood of a leaf scar; they may be solitary or in groups. It is estimated, however, that less than 1 per cent. of the flowers develop into mature fruits, although two, three, and even six fruits eventually may develop from one group of flowers.

Six months usually elapse between florescence and the maturation of the fruit.

If a young cocoa tree which is bearing its first crop of ripe fruits is examined, it will be observed that the stem is slightly swollen at the point where a fruit-stalk is attached. Should the fruit be separated from the tree by cutting through its stalk with a sharp knife, so as to leave a piece of the stalk adhering to the stem, a layer of cork-tissue subsequently forms at its base, which cuts off its connection with the stem and it falls to the ground. At the point of separation a slight depression is observed in the swelling or cushion on the stem. In Plate 7 can be seen sections of fruit-stalks adhering to the trunk, and also nicely healed, scar-like depressions from where fruit-stalks have fallen.

The large protuberances shown on the stem in the same plate are the result of the swellings formed during the production of fruit of several seasons. New flowers and fruits also may be seen springing from them.

Let us return to the young fruiting tree. If the ripe fruit is carelessly pulled off, part of the cushion-like swelling at the base of the fruit-stalk in all probability will be removed with it, and the tree's power of producing further crops of flowers and fruits from that region will be checked. Similarly, when a fruit is torn from an older tree, part of the cushion almost invariably is wrenched away with it.

FLOWERS, FRUITS, AND PERENNIAL "FLOWERING CUSHIONS" OF THE COCOA TREE

p. 116]

The labourers frequently climb the trees to collect the fruit from the high branches, and by this means cause considerable damage to the "flower-cushions."

The wounds caused by careless picking also afford convenient openings for disease infection.

It will thus be apparent that unless due care be exercised in reaping cocoa fruits the productive capacity of the trees will be appreciably diminished.

Reaping Implements.—All the fruits on the lower part of the tree should be severed by means of a sharp knife; those out of reach can be cut by means of variously shaped cutting-implements supported on poles of convenient length. There are numerous forms of the latter in use; some are shaped like a small bill-hook, with either a sharpened, pointed extension above the hook, or an extension with a cutting edge at right angles to the handle. Another has its cutting edge in the shape of a V. West African natives often employ a flattened, spear-shaped cutter, with which they are particularly dexterous.

Whatever form of cutter be employed it is most important that it should be made of first-class material, capable of maintaining a keen edge. It is impossible to sever properly a cocoa fruit with a blunt instrument, whatever its shape may be.

The main requirements of a cocoa reaping-knife are that, (1) it should sever the fruit-stalk without dragging or tearing the tissues, and without injury to the "flower-cushion"; (2) it will detach satisfactorily a ripe fruit from a bunch of immature ones; (3) it should be light in weight, but at the same time strong, durable, and capable of being easily sharpened.

However well an implement may be adapted for cutting the fruit it is certain to prove destructive in the hands of a careless operator. The collection of fruit requires as much careful supervision as any other operation connected with the production of cocoa, for upon its proper performance depends, in a large measure, not only the quality of the actual crop being harvested, but also the quantity of subsequent crops. The quality of the crop is affected by the cutting of immature fruits and by missing the ripe ones, which become over-ripe by the time the next collection takes place. Injuries caused to the "flower-cushions" by the careless handling of reaping-knives must tend to diminish subsequent yields.

Bean Extraction.—On some estates the beans are extracted from the fruits in the neighbourhood of the collecting grounds, on others the fruits are conveyed to the fermenting-houses and the beans are extracted there. The latter method has certain advantages in its favour, for the beans can be protected better from rain, which impairs their fermentative properties, and there is less likelihood of their becoming contaminated with foreign substances.

The fruit-shells contain valuable plant-foods, and it is advisable to incorporate them in the soil, so that their conveyance to the fermenting-house and back to the plantation entails unnecessary labour.

The fruits are usually broken open by hand. On some estates a knife is used; the operator holds the fruit in the palm of one hand and the knife in the other, a transverse cut is made in the shell of the fruit and a sharp jerk of the knife-hand splits it open. A certain amount of skill is required to prevent the knife injuring the beans.

On other estates the fruits are beaten with a small, heavy club, or the fruit is banged on a hard substance until it is sufficiently crushed to be easily opened. Usually the beans are extracted by different labourers, as one labourer opening the fruits can keep two others employed in extracting the beans and separating the stringy placentas from them.

When the fruits are opened in the plantation, frequently the beans are placed on banana leaves spread on the ground preparatory to being transported to the fermenting-house. This method is open to objection, as it entails unnecessary labour in removing the beans to various receptacles before they can be taken to the fermenting-house. A better plan is to supply the labourers who extract the beans with baskets or some similar article in which the beans can be placed as they are extracted from the fruit-shells. Suitable baskets for this purpose can be made of strips cut from the petiole of various palm leaves.

Beans which have commenced to germinate or have been injured by fungus, insect, or animal pests should be placed apart and fermented separately. This will save much labour when the cured beans are being graded for market.

Necessity for Expediting Transport of Beans from the Plantation to the Fermenting-House.—When the freshly extracted beans are bulked, fermentation soon commences, and especially during hot, damp weather. It is therefore necessary to convey them to the fermenting-house as soon as possible in order to prevent fermentation occurring in the plantation. To enable this to be effected the labour force should be so organised that the work of collecting the fruits, extracting the beans, and transporting them to the fermenting-house proceeds uninterruptedly.

If at the end of the day it is found impossible to place all the beans extracted in the fermenting-boxes before the next day, these should not be mixed with those extracted on the following day, as fermentative changes almost invariably will have commenced in them. On one occasion in San Thomé the writer found that the temperature of a heap of beans which had been left in the plantation for twenty-four hours had risen 7° Fahr. during that period.

The actual records taken were as follows:

Date.	Hour.	Shade temperature.	Temperature of cocoa beans.
		Fahr.	Fahr.
November 4, 1909 .	5.30 p.m.	94°	96°
November 5, 1909 .	8.0 a.m.	76°	99°
November 5, 1909 .	5.30 p.m.	80°	103°

At one estate the writer visited in San Thomé a fruit-breaking machine (manufactured by Masson, New York) was in operation. It appeared to be serviceable, but so many difficulties were experienced in moving it about the plantation that it is extremely doubtful whether it will replace hand labour. The manager was of the opinion that its cost did not justify its employment.

Decauville Railways.—On large cocoa estates the transport of the beans to the fermenting-house is extremely costly, even when wagons or carts, drawn by horses, mules, or bullocks, are employed.

Aerial ropeways, similar to those used on Ceylon tea estates for conveying the freshly plucked leaf to the factory, would provide a more expeditious and probably a more economical method for transporting cocoa beans to the fermenting-house than the employment of animal-drawn vehicles.

On several of the large cocoa estates in San Thomé the cocoa beans are conveyed to the fermenting-house in small wagons which run on light Decauville railways. The fermenting-house usually is situated at the lowest part of the estate, and the rails are so arranged that the wagons descend by gravitation. Each wagon is supplied with a substantial brake at each end by which the speed may be regulated down steep inclines. The writer travelled by this means on one of these wagons over 40 kilometres (25 miles) of these rails on the "Rio do Ouro" estate in San Thomé. The rails are placed 65 cm. (26 in.) apart. The total length of Decauville rails, on the "Rio do Ouro" estate, which ramify the plantations in all directions, is 102 kilometres (63 miles).

In addition to these a more substantial line of rails, 85 cm. (34 in.) wide runs, from the curing-houses to the landing stage, on which the cured cocoa is transported in wagons drawn by a small locomotive. This line is 10 kilometres (6¼ miles) in length.

A mule is sufficient to draw the empty wagons from the fermenting-house to the different parts of the plantations where the fruit is being harvested. At convenient distances small sheds are placed alongside the rails. The floor of these sheds slopes towards the rails, and is arranged so that a wooden trough connects it with the top of a wagon drawn up alongside. As the cocoa beans are extracted from the fruit-shells they are placed in baskets. When a basket is filled it is taken to the nearest shed and emptied therein. When the shed is full a wagon is sent for and the beans are shovelled into the wagon through a trap-door opening, situated in the front of the shed on a level with the floor. Plate 8 shows an empty wagon drawn up in front of one of these sheds.

To facilitate the removal of the beans from the wagons to the vessels in which they are to be fermented, the rails usually run alongside the vessels. Plate 9 shows a row of fermenting-cases at the "Rio do Ouro" estate, San Thomé. Part of the roof of these is movable, and

Decauville-rail Car and Shed used as a Depôt for freshly shelled Cocoa Beans

p. 120]

the beans are shovelled direct into the cases from the wagons shown in the upper part of the plate.

The type of fermenting-cases in use at the "Agua Izé" estate, San Thomé, is illustrated in Plate 10. The cases are arranged on either side of a large building and the wagons are run through the centre.

At some estates in San Thomé the beans are fermented in the wagons.

CHAPTER XIV

COCOA FERMENTATION

Effects of Fermentation.—The necessity for fermenting or sweating cocoa is now generally acknowledged, and it is adopted in nearly every country where cocoa is grown. The principal objects effected by this process are: (1) The removal of the greater portion of the sweet slime or parenchymatous tissue in which the beans are enveloped, (2) the dissociation of the bean from its testa or seed-coat, (3) the strengthening of the testa, (4) the improvement of the flavour and colour of the kernel.

The pulpy envelope of the beans is extremely difficult to remove before it has been subjected to the fermentation process.

The beans take a much longer time to dry when this has not been removed, and are dark and unsightly in appearance when dried. The dried pulp has hygroscopic properties, and when the beans are exposed to moisture it becomes glutinous and is then more liable to fungus (mould) attacks.

The separation of the bean from its testa improves its fracture or "break" and facilitates shelling.

The testas of beans which have been toughened by fermentation are less likely to be broken during the drying process and also during transport, thus rendering the contents less susceptible to mould attacks.

The astringent and raw, bitter flavour of the fresh beans of many varieties of cocoa is due to the tannin they contain, which is decreased by fermentation. Harrison's analyses of cocoa beans in British Guiana show that fresh Calabacillo beans contain 5 per cent. of tannin, which is reduced during curing to 3·61 per cent.

Action of Oxidising Enzymes. Loew (*Porto Rico Experiment Station Report*, 1907) maintains that the change of colour in the bean from white or violet to brown is only indirectly effected by fermentation, as the brown coloration is due to the work of oxidases or oxidising enzymes. These oxidases are stored up in the protoplasm of the bean's cells. When the cells are killed without injury to the oxidases, the latter are liberated upon the death of the protoplasm and become active.

If the oxidases are killed by boiling or the application of strong acids, the characteristic coloration will not take place. Loew describes an experiment which he conducted to prove the action of oxidising enzymes on cocoa beans. A further control experiment was made, in which the pulped cocoa (bean with testa and attached slime layer) was boiled for about twenty minutes with 2 per cent. dilute sulphuric acid. The slimy tissue contracted, and together with the swollen testa was easily separated from the bean. These beans showed a pure red coloration on the outside, while the interior was violet, and no trace of brown colour appeared even after many hours' exposure to the air, since the oxidising enzyme (oxidase) had been killed, together with the living matter (the protoplasm of cells).

The protoplasm of plant cells dies when they are subjected to a temperature of 115° Fahr., but a further rise of from 40° to 55° Fahr. is necessary to destroy the oxidising enzymes.

Loew further remarks that cocoa beans which have been simply sun-dried are uniformly deep brown.

This statement is, however, not applicable to all classes of cocoa. The colour of the beans of the Forastero-Amelonado variety generally cultivated by the natives in West Africa is distinctly improved by fermentation. Those beans which the natives dry in the sun without fermentation have a dark blue fracture, whereas properly fermented beans of this variety have a typical chocolate fracture when dried. Beans of this variety which have been insufficiently fermented are also bluish in colour, but this is not so pronounced as in the unfermented beans.

The dark blue fracture is objected to by buyers, and when it is exhibited in cocoa beans they always realise lower prices than properly fermented beans of the same type. Even when cocoa is fermented properly the characteristic brown or chocolate colour is only present in the external portions of the bean, and if a bean is cut it will be found to have retained its original colour in the centre; complete coloration is not effected until the beans have been dried.

If cocoa beans, freshly taken from their fruit-shells, are placed in a heap and the temperature of the mass registered, it will usually be found that the temperature of the heap will commence to rise in an hour or two, and may continue to rise, if the beans be left undisturbed, for seven or eight days. At the end of this period there may be a difference of 50° Fahr. from the original temperature of the heap. The rate at which the temperature will rise and the extent of the rise will vary, within certain limits, in proportion to the size of the heap, the air temperature, and the amount of humidity in the atmosphere. With the increase of temperature liquid matter oozes from the heap owing to the decomposition of the pulpy envelope of the beans. The first exudations have a sweet fruity odour, the later a vinous and then an acetic acid odour. Provided that the temperature of the heap has not exceeded 140° Fahr., the beans will not be injured from a commercial standpoint. The sugary pulp will be found to have shrunk to a considerable extent and the remainder can be easily washed off. The beans have now been fermented.

Yeasts and Bacteria.—Preyer (*Tropenpflanzer*, pp. 151–173, April 1901), who studied the fermentation of cocoa in Ceylon, states that *Saccharomyces Theobromæ*, a yeast, produces the best fermentation in Ceylon, and mentions that *S. cerevisiæ*, and a species similar to *S. ellipsoides*, *S. membranæfaciens*, as well as a mould, *Penicillium sp.*, have been found by him in fermenting cocoa in that island. He successfully bred pure cultures of the organisms associated with the fermentation of cocoa. Lutz found, in addition to *S. Theobromæ*, *Sterigmatocystis nigra*, *Pseudo-Absidia vulgaris*, and a new fungus, *Fusarium Theobromæ*, Lutz.

