IMPROVED METHODS OF COFFEE PRODUCTION

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TABLE OF CONTENTS

INTRODUCTION

Coffee is one of the most important money crops produced in the majority of the countries along the equator. According to the New York Coffee and Sugar Exchange, Inc., in the period 1931-32 the total world exportation of coffee amounted to approximately 34,390,100 bags, of about 132 pounds each, with a value of $45,394,932.00, the value being based on a price at 10 cents a pound, as given by the Statistical Abstract of the United States Bureau of Foreign and Domestic Commerce for 1931. Although the part which coffee plays in world trade is important its production has not had the study that such a crop deserves. Very little is known regarding the response of the different varieties to different soils and climatic conditions, the best and most practical method of cultivating the plant, the part that shade plays in the growing of the crop, the effect of different types of pruning on yield, the best and most practical way of cleaning and preparing the bean for market, etc. In fact, from the literature reviewed, it appears that the investigation of coffee production, from a scientific point of view, has hardly begun.

In the present work an attempt has been made to review and summarize such literature on coffee production as was available to the writer.

COFFEE PRODUCTION AND CONSUMPTION

The production and exportation of coffee on a commercial scale is confined to South and Central America, Mexico, the West Indies, Asia, the Pacific Islands, and Africa. An idea of the world exports of coffee may be obtained from the table below which gives in five-year periods, from 1909 to 1928, the exports of green coffee for all of the important coffee producing countries. The data for this table were obtained from Bynum's (18) report on "The world exports of coffee." The figures represent thousands of bags of 132 pounds each.

South America

Brazil, Colombia, Venezuela, and Ecuador are the chief producers of the countries in South America, with Surinam, Peru, British Guiana, and Bolivia following.

Brazil is the largest coffee producing country in the world. According to Bynum's report, its percentage of the world's total production was approximately 76 for the period 1910-14, 77 for the period 1915-19, 66 for the period 1920-24, and 71 for the period 1926-30. The total production for 1932 was approximately 15,880,000 bags of 132 pounds each (151). (In this discussion, whenever the word bag is used

TABLE I. World's coffee production in thousands of bags.

Country	1909-1913 Average	1914-1918 Average	1919-1923 Average	1924-1928 Average
South America				
Brazil	12,642	11,882	12,799	14,091
Colombia	774	1,116	1,863	2,331
Venezuela	843	843	898	803
Ecuador	62	49	64	104
Surinam	3	8	37	40
Peru	8	4	1	8
British Guiana	1	3	5	5
Bolivia		1	2	1
Total	14,333	13,905	15,669	17,383
Central America				
Guatemala	633	650	718	754
Salvador	478	578	615	738
Costa Rica	215	235	237	290
Nicaragua	155	167	195	249
Honduras		5	9	22
Total	1,481	1,635	1,774	2,053
West Indies				
Haiti	499	406	565	553
Porto Rico	332	285	138	119
Jamaica	63	60	54	65
Dominican Rep.	26	31	25	60
Guadeloupe	17	12	10	12
Total	937	794	839	809
Mexico	366	360*	289	404
Asia				
Neth. East Ind.	401	446	1,077	1,399
British India	210	193	194	189
Arabia (Aden)	117	89	99	100
Strits Settlem.	40	33	149	
French Indo-China	3	4	11	8
Federated Malay States	12	6		
Total	784	770	1,531	1,769

Table I (Continued)

Country	1909-1913 Average	1914-1918 Average	1919-1923 Average	1924-1928 Average
Pacific Islands				
Hawaii	26	30	27	36
New Caledonia	8	5	12	14
Total	34	35	39	50

*Four year average only.

in connection with production of coffee, it will be understood to represent a unit of 132 pounds.) Of the coffee produced in Brazil in the period 1926-30, 52 per cent went to the United States and 13 per cent to France while 16 per cent went to Italy, the Netherlands, and Germany. The remainder was distributed among a large number of other countries.

Colombia, which ranks second to Brazil in production, produced in 1932-33 approximately 3,348,239 bags (151). On the average about 90 per cent of Colombia's coffee comes to the United States. The Netherlands consume about three per cent.

Venezuela in the year 1932-33 produced approximately 950,000 bags (151). Data show that this country has fallen in world trade in coffee from second to fourth place. For the period 1909-1913, Venezuela's part in world trade was 4.7 per cent of the total and for the period 1924-28, 3.5 per cent. The United States and Germany constitute the two most important markets for this coffee.

The development of the industry in Ecuador has been notable. From the period 1909-13 to the period 1924-28, Ecuador's exports have gained 69 per cent. Spain is the main market for Ecuador's coffee, with France, Italy, and Chile following next in order.

Surinam, Peru, British Guiana, and Bolivia are not important in the volume of the world's coffee trade, neverthe-

less, they present interesting developments. For the most part coffee from Surinam and British Guiana goes to the Netherlands, whereas the coffee from Bolivia and Peru goes to Chile.

Central America

During the period 1924-28 the five republics of Central America produced 8.9 per cent of the world's total exports of coffee. For the year 1930 the exports in bags for four of the republics were approximately as follows: Guatemala, 952,000; Salvador, 979,000; Costa Rica, 393,000; and Nicaragua, 255,000 (174). In general, the United States is the largest single market for Guatemalan and Honduran coffees, Germany for Salvadoran, the United Kingdom for Costa Rican, and France for Nicaraguan (17).

West Indies

The exports of the West Indies group of countries, comprising Haiti, Porto Rico, Jamaica, Dominican Republic, and Guadalupe, average about 3.5 per cent of the world's total. Haiti and the Dominican Republic, which are the leading producers of the group, in 1932 exported together approximately 803,000 bags. Porto Rico, which in previous years was among the large producers of coffee, today exports only approxi-

mately 6,000 bags. France imports almost two-thirds of Haiti's coffee. Cuba, the United States, Spain, and Germany have in the past ten years imported most of Porto Rico's coffee. Canada and the United Kingdom are Jamaica's chief importers. The United States and France consume most of the coffee of the Dominican Republic.

Asia

The Asiatic group of coffee producing countries, such as British India, Arabia, French-Indo-China, Federated Malay States, etc. together with the Netherland East Indies produce about eight per cent of the world's total coffee. The Netherlands in 1932 exported approximately 1,896,000 bags. The United States and France consume most of the coffee from these countries.