Harrison has also investigated this subject in British Guiana. He considers that the process of fermentation or "sweating" in cocoa consists in an alcoholic fermentation of the sugars in the pulp of the fruit, accompanied by a loss of some of the albuminoid and indeterminate nitrogenous constituents of the beans. The albuminoid constituents probably are first changed into amides and other simpler compounds, which may be further broken up during the process of fermentation. Some of the carbohydrates, other than sugar, undergo hydrolysis and either escape in the runnings from the boxes in the form of glucose or undergo, in turn, the alcoholic and acetic fermentations. Harrison's results of the analysis of fermented and unfermented Forastero (*Calabacillo*) cocoa beans are as follows :

Constituents.	Fresh beans.	Cured beans.
	Per cent.	Per cent.
Fat	29·25	29·25
Tannin	5·00	3·61
Cocoa red	2·95	1·39
Theobromin	1·35	1 00
Caffein	0·11	0·03
Starch	3·76	3·22
Glucose	0·99	0·60
Hemicelluloses	5·11	3·74
Woody fibre	3·03	2·78
Protein	6·69	4·42
Amido compounds	·53	2·06

The protoplasm or living matter in the beans is not killed during the fermentation process until the temperature rises to about 115° Fahr. As this does not usually occur until the second or third day, it is possible that the action of the living cells is responsible for some of the changes effected during fermentation. In regard to these changes Loew states : "This would account for the decrease of starch, glucose, and hemicelluloses, which may be consumed by the respiration process, but the other changes are due to several enzymes. A proteolytic enzyme brings on the decrease of protein and the corresponding increase of amido compounds, while oxidising enzymes, generally liberated from the protoplasm upon its death, cause the decrease of tannin and cocoa red and their change to other compounds. The most conspicuous changes are therefore only possible after the death of the protoplasm, which is a desirable factor.

Germination during Fermentation.—The same writer considers Zipperer's idea, that the changes are brought about by the germination process of the beans, to be erroneous ; also that the rise of temperature of the fermenting pulp cocoa is due to this process, and concludes that germination changes are not apparent. This latter remark is difficult to understand; for when fermentation progresses slowly at the commencement, germination changes undoubtedly do take place in the beans. If sections of the beans are made, a pronounced development of the radicle is often evident; and, in the numerous fermentation experiments which the writer has conducted in the Gold Coast and in San Thomé, he has frequently observed the radicle protruding through the testa of numerous beans in the fermenting-boxes, although traces of this nature were not observable when the beans were first placed in the boxes. When such cocoa is dried, the radicle often becomes separated from the bean, leaving a hole by which the weevils of a beetle (*Arœocerus coffeœ*) and the larvæ of a Pyralid moth (*Ephestia cautella*, Wlk.) obtain an entrance to the bean.

Wright (*loc. cit.*) states in regard to fermentation: "Though the process involves a relatively high temperature it is very rare that the latter destroys the embryo of the bean; to a certain extent fermentation is a continuation of the processes commenced in the beans after maturity. Ordinarily fermented beans, if dried under unfavourable conditions, will germinate, the prevention of such developments being one of the main objects of curing; this proves that the fermenting of cocoa does not involve chemical changes harmful to the vitality of the beans."

The correctness of this statement obviously depends upon the definition of ordinarily fermented beans. The mild-flavoured beans of Criollo and similar varieties do not require such a high temperature during the fermenting process as is necessary for the astringent beans of various Forastero types, in order to improve their flavour by removal of tannin.

It is therefore possible to ferment the mild-flavoured beans without destroying their vitality; but in order to improve the flavour of the astringent beans it is necessary to raise the temperature sufficiently high to destroy the vitality of the beans before the oxidising enzymes responsible for the modification of the bitter principle are liberated and able to commence their work.

Fermentation a Biological Process.—Sack (*La quinzaine*

Coloniale, January 25, 1909) conducted experiments to ascertain whether the fermentation of cocoa is due to a chemical or a biological process. Seven kilos. (15·4 lb.) of cocoa beans, freshly taken from the fruit-shells, were placed in four different baskets. To one of these was added formaldehyde and to another chloroform. These two substances check the development of the lower organisms, but do not affect chemical reactions.

The cocoa beans in the two untreated baskets fermented in the usual way, but no fermentative changes occurred in the beans treated with formaldehyde and chloroform. Upon formaldehyde and chloroform being respectively added to the two baskets of fermenting beans, the fermentation was stopped and the temperature was reduced.

In order to prove that the presence of air is essential in cocoa fermentation, four cylinders were taken and 4 kilos. (8·8 lb.) of fresh cocoa beans were placed in each. Arrangements were made for the free ingress of air to two of the cylinders and the other two were hermetically closed. Fermentation took place in the beans in the aerated cylinders, but those in the hermetically closed cylinders rapidly decomposed. When air was withheld from the fermenting beans decomposition rapidly set in.

The necessity for air in connection with cocoa fermentation is well demonstrated in practice. Fermentation changes are always first manifested in the portions of the bean-mass best aerated. When too large quantities of beans are bulked, the beans in the centre of the mass will often show no signs of fermentative activity, although it may be proceeding satisfactorily in the outer portions of the mass. If no proper provision is made for the escape of the liquid which oozes from the bean-pulp, fermentation is arrested at the bottom of the heap and decomposition soon sets in.

The carbohydrates in the pulpy envelope of the beans provides nutrition for the development of numerous yeast cells, *Saccharomyces spp.* These multiply rapidly and convert the sugar into alcohol. Nourishment is also provided for various bacteria, among them the well-known acetic acid bacillus. The pulpy envelope is gradually decomposed by the action of the yeasts, and bacteria and the juice thus formed drain away. The respiration of these organisms and the fermentative activity generate heat and gradually a considerable elevation of temperature is reached.

If the pulp be removed no fermentation of cocoa beans takes place, when they are placed in a heap or in a fermenting-box; but if such beans be soaked in a sugar solution, fermentative activity is soon set up. The fermentation of freshly shelled beans, which have been heavily rain-washed in the plantation, is sometimes induced by planters by the application of saccharine liquids or by the admixture of normally fermenting cocoa beans.

Cured cocoa beans usually possess a slight aromatic odour, but the characteristic aroma of cocoa is not properly developed until the beans are roasted in the process of manufacture. This aroma is associated with the fat of the cocoa bean, so that it is possible that its development commences with the heat generated in the fermenting heap and is further developed during the drying process.

According to Loew only beans in which the oxydising enzymes have produced changes can yield the true aroma by roasting, not the fresh beans.

Characters of Beans with White and Purple Cotyledons.—One of the primary objects of cocoa fermentation is to remove the bitter and astringent property of the raw beans. The white beans of the Criollo varieties and *Theobroma pentagona* are far less bitter and astringent than the purple beans of the Forastero varieties and *T. sphærocarpa*. This is one of the reasons why the former require less fermentation than the latter; another reason is that the integument or seed-coat of the beans with white cotyledons is almost invariably thinner than that of the beans with purple cotyledons. Wright (*loc. cit.*) gives the following table showing the average proportionate weights of the integuments and kernels of different varieties of 100 cured cocoa beans at Peradeniya:

	Weight of kernels only.	Weight of integuments.	Total weight.	Percentage weight of integuments.
	Grammes.	Grammes.	Grammes.	
Caracas . .	116·2	10·8	127	8·5
Forastero-Cundeamor . .	103·0	10·3	113·3	9·0
Amelonado .	94·7	10·3	105	9·8

These characters vary in the different varieties which produce white beans as well as those which produce purple beans; and may even vary in the same variety cultivated in different countries. It is therefore impossible to state definitely what is the proper period of time to ferment the beans of any one variety, especially as fermentative activity is largely influenced by climatic conditions, the stage of development of the beans under treatment, the quantity of beans in the bulk, and the aeration of the bulk.

During hot, moist weather fermentation proceeds far more rapidly than during dry, cool weather. Beans which would be fully fermented in four days under the former conditions would probably take six days under the latter conditions. Immature beans take longer to ferment than mature beans, while over-ripe beans, which have already been subjected to mild fermentation in the fruit-shells, obviously do not require so much further fermentation as the properly matured beans.

If unduly large quantities of beans are bulked for fermentation without proper provision for aeration, it is invariably found that fermentation is not uniform throughout the mass. The organisms responsible for fermentation require air to enable them to perform their work, and if this is withheld decomposition is more likely to set in than fermentation.

In the various experiments conducted by the writer, it was observed that a layer of beans about 2 ft. deep gave satisfactory results if the beans were placed in receptacles made of suitable material, perforated on all sides with air holes, and lightly covered with sacking or some similar material which is not impervious to air.

Fermenting-Chambers.—Strong, durable wood is well adapted for the manufacture of fermenting-chambers, but it should be fastened together in such a manner that the iron nails or screws used for this purpose do not come in contact with the beans. The liquid matters which exude from fermenting cocoa beans act upon the metal and discolour the beans. The floor of the chamber should be either well supplied with holes or should slant towards an opening to facilitate the draining away of the liquor given off during fermentation, and the floor of the chamber should be raised above the ground on wooden blocks. If this liquor stagnates at the base of the fermenting-chambers, the integuments of the beans which come in contact with it will be discoloured and their contents injured. The mustiness common to badly fermented cocoa is frequently due to inadequate drainage in the fermenting-chambers. The holes should be either made sufficiently small to prevent the cocoa beans falling through, or, if bigger holes be made, each should be covered with a piece of copper gauze.

Even when fermenting-chambers are well provided with air holes fermentation is most active amongst the beans which are situated near the sides and top of the chambers. To ensure uniform fermentation throughout the mass the beans should be daily thoroughly mixed together in the chamber or emptied from one chamber to another. If the chamber be filled with beans the latter is obviously the most practical method of mixing them. When large quantities of beans have to be dealt with it would be advantageous to arrange the chambers in tiers one above the other; a tier of chambers being allowed for each day's fermentation. If the freshly collected beans were placed in the highest tier they could be daily moved to the next lower tier, and fermentation could be completed in the lowest tier.

It is necessary to keep the fermenting-chambers thoroughly clean, both for the purpose of maintaining them in a sanitary condition and to prevent the dirt which congregates in them discolouring the cocoa beans.

An efficient drainage system should be provided below the chambers to carry away the drainings from the chambers, as these, when allowed to stagnate, produce an evil-smelling odour which must be injurious to the health of the labourers employed in handling the beans, and it is also possible that the cocoa beans may become contaminated with the effluvium.

When treated as suggested above from three to five days' fermentation will be generally found sufficient for the beans with white cotyledons, but the beans with purple cotyledons usually require from five to eight days' fermentation.

Fermentation is usually completed when the pulp is readily removed by pressing the beans between the fingers; and a transverse section of the beans shows that the convolutions of the cotyledons are well separated, and the interstices thus formed are filled with liquid matter.

If the temperature of the fermenting beans rises above 140° Fahr. there is a danger of the beans becoming discoloured and their marketable value depreciated.

A musty flavour is often associated with over-heated cocoa, which also decreases its market value. To avoid this a plunging thermometer should be placed in each day's collection of beans, and moved with the beans from chamber to chamber. If an indication of a rise of temperature above 140° Fahr. be observed the beans should be spread out in the shade for an hour or two and then returned to the fermenting-chamber.

After fermentation is completed the beans should be at once removed from the fermenting-chamber, as otherwise fungus moulds may attack them and injure their flavour.

The liquid which drains from fermenting cocoa yields a serviceable vinegar. Olivieri states that if it is concentrated by evaporation it is converted into a brown gluey substance which can be used as a polishing varnish.

CHAPTER XV

METHODS OF FERMENTATION

The methods adopted in the fermentation of cocoa vary considerably in different countries.

The fermentation of cocoa is by no means a new process. In Aublet's *Plantes de la Guiane*, which was published in 1775, the method of fermenting the beans of *Theobroma guianensis*, Aubl., is described.

The beans were thrown into a vessel; the matter surrounding them fermented within twenty-four hours and liquid formed. This liquid became acid, and spirit could be distilled from it.

When the germ was killed and the membranes had turned brown the beans were taken out of the vessel and dried.

Tropical America.—According to Preuss, in parts of Venezuela cocoa is only fermented for one day; the beans are then covered with red earth and afterwards are spread out in the sun to dry.

In Nicaragua the beans of the Criollo varieties and those of *Theobroma pentagona* are fermented for only two days, while the Forastero varieties are fermented for four or even five days. In Salvador and Guatemala, cocoa is usually fermented for one or two days.

Trinidad.—Preuss describes the method of fermentation in vogue on an estate in Trinidad. The fermenting-house contains sixteen compartments, with wooden walls. The dimensions of each compartment are approximately as follows: 2 metres (6½ ft.) long and 1·5 metres (5 ft.) in height and breadth. Between any two compartments and along the sides of the compartments a layer of clay and grass, about 20 cm. (8 in.) thick, is placed to serve as a non-conductor of heat. Each compartment is fitted with a lid. The compartments are two-thirds filled with cocoa beans, and when these have been well covered up with banana leaves the lid is closed. After one or two days have elapsed the beans are changed to another box; the same procedure is followed until fermentation is completed. The period of fermentation of different Forastero varieties is said to vary between eight and fourteen days.

The length of time occupied in fermenting the Criollo varieties in Trinidad is said to vary between two and five days.

Jamaica.—The following instructions for the fermentation of cocoa have been issued to Jamaica planters by the Botanical Department in that island (*Bulletin, Botanical Department, Jamaica*, August 1900). "A simple box is made 1 ft. deep and varying in length and width according to the quantity of the cocoa; the contents of 1,000 fruits requires a box 2 ft. 6 in. long, 2 ft. wide, and 1 ft. deep (inside measurements) and will fill such a box to a depth of 9 in. It must be constructed so that no iron nails come in contact with the cocoa to discolour it.

"The bottom of the box is bored with numerous holes and is raised from the ground on two blocks of wood. It should be under cover and in a clean place, free from dust; no lid is required. After filling with cocoa it is covered with a piece of clean sacking. Each morning the whole mass is turned up with the hands, the cocoa which was at the side and bottom being moved towards the centre. If the quantity is small, it is dried on the fifth day; if larger (say over 2,000 fruits), on the sixth day, i.e. after five full days' 'sweating.' The box should be thoroughly washed and dried, and also the sacking, before beginning a fresh batch. Thus by a short fermentation of a shallow mass, with plentiful access of air, better results will be obtained than by keeping the mass closely packed together in a deeper vessel. The close packing of the mass does not make it hotter; on the contrary the more air that reaches the mass, up to a certain limit, the hotter the cocoa will become. It is usually inadvisable to ferment for a longer time, but on the other hand a shorter time endangers the risk of the cocoa retaining too much of its bitter flavour."

India.—The coolie dexterously strips all the beans off the centre pulp. The waste is thrown round the trees and acts as manure, while the beans are removed to the fermenting cistern. It takes from five to nine days to ferment the cocoa properly, and it is then ready for washing. As with coffee, it is trampled first with the feet and then removed in baskets and carefully hand-washed. Watt (*Dictionary of the Economic Products of India*).

Ceylon.—To encourage proper fermentation in this country the fresh cocoa beans are either made into piles upon the floor or are placed in vessels and covered with banana leaves or some similar material.

To prevent the undue rise of temperature in the beans and to ensure all the beans being uniformly fermented they are turned every day or two.