Africa

Probably the most interesting development among the coffee producing countries is that of the African group, where, for the period 1924-28 as compared with 1909-13, a gain of 819 per cent was recorded for the area including Kenya Colony, Uganda, Nyasaland, and Tanganyika Territory. In general, most of the coffee from Africa goes to the United Kingdom. This group contributes about 3.5 per cent of the world's total coffee.

Mexico and Hawaii

In the period 1924-28, these two countries supplied about 1.7 and 0.2 per cent, respectively, of the world's coffee trade. The United States is the chief market for these coffees.

Some idea of the consumption of coffee may be obtained from the following table, in which is calculated the annual average consumption per capita for the more important coffee consuming countries, for the five-year periods 1909-13, 1921-25, and 1925-30. The data for this table are from the International Review of Agriculture, Volume 22, page 410T (178).

TABLE II. World consumption of coffee and consumption per capita.

Country	Average annual consumption in 100,000 lbs.			Annual consumption per capita in lbs.		
	1909-13	1921-25	1925-30	1909-13	1921-25	1925-30
United States	8576	12884	14692	9.0	11.7	12.3
France	2458	3693	3646	6.2	9.3	8.8
Germany	3995	1433	2932	6.2	2.4	4.6
Italy	582	1025	1012	1.8	2.6	2.4
Sweden	743	871	937	13.4	14.6	15.4
Belgium	780	855	908	10.4	11.2	15.5
Netherlands	944	780	758	15.7	10.8	9.9
Denmark	320	481	567	11.7	14.3	16.1
Argentine	282	465	540	3.7	4.9	4.9
Spain	293	472	511	1.5	2.2	2.2
Finland	287	337	384	9.2	9.7	10.6
Great Britain and Ireland	236	278	377	0.4	0.7	0.9
Norway	289	348	364	11.9	12.8	13.0
Switzerland	245	291	291	6.4	7.5	7.3
Union of S. Africa	258	302	282	4.4	4.2	3.5
Canada	126	205	269	1.8	2.2	2.9
Algeria	165	196	234	3.1	3.3	3.7
Total	20582	24916	28704	5.7	6.4	7.1

VARIETIES

The coffee varieties of commercial importance, according to McClelland (120), can be placed in three groups; the Arabian, the Liberian, and the Robustoid. Of these the Arabian is by far the most important. In this group are found the best cup coffees and for this reason the coffees of this group have been more extensively cultivated.

According to Galang (51), Arabian coffees grow best at lower altitudes where a well marked, short, dry season prevails. Observations have shown, however, that these coffees grow well as high as 2000 meters. In character, the trees of this group are smaller than those of the Liberian group, with thinner leaves and producing a fruit which falls readily from the tree when ripe and needs, therefore, picking at short intervals. In this group are found such coffees as Porto Rico, Burbon, Columnaris, Mocha, San Ramon, etc. A detailed consideration of the different varieties is given in later pages of this discussion.

The Liberian group of coffees is considered inferior in quality. In growth, the coffees of this group assume the proportions and appearance of trees rather than of shrubs. They have more of an upright than a spreading habit of growth,

with stiff, straight trunks. The leaves are oval or elliptical in shape and are stiff and leathery in texture. In all of the varieties of this group, Excelsa excepted, the fruit is large and the pulp thick and firm. Unlike the Arabian coffees, the fruit, when ripe, does not fall from the tree. In this group are included such coffees as Excelsa, Deweveri, Abeocuta, and Liberica. These coffees are said (51) to grow better at the lower altitudes, regions near sea level being the best, and to stand much drought.

The Robustoid group includes Robusta coffee and its related species such as Qillou and Uganda. These coffees are intermediate in growth between the Liberians and the Arabians. They are poor in quality and for this reason have been slow in coming into commercial use.

Before entering into the discussion of the different varieties of the different groups, as given above, it may be advisable to summarize in tabular form, some of the data obtained by McClelland (120) from his varietal trials of coffee in Porto Rico. The data presented in the tables were obtained from coffee trees growing in a soil of medium fertility at the Mayaguez Experiment Station.

TABLE III. Ripening season and percentage of crop harvested each month for the respective coffee varieties (average for 7 years) - McClelland (120).

Variety	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Mocha	5	37	52	6								
Burbon	15	31	37	14	3							
Murta	6	40	38	11	5							
Porto Rico	14	32	24	27	3							
Erecta	3	39	40	13	5							
Padang	1	31	41	22	5							
San Ramon	2	12	28	21	26	11						
Maragoipe		7	34	37	18	4						
Columnaris		5	27	40	22	6						
Conephora			1	13	29	44	10	3				
Quillou			1	15	27	45	9	2	1			
Congensis			3	13	20	43	13	8				
Robusta			1	7	19	46	18	9				
Dewevrei			2	6	26	28	20	9	4	1	1	3
Liberica	2			1	9	41	26	16	4	1		
Excelsa						5	5	28	22	18	15	7

TABLE IV. Average production of coffee berries per tree.* (McClelland-Porto Rico).

Variety	No. of years record	Production per tree (Liters)
Arabian Group		
Padang	11	2.7
Bourbon	5	1.8
Erecta	11	1.0
Columnaris	11	2.1
Maragoipe	11	1.6
San Ramon	7	0.9
Mocha	11	1.1
Murta	8	1.1
Liberian Group		
Liberica	6	3.5
Excelsa	3	3.0
Dewevrei	8	5.7
Robustoid Group		
Robusta	5	1.7
Canephora	5	2.0
Quillou	5	1.3

*The yield record for the varieties was started as soon as they bore fruit.

TABLE V. A comparison of different varieties of coffee as to the number, size, and weight of beans.

Variety	Av. no. of berries per liter	No. beans per lb. sundried, cleaned coffee	Per cent pea-berries	Wt. of 1000 dry beans (Grams)
Liberica	139	1,612	14	242.4
Maragoipe	209	1,674	6	235.5
Dewevrei	263	2,144	10	189.2
Padang	328	2,494	11	157.3
Erecta	352	2,742	17	144.7
Bourbon	---	2,973	11	130.6
Porto Rico	357	2,725	6	146.9
Columnaris	388	2,749	10	146.4
Excelsa	410	2,707	29	154.1
San Ramon	415	3,352	6	119.9
Mocha	543	5,021	14	78.9
Robusta	564	2,726	24	144.4
Congensis	638	3,285	29	122.5
Canephora	654	2,791	41	143.1
Quillou	681	2,903	23	136.9

In preparing coffee for the market the skin, the pulp, the parchment, and the silver skin are removed from the beans. Investigations have shown that varieties differ as to the proportion in which these materials form part of the grain. In the following table the loss in weight in the process of preparing the beans for market as reported by McClelland is shown for several varieties.