The period of fermentation varies in accordance with the variety under treatment from two to five days. It has already been shown that Crollo and Forastero varieties are often found growing mixed together in the same plantation in Ceylon. When the beans of these different varieties are not separated it is impossible to obtain a uniformly fermented product. At the Experiment Station, Peradeniya, a series of tanks, lined with cement, has been made; on two sides of each tank are a large number of holes with an average diameter of 7·3 cm. (3 in.). Through each hole a perforated bamboo is pushed, the latter being of such a length as to stretch from one side of the tank to the other. By this means air can be let into or drawn through the fermenting heap, according to requirements. The floor is made with a slope to one point, where a perforated sieve is placed, to allow the watery products of fermentation to escape.

The writer tried cement tanks as cocoa fermenting receptacles in the Gold Coast, but found that the acid exudations from the fermenting beans acted upon the cement and destroyed the walls and floor.

Guam.—In regard to cocoa fermentation in this country, according to Safford (*Useful Plants of Guam*, U.S. National Museum, 1908): The cocoa beans are sometimes placed in jars and allowed to "sweat," or undergo a sort of fermentation, which improves their flavour. Some growers, after having dried the beans in the sun, keep them until required for use, when they are roasted, ground, and made into chocolate.

Java.—Van der Held has published the following suggestions relative to cocoa fermentation in Java. Preferably, wooden receptacles should be used, which can be conveniently covered and placed in situations sheltered from the wind.

Small movable vessels capable of being readily cleaned should be employed where only small quantities of beans have to be dealt with. On larger estates he advises the adoption of the following apparatus: The walls of the receptacles should be made of movable boards which slide into grooves or supports; the dimensions of each compartment being 2 metres (6½ ft.) long by 1 metre (3¼ ft.) broad and deep. The compartments should be arranged in rows in the form of an amphitheatre, so that if the beans be first placed in the upper row of compartments they may be readily transferred to a lower tier by shifting the movable walls. The bottoms of the receptacles should be perforated with holes about ½ cm. in diameter to allow the liquid which drains from the fermenting beans to pass away.

West Africa.—The bulk of the cocoa exported from British West Africa was, up to some ten years ago, simply dried in the sun. Amelonado is the principal variety grown, and its fresh beans have an astringent flavour. The sun-dried beans retain their bitterness, the "break" is defective, and they are consequently rated at a low market value. Cocoa-curing experiments conducted in the Gold Coast have shown that the beans of this variety, when properly fermented and cured, yield a much superior product, and these have been classed by European buyers with Ceylon and West Indian cocoas. Samples of cocoa prepared during these experiments were awarded medals at the Paris Exhibition, 1900, and also at the St. Louis Exhibition, 1905. Separate series of experiments were carried out with a view to determine the period of fermentation best adapted to the beans of this variety and also the relative advantages attaching to long and short periods of fermentation, as well as the advisability of washing the beans after fermentation.

In 1903, three lots of cocoa were prepared as follows:

$\frac{\text{I}}{\text{A.B.G.}}$ 10 cwt., fermented for six days, not washed.

$\frac{\text{II}}{\text{A.B.G.}}$ 10 cwt., fermented for six days, washed.

$\frac{\text{III}}{\text{A.B.G.}}$ $3\frac{3}{4}$ cwt., fermented for three days, and then washed.

This cocoa was shipped to Hamburg for sale, and the valuation and reports upon it, prepared by two of the principal brokers in that city, are given below :

Report I

$\frac{\text{I}}{\text{A.B.G.}}$ Eight bags are in quality very satisfactory, and are in exterior appearance, and when cut, very similar to the best Cameroon cocoa, and it is to be expected that this product will be as good for manufacture. The value is about 54 pfennig per $\frac{1}{2}$ kilo. (54*s.* per cwt.).

$\frac{\text{II}}{\text{A.B.G.}}$ Eight bags are, in spite of the fact that they have been fermented during six days, too blue in the cutting. It would be, therefore, advisable to give this specimen a trial and ferment it for nine days. The value is about 52 pfennig per $\frac{1}{2}$ kilo. (52*s.* per cwt.).

$\frac{\text{III}}{\text{A.B.G.}}$ Three bags. The quality is quite satisfactory, but as they are fermented only three days, the cut beans are too blue. A blue fracture gives a bitter taste, whereas a brown fracture gives a sweet taste. The cocoa must be fermented six to eight days. The value is about 53 pfennig per $\frac{1}{2}$ kilo. (53*s.* per cwt.).

Should it be possible to prepare the cocoa of such a light colour as annexed sample, the cocoa would fetch a much higher price. Various companies in Africa have tried in vain to get such a light colour ; up to now only the Bibundi Plantation Company and the Botanic Garden at Victoria have succeeded. Such cocoa has a probable value of about 57 to 60 pfennig per $\frac{1}{2}$ kilo., but could, according to our opinion, be sold at such a high price only in limited quantities.

REPORT II

$\frac{\text{I}}{\text{A.B.G.}}$ Eight bags, and $\frac{\text{III}}{\text{A.B.G.}}$ three bags. Between these two species there is no big difference, as the eight bags, No. I, are not fermented enough. As through the longer fermentation the loss in weight is higher by only a small difference in price, the question arises as to whether it is not more profitable to ferment the cocoa only three days.

$\frac{\text{II}}{\text{A.B.G.}}$ Eight bags. The appearance of this cocoa is very poor. As this specimen is only an inferior quality of cocoa, the value is unfavourably influenced by its bad appearance, whereas the appearance of high-grade cocoa is of not so great importance. The price difference between this and washed cocoa we estimate to be 1 to 1½ pfennig per ½ kilo. If this small difference in price is due to the method of preparation, it is possibly more profitable to bring the cocoa on the market unwashed, taking the loss in weight into consideration.

The valuations per ½ kilo. of the three specimens are as follows:

I. About 54 pf. = 54*s.* per cwt.
II. ,, 52½ pf. = 52*s.* 6*d.* per cwt.
III. ,, 53 pf. = 53*s.* per cwt.

At the time these valuations were given ordinary fermented Gold Coast cocoa was valued at 51*s.* per cwt.

A small sample of each of the grades numbered $\frac{\text{I}}{\text{A.B.G.}}$ and $\frac{\text{II}}{\text{A.B.G.}}$ respectively in the Hamburg reports were sent at the same time to Messrs. Hamel Smith & Co., East and West India Merchants, 112, Fenchurch Street, E.C., with a request for expert opinion on them, and the following is an extract from the report received:

The samples were submitted to Messrs. C. M. & C. Woodhouse, who reported as follows:

"*Sample* A.—Ripe washed cocoa, well cured, but very small beans; value per cwt. 55*s.*

"*Sample* B.—Good greyish-red, not quite sufficiently cured, fair size; value per cwt. 55*s.*"

Judging from this opinion it would appear that it would be more profitable for the grower to send his cocoa to market unwashed. Extra expenditure is incurred for labour by washing cocoa, and the weight of the product is decreased by this operation.

The Hamburg brokers valued the washed cocoa at approximately 4 and 3 per cent. higher than the unwashed cocoa similarly fermented, i.e. for six days.

The opinions of the brokers were contradictory in regard to a period of six days' fermentation being sufficient for this class of cocoa.

The small difference in the value given to cocoa fermented during three and six days respectively was not sufficient to compensate for the extra loss in weight associated with the longer period of fermentation. The loss in weight by fermenting for three and six days was found to be approximate'y 10 and 17 per cent. respectively; that fermented for the longer period was only rated at a price about 2 per cent. higher than that given to the less fermented cocoa.

A more comprehensive series of experiments was then conducted to ascertain what are the actual losses sustained by fermenting cocoa during periods varying from 4·5 to 12 days. The results obtained were as follows :

No. of Experiment.	Period of fermentation.	Mean temperature for the period.	Loss in weight during fermentation.
	Days.	Fahrenheit.	Per cent.
IV.	4·5	92·63°	11·42
V.	6·5	106·99°	17·85
VI.	7·5	112·73°	17·57
I.	8·5	109·13°	20·52
III.	10·5	102·53°	26·08
II.	12	95·77°	27·21

A report from the Imperial Institute has been published (*Bulletin of the Imperial Institute*, vol. v. [1907], pp. 361–9), giving the results of the examination and valuation of a number of samples selected from the various lots of experimentally cured cocoa, above referred to, as well as upon several shipments of cocoa prepared by native growers which was made at the instance of the Government. The following is the substance of the report from the Imperial Institute :

"COCOA FROM THE GOLD COAST

"A number of samples of cocoa beans were forwarded to the Imperial Institute for examination by the Director of the Botanical and Agricultural Department of the Gold Coast Colony in August 1905.

"The collection of samples was stated to represent the products obtained in a series of experiments conducted 'in the preparation of cocoa grown in the Botanical Gardens at Aburi with a view to ascertaining the most satisfactory method to adopt in preparing this product for market.'

"**Description of Samples.**—Seven samples of cocoa beans were received. These were described as follows:

No. I	. Fermented 8·5 days	.	Washed
,, IV*a*	. ,, 4·5 ,,	.	,,
,, IV*b*	. ,, 4·5 ,,	.	Unwashed
,, V*a*	. ,, 6·5 ,,	.	Washed
,, V*b*	. ,, 6·5 ,,	.	Unwashed
,, VI*a*	. ,, 7·5 ,,	.	Washed
,, VI*b*	. ,, 7·5 ,,	.	Unwashed

"All seven samples consist mainly of medium-sized beans, but in several a number of small and shrivelled beans are included. The colours of the beans are on the whole poor, Nos. IV*a*, IV*b*, and I being the best in this respect. The husked cocoas, in all cases, show a faint purple tint and do not 'break' readily, indicating that they are incompletely fermented. This is the case even with samples Nos. I and VI, which are described as having been fermented for 8·5 and 7·5 days respectively. As regards the colour and 'break' of the husked cocoas, Nos. IV*a* and IV*b* appear to be the best of the seven samples, in spite of the fact that they were fermented for the shortest period (4·5 days). Nos. I, IV*a*, and IV*b* contain a few mouldy beans, and the others a larger proportion, in one case nearly 10 per cent. of partially perished beans. The flavour and aroma of all the samples are mild and rather poor when compared with those of good West Indian cocoas.

"**Chemical Examination.**—The samples were analysed in the Scientific and Technical Department of the Imperial

Institute, and gave the results recorded in the following table :

No. of sample.	Method of preparation.	Husk.	Calculated on the husked samples.			
			Moisture.	Fat.	Ash.	Total alkaloid.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I	Fermented 8·5 days and washed . .	8·0	4·55	48·29	2·39	1·28
IV*a*	Fermented 4·5 days and washed . .	8·0	4·87	46·63	3·05	1·65
IV*b*	Fermented 4·5 days unwashed . .	8·0	4·75	46·17	2·90	1·58
V*a*	Fermented 6·5 days and washed . .	8·0	4·89	44·51	2·74	1·20
V*b*	Fermented 6·5 days unwashed . .	11·4	5·00	45·30	2·66	1·40
VI*a*	Fermented 7·5 days and washed . .	8·4	4·55	44·50	2·67	1·22
VI*b*	Fermented 7·5 days unwashed . .	10·4	4·90	45·20	2·87	1·21

"The results of the chemical examination show that the samples are satisfactory so far as chemical composition is concerned. It is of interest to note that the analyses indicate that samples Nos. IV*a* and IV*b*, in spite of their short period of fermentation, have been more thoroughly fermented than several of the others ; thus the amount of husk in No. IV*b*, though unwashed, is only 8·0 per cent., identical with that found in the washed twin sample IV*a*, indicating that in these two samples practically the whole of the pulpy saccharine matter originally adherent to the shell had been utilised in maintaining the fermentation, so that none was left to be removed by the subsequent washing.

"**Commercial Valuation of Samples.***—Specimens of all seven cocoas were submitted in the first instance to a firm of manufacturing confectioners, who reported on them as follows :

" 'These samples are considerably better than ordinary West African cocoa ; this however is not saying much, as this is the lowest grade of cocoa excepting Hayti for which there is any considerable market.

" 'The writer prefers the flavour of the unwashed

* Since these valuations were made prices of cocoa beans have risen very considerably, so that the figures quoted are only of value for comparison with prices obtainable for standard varieties at the same time, viz. medium Ceylon at 46*s.* to 53*s.* and San Thomé at 50*s.* to 53*s.* per cwt.

samples in each case. He would say that sample IV*b* is very similar to a mild Grenada, whilst samples V*b* and VI*b* have more of the Trinidad quality. Some of the samples show signs of mould, which of course detracts from their value.'

"This firm also offered the following general remarks with regard to the condition of the West African cocoa trade:

"'The bulk of the cocoa which comes over to the European market from West Africa has received hardly any fermentation at all. The pods are simply opened and the beans dried without any attempt at proper fermentation. In our opinion no amount of grading of this kind of cocoa would materially improve the price. On the other hand, if the cocoa is properly prepared, as is done in the Portuguese island of San Thomé and in the British island of Grenada, a superior quality of cocoa would be obtained, and if fermentation is done regularly the quality will be uniform.'

"Samples of the cocoa were also submitted to a firm of brokers in London for valuation. They reported on them as follows:

"'*Sample No.* I.—Bold, reddish, even but dark "break"; worth about 50*s*. to 51*s*. per cwt.

"'*Sample No.* IV*a*.—Pale reddish, fairly good "break"; worth about 50*s*. per cwt.

"'*Sample No.* IV*b*.—Pale reddish, apparently washed, part lean and small; worth about 49*s*. per cwt.

"'*Sample No.* V*a*.—Dull reddish, fair "break"; worth about 49*s*. per cwt.

"'*Sample No.* V*b*.—Very dull, dark "break"; worth about 47*s*. per cwt.

"'*Sample No.* VI*a*.—Very dark, dull "break"; worth about 48*s*. per cwt.

"'*Sample No.* VI*b*.—Very grey and coated, but fair "break"; worth about 48*s*. per cwt.

"'During the past few months [i.e. late in 1905] prices of almost all descriptions of cocoa have favoured buyers, owing to large crops of Trinidad, Bahia, and African sorts, and present values are moderate. Cocoa cured and prepared as samples represent would attract attention and compete with San Thomé and West Indian kinds and would fetch good prices here.'

" As most of the West African cocoa which reaches this country is imported *via* Liverpool, it was considered advisable to have the samples valued also by a firm of brokers in Liverpool. This firm reported as follows :

" ' Samples Nos. V*a*, V*b*, and IV*b* we consider good cocoas, the value of which to-day would be 42*s*. to 43*s*. per cwt. ex quay Liverpool, usual terms.

" ' The other four samples contain defective beans and are therefore not quite the same value as the first three. They would probably realise 40*s*. to 41*s*. per cwt., usual terms. The " usual terms " means landing expenses, and less 2½ per cent. discount, merchants' and brokers' commission, etc., all to be paid by importer.'

" **General Conclusions and Recommendations.**—The foregoing results show that these samples of cocoa appear to be superior to the ordinary West African cocoa now imported into this country, and that if cocoa similar to the present set of samples could be regularly exported it would probably secure better prices than are now generally obtainable for the West African product.

" These preliminary experiments in the improvement of cocoa may therefore be regarded as having given promising results, and it is desirable that they should be continued. Judging from the results of the present examination, it would seem that future progress may probably best be made by devoting attention to the mode in which the fermentation is carried out, since on this the flavour, aroma, and colour of the product will principally depend."

The further action taken is indicated in another report from the Imperial Institute.

" The information contained in the foregoing report was communicated to the authorities in the Gold Coast Colony, and it was suggested that small consignments of the best quality of cocoa produced by different planters should be sent to the United Kingdom for sale, in order to obtain trustworthy information regarding the value of the better grades of Gold Coast cocoa in the open market.

" This suggestion was approved by the Governor of the Gold Coast, and subsequently information was received that it had been decided to ship 20 tons of cocoa, selected by the Director of Agriculture and consisting of ' 1 ton lots,' from twenty different farmers, for sale in this country. It was arranged by the Imperial Institute that these consignments of cocoa should be sold at public auction in Liverpool.

"The first consignment, consisting of 114 bags ex 'Nigeria,' was received by the brokers on January 19, 1907.

"The brokers withdrew samples of the different lots included in this consignment and furnished the following report regarding them :

"'No. 1, 20 bags. Bright, clean beans of fair size but not sufficiently fermented ; very saleable quality, worth 67*s.* to 68*s.* per cwt.

"'No. 2, 20 bags.—Bright, clean, and sound beans of fair size but only partly fermented ; very saleable quality, value 68*s.* per cwt.

"'No. 3, 19 bags.—Bright, sound beans, on the whole fairly well fermented but containing some percentage of unfermented beans mixed with small beans ; very saleable quality, value 68*s.* to 69*s.* per cwt.

"'No. 4, 15 bags.—Large beans of good quality and well fermented. The most desirable lot ; very saleable, value 73*s.* to 75*s.* per cwt.

"'No. 5, 13 bags.—Sound beans of fair quality but mostly unfermented and mixed with small beans ; saleable, value about 66*s.* per cwt.

"'No. 6, 9 bags.—Bright beans of fair quality but mixed with small and defective beans ; value about 64*s.* per cwt. ; saleable.

"'No. 7, 7 bags.—Beans of moderate quality and fair size ; distinct traces of mouldy beans ; value about 63*s.* per cwt.

"'No. 8, 11 bags.—Fair quality, mostly unfermented beans mixed with small and thin beans ; value about 65*s.* per cwt.'

"The whole of this consignment was sold at an average price of 68*s.* per cwt.

"All the parcels were saleable cocoas, but No. 4 was specially commended as representing the standard of quality which should be aimed at. Such cocoa would compete with the better kinds, such as San Thomé, whereas if only slightly below this in quality, the price realised would be from 5*s.* to 7*s.* 6*d.* per cwt. lower.

"The second portion of the consignment consisted of 60 bags ex 'Akabo,' which were received at Liverpool on February 2, 1907. The following opinions of the different lots were supplied by the brokers previous to the sale:

"'IV, 5 bags.—Good, fair beans of good size mixed with slatey beans. Value about 68*s*. per cwt.

"'V, 7 bags. Fair quality, mixed with small and defective beans. Value about 67*s*. per cwt.

"'VI, 12 bags. Fair quality but small and unfermented. Value about 67*s*. per cwt.

"'VII, 13 bags. Fair quality, mixed with small and lean beans. Value about 68*s*. per cwt.

"'VIII, 9 bags. Fair quality, mixed with small and defective beans. Value about 67*s*. per cwt.

"'IX, 14 bags.—Moderate quality very small, badly cured, and mixed with defective beans. Value about 65*s*. per cwt.'

"The lots were sold separately and realised the following prices in bond:

IV.—70*s*. per cwt.	VII.—69*s*. per cwt.
V.—68*s*. ,, ,,	VIII.—65*s*. ,, ,,
VI.—67*s*. ,, ,,	IX.—65*s*. ,, ,,

"The brokers stated that they were rather surprised at the high price realised by one or two of the lots, which went to a Continental buyer.

"Samples of the different lots were supplied to several English manufacturers, and in certain cases criticisms and valuations were obtained, which may be quoted.

"One firm stated that they could not report favourably upon the cocoa, since none of the lots would rank as average good Grenada estate cocoa. They added that lower grades of cocoa, like the present consignments, are often keenly bid for by makers of common chocolate, and realise prices which, in their opinion, are much higher than the quality justifies. They prefer not to buy such cocoas themselves, so long as good estate cocoa can be obtained at a reasonable price. In their opinion Nos. 2, 3, 4 (ex 'Nigeria') and No. IV (ex 'Akabo') appeared to be the best samples; at the same time they considered that better cultivation and more experience in fermenting the beans would lead to considerable improvement in the quality of the cocoa.

"A second firm of manufacturers classified the cocoas, as regards commercial value, in five divisions as follows:

A. . .	Nos. 4 and IV.
B. . .	,, 3 ,, 7.
C. . .	,, 1 ,, 2.
D. . .	,, 5, 8, V, VI, VII, VIII, and IX.
E. . .	,, 6.

"The Arabic numbers represent the samples ex 'Nigeria,' the Roman those ex 'Akabo.'

"They stated that samples 4 and IV alone appeared to have had any effective fermentation, and that even in these samples it is not quite regular.

"**Conclusions.**—For comparison with the prices obtained for these Gold Coast cocoas the following particulars may be quoted regarding the current rates for cocoa in Liverpool and London at the time of the sales:

Liverpool Market, January 23, 1907

	Per cwt.
San Thomé	73*s*. to 74*s*.
African	62*s*. to 70*s*.

January 30

San Thomé	69*s*. to 72*s*.
African	60*s*. to 69*s*.

February 6

San Thomé	80*s*. to 84*s*.
African	60*s*. to 69*s*.

London Market, January 23, 1907

Ceylon	. Plantation: special marks	76*s*. to 95*s*.
,,	. ,, red to good .	76*s*. to 86*s*.
,,	. Native estate, ordinary to red	65*s*. to 77*s*.
Java and Celebes	. Small to good red . .	60*s*. to 95*s*.

African:		Per cwt.
San Thomé / Cameroons	Grey to colory . . .	78s. to 85s.
Accra	Fair reddish . . .	63s. to 75s.
Congo	Red to colory . .	70s. to 82s. 6d.

"A comparison of the brokers' valuations of the eight lots ex 'Nigeria' with the Liverpool prices of the same date shows that one sample, No. 4, was considered to be superior to the best West African cocoa then offered on the market. Three other samples, Nos. 1, 2, and 3, were valued at a little below the top market price, viz. at 66*s*. to 69*s*. per cwt., whilst the other four lots were valued at from 63*s*. to 66*s*. per cwt. at a time when 60*s*. was the lowest market quotation for West African cocoa.

"Sample No. 4 of this consignment was of very good quality and was commended by the manufacturing firms consulted. There is no doubt that if cocoa of this quality can be regularly prepared in the Gold Coast it will realise very good prices in the market.

"The six lots ex 'Akabo' realised from 65*s*. to 70*s*. per cwt. compared with the market price of 60*s*. to 69*s*. per cwt. Only one sample, No. IV, realised 70*s*. per cwt., but three others, Nos. V, VI, and VII, fetched 68*s*., 67*s*., and 69*s*. per cwt. respectively; whilst the other two were sold at 65*s*. per cwt.

"The principal defect of these Gold Coast cocoas as a whole is insufficient fermentation, which considerably reduces their market value in comparison with other varieties. If the preparation of the cocoa could be improved in this respect, much better prices would be realised. In addition, the presence of small and mouldy beans in many of the samples also reduces their quality and value. The occurrence of a considerable proportion of small beans is no doubt due to defective methods of cultivation, whilst the development of mould in some of the cocoas may be attributed to insufficient drying after fermentation. Considerable improvement could be effected in all these directions, with the result that the quality of the cocoa would be greatly enhanced. The native farmers should be encouraged to produce cocoa similar to sample No. 4 ex 'Nigeria.'"

In connection with these results it is interesting to compare those obtained in a series of experiments conducted at the Experiment Station, Peradeniya, Ceylon (Wright, *loc. cit.*).

Samples of different varieties were fermented for definite periods of time and the weights of the fresh, fermented, washed, and cured cocoa taken at the respective stages. The following are the results obtained :

Variety.	Period of fermentation.	Range of temperature during fermentation.	Weight of cocoa.		Loss on fermentation.
			Fresh.	Fermented.	
	Hours.	Degrees Centigrade.	lb.	lb. oz.	Per cent.
Caracas . .	37 to 38	25·0 to 43·3	416	384 0	7·6
Forastero .	61 ,, 62	25·0 ,, 44·1	543	471 0	13·2
Amelonado .	85 ,, 86	25·0 ,, 40·1	203	174 0	13·3
Mixed Beans .	39	27·0 ,, 30·5	439	392 0	10·9
,, ,, A.	39	26·8 ,, 28·8	250	210 10	15·6
,, ,, B.	63	26·8 ,, 30·8	250	205 6	17·8
,, ,, C.	87	26·8 ,, 33·7	250	197 10	20·9

Nearly the whole of the 14,000 tons of cocoa now being annually exported from British West Africa is produced by native cultivators. The Agricultural Departments in these Colonies have been particularly energetic in their efforts to educate the natives to the importance of properly cultivating and fermenting this product. The beans of the Forastero-Amelonado variety which they cultivate, even when grown and cured under the most satisfactory conditions, are of a decidedly inferior quality as compared with those of the Criollo varieties produced under similar conditions. There is ample evidence that the native is beginning to appreciate the advantages attaching to the fermentation of cocoa ; and if he has not yet succeeded in producing a properly finished article, this is not so much due to the apathy so commonly attributed to him, as to his lack of knowledge of the proper methods of cultivating and curing this product.

His attempts at cocoa fermentation are often of the crudest imaginable. In some instances the freshly collected beans are merely heaped on mats in the corner of a hut and covered up with banana leaves until the fermentative processes have sufficiently decomposed the pulpy envelope of the beans to enable it to be readily washed away.

Some farmers collect various forms of receptacles, such as kerosene tins, flour or cement barrels, packing cases or baskets, and place the beans in these to ferment. With a view to obtaining a more uniformly prepared product the beans in a heap or vessel are occasionally stirred whilst fermentation is proceeding. The period allowed for fermentation to be effected is usually three or four days, irrespective of climatic conditions or the size of the fermenting heap. The effect which fermentation has upon the interior of the beans is not usually considered. Some of the more enlightened farmers are, however, beginning to appreciate the necessity for modifying the natural astringency of the cocoa beans and are adopting better methods of fermentation.

San Thomé.—It is doubtful whether greater quantities of cocoa are handled on any estate in the world than on those being dealt with on some of the largest estates in San Thomé.

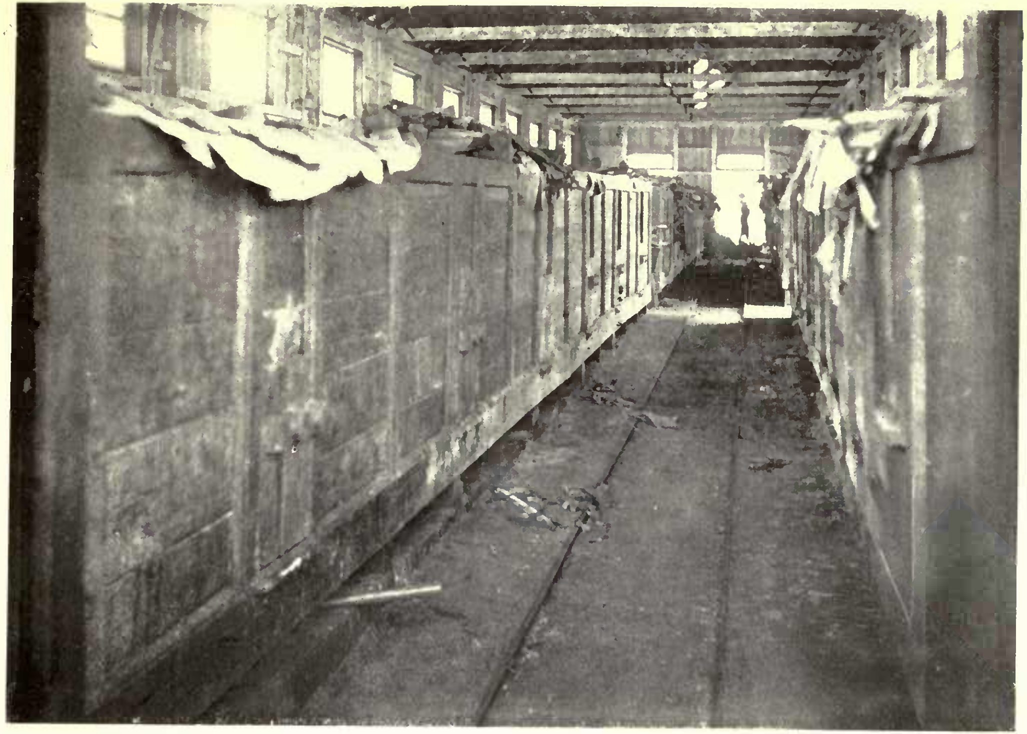
Some of these estates produce more than 2,000 tons of cured cocoa per annum: the "Agua Izé" estate exported 3,000 tons of cured cocoa during the year 1908. For such enormous quantities to be properly and expeditiously fermented a considerable area of fermenting space is obviously required.

Plate 9 shows a portion of one of the rows of fermenting-chambers at the "Rio do Ouro" estate. In this row there are thirteen chambers; each chamber is divided into two sections. The back division is 4 metres (13 ft.) long and 1·3 metres (4·2 ft.) broad. Owing to the slope of the roof the height varies from 1·25 metres (4·1 ft.) to 1·5 metres (4·9 ft.). The front division of each chamber is the same length as the back division; it is 1·1 metres (3·6 ft.) broad and 1·2 metres (3·9 ft.) high.

The floor and back wall of each division are perforated with numerous holes for the purpose of aerating the fermenting mass and to allow the liquid matters which exude from the fermenting beans to pass readily away. This liquid falls into the masonry drain which runs under the whole length of the thirteen chambers, from which it is conveyed away by a central drain.