TABLE VI. Reduction in weight of coffee occurring during preparation for market. (Varieties are listed according to ratio of weight of coffee berry to weight of cleaned coffee.)

Variety	Fresh wt. of 1 almud* of coffee berries (lbs.)	Lbs. of sundried cleaned beans per almud	Per cent loss in weight
Quillou	31-3/8	8	12
Canephora	29-1/2	7-3/8	12
Congensis	29-1/16	7	13
Robusta	29-9/16	6-3/4	14
San Ramon	28-15/16	5-11/16	15
Porto Rico	29-1/4	5-7/16	17
Maragoipe	29-7/8	5-7/16	17
Mocha	28-7/16	5-3/16	20
Columnaris	28-5/16	5	18
Erecta	28-15/16	4-5/8	19
Bourbon	28-1/4	4-1/2	16
Padang	29-3/16	4-7/16	18
Excelsa	28-10/16	4	26
Liberica	28-1/16	2-3/4	33

*An almud is equal to about five pounds of marketable coffee or about 28.3 pounds of coffee in the berry.

Arabian Group

The Arabian group of coffees includes the following: (In discussing the coffee varieties here reported the work of McClelland in Porto Rico has been used freely. Reference is made to the work of other persons named by McClelland under the bibliography number of McClelland, namely (120)).

Porto Rican

This coffee is grown very extensively at both high and low altitudes in Porto Rico. It is reported, however, that the product from the higher altitudes is considered better and sells at higher prices. This coffee is comparatively low in caffein and has a pronounced aroma and a high color value which make it a very desirable article of commerce where these characteristics are appreciated.

Padang

This coffee is highly thought of in the world's markets. It is a Sumatran variety and resembles Porto Rican in bean and tree character. Seed of this coffee planted at the Porto Rican Coffee Station in December 1908, produced seedlings which were transplanted in the field the following August. In 1911, 1912, 1913, and 1914, the transplanted seedlings were four, six, nine, and ten to eleven feet high, respectively.

Bourbon

Wildeman (120) says that this coffee, owing to its fine aroma, has always been one of the most highly esteemed sorts. According to Laliers (120) it is grown in the deepest and richest soils on one-fifth of the plantations of the State of Sao Paulo, Brazil, and is more exacting in its requirements than the ordinary Brazilian coffees. In Salvador, C. A., this coffee is grown at elevations of from 2000 to 3000 feet in the open, without shade, with good results.

Pointed Bourbon

This differs from Bourbon proper in tree, foliage, and fruit. The tree grows very slowly. Eight year-old trees measure on the average six feet. Fully developed trees average 8 to 10 feet in height. The bean is pointed in shape, and McClelland states that it should not be mixed with typical Arabian coffees for marketing since it differs from them in shape. The tree, being small, gives low yields.

Erecta

This coffee, in Java, is found from time to time in the plantations of Coffee Arabica typica. Cramer (120) of the Department of Agriculture, Dutch East Indies, believes that it probably is a mutation repeating itself and considers it

well suited in spots exposed to heavy winds. In Porto Rico, during six years beginning with 1911 (two years after the trees had been planted from seed), 236 trees of this coffee attained an average height of approximately two, three and one-half, five, six and one-half, eight, and ten feet respectively. The tallest tree in the group measured 17 feet, and many were 13 to 14 feet high. McClelland states that the rather high productivity of this coffee, together with its vigorous growth, recommends it for trial.

Columnaris

According to Cramer (120), Columnaris is distinguished by its vigorous growth; the tree may become 25 feet high, forming a long column, covered with dense foliage. In Porto Rico, in the coastal region, which is less favorable for coffee than are the uplands, its general appearance is that of coffee produced in very fertile soil at an elevation of several thousand feet. The tree, because of its size, produces large crops, but the fruit is difficult to pick. At the Coffee Station in Porto Rico, Columnaris begins to bear a year later than the average Arabian coffees. The variety is, however, recommended for planting on the island.

Maragoipe

Keable (120) states that this coffee was discovered in 1870 near the town of the same name in Bahia, Brazil. He also reports that the variety is commercially important and has been rather extensively grown in Guatemala. Maragoipe differs from typical Arabian in both foliage and internodal length. The internodes attain such a length as to limit their production on a given area. The leaves of the variety are larger than those of other varieties of Arabian coffee, some of them ranging from 7 to 10 inches in length and 3 to 4 inches in breadth. Cramer (120) says that it is "The finest coffee known; it has a highly developed, splendid flavor. Maragoipe is, however, a light yielder."

San Ramon

Hill (120) states that San Ramon coffee originated in one of the Central American republics, and that the tree is made by nature to stand a very exposed windy outlook. In Salvador, it seems to do well in places where the Arabian has been growing for years but has become unprofitable, and where winds make the cultivation of Arabica or Maragoipe difficult. McClelland points out the fact that San Ramon coffee comes into bearing very young and has a long bearing season. He recommends it for trial on exposed situations where the typical

Arabian coffee does not do well and states that its stocky growth facilitates harvesting, but the small size of the beans is a disadvantage in marketing as large beans sell at better prices.

Mocha

Little over 200 years ago practically all the coffee exported from Arabia was shipped through the port of Mocha whence came the name "Mocha coffee." The production of this coffee today is limited and relatively insignificant in quantity, but, owing to the establishment of the name as a trade term, considerable quantities of coffee from various sources have been sold as Mocha. Cramer (120) suggests that this variety probably is a distinct species (C. mokka), although he classes it as a variety of C. arabia, of which it usually is considered a subspecies. McClelland finds that in general appearance the tree differs noticeably from the typical Arabian, having shorter internodes and much smaller fruit and foliage. Though in quality this coffee is excellent, it is not recommended for planting in Porto Rico because the berries are so small that the number contained in a given measure is nearly double that of most of the other varieties and this makes the cost of picking abnormally high. Also, the weight of the dry beans, in proportion, is lower than for any of the other coffees.