With the exception of the small piece of zinc roofing of the front section, the chambers are constructed of substantial, durable wood. The roof of the back section

PLATE 9



Fermenting Chambers, "Agua Izé" Estate, San Thomé

p. 148]

moves off on hinges, which enables the cocoa beans to be directly shovelled into this section from the trolleys, also shown in the plate. Each trolley holds about 1½ tons of freshly shelled cocoa, and generally three trolley loads are placed in each chamber. The roof is then closed.

During the dry, cool season the beans are left in the back section of the chamber for three days, but two days are considered sufficient in the hot, rainy season. They are then shovelled into the front section of the chamber through two sliding trap-doors which communicate between the two sections of each chamber. The fact that the floor of the back section is on a level with the top of the front section considerably facilitates this operation. Fermentation is then allowed to continue for a period of two and three days in the hot and cool season respectively.

The floor of the front section is 80 cm. (2·6 ft.) above the ground. The fermented beans are conveyed away to the drying platforms on small trolleys, which run on rails, so placed as to bring them alongside the sliding doors provided in the front of the chambers. The top of the trolley being on a level with the floor enables the beans to be expeditiously shovelled from the chamber into the trolley.

Only Forastero varieties of cocoa are cultivated in San Thomé, and the writer found that the cocoa cured by the above described methods was inadequately fermented. This no doubt was due to the beans not being sufficiently aerated during the fermenting process, and to a too restricted period of fermentation. During the first stage of fermentation the beans are completely closed in. It is extremely doubtful whether sufficient air enters by the perforations in the floor and side of the chamber to aerate properly a mass of closely packed beans 4 ft. wide, 4 ft. deep, and 13 ft. long.

On several occasions when the beans were being transferred from one section to another, after the expiration of the first period of fermentation, it was observed that fermentation had only commenced in the beans nearest to the sides and roof of the chamber. In the operation of shovelling the beans from one section to the other, a thorough admixture is effected and a more uniform fermentation of the whole mass is then very shortly evident. During the second period of fermentation the beans are not covered in, so they receive more air, which, being distributed amongst the organisms responsible for fermentation while in an active state of development, is doubtlessly conducive to better fermentation.

The under-mentioned temperatures were recorded in fermenting cocoa beans, during the wet and dry seasons respectively, by the manager of this estate :

DRY SEASON

Date.	Hour.	Temperature degrees Fahr.
May 1909		
June 1909	7 a.m	95
,, ,, ...	12 p.m.	104·4
,, ,, ...	5.30 p.m.	105·8
,, ,, ...	6 a.m.	114·5

After the last-mentioned record was taken, the beans were turned into the second fermenting-chamber, where they remained at a temperature of 114·5 until fermentation was completed.

WET SEASON

Date.	Hour.	Temperature degrees Fahr.
September 1909		
,, ,, ...		
,, ,, ...	7 a.m.	100·4
,, ,, ...	4 p.m.	107·6
,, ,, ...	7 a.m.	109·5
,, ,, ...	4 p.m.	118·0
,, ,, ...	7 a.m.	120·0
Beans turned into second chamber		
September	4 p.m.	120
,, ...	7 a.m.	123
,, ...	4 p.m.	120
,, ...	7 a.m.	115·5

Plate 10 shows the system of fermenting-chambers in use on the "Agua Izé" estate. The chambers are strongly built of wood, and in the house in which the photograph was taken are arranged in three lines, each line containing fifteen chambers. Each chamber is 2·5 metres (8·1 ft.) long, 1 metre (3·25 ft.) broad, and 1·6 metres (5·2 ft.) high, and is capable of holding about 5 tons of freshly shelled cocoa. Decauville lines run between the rows of fermenting-chambers, and upon these the cars containing the cocoa are brought alongside the particular chamber it is desired to fill. When the chamber has been filled the beans are well covered over with banana leaves. The periods of fermentation are similar to those previously described as obtaining at the "Rio do Ouro" estate. At the expiration of the first period of fermentation the beans are shovelled into an adjoining chamber left vacant for its reception. Each chamber is raised above the ground on wooden blocks, and its floor is perforated with holes for the drainage of the liquids produced during fermentation.

At the "Boa Entrada" estate the cocoa is fermented in stout wooden boxes 1·2 metres (3·9 ft) square, which are placed in an open shed. During cool, dry weather the fermenting beans are covered up with banana leaves or some similar material, but this is not considered necessary during the hot, rainy season. The period of fermentation varies in accordance with climatic conditions from five to nine days; in other respects the method of fermentation is similar to that just described.

With a view to correcting the acidity associated with the cocoa produced on this estate a special building, devised by Schulte, has been erected, in which the cocoa is placed before fermentation is completed, and the beans subjected to a constant temperature of 54° Cent. (130° Fahr.).

The building consists of two rooms, into which trolleys are run on Decauville rails. Each trolley carries five perforated wooden trays arranged one above the other. The dimensions of the trays are approximately as follows: 1·2 metres × 70 cm. × 15 cm. (3·9 × 2·3 × ·5 ft.).

The beans are first fermented for two days in the ordinary way, then spread out in the sun for six hours, after which they are spread thinly on the trays until sufficiently dried for export.

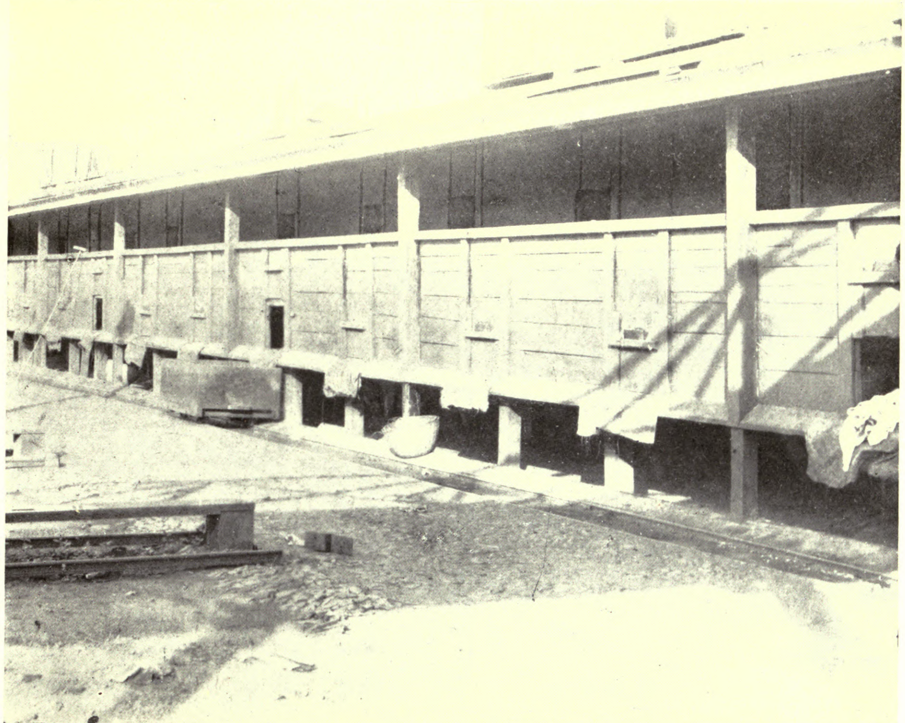
The heat for the building is provided by a flue-pipe which runs round it near the floor and is connected with a furnace. The manager of the estate informed the writer that cocoa prepared by this method realised about 500 Reis per arroba (2*s*. per 33 lb.) more than that prepared in the manner previously described, which does not compensate for the extra cost of labour and apparatus involved.

Most of the San Thomé cocoa plantations contain at least six distinct kinds of cocoa. As no care is taken either to separate these types in the field or to ferment the different types separately, the cured product is somewhat mixed in character.

Experiments were conducted by the writer in San Thomé with a view to ascertaining the loss in weight sustained by five of these varieties during fermentation. The beans from 100 fruits of each variety were fermented for four days, then washed and dried ; they were weighed both previous to fermentation and also when cured. The results obtained are given below :

No. given to fruit in Plates 1 and 2.	Variety.	Weight before fermentation.	Weight of cured beans.	Percentage of loss in curing.
		grammes.	grammes.	
I	Forastero : *Liso colorado* .	15,176	6,190	58·94
II	,, *Liso amarillo* .	13,363	5,361	59·88
III	,, *Amelonado pequeno*	8,321	3,658	56·04
IV	,, *Amelonado* . .	11,335	5,223	53·92
V	*Theobroma sphærocarpa* . .	8,479	4,000	52·82

PLATE 10



Fermenting Chambers, "Rio do Ouro" Estate, San Thomé

p. 152]

CHAPTER XVI

WASHING AND SUN-DRYING COCOA

In properly fermented cocoa beans the white parenchymatous layer of tissue with which they were originally enveloped has considerably decreased in volume, and consists of a shrunken, discoloured, uneven mass of slimy matter. The beans must now be dried to convert them into marketable condition, and this may be done without the removal of the slime or after it has been washed away.

Washing Cocoa.—The advisability of removing the slime tissue from fermented cocoa beans is often questioned. In some cocoa-growing countries it is removed by washing the beans in cold water, while in others this is neither considered necessary nor advisable. Cocoa beans are generally washed in Ceylon, and less generally in Samoa, Guatemala, Salvador, and West Africa. The principal advantages accruing from washing cocoa beans are: (1) they dry more rapidly, (2) contain a higher percentage of the substances required by the manufacturer, (3) have a cleaner and brighter appearance.

The most important objections advanced against washing cocoa are that extra labour is entailed, and the weight of the produce is reduced. Some growers maintain that the integuments of washed beans are more brittle than those of unwashed beans, and are therefore more liable to be broken. The dried slime has both strengthening and elastic properties which undoubtedly protect the beans from breakage; at the same time it is more hygroscopic than the washed and dried integuments, and the beans are therefore more susceptible to mould attacks.

Experiments which were conducted in the Gold Coast by the writer, to ascertain the actual loss in weight sustained by washing cocoa, showed that it amounted to 2 per cent. in the beans of the Amelonado variety.

It was, however, found that beans of the same variety grown in San Thomé only lost 1·46 per cent. of their weight in the washing process.

Experiments with different varieties carried out in Ceylon, with a similar object in view, gave somewhat variable results, the loss being from 2 to 7 per cent.

Preuss recorded the following results of his investigations on this subject in Kamerun (variety of cocoa not stated):

	Weight.	Per cent.
	grammes.	
A.—100 washed beans . . .	113	
1. Weight of kernels . . .		91·33
2. Weight of shells or integuments		8·66
B.—100 unwashed beans . . .	121·25	
1. Weight of kernels . .		87·5
2. Weight of shells or integuments		12·5

The above figures indicate that Kamerun cocoa loses about 3·84 per cent. by being washed.

Eigen (*Der Tropenpflanzer*, February 1903) found that Kamerun cocoa might lose as much as 6 per cent. by this process.

Advantages and Disadvantages of the Washing Process.—Similarly fermented samples of washed and unwashed cocoa beans were sent by the writer to Hamburg and London for valuation. Hamburg cocoa brokers appraised the washed samples at from 3 to 4 per cent. higher than the unwashed samples. The London broker, however, rated both samples at the same value. It would thus appear that so far as the cocoa yielded by the Amelonado variety in West Africa is concerned a net gain of from 1 to 2 per cent. is likely to be obtained by washing cocoa intended for the Hamburg market, but a loss of 2 per cent. might be sustained by washing cocoa for the London market.

With a view to eliciting further information on this subject the writer has recently consulted two of the largest cocoa-buying firms in Great Britain. One of them states: "Washing cocoa. We believe this to be a useless and even to some degree a harmful practice, as it makes the shell brittle and less protection to the bean, and it is naturally more likely to take up foreign scents and to lose its own aroma; we should not give a higher price for cocoa because it was washed." And further: "We consider the preparation for market of by far the largest proportion of Bahia, Trinidad, Grenada, San Thomé, and Kamerun cocoa is perfectly satisfactory to the consumer, and dislike any tampering with the bean, as by washing, claying, oiling, etc." The opinion of the other cocoa-buying firm consulted is directly contradictory, i.e.: "We prefer washed cocoa, because in this case the shell is more likely to be clean and thinner, and therefore there would be less loss of weight when the clean bean is finally secured"; and "In buying cocoa we certainly do go into the question of loss of weight by moisture and shell and have carefully worked out a table of the various cocoas, showing their different losses. In many cases the loss through moisture and shell amounts to some 25 lb. and over per cwt."

It is thus apparent that even in the same market, buyers are not in accord on this subject, for while one section of buyers favours washed cocoa the other may prefer the product unwashed. The grower must therefore decide for himself which method is likely to be the more profitable to him. When artificial drying facilities are not available he should seriously consider the advisability of washing his cocoa in view of the more hygroscopic character of unwashed beans and the fact that they require a longer drying period.

As an instance of the advantages accruing from washing cocoa the enhanced price which Ceylon washed cocca realises as compared with Trinidad unwashed cocoa is sometimes quoted.

The superior price obtained for the former is, however, more due to its containing a greater percentage of cinnamon-coloured kernels, which is a characteristic of the beans with white cotyledons when cured.

The residual slime is usually washed off fermented cocoa beans by placing them in a basket under a stream of running water and vigorously rubbing them with the hand or by trampling upon them with the naked feet.

Claying and Polishing Cocoa.—The practice of coating fermented cocoa beans with red earth, brick dust, red ochre, and similar substances obtains in Trinidad, Venezuela, and in a less degree in several other countries. According to Olivieri (*loc. cit.*) it consists in introducing red, ferruginous earth, devoid of organic matter, at the rate of ¼ to ½ lb. per barrel (110 lb.) of wet cocoa. It is reported to produce uniformity of colour, to preserve the aroma, and to prevent mould. Powdered red earth is used. The fermented beans, after being partially dried in the sun, are piled in longitudinal heaps on the drying platforms and the pulverised earth is sifted over them. It is then incorporated with the beans by thoroughly stirring them with wooden shovels; and the earth adheres to the mucilaginous matter which remains clinging to the integuments. They are then spread out in the sun to dry. When drying is nearly completed they are piled into heaps and lightly sprinkled with water until the whole mass becomes sticky. The labourers then trample them with their naked feet until the seed-coats assume a glossy appearance, when they are again spread out in the sun until sufficiently dry for export. Buyers whom the writer has consulted were unanimous in objecting to the practice of covering the beans with foreign substances, in view of the losses sustained in manufacture. Bannister (*Journal of the Royal Society of Arts*, 1890) found that the integuments of clayed cocoa beans from Trinidad contained as much as 5·12 per cent. of sand and 2·87 per cent. of silica.