Murta

Laliere (120) states that Murta is characterized as a degenerated variety of Bourbon and is grown in Brazil. At the Porto Rico Coffee Experiment Station it has proved to be a mongrel (124), approximately half of the seedlings being of the Murta type, with others ranging from small, dwarf, with many upright branches resembling tiny green rosettes, to the ordinary Arabian type. The fully developed Murta tree is seven to nine feet in height, with a spread of four feet. McClelland states that lateness in coming into bearing and low yields are disadvantages, but ease of picking, due to the small size of the tree, is in favor of this variety.

Liberian Group

The Liberian group of coffees includes the following which are the most important commercially.

Liberica

Of coffees in Liberia, Graham (120) says that the one known as Coffea liberica is cultivated very successfully in hot, moist lowlands or hills of no great altitude, and that in the wild state the tree often attains a height of from 30 to 40 feet, producing a berry which is from 30 to 40 per

cent stronger in flavor than the average coffee and therefore is used to a large extent in blending with mild coffees. Cramer (120) observes that in Java well developed trees may measure 50 feet in height and states that the tree is better adapted to lower altitudes, regions near sea level being the best. Galang (51) states that this coffee should not be grown at altitudes above 350 meters and points out that the variety succeeds well in districts with a pronounced dry season and a rainfall of about 1200 millimeters, but that it yields better in places where there is a uniform distribution of rainfall. van Zwaluwenburg (179) reports that some varieties of coffee seem to be practically immune to minor injury due to the thickness of their leaves, among which is the Liberian coffee and several other species belonging to the same group. Galang (51) states "the tree is quite resistant to the nematode worm, but no new plantations of this variety are being set out in Java, as it was found to be badly affected by leaf disease."

In Porto Rico, Liberica was found to give a fair crop after the sixth year of planting from seed. Galang (51) claims the tree is a robust and prolific bearer. McClelland states than when the heavy reduction in weight from berry to marketable bean is considered in connection with the individual yield, and also the wider spacing required for trees of this species, it will be seen that the harvest is costly and the yield per acre very light. In a comparative test at the Lamao

Experiment Station in the Philippines, Excelsa and Libria coffees were found to be the two highest yielders in a 10 year test which included Robusta, Dybouskii, Quillou, Canephora, Congo, Uganda, and Abeocuta (185, 186).

Excelsa

This coffee is said to have been discovered by Aug. Chevalier in West Africa, in 1905, near Lake Tchad. Cramer (120) reports that it is not particular as to soil, and is suited to the same climate as is Liberian, but will do very well also at higher altitudes. He states further that at Bangelan (Java) the best fields produce 760 to 1500 pounds per acre. He pronounces the quality of this coffee as good and its growth as vigorous, and asserts that it is one of the best kinds to grow. McClelland writes "Excelsa is the most promising of the Liberian group of coffees so far tested at the station (Porto Rico). Its good cup quality, vigorous growth, comparatively low (for the Liberian group) ratio of reduction in weight, indications of productivity, and resistance to the leaf miner recommends it for trial, especially in localities which suffer from ravages of this pest." Galang (51) says that the tree is very resistant to the attack of the nematode worm, and because of its resistance to blight and to drought it is becoming very popular in the Philippines at the lower elevations and where the rainfall is not well distributed.

Dewevrei

This species is indignous in the African Congo. Plantings of this coffee at the Porto Rico Station have shown an extremely wide variation in type and suggest a heterogeneous collection of several varieties. Individual trees differed in size of foliage; in color of blossoms, some being white and others pale pink; in number of petals, flowers having five, six, seven, and as many as eight petals; in size, shape, and color of fruit; color of silver skin; and shape of bean. In August, 1913, 56 trees of about 3½ feet in height were transplanted from the nursery to the field at the Porto Rico Station. Two years later, the trees had attained an average height of 5½ feet, and annually thereafter for five years they were, 7.75, 9.50, 11.25, and 14.75 feet high, respectively. In another two years the average height was 17.5 feet, and the tallest tree was about 25 feet. Fully developed trees are said to attain a height of 50 feet. The individual trees at the Porto Rico Station differ widely in their season of ripening, and mature berries can be found on some trees during almost any month of the year. These trees come into bearing two years after planting.

Abeocuta

Galang (51) states that this coffee stands between the Liberian and the Excelsa in vigor and is more susceptible to

leaf disease than Excelsa. The berries are large with a thick pulp. Being inferior to Excelsa in quality it is not recommended by McClelland for Porto Rico. However, Galang states that it is worthy of trying in the Philippines because of its strong flavor and vigorous growth.

Robustoid Group

Coffees of the Robustoid group are planted very extensively in Java and Sumatra. This group includes:

Robusta

Cramer (120) states that what is known as Robusta coffee is probably a group of coffees of different varieties rather than a pure species. He points out that Robusta is marked by rapid growth, early fruiting, and high productivity. He states that it grows best in wet climates, especially those with regularly distributed rains. In such climates the crop comes all the year round. In Java, Robusta is grown from sea level up to more than 3000 feet, and in Sumatra at even higher altitudes. The general altitude for best growth has been put at 1000 to 3000 feet above sea level. Under favorable conditions this coffee has been reported to yield as high as 1500 pounds to the acre. Gallagher (52) states than in Java the tree begins to yield the second year from seed. Cramer (120) states that Robusta ranks in quality little

under good average Santos. McClelland, in Porto Rico, does not recommend the growing of Robusta for export, but believes it to be a good coffee to serve that part of the local trade which prefers a cheap coffee rather than a high priced coffee of good quality.

Canephora, Quillou, and Uganda

These coffees are very similar to Robusta in growth habit and in the quality of the product. Quillou, under favorable conditions, is reported (120) to yield well over 2500 pounds of merchantable coffee per acre. Galang (51) states that this coffee is rather resistant to leaf disease.

Hybrids Kawisari B and D

These are two hybrids becoming very popular in Java because of their immunity to leaf disease and their excellent flavor. The two hybrids are said to withstand unfavorable soil and climatic conditions and to yield well (51).

CULTURAL PRACTICES IN COFFEE PRODUCTION

Soil

Under favorable conditions coffee thrives well in a large variety of soils. However, reports indicate that to insure good results the soil for coffee should be deep, loose, friable, well drained, and preferably of volcanic origin. Soils which are rich in lime, poorly drained, and shallow are not adapted to the growing of the plant (24) (51).

Gethin Jones (72), in his survey of the coffee soils of Kenya, Africa, has correlated the growth of the coffee trees with the condition of the soil and finds that too high a water-table, insufficient aeration, the presence of clay or iron pan, sudden changes from heavier to lighter subsoils, and lack of depth of the soil are factors generally associated with poor growth of the tree. He finds that coffee needs a slightly acid soil, fairly rich in humus and potash but not necessarily rich in phosphorous. He believes that red soils, which are generally considered good for coffee, are so because they contain adequate amounts of minor nutritional elements which are essential to the plant.

Gracie and Trench (58) have found in their work with the coffee soils of Kenya a correlation between mealybug infestation and potassium deficiency in the soil. They find that potassium deficiency - and consequently mealybug infection - is correlated with high acidity of the subsoil. They point out that plants growing in a soil deficient in potassium may be recognized by the shorting of their internodes and by a reduction in the size of the leaves, the leaves appearing more numerous as well as more closely packed together than normal. The authors find also a yellowing of the leaves, quite similar to that caused in plants by a deficiency of potassium, to be common to coffee growing in soils high in lime and believe a deficiency of manganese to be the cause.

Preparation of the Land

Though in all the literature reviewed no work is reported as to the best method of preparing the land, some suggestions are given which may be worthy of mention.

McClelland (118) points out that when cleaning the land for planting, the leguminous trees should be left to furnish shade for the coffee. He states that if the timber which is cut, instead of being burned, as is the general practice, is allowed to remain on the ground a great deal of humus and fertility will be conserved for the coffee trees, and that where there is danger of soil washing the felled trunks, laid

at right angles to the slope of the hill, will tend greatly to reduce the amount of soil carried off.

"El Manual del Cafetero Colombiano" (111) states that as soon as the land has been cleared it should be plowed deep and that this should be done at least eight months in advance of planting to insure good aeration of the soil. Where this cannot be done, it is suggested that the land be holed one to two months previous to the transplanting of the coffee trees.

David (41) points out that in the Philippines it has been found advisable to plant some sort of crop before the cleared soil is planted to coffee. Corn, upland rice, and potatoes are recommended by him as having given good results.

McClelland (118) suggests that it is advisable to lay out the main roads and the smaller foot paths before the land is holed as this avoids difficulties later and saves labor. He also points out that where the slopes are very steep the rains will cause less washing if ditches are placed at intervals, not exactly at right angles to the slope but with a gentle and steady incline to natural drains, and that these ditches should be made before setting the coffee, else it would be difficult to obtain the desired fall.

The best size and type of hole to make depend greatly on the kind of soil. In Porto Rico (118) "2 feet cube" holes have been found very satisfactory for Arabian coffee. In Ceylon (61) holes "18 inch cube" are used for Robusta coffee. In Central America the holes are generally made 24 inches

deep by 18 inches in width and length. McClelland (118) suggeststhat when digging the hole the surface soil should be put above or at the side of the hole where it will be convenient for later filling, and that the subsoil should be placed at the lower side of the hole to form a table or individual terrace. He finds that where the slope is very steep a few stakes driven in, inclined in the same direction as the slope and having others placed crosswise, will help to hold the new soil until it settles in its new position.

The distance at which the holes must be dug depends on the variety of coffee that is to be planted and on the topography of the land. Where coffee is grown on level land the trees are generally planted much farther apart than when the land is steep or rolling and suffers severely from erosion. David (41) recommends for the Philippines, under normal conditions, a distance of 2.5 by 2.5 meters for Arabian coffee, 3.0 by 3.0 for Robusta, and 4.0 by 5.0 for Liberica. In Ceylon (61) Robusta is planted at a distance of 3.3 by 3.3 meters. Galang (51) gives a planting distance of 4 by 4.5 meters for Excelsa coffee.

In Colombia (111) the "triangulation system" of planting coffee has been found to be superior to the "square system."

Seed

Selection

In ordinary practice the custom is to use seed from any source whatever. However, for best results, the seed should be obtained from matured berries on healthy and productive trees. In Colombia (111) it is advised to gather for seed only the larger berries of the first crop, borne on the stronger primary and secondary branches.

Cleaning and curing the seed

In Java (51), the berries once selected are pulped by hand and the beans washed in fresh water with sand or ashes to remove the slime and so prevent fermentation. Sometimes the beans are dusted with powdered charcoal to hasten their drying before any fungus infection may attack them. In Colombia (111) on the contrary, the beans are allowed to undergo fermentation for about 10 hours before they are washed and dried.

McClelland (123) conducted experiments in Porto Rico to see if by excluding the moist air of the tropics, he could preserve longer the viability of the seed. He kept well matured, shade dried coffee seed in cotton sacks which allowed free passage of air and in tightly closed jars containing

calcium chloride as a drier. Every two weeks 100 seeds were planted from each container. The results showed that the viability of coffee seed is destroyed by very severe drying and that a certain amount of moisture as yet undetermined, is necessary for its prolongation.

In the Philippines, Youngberg (185) preserved coffee seed in cloth bags, paper envelopes, moss, sawdust, and in moist charcoal, moist sawdust, and moist moss. His results indicated that the dry materials, including the paper envelopes, and the cloth bags, preserved the vitality of the seed for two months only, whereas the moist materials preserved the vitality from three to 15 months. The seed in the wet moss remained viable the longest. The highest percentage of germination was obtained during the tenth month (94%) and the lowest in the last or sixteenth month of the test (16%). The experiment was repeated twice with similar results.

Germination tests with different species of Robusta and Liberica coffees at the Peradeiga Experiment Station, Ceylon (62) showed that fresh berries could be kept in an ordinary place for two weeks without falling off in their germination capacity. After two months coffee in the parchment showed a germination capacity of only about 16 per cent; after four months the germination was so small that the seed was practically valueless.

In the Philippines (186) fresh coffee seed submerged in water kept their vitality for over a month.

In Porto Rico (123) tests have shown that properly prepared seed should remain viable for four months but that after eight months hardly any seed can be expected to germinate.

Planting the seed

The seed is planted either in boxes or in seed beds. Planting in boxes usually insures a little more care and attention in the preparing of the soil, which is quite important, though for large plantings this method is impractical. It is recommended (118) that the bed be made on finely pulverized ground and that its preparation be begun several weeks in advance of planting to provide for good aeration of the soil.

Figueroa (50) points out that it is advisable before the seed is planted to grade it, keeping only the large seed of uniform size. He advocates planting 1.5 to 2.25 inches apart and one-fourth inch deep.