Hart (*loc. cit.*) offers the following remarks in regard to the practice of polishing cocoa with various substances: "In Trinidad various mixtures are used for colouring purposes and for bringing out the polished appearance of the cocoa; among them may be mentioned, starch, red ochre, noucou or annatto, and red earth or clay. The red clay of San Antonio estate, Trinidad, is described by J. Bowrey, Government Analyst of Jamaica, as a very fine ferruginous clay free from organic matter, and it is said to answer the purpose admirably. Dressing or colouring of cocoa is, however, more practised by merchants who purchase from the small growers than by the well-to-do planter, as by this means they are able to put an even appearance on samples of different qualities;

but cocoa of finest quality and appearance can be made without the addition of any single particle of extraneous matter, if the methods of the best estates are adopted."

Curing or Drying Cocoa.—Fermented cocoa beans are dried either by exposing them to the sun and air or by subjecting them to artificial heat. The latter method is becoming yearly more general, especially on large estates, where sufficient bright weather does not obtain during the principal crop seasons.

Sun-drying produces a more uniform product and also imparts a brighter and more attractive appearance to the beans.

Sun-Drying.—The beans which are to be dried by natural agencies are spread out thinly in the sun on various substances, such as coir-matting, cement floors, or on wooden platforms. The beans are frequently stirred with wooden rakes to ensure uniform drying. During very hot weather the beans are sometimes protected from the sun for two or three hours during the hottest part of the day to prevent too rapid drying. If the moist beans are exposed to too much heat the integument of the bean shrivels and assumes a hard, baked consistency which is readily fractured. The pale brown colour of the integuments of washed cocoa beans is gradually altered, during the drying process, to a bright reddish brown, and if the moisture be gradually evaporated, the integument assumes a more pliable character. The kernels of white beans change to a light cinnamon-brown colour and those of purple beans to a deep chocolate-brown colour, if fermenting and drying have been properly conducted. Beans which have been well fermented and cured crackle when lightly pinched.

Drying Platforms.—Platforms on which cocoa is dried are often mounted on small wheels, which enable them to run upon rails under the shelter of a roof at night or during rainy weather. In some countries the beans are spread out to dry upon the floor of a building with a movable roof; the latter is fitted with wheels which run on rails, so that it can be expeditiously replaced in case of sudden rainfall.

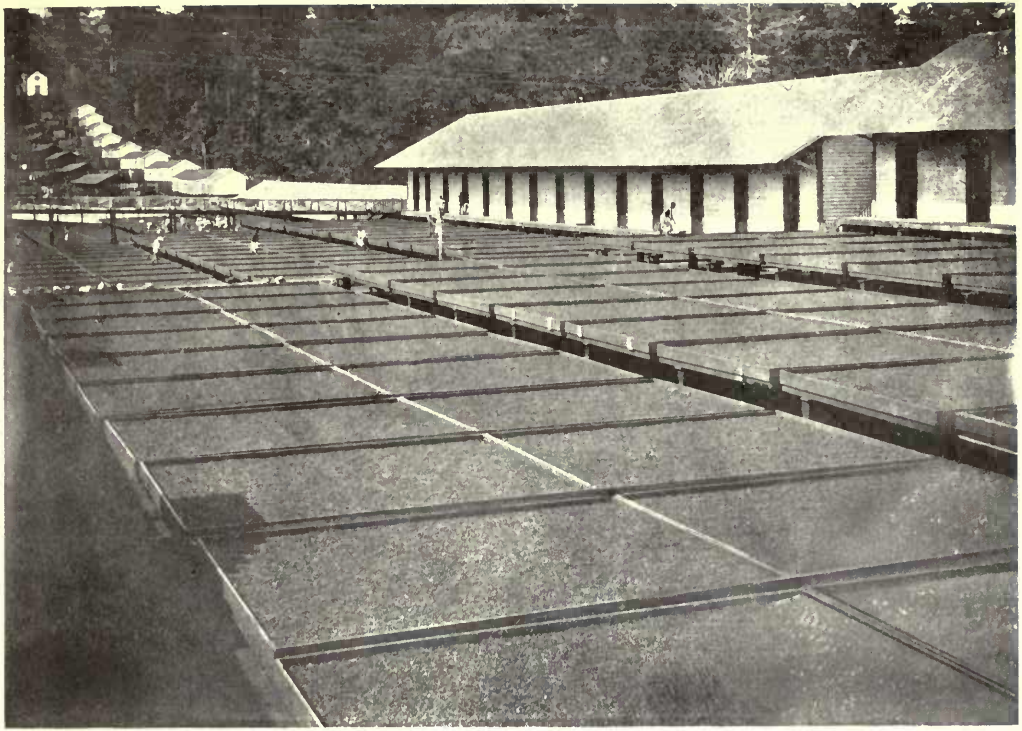
Plate 11 shows the type of drying platforms which have been adopted at the "Rio do Ouro" estate in San Thomé. Part of the system shown contains four tiers of trays, and the other part only three tiers of trays; there are two trays to each tier. The trays are made of wood and measure about 16½ ft. long, 13 ft. broad, and are 4 in. deep. To facilitate the passage of the labourers engaged in turning the beans a platform 10 in. wide has been fixed between each row of trays. Underneath the trays, wheels are fixed, which run on steel rails leading underneath the floor of large storehouses. At night and during wet weather the trays are run under these buildings. The floors of these storehouses are much wider than a tier of trays, so that the cocoa spread upon the trays is efficiently protected both from rain and dew. This method of drying cocoa reduces labour expenses to a minimum, and gives excellent results during fine weather, but it is defective during continuous wet weather. Many of the proprietors of San Thomé cocoa estates have supplemented their platform drying systems with various forms of artificial drying apparatus.

Where cocoa can be efficiently dried in the sun this method is preferable to artificial drying, both on account of the superior quality of the product which is obtained and the lower expenditure incurred. Hart considers that 80 sq. ft. of drying space is sufficient for 1,000 productive trees. Olivieri is of opinion that in Trinidad 800 sq. ft. of drying space is sufficient for a yearly output of from 11,000 to 12,000 lb. of cured cocoa; or in other words, a square foot of drying space is necessary for every 12½ to 15 lb. of cured cocoa produced annually.

Grading Cocoa.—The most carefully fermented and cured cocoa contains discoloured, shrivelled, and broken beans, as well as shells, dirt, and other foreign matter. It has been previously pointed out that the beans in a single fruit vary in size and shape; it is impossible to prevent some beans getting broken during the fermenting and curing processes, and contamination with a small proportion of foreign substances invariably occurs. If the cured beans were marketed in this condition the value of those of superior quality would be depreciated, as buyers prefer what they term an "even grade" of cocoa.

The discoloured beans should be hand-picked. The beans may be graded according to size by hand, or by passing them through sieves of different mesh, or through

PLATE 11



Cocoa-Drying Platforms

p. 158]

winnowing machines to which these sieves are attached. Winnowing machines grade the beans into different sizes and separate the broken beans and foreign matters at the same time.

It is sometimes found sufficient to divide the cured beans into two grades, but a division into three grades is preferable.

Packing Cocoa for Export.—Cured cocoa is usually packed for shipment in sacks ; these should be of good, stout material, or losses may occur in transit.

The mouth of the sack, after being filled, should be sewn up with strong cord and not tied ; by this means a greater quantity of beans can be placed in a sack and there is less danger of the cord working loose and allowing the contents to escape.

The quantity of cocoa contained in a sack varies in different countries.

Where the sacked cocoa is subjected to a great deal of handling previous to shipment it is doubtful whether it is advisable to place more than 112 lb. of cocoa in each sack ; but where good facilities exist for transporting the cocoa to the port of shipment it may be packed in larger quantities.

Storing Cocoa.—Previous to storing cocoa the planter should satisfy himself that the beans are perfectly dry, as the presence of moisture encourages the growth of mould, which imparts an unpleasant flavour to the kernels and depreciates their market value.

If the curing process is unduly prolonged, mould appears on the integument, and if not removed, may penetrate to the kernel.

It is often possible to remove a slight attack of mould from the exterior of the beans by rubbing them vigorously and thoroughly drying them.

When too much mould has formed for it to be disposed of in this manner it is advisable to wash the beans with water and to dry them rapidly.

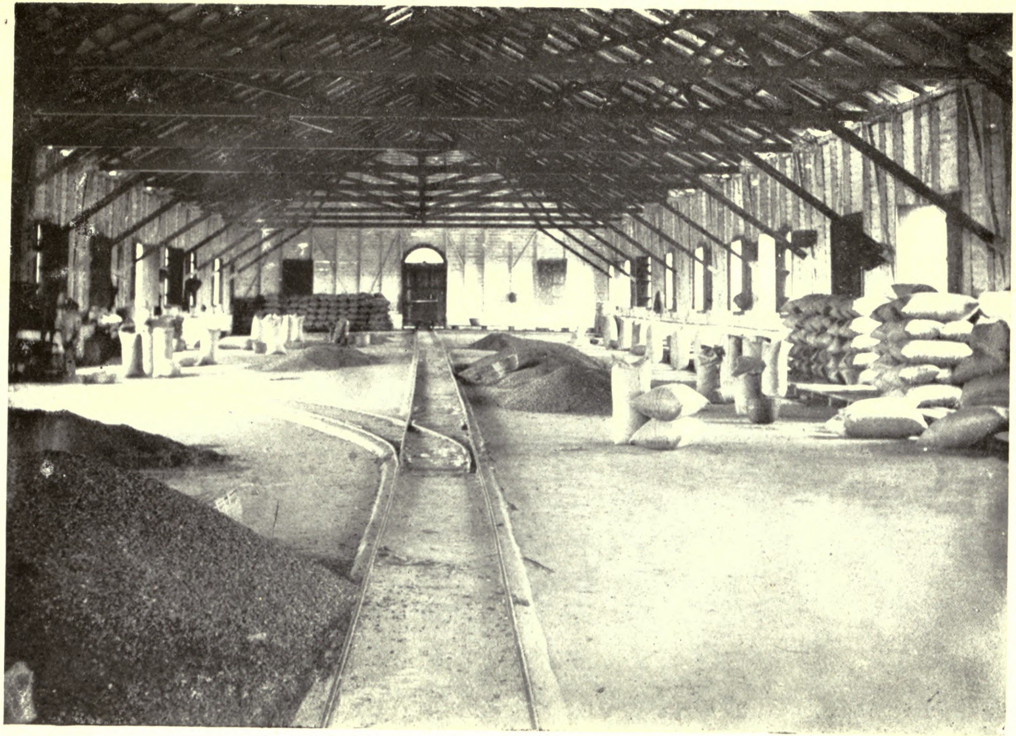
Cured cocoa beans are sometimes attacked by insects. The writer observed two insects destructive to stored cocoa in the Gold Coast, i.e. *Aræocerus coffeæ*, a small beetle, and *Ephestia cautella*, Wlk., a Pyralid moth.

It is stated that the same insects are also troublesome in cocoa warehouses in England. The larvæ of both these insects feed upon the cotyledons, and the integuments of badly infested beans contain little else but their excreta. Pyralid moths have been often observed hovering over, and settling upon, cocoa beans which have been spread out in the sun to dry. It is probable that this moth lays its eggs in or upon the beans at this period, and although the beans appear to be quite sound when placed in the storehouse, they may be badly attacked by larvæ shortly afterwards.

Storehouses which are infested with either *Aræocerus coffeæ* or *Ephestia cautella* should be frequently cleaned out and limewashed, and the cocoa stored in them should be constantly examined.

The larvæ in the beans may be destroyed by pouring a small quantity of carbon bisulphide upon cotton-wool, or some similar absorptive material, and placing this in each sack containing larvæ-infected beans, and tightly closing the sack. About a fifth of a drachm of the liquid is usually sufficient to kill all the larvæ in a sack of cocoa. Owing to its inflammability it is inadvisable to bring naked lights in the neighbourhood of the vapour of carbon bisulphide. This substance has no injurious effect upon cocoa, and its unpleasant odour disappears when the beans are exposed to air. The vapour of carbon bisulphide appears, however, to have no effect on the eggs of the insects; it is therefore sometimes necessary to apply the substance on more than one occasion, as, although the first application may destroy all the larvæ present in the beans, more may develop from the unhatched eggs.

PLATE 12



Cocoa-Store and Packing Shed in San Thomé

p. 160]

CHAPTER XVII

YIELD AND EXPENDITURE

It is only possible to give very approximate figures in regard to the yield of cocoa and the cost of production.

Not only does the yield of a particular variety of cocoa vary considerably in different countries, but it may differ in the same country owing to variations in the soil, climate, and cultural methods adopted.

The estimated cost of production in a particular district is not necessarily applicable in another, as it is largely influenced by the local conditions affecting labour, transport, land-tenure, and various other factors.

Yield of Cocoa

The manner in which the production of cocoa has been increased in various countries by the judicious application of manures has been already amply demonstrated in this work.

Tropical America.—According to H.B.M. Consul at Bahia, the average yield in that country is at the rate of 2½ kilos. (5½ lb.) of cured cocoa per tree, when 625 trees are planted per hectare, i.e. 284 trees per acre. He considers that higher yields could be obtained by a more intelligent care of the trees. On one carefully cultivated plantation the yield has been 6 kilos. (13·2 lb.) per tree, while on another estate in the Belmonte district, it was as high as 15 kilos. (33 lb.) per tree. In Nicaragua the average yield per tree is estimated at 1 lb., and Preuss considers that a similar yield is obtained in Ecuador. Previous to the outbreak of the "Witch-broom" disease in Surinam an average yield of 440 lb. of cocoa per acre was obtained, but this subsequently fell to 72·6 lb. per acre. Jumelle states that on some plantations in Mexico from 5 to 8 lb. of cured cocoa per tree are obtained.

Ceylon.—On the various estates in Ceylon which the writer visited in 1902 the average yield varied from 1½ to 4 cwt. per acre. According to Wright, from 250 to 350 lb. of cocoa per acre is considered a moderately good yield, one of 500 to 900 lb. and over very good, and below 150 lb. inferior. During the years 1893–1906 the average yield of cocoa in Ceylon varied between 1·3 cwt. and 2·7 cwt. per acre. On one estate in the Dumbara district an average of 1,026 lb. per acre is reported to have been harvested in 1905.