Chardon (24) states that the seed should be planted the flat side down and at a depth of 1 inch; whereas Gonzalez (55) reports that the grain may be dropped in the hole in any way since his experiments have shown that the position of the seed does not affect the germination or seedling growth.

McClelland (118) suggests that the seed should be spaced two inches each way. He directs that in planting the seed be laid on the surface of the soil and then pressed lightly

with the finger, taking care not to push it down too deep. He believes that one-fourth of an inch is sufficiently deep.

Galang (51) states that the seed may be sown broadcast at the rate of 2000 to 2500 seed to the square meter if the seedlings can be transplanted promptly to the nursery, but that if this cannot be done it is best to spread the seed over an area twice as large in order to provide stronger plants.

On the average, if the seed is fresh, it may be expected to germinate in 25 to 30 days, but if it has been allowed to dry 50 to 60 days probably will be required before seedlings make their appearance.

Nursery

Location and preparation

Regarding the location of the nursery most authorities emphasize that, above all, it be located where water is available during dry weather and that, if suitable locations can be found, the beds should be well distributed over the prospective planting in order to save labor and lessen the injury to the plants when transplanting them to the permanent place in the field. It is suggested (118) that the beds should be so located in regard to surroundings that, if covered, the plants may receive fully as much sun light after the covering has been removed as any of them will receive when planted in

the field. Otherwise the transplanting from a shaded to a more or less unshaded location will add unnecessarily to the shock received by the plants.

As to the preparation of the nursery bed, most investigators recommend that they be made four feet wide, with furrows two feet between, on six months old plowed ground, to which well rotted manure had previously been applied. It is also advised that the beds be built up higher than the surrounding land to provide drainage and to facilitate the removal of the plantlets later.

Setting the plantlets

Chardon (25) reports that very good results are obtained by transplanting the seedlings to the nursery "when the plantlet is in the round pair leaf stage", that is, about three months old.

In Colombia (111) it is recommended to set the plantlets when they have four to five pairs of leaves at a distance of 20 by 30 centimeters apart.

McClelland (116) recommends spacing six inches apart when the plants are removed from the nursery bed the season following their planting. If the plants are left in the nursery until the second season they should be spaced no closer than eight inches.

The small seedlings are removed from the seed boxes or bed with a trowel or any other instrument which will lift them without injuring the roots. It is suggested (118) that plants with feeble and poorly developed root systems be discarded and that where the tap root is rather long it be shortened by cutting it with a knife or scissors.

It is advised that plants should not be set deeper in the nursery bed than they were in the seed beds. Deep setting is a factor which is apt to favor damping off, or other fungus diseases of the stem.

The bed must be kept free of weeds at all times and when watering it is advisable to give "fewer and more thorough waterings than more frequent waterings of the kind which do little more than sprinkle the surface and simply induce damping off (118)."

Transplanting

In Porto Rico (114) experiments on different methods of transplanting coffee showed that Arabian coffee seedlings with five to six pairs of leaves could be transplanted just as well with the root system bare of earth as with the roots encased in a ball of earth. With older seedlings the results showed that when transplanted with a ball of earth the trees grew better and the yield was greater and earlier than those transplanted with the roots bare of earth. The results seem

to indicate, however, that a better stand may be obtained by leaving the trees in the nursery until the second summer after planting than by putting out seedlings with five to six pairs of leaves. McClelland suggests that the increase in growth and vigor from using older seedlings would appear to be worth the extra labor and expense.

When transplanting, care should be observed to prevent exposure of the roots to the sun as this will dry them very quickly.

Cultivation

Wakefield (191) has concluded from his rather extensive experiments that the physiological activities in the coffee plant have an important bearing upon the cultural operations and the time at which they should be performed. He and Sanders (158), working in Tanganyika Territory, Africa, have observed that the coffee plant possesses both a superficial and a deep system of roots. The first run parallel with the soil surface and function only in the aerated top soil. These roots appear to be essential to the absorption of nitrates, so essential for the formation, setting, and ripening of the fruit. When cut or broken these roots are lost as they are seldom replaced by others.

The second type of roots grow downward into the unaerated subsoil of low nitrate content and appear to be concerned

mainly, if not entirely, with the water and the mineral salt supply. It appears that the absorbtive, fibrous rootlets carried by the downward roots do not require much oxygen for their development. Wakefield states that there appear to be different requirements for the two systems of roots, just as there appears to be a difference in their function.

Recent research has shown that the demand of fruit trees for nitrates is greatest during the period from the time of flower formation to the time of ripening of the fruit. If this demand is not satisfied from the first, then the flower setting will be poor and there will be an extensive fall of both flowers and young fruit. From observations carried out both in Tanganyika and Kenya it is obvious, Wakefield states, that this nitrate demand also occurs in coffee and that the pruning of the more superficial roots, either purposely or by improper methods of cultivation, tends to cut off almost completely the nitrate supply and to produce a wide carbon-nitrogen ratio. This results in a heavy set of fruit, very little of which ever matures. Wakefield states, therefore, that if coffee trees are to mature their crop to their maximum genetical capacity, the surface soil must be maintained by anti-erosion measures and damage to the shallow lateral roots must be avoided at all costs. He advocates "envelope forking" as the most efficient, cheapest and most satisfactory method of soil husbandry for economical coffee production.

"Envelope forking" consists of driving a fork 15 to 18 inches long into the soil at right angles to the roots radiating from the tree, so that the roots are merely slightly combed by the backward and forward movement which it is necessary to give to the fork to drive it well and to obtain the amount of aeration desired. The forking should start not closer than 18 inches from the trunk of the tree and is done every nine inches to one foot until about one foot beyond the farthest extremity of the longest branches. It has been pointed out (158) that "envelope forking" should not be carried out during the periods of root rest (dry season) in coffee planted at the correct level, but that with deep planted coffee it is immaterial whether the operation is carried out during the period of root rest or not. It has been found that with this system of soil aeration the feeding rootlets are in greater profusion and start growing earlier than with unforked trees. Wakefield states that the use of plows, deep disc cultivators and even the forked hoe must be regarded as dangerous methods of cultivating coffee.

David (41) states that the practice of heaping the soil around the tree, as is often done, is not good as this only serves to increase the number of surface roots and these are generally destroyed by hoeing. He points that hoeing should be done from the middle of the row toward the tree. He found mulching the trees through the dry season with vegetable wastes very practical. Lustro (95) found that trees where

mulch was used excelled the control trees in height, spread of branches and fruiting.