At the Experiment Station, Peradeniya, where some 100 to 116 acres were planted with cocoa, the undermentioned yields have been recorded :

Year.	Number of trees.	Total yield of cured cocoa.	Yield in lb. per tree.
		cwt.	
1903 . . .	29,225	136·5	0·52
1904 . . .	28,572	240·75	0·94
1905 . . .	33,199	361·4	1·21

One plot manured with sulphate of ammonia, at the rate of 250 lb. per acre, is estimated to have yielded 8½ cwt. of cured cocoa per acre in 1907, while the unmanured plots yielded at the rate of 4¾ cwt. per acre during the same year.

Java.—The Venezuelan-Criollo variety in Java is reported to produce ·275 lb., ·55 lb., 1·1 lb., 1·65 lb. of cured cocoa per tree when it is four, five, six, and seven years of age respectively ; and when from ten to twenty-five years of age, a single tree produces from 1·65 to 2·2 lb. of cocoa.

West Indies.—According to the *West Indian Bulletin*, vol. viii., cocoa trees in Trinidad yield at the rate of from 1½ to 2 lb. per tree. In this island the trees are planted from 10 to 16 ft. apart, but at an average distance of 12 ft. ; 1·4 lb. per tree is considered a fair yield, but more than double this amount is sometimes obtained. Olivieri is of opinion that the average yield in Trinidad is 600 lb. per acre, or 2 lb. per tree ; and in districts where the soil is rich 900 lb. per acre, or 3 lb. per tree, are generally obtained.

From a tree growing in the Trinidad Botanic Gardens 15·75 lb. of cocoa were harvested in 1907.

Cocoa trees in Grenada are reported to yield an average of 784 lb. per acre.

During the years 1905–6 the average yield of cocoa per acre in St. Lucia was estimated at 300 lb.

It is considered that a highly cultivated estate in Tobago, in full bearing, should yield at the rate of 825 lb. per acre.

Samoa.—Old cocoa plantations in this country yield at the rate of 450 lb. per acre. Vice-Consul Frood mentions one plantation of four-year-old trees which yielded 750 lb. per acre. Well-cared-for estates have produced as much as 10 cwt. of cured cocoa per acre.

West Africa.—The yields of cocoa harvested from trees planted at 15 ft. apart in the Botanic Gardens, Aburi, Gold Coast, are as follows :

Year.	Age of trees in years.	Number of trees.	Area.	Yield of cured cocoa per acre.	Yield of cured cocoa per tree.
			Acres.	lb.	lb.
1898 . .	6	1,080	5·66	848·9	4·45
1903 . .	11	819	4·29	847·6	4·44
1904 . .	12	800	4·19	873·5	4·59
1908 (Oct. 23 to Dec. 31) .	16	250	1·4	—	6·49
1909 . .	17	Block A.	—	—	11
		,, B.	—	—	8
		,, C.	—	—	6

In native-owned cocoa plantations the yield varies from 2 to 5 lb. per tree.

The total area of native-owned cocoa plantations in the Gold Coast was estimated in 1908 at 70,000 acres. During that year 28,545,910 lb. of cocoa were exported, which indicates that the average yield per acre was 408 lb.

Dodd informs the writer that cocoa trees commence to bear fruit in Southern Nigeria when they are three or four years of age, and yield about ½ lb. of cured cocoa per tree. This increases yearly, and at six years of age a tree may produce from 2 to 4 lb. In good soil an average yield of 5 lb. per tree is obtained.

In the Kamerun the average yield was estimated, in 1904, at 2·2 lb. per tree.

San Thomé.—Well-managed cocoa estates in San Thomé yield at the rate of 1,200 kilos. per hectare (1,068 lb. per acre), but where the soil is poor, less than half of this amount is recorded.

The average yield is considered to be approximately 1,000 kilos. per hectare (890 lb. per acre).

Cost of Producing Cocoa

Trinidad.—According to Hart, land suitable for cocoa cultivation can be obtained from the Trinidad Government at £1 per acre, exclusive of survey and other fees, but any particular block of land applied for is subject to competition.

Labourers are paid from 25 to 60 cents, 1*s.* 0½*d.* to 2*s.* 6*d.* per day.

In this island cocoa estates are generally planted on what is known as the contract system. The land is cleared at the owner's expense and it is then handed over to one or more contractors.

The contractor usually retains possession for about five years. During this period he plants the cocoa and shade trees, as arranged by contract, drains the land, and grows catch crops for his own profit. When the estate is taken over by the proprietor, the contractor is paid at the rate of 1*s.* or 1*s.* 3*d.* for each bearing cocoa tree, and smaller amounts, in proportion to size, for less developed trees. Where shade trees are planted they are paid for at the same rate as mature cocoa trees.

With regard to the cost of clearing new land in Trinidad, Hart considers that the felling and burning off costs between 15 and 25 dollars per quarrée (19*s.* 6*d.* to 32*s.* 6*d.* per acre). By the contract system a cocoa estate may be established at from £12 to £15 per acre, exclusive of buildings. The annual working expenses of the estate may be calculated at from £3 to £5 per acre. The necessary buildings for an estate of 300 acres can be erected for £200 to £250; in this estimate, neither dwelling-houses nor artificial drying-chambers are provided for. Weeding or cutlassing is usually carried out twice a year, and costs about 5*s.* per acre.

Picking and drying cost from 5*s.* to 6*s.* per cwt. of dried cocoa.

Picking and placing the beans in the fermenting-house costs from 3*s.* 4*d.* to 5*s.* per 110 lb., but these operations are sometimes carried out for as low as 2*s*. 6½*d*. per 110 lb., as is shown below.

		s.	*d.*
Four men @ 1*s*. 8*d*. per day reap sufficient fruits to yield 6 barrels of beans, i.e. 660 lb.	=	6	8
Two women @ 1*s*. 0½*d*. to pick up fruits	=	2	1
One man @ 1*s*. 8*d*. to pile into large heaps	=	1	8
One man to break or cut fruits (½ day's work)	=	0	10
Job work extracting beans, @ 5*d*. per barrel	=	2	6
Job work conveying beans to fermenting-house	=	1	6
	6)	15	3
		2	6½

Samoa.—According to Vice-Consul Frood a sum of £2,500 is required to start a cocoa plantation in Samoa. The cost per acre from the time of clearing the land up to the collection of the first crop is estimated at from £25 to £30.

West Africa.—Chevalier estimates that in French West Africa an expenditure of 500,000 francs (£20,000) is sufficient to supply the necessary buildings and equipment for an estate of 200 hectares (494 acres) and also cover all costs connected with planting this area and maintaining it until the trees are four years of age. He considers that the returns from this area, together with another £20,000, should be sufficient to bring the total area planted up to 500 hectares (1,235 acres) within ten years from the date operations commenced.

In a report written by the Governor of Fernando Po it is stated that cocoa trees in that island commence to bear fruit when they are four years of age. In five years the capital invested yields interest, and in seven years the whole of the capital is reimbursed.

At the "Agua Izé" estate, San Thomé, it is estimated that 3,000 hectares (7,410 acres) have been planted with cocoa and various other crops.

Count Faro (*A Ilha de San Thomé e Roca Agua Izé*) states that the annual expenditure on this estate, including the salaries of some fifty European employees, is 26,500,000 reis (£5,300).

Tobago.—The following remarks and estimates of cost of bringing cocoa into bearing in Tobago have been extracted from Pamphlet series, No. 41, *Tobago, Hints to Settlers*, issued by the Imperial Department of Agriculture for the West Indies.

It is estimated that a bag of cocoa (165 lb.) can be produced in Tobago for £1 15*s*.

Crown land costs £2 per acre. Labourers are paid from 10*d*. to 1*s*. 2*d*. per day and women from 6*d*. to 8*d*. per day.

Abandoned sugar-cane estates may be cleared, planted, drained, and kept clear of weeds during the first year for £5 per acre ; this sum likewise includes the purchase of bananas, cassava, cocoa beans, and nursery. When a cocoa estate is established on such lands the total cost for eight years is estimated at £12 10*s*. per acre, exclusive of superintendence.

In heavy forest land an expenditure of £7 10*s*. per acre is considered sufficient to fell, clear, plant, drain, and keep clear of weeds for the first year, including purchase of bananas, cassava, cocoa beans, and nursery. The total cost for eight years, in this case, is estimated at £15 per acre, exclusive of superintendence.

It is pointed out that the above figures are for actual outlay on cultivation alone, and do not allow for expenditure on road-making or fencing. Cocoa estates are frequently established by the contract system, previously described. At the expiration of the period of contract the cocoa trees are counted, 1*s*. is paid for each full-bearing tree, 6*d*. for each tree not full bearing, but over three years of age, and 3*d*. each for trees under three years of age.

CHAPTER XVIII

COMMERCIAL COCOA, ITS MANUFACTURE AND USES

Chemical Composition of Cured Cocoa Beans

We have seen that cocoa is exported from nearly every tropical country on the globe, and the methods employed in cultivating and preparing this product for market have been described. The chemical constituents of cured cocoa beans, from various countries, have been determined by several investigators, and the results obtained are given for comparison.

Beckurts (*Archiv. der Pharm.* ccxxxi., pp. 687–694) examined twenty-three trade samples of cocoa beans, and found that the amount of fat in different samples varied from 42 to 57·4 per cent., the theobromine from ·63 to 2·2 per cent., the starch from 7·56 to 16·53 per cent., and the ash from 2·2 to 3·75 per cent.

The average weight of cured cocoa beans, received from different countries, was determined by Ridenour (*Amer. Jl. Pharm.*, April 1895, pp. 207–9) by taking the average weight of 50 beans of each kind. He obtained the undermentioned figures :

Origin :	Bahia.	Surinam.	Java.	Trinidad.	Trinidad (roasted).	Ariba.
Weight, Grammes .	·856	1·175	·994	1·295	1·189	1·434
Origin :	Curacao	Caracas (roasted)	Grenada	Tobasco	Machalle	Maracaybo
Weight, Grammes .	1·447	1·214	·920	1·266	1·237	1·364

The results of the chemical examination of these cocoas are given in the table on the next page.

	Bahia.	Surinam.	Java.	Trinidad.	Trinidad (roasted).	Ariba.	Caracas.	Caracas (roasted).	Grenada.	Tobasco.	Machalle.	Maracaybo.	Average.
Fat (cocoa butter) .	42·10	41·03	45·40	43·66	41·89	43·31	36·81	37·63	44·11	50·95	46·84	42·20	42·99
Theobromine .	1·08	·93	1·16	·85	·95	·86	1·13	·99	·75	1·15	·76	1·03	·97
Albuminoids . .	7·50	10·54	9·25	11·90	12·02	10·14	10·59	12·36	9·76	7·85	12·69	11·56	10·51
Glucose . . .	1·07	1·27	1·23	1·38	1·48	·42	2·76	1·76	1·81	·94	1·60	1·09	1·40
Saccharose . .	·51	·35	·51	·32	·28	6·37	1·56	·51	·55	2·72	·46	1·36	1·29
Starch . . .	7·53	3·61	5·17	4·98	5·70	1·58	3·81	6·07	6·27	3·51	1·35	1·69	4·27
Lignin . . .	7·86	3·90	6·10	5·65	5·87	4·62	3·28	9·05	5·55	6·44	5·95	7·16	5·95
Cellulose . .	13·80	16·24	13·85	13·01	19·64	14·07	16·35	11·69	13·49	12·57	11·32	17·32	14·44
Extractive matter (by difference) .	8·99	13·53	8·90	8·31	5·84	9·00	12·72	9·22	9·72	9·26	9·02	6·79	9·30
Moisture . .	5·96	5·55	5·12	6·34	2·63	5·90	6·63	5·69	5·28	1·55	5·86	5·67	5·18
Ash . . .	3·60	3·05	3·31	3·60	3·70	3·73	4·36	5·03	2·71	3·06	4·45	4·13	3·70

The following is an analysis of Trinidad raw cocoa nibs (Inland Revenue Laboratory):

	Per cent.		Per cent.
Moisture	5·23		79·84
Fat	50·44	Gum	2·17
Starch	4·20	Cellulose	6·40
Albuminous matter:		Alkaloids	·84
Soluble	6·30	Cocoa red	2·20
Insoluble	6·96	Indefinite organic matter,	
Astringent principle	6·71	insoluble	5·80
		Ash	2·75
	79·84		100·00

Cured cocoa nibs of three different varieties of Ceylon-grown cocoa have been analysed by Bamber and Bruce, with the under-mentioned results:

Variety.	Forastero-Amelonado.	Caracas.	Forastero-Cundeamor.
	Per cent.	Per cent.	Per cent.
Moisture	4·75 to 4·90	4·20 to 5·40	4·50 to 6·50
Ash	3·26 ,, 4·09	3·64 ,, 3·72	3·76 ,, 3·92
Fat	43·45 ,, 54·40	42·54 ,, 51·40	44·12 ,, 52·50
Fibre	2·42 ,, 9·62	2·34 ,, 9·62	2·42 ,, 6·44
Proteids	13·25 ,, 13·56	12·12 ,, 13·13	12·37 ,, 12·81
Alkaloids	0·72 ,, 0·86	0·68 ,, 1·16	0·54 ,, 1·04
Carbohydrates, etc.	19·77 ,, 24·95	22·67 ,, 27·20	20·81 ,, 28·27
Total Nitrogen	2·32 ,, 2·41	2·13 ,, 2·46	2·13 ,, 2·35

Records obtained by several observers, as compiled by Jumelle, *La Cacoyer*, are given in the table on p. 171.

In connection with these analyses it is important to point out that the chemical composition of cocoa may be affected by different methods of fermentation.

Beans of the Forastero-Amelonado variety, grown in the Botanic Gardens, Aburi, Gold Coast, were fermented for different periods.

Examination at the Imperial Institute of the differently fermented beans gave the under-mentioned results (*Bulletin of the Imperial Institute*, Vol. V., No. 4, 1907, p. 362):

CALCULATED ON THE HUSKED SAMPLES

No. of sample.	Method of preparation.	Husk.	Moisture.	Fat.	Ash.	Total Alkaloid.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I	Fermented 8·5 days and washed	8·0	4·55	48·29	2·39	1·28
IV*a*	Fermented 4·5 days and washed	8·0	4·87	46·63	3·05	1·65
IV*b*	Fermented 4·5 days unwashed	8·0	4·75	46·17	2·90	1·58
V*a*	Fermented 6·5 days and washed	8·0	4·89	44·51	2·74	1·20
V*b*	Fermented 6·5 days unwashed	11·4	5·00	45·30	2·66	1·40
VI*a*	Fermented 7·5 days and washed	8·4	4·55	44·50	2·67	1·22
VI*b*	Fermented 7·5 days unwashed	10·4	4·90	45·20	2·87	1·21

As previously mentioned some buyers take into consideration the proportion of shell present in estimating the value of cocoa.