McClelland (118) states that the most advantageous time for cultivation is towards the end of the rainy season or the beginning of the dry.

Cover Crops

Cover crops have been found to be of much value in the culture of coffee. In plantations where shade is deficient and weeds are troublesome it has been found to be an excellent practice to plant a leguminous cover crop as a means of keeping the weeds down and of decreasing soil erosion. Wakefield (191) states that the ideal cover crop for coffee is a deep rooting, deep feeding, procumbent, perennial legume, capable of giving a good soil cover, preventing soil wash and suppressing weed growth. Also, at the same time, it should yield vegetative material or organic matter, which, when "envelope forked", becomes incorporated with the soil.

Trench (82) recommends that Kenya farmers plant cover crops when the trees are small or when heavy pruning is carried out, but not when the trees are of such size that the lateral branches are touching each other. Sanders and Wakefield (158), with the same idea, state that turning in of cover crops may be done with good results in young coffee as long as

the roots have not spread much, but with older trees the practice is not advisable.

Trench (82) compared various plants for cover crop planting in coffee with the following results: (a) Crotolaria incana; satisfactory; is ready to turn under from 12 to 14 weeks; will become woody if allowed to grow too long. (b) Field peas: very poor nodule producers; are ready to turn under in from 8 to 10 weeks. (c) Nandi cowpea (Viga sp.): will grow at higher altitudes than any other variety tested and is very resistant to leaf blight; nodules freely and is ready to turn in from 10 to 12 weeks. (d) New Zealand grass pea: an excellent cover and wash stop crop; nodules freely and is ready to turn in from 14 to 16 weeks. (e) Hairy vetch: early growth is slow but ultimately forms a mat overcoming all weeds; nodules freely.

Hollond (63), in Ceylon, found Infigofera endecaphylla to be a good crop to stop soil wash and recommends it for that purpose.

The Jack bean, Canavalia ensiformis, is reported (118) to be the best all around leguminous cover crop for coffee under Porto Rican conditions.

Catch Crops

David (41) points out that in experiments conducted in the Philippines, catch crops such as tobacco (Nicotina tabacum L) and sweet potatoes (Ipomea batatas L) were found to yield good returns, but were found to be rather exhausting to the soil. He states that catch crops when planted on young coffee are beneficial to the farmer as well as to the coffee trees, which benefit from the tillage that the catch crop demands.

Pruning

There are three recognized methods of pruning coffee: (1) the capping or Costa Rican method; (2) the agobiado or Guatemalan method; and (3) the Colombian method. Of these the capping method was greatly improved by Yglesias (183) in 1931 and it is thought that a detailed consideration of this method may be desirable.

The method as worked out by Yglesias consists of five steps, namely: pruning to multiply, pruning to renovate, pruning to substitute, pruning to eliminate, and pruning the suckers.

Pruning to multiply

This operation is practiced on the main or primary stem of the plant with the object of developing secondary and

tertiary stems. Before the plantlet has developed its primary branches and when it is still in the nursery, the main stem is "capped" or pruned off just above the third or fourth pair of leaves. This causes the shoot bud in the axil of each of the leaves of the top most pair to develop and grow to form a secondary stem. When the two secondary stems produced by this "capping" reach the size of a pencil in thickness they are in turn pruned above the fifth node. This, as was the case in the previous "capping", forces the development of the shoot bud in the axil of each of the leaves of the top most pair to develop, with the result that four tertiary stems are formed. As it is upon these tertiary stems that the substitution pruning is carried on, they are generally termed "stems for the substitution pruning." The tertiary stems, like the secondary, are also pruned above the fifth node, with the result that eight quaternary stems develop.. As it is on the quaternary stems that the larger part of the fruit is produced, they are allowed to grow freely until they have produced one to three crops, when they will be removed by "substitution pruning."

Pruning to renovate

This operation is practiced on the primary lateral branches which have fruited for two consecutive years. The method generally practiced when pruning the primary laterals

is to remove them wholly from the tree as soon as their fruiting capacity has been exhausted, with the result that after a period of years large proportions of the stem are left bare, as primary laterals once removed cannot be replaced. Through the renovation system of pruning, Yglesias claims that the primary branches of the plant can be maintained in a fruiting condition for an almost indefinite period of years. To accomplish this the unproductive primary branches are pruned back to the first or second node from the main stem. As was the case when the stem was "capped", the pruning of these branches results in the development of the adventitious buds at the node of the cut primary to form secondary lateral branches. These, after they have yielded for two consecutive years may be pruned back to the first or second node from the primary with the development of tertiary lateral branches, and so the process may be continued. As the primary branches are not all producing at once, but in succession, from the bottom up, when the lower ones are being renewed, the upper ones are producing or vice versa, so that at any time the plant is ready to bear fruit.

Pruning to substitute

The purpose of this operation is to remove the quaternary stems which cannot be pruned back because of the excessive amount of shoot growth that results, nor can they be allowed to grow freely as they would grow too long and become unpro-

ductive. In order to remove them the substitute pruning method is used. This consists in pruning - after the quaternary branches have produced their first crop - two of the four tertiary branches at the node which will be the node below the fork formed by the quaternary stems on the fourth node of the cut tertiary stems. The following year the operation is repeated on the remaining two tertiary branches which were not pruned the previous year. The following year, that is, the third year from the commencement of the substitute pruning, the operation is repeated by pruning the first pruned tertiary branches at the third node. The fourth year the same operation is done with the other two tertiary stems, and so the process is continued until the stem of the tertiary branch has all been used. To renew the lost tertiary stems, the secondary stem is then cut just above the fourth node and the tertiary stems that result from this "capping" are treated the same way as the previous ones, and the substitution pruning is started over in the same manner as before. According to Yglesias this type of pruning theoretically should keep the plant "young" for 104 years.

Pruning to eliminate

This operation consists of removing from the plant all branches which have died or have become unproductive.

Pruning the suckers

Ygelsias states that when pruning the suckers it is often advisable not to remove them altogether from the plant as these are some times needed to provide substitute branches in the tree. He advises that the sucker be pruned back to one node from the main stem. He reports that suckers treated this way generally stop growth or grow very little and thus can be conserved.