The proportion of the shells and the mean weight of the beans of different cocoas have been determined by Brayning (*Journal d'Agriculture Tropicale*, p. 31, July 1901), as follows :

Origin.	Kernel,	Shell,	Mean weight of unshelled beans.
	per cent.	per cent.	Grammes.
Java	92·9	7·1	1·236
San Thomé	92·3	7·7	1·348
Surinam (1)	91·4	8·6	1·149
Trinidad	90·9	9·1	1·286
Para	89·8	10·2	1·136
Porto-Plata	89·5	10·5	1·292
Haiti	88·6	11·4	1·317
Bahia	88·4	11·6	1·379
Puerto-Cabello	88·1	11·9	1·598
Surinam (2)	88·1	11·9	1·637
Guayaquil (Machala)	88·0	12·0	1·537
Guayaquil (Ariba)	87·0	13·0	1·628
Carupano	86·8	13·2	1·469
Caracas	86·6	13·4	1·504
Grenada	86·6	13·4	1·230

The varying proportions of particular constituents, which different investigators have found in cocoa from the same country of origin, are probably due to the different methods of cultivation and preparation adopted, as well as to the examination of more than one variety of beans.

Analyses of the Kernels of Cured Cocoa

	Lampardius.	Payen.		Plairfair and Lankester.	Boussingault.		Mitscherlich (Guayaquil).		Muter.	Zipperer.						
										Ariba.	Guayaquil.	Caracas.	Puerto-Cabello.	Surinam.	Trinidad.	Port-au-Prince.
Water .	5·20	10·00	12·00	5·00	11·60	7·60	5·06	6·30	5·98	8·35	6·32	6·50	8·40	7·07	6·20	6·94
Cocoa butter	53·10	48·00	50·00	50·00	53·30	49·90	45·00	49·00	42·67	50·39	52·68	50·31	53·01	50·86	51·57	53·66
Albuminoid substances	18·70	21·00	20·00	20·00	12·90	10·90	13·00	18·00	12·21	19·44	12·04	17·23	13·31	21·45	15·79	13·28
Starch and traces of sugar .	10·91	11·00	10·00	7·00	6·70	2·40	14·60	18·00	19·03	5·78	8·39	7·65	10·05	6·41	11·07	8·96
Gums . .	7·75	—	—	6·00	—	2·40	—	—	6·40	—	—	—	—	—	—	—
Cellulose .	—	3·00	2·00	—	9·10	10·60	6·08	—	5·95	2·66	2·41	2·61	2·52	2·68	2·64	2·53
Woody fibres	0·90	—	—	4·00	—	—	—	—	—	—	—	—	—	—	—	—
Theobromine	—	4·00	2·00	2·00	2·40	3·30	1·02	1·50	0·90	0·35	0·33	0·77	0·54	0·50	0·40	0-32
Cocoa red .	2·01	—	—	2·00	—	—	3·05	5·00	5·90	} 8·91	13·72	10·76	7·85	8·31	9·46	11·39
Tannins, etc.	—	—	—	—	—	0·20	—	—	—							
Mineral matters .	—	3·00	4·00	4·00	4·00	4·00	3·05	—	3·96	4·12	4·11	4·17	4·32	2·72	2·87	2·92
Tartaric acid	—	—	—	—	—	3·40	—	—	—	—	—	—	—	—	—	—
Other substances .	1·43	—	—	—	—	5·30	9·14	—	—	—	—	—	—	—	—	—
Total .	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Fat (Cocoa Butter).—A study of the various preceding analytical results shows that fat is the predominant constituent of cured cocoa beans. It may constitute as much as 54·40 per cent., or it may be only present in the proportion of 36·81 per cent. of the total weight of the product.

Although cocoa butter is not considered injurious, it is generally found unpalatable in large quantity, and its partial removal is one of the first processes of manufacture. This substance melts at 84° Fahr.

Fresh cocoa butter is yellowish-white, but if exposed to light, becomes entirely white, and possesses a mild cocoa odour and a sweet agreeable taste. Both these characters are eliminated by boiling the fat with absolute alcohol. When pure it has the peculiar property of not becoming rancid, however long it may be kept.

Its specific gravity varies, in accordance with age, from 0·945 to 0·982. It is used in the perfumery, soap, and pharmaceutical industries, in which it is especially valuable owing to its neutral qualities. In chloroform, oil of turpentine, ether, and acetic ether it is very soluble. Cocoa butter is sometimes adulterated with a mixture of stearine, paraffin, and beef fat.

Albuminous Matters.—The percentage of albuminoid substances in cured cocoa beans appears to be fairly constant at from 13 to 14 per cent.; but they have been recorded as high as 21·45 per cent. and as low as 7·50 per cent.

These substances are of a somewhat complex nature; about one half are considered soluble, which is a larger proportion than that of the albuminoids of either tea or coffee.

Starch and Sugars.—In order of importance by weight the starch and sugars rank next to the fat and albuminoids as constituents of cured cocoa beans. According to the analyses quoted the proportion in which they are present varies from 2·40 to 18·0 per cent. of the total weight of the beans.

The highly nutritive properties of cocoa are due to the fat, nitrogenous materials, and starch which it contains.

Alkaloids.—To the alkaloids of cocoa its stimulating properties are due.

Payen's analyses show that cured cocoa kernels may contain as much as 4 per cent. of alkaloid, but Zipperer only found ·32 per cent. of this constituent in cured kernels of Port-au-Prince cocoa.

Theobromine is the principal alkaloid of cocoa, and the analyses of different chemists demonstrate that it usually constitutes 1·2 per cent. of the kernels. This substance is closely allied to theine or caffeine, the alkaloid of tea and coffee, and like it is poisonous in large quantities. Theobromine has a bitter taste and is sparingly soluble in boiling water.

Harrison's analytical determinations of fresh and cured beans of Calabacillo cocoa show that, in addition to theobromine, ·11 and ·03 per cent. of caffeine was present in the fresh and cured beans respectively.

Cocoa and Chocolate Manufacture

In order to obtain the opinions of buyers of the descriptions of cocoa most favoured by them, the writer has consulted two of the largest manufacturers of cocoa and chocolate in Great Britain, and he is indebted to them for the following remarks on this subject.

I

"**Washing Cocoa.**—We believe this to be a useless and even to some degree a harmful practice, as it makes the shell brittle and less protection to the bean (seed), and the bean is naturally more likely to take up foreign scents and to lose its own aroma ; we should not give a higher price for cocoa because it was washed.

"For cocoa and chocolate some different classes of cocoas are useful. For cocoa the strong Guayaquil type is considerably used, and it would be a satisfaction to us to see this type cultivated in other parts of the world than in the Republic of Ecuador. (It always brings higher prices than Forastero.) For general purposes the Forastero types of cocoa are useful, and we should not call these common, although they are not of the very highest grade. For chocolate a certain amount of the lighter Criollo cocoa is used in the highest brands, but as it has very little flavour of its own the consumption will always be limited, and we should not recommend the extending of this cultivation, although the market price is higher.

"One thing that should be watched very carefully by native cultivators is the ripeness of the cocoa. The yellow pod (fruit) grown so largely in the Gold Coast is ripe when pale yellow, and when golden (when it looks fully ripe) is nearly always over-ripe and sprouting; and needless to say, cocoa that has already germinated has lost some of its best flavour.

"We consider a certain amount of fermentation essential for good cocoas.

"When cocoa is sufficiently mixed with other ingredients in low-class chocolates, or even in a higher class of milk-type chocolate, where the proportion of cocoa is small, it is possible to cover up some defects, and for this reason the demand for the very cheapest undried West African cocoa on the Hamburg market (and to a less extent in England) will no doubt continue. It will, however, be noted that when markets are lowest the difference between the price of good and bad will be greater than when markets are at their highest, and so it should always pay in the long run to turn out good cocoa at the additional expense of careful fermenting and drying.

"We consider the preparation for market of by far the largest proportion of Bahia, Trinidad, Grenada, San Thomé, and Kamerun cocoa is perfectly satisfactory to the consumer, and dislike any tampering with the bean as by washing, claying, oiling, etc."

II

"We do prefer washed cocoa, because in this case the shell is more likely to be clean and thinner and therefore there would be less loss of weight when the clean nut (seed) is finally secured.

"Large nuts are of course preferred, because there naturally would be less shell than with the smaller beans (seeds), and the difference in value might easily run to 1*s.* per cwt.

"We buy both artificially and sun-dried cocoa, often without knowing which process has taken place, but we imagine that the artificially dried cocoa is more protected from variation in the weather. We understand that on the more modernised estates artificial drying is largely resorted to.

"We can give you no information as to vacuum-dried cocoa.

"We buy certain kinds of clayed cocoa, but do not seek after them on account of the loss in weight through the heavy clayed shells. We are alluding to cocoas such as clayed Caracas and Puerto Cabello.

"In buying cocoa we certainly do go into the question of loss of weight by moisture and shell, and have carefully worked out a table of the various cocoas showing their different losses. In many cases the loss through moisture and shell amounts to some 25 lb. and over per cwt."

The general processes associated with the preparation of commercial cocoa products from the cured beans consist in:

(1) Cleaning and grading the beans; (2) Roasting; (3) Breaking and shelling; (4) Grinding and fat extraction; and (5) Mixture of ingredients.

Upon arrival at the factory cocoa beans are cleaned and graded, by placing them in barrel-shaped sieves. The latter are made to rotate, and dust and other foreign matters are carried away in the air-current supplied by fans. The beans are separated into three or more sizes to ensure uniformity in roasting, since the larger beans require a longer period of roasting than smaller ones.

The graded beans are automatically carried into the hoppers for the roasting process, when they are subjected to a high temperature. At the present day roasting is generally performed by high-pressure steam, which is more economical and cleaner than fuel. This operation improves both the aroma and flavour of the beans, as their bitter principle is modified. The starch present is changed to dextrin, which is more readily soluble in water than starch.

The roasting facilitates both the shelling and grinding processes, as the beans are more easily fractured in the dried state.

	Husk.	Fat.	Nitrogen.	Albuminoids.	Ash.	Ash soluble in water.	Ash soluble in HCl.	H_3PO_4 in ash.	Moisture.	Starch, Gum, Cellulose, etc.
Caracas . .	13·8	48·4	1·76	11·14	3·95	2·15	1·80	1·54	4·32	32·19
Trinidad . .	15·5	49·4	1·76	11·14	2·80	0·90	1·90	0·93	3·84	32·2
Surinam . .	15·5	54·4	1·76	11·14	2·35	0·80	1·85	1·23	3·76	28·35
Guayaquil . .	11·5	49·8	2·06	13·03	2·50	1·75	1·75	1·87	4·14	30·47
Grenada . .	14·5	45·6	1·96	12·40	2·40	0·60	1·80	1·35	3·90	35·70
Bahia . .	9·6	50·3	1·17	7·40	2·60	0·90	1·70	1·26	4·40	35·30
Cuba . .	12·0	45·3	1·37	8·67	2·90	0·95	1·95	1·13	3·72	39·41
Para . .	8·5	54·0	2·00	12·66	3·05	1·40	1·65	1·00	3·96	26·33

Chemical Composition of Roasted Beans.—The table on this page gives analyses of various kinds of roasted cocoa beans (shelled) made by Hisch and published by Blyth.

When cool the beans are passed through a machine which cracks the shells; and the latter are then removed by a winnower.

We have already seen that the shells may comprise from 7·1 to 13·4 per cent. of the total weight of the cured beans and from 8·5 to 15·5 per cent. of the beans after they have been roasted. The shells are sometimes ground into powder and used as an adulterant of inferior chocolate; or they may be employed as manure or cattle food.

The shelled and roasted kernels are now ground into a paste between heated rollers, which cause the fat to melt and a large proportion of it is run into moulds and allowed to cool and solidify. In this condition the fat or cocoa-butter is often stored, since there is no danger of its becoming rancid. When the grinding process is nearing completion, various ingredients are incorporated in the paste with a view to improving both its flavour and solubility.

The flavouring agents added generally consist of vanilla, volatile oils, and various spices, while starchy matters and sugars are employed to improve its miscibility.

Strictly speaking, manufactured cocoa is not soluble in the form in which it is drunk as a beverage, but is only completely mixed with the fluids, such as hot milk and water, with which it is prepared.

In this respect it differs from tea and coffee, as it is the infusion from these two substances which provides the beverage, whereas with cocoa the whole of the substance, after being thoroughly mixed with liquid, is consumed.

In the preparation of chocolate a larger proportion of the fatty matter is allowed to remain; and if sweet chocolate be required, a considerable quantity of sugary substances, as well as various flavouring materials, are added to the paste formed in the grinding process.

In Canada the following draft proposals for Food Standards in regard to cocoa and chocolate have been published.

Cocoa and Cocoa Products

"Cocoa nibs, cracked cocoa, is the roasted, broken cacao bean freed from its shell or husk.

"Chocolate, *plain chocolate*, *bitter chocolate*, *chocolate liquor*, *bitter chocolate coatings*, is the solid or plastic mass obtained by grinding cocoa nibs without the removal of fat or other constituents except the germ, and contains not more than three (3) per cent. of ash insoluble in water, three and fifty-hundredths (3·50) per cent. of crude fibre, and nine (9) per cent. of starch, and not less than forty-five (45) per cent. of cocoa fat.

"Sweet chocolate, *sweet chocolate coatings*, is chocolate mixed with sugar (sucrose), with or without the addition of cocoa butter, spices, or other flavouring materials, and contains in the sugar-and-fat-free residue no higher percentage of either ash, fibre, or starch than is found in the sugar-and-fat-free residue of chocolate.

"Cocoa, *powdered cocoa*, is cocoa nibs, with or without the germ, deprived of a portion of its fat, and finely pulverised, and contains percentages of ash, crude fibre, and starch corresponding to those in chocolate after correction for fat removed.

"Sweet cocoa, *sweetened cocoa*, is cocoa mixed with sugar (sucrose), and contains not more than sixty (60) per cent. of sugar (sucrose), and in the sugar-and-fat-free residue no higher percentage of either ash, crude fibre, or starch than is found in the sugar-and-fat-free residue of chocolate."

The principal substances employed in the adulteration of cocoa are :

Venetian red, sugar, starches, peroxide of iron, and brick-dust.

Chocolate is adulterated with cocoa oil, beef and mutton fat, starches and oil of almonds.

Blyth says : "By a simple estimation of the fat and the chief constituents of the ash, supplemented by the use of the microscope, all known adulterations can be detected."

INDEX

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BULLETIN

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EDITED BY THE DIRECTOR