The agobiado and the Colombian methods differ in principle from the capping system in the way the tree is trained. The agobiado system aims to develop a tree with three or four leading branches from the base. The Colombian system aims to have only one main stem which is cut back three times as the plant grows to give it strength.

Trench (80) states that in Kenya the planters have found the capping system decidedly advantageous over the agobiado system in that the branches are established more rapidly.

Effect of topping coffee on yield

McClelland (114) took records for a period of 10 years on Arabian coffee which had been (1) pruned; (2) untopped but pruned to the original stem; (3) topped to five feet; and (4) topped to four feet. He found a distinct loss in the produc-

tion of berries from topping as well as a loss in labor from the subsequent removal of suckers necessary in this treatment. The average annual production for the first three years of the experiment for the four groups was 2.3, 2.5, 2.2, and 2.0. liters, respectively. For the entire 10 years the average production was 2.8, 2.1, 2.1, and 1.6 liters, respectively. He states that although in the experiment the wholly unpruned trees gave the highest production, it should not be inferred that it is not advisable to prune.

In another experiment in Porto Rico (122) high growing trees which had lost their leaves were cut at distances varying from a few inches to six feet above ground. From the renewed growth made by the trees it was concluded that in top working coffee the trees should not be cut higher than six inches from the ground because the greater part of the crop for that year is lost regardless of how high the trees are cut. If the trees are cut low a better spreading of the side branches is obtained. In Ceylon (10) similarly conducted experiments gave similar results.

Holland (61) recommends not to top work coffee trees unless they are in an extremely unproductive condition.

Grafting

Grafting has become an important means of propagating coffee where the presence of leaf disease has made it desirable

to propagate resistant varieties. In Central and South America this method of propagating coffee has not as yet received the attention that it deserves but there is no doubt that with time it will be used more extensively.

Galang (51) states that even though comparative yields have shown that coffee trees from seedlings yield more, over a period of years, than grafted trees, grafting should be used to propagate coffee as this method insures trees more uniform in growth, less variable in yield, and more uniform in ripening.

Srinivasan (165) and Antez (27) concluded from their experiments that while both strap grafting and cleft grafting can be used successfully in coffee the latter gives a stronger union. Gillett (54) is of the same opinion as Srinivasan and Antez and believes that for best results the graft should be made on old brown wood on the root stock and the cut should be just above an internode. He states that the most successful scions seem to be those obtained from the first nonperioled portion of the tree or sucker. Antez considers the condition of the stock more important than that of the scion which can be taken from the sucker with the stem still green. In his experiments he cut the stock at the first internode below the green portion.

In experiments conducted in the Philippines (51) with young, green scions and with old, woody scions, it was found that the first type of scion gave only 14.1 per cent of suc-

cess while the second gave 37.8 per cent. Similar results were obtained by Bagaloso (11).

Romero (157) found that main stems and vertical suckers with or without terminal buds make good scion material but that lateral branches without terminal buds gave a growth practically all of which was in one direction, the plant failing to produce branches from the main stem.

In the Philippines, the best covering material for grafts was found to be glass tubing (11, 157) whereas in Java paraffin paper tubes are claimed to give the highest percentage of successes. Bagaloso (11) in his experiments with banana leaf petiols and sphagnum moss, found these materials extremely poor for covering grafts and advocates the use of paraffin paper tubes.

"K.E.T." (74) reports a method for grafting coffee seedlings which gave a high percentage of successes. This method consists in making a vertical cut through the plumule and hypocotyle of the stock seedling so that the cotyledons fall apart. The seedling which is to form the scion is then cut just above ground in such a manner that the cut forms a long tapering wedge. The point of the wedge is then inserted in the bottom of the slit made in the stock, taking care that the cut surfaces come in contact well. The graft is then wrapped and allowed to grow. Though a very large percentage of grafts has been obtained by using this method, it is not as yet recommended be-

cause further data are needed to determine subsequent behavior of the plants in the field.

Mayne (104) reports that in Mysore grafting takes best in the nursery in May and in the field in June. The average rainfall for May is 93 inches and for June 16 inches.

Cramer (38) finds that under conditions prevailing in Java, Liberian and Excelsa coffees make the best stock for grafting. Romero (156) reports Excelsa superior to Quillou for stock under the conditions of the Philippines.

In Java (51) a series of experiments with pollination has revealed that some individuals are self sterile. It would seem then, that trees in large fields of grafted plants derived from a single colon might be inter-sterile. This assumption seems to have been somewhat substantiated by the fact that the boundary trees of grafted plantations, where these plantations joined others planted with trees of different descent, bore well, while the interior of the plantations yielded a poor crop. To avoid this undesirable outcome, Ferwerda (48) recommends the use of self fertile colons, the mixing of grafts and seedlings, and the mixing of colons. He states that the flowering time of the colons should be determined by trials and observations since it may be different for different localities. He also points out that some colons are universally female and others universally male, the proportion of serviceable colons being low.

Gillett (54), trying to propagate coffee by cuttings, found that hard wood cuttings gave good aerail growth but developed no roots. He obtained good results from etiolition of sucker growth. He stumped old trees and allowed suckers to develop at the base. Once the suckers had grown from 18 to 24 inches he rang-barked them near the stump and placed over them a "debbie" open at both ends. The "debbie" was then filled with dirt and the suckers allowed to grow freely. Gillett found that after two months, roots developed from the callous formed at the region of the ring.

McClelland (130) experimented with cuttings from softwood, wood of intermediate maturity (turning from green to brown), and with hardened wood. He failed to get roots to develop from any of the cuttings. In a trial where he split open at the base cuttings of about one-fourth inch diameter and planted them in this way he got a high percentage to root. The slit in the cutting had to be held open to insure rooting. He held the slit open by placing in it a small stone. He used decayed cocoanut fiber and washed gravel in which to plant the cuttings.

Bagaloso (11) in his experiments on topping coffee trees found that not all the trees can be top worked as some produce water sprouts too small to be grafted. He found that the time from topping to the emergency of the water sprouts varied from 18 to 49 days according to the vigor of the stock plant and that generally the sprouts were ready for grafting 250 days after emergence. In his grafting experiments he

found that neither the size of the stock nor the size of scion had any direct relation on the success of grafting.

Shade

The shading of coffee has been one of the most disputed questions in the cultivation of coffee. The literature on the subject, practically all of which is based on theory, abounds in opinion of the most contradictory import. Cook (36), for instance, basing his conclusion on pure theory, states that without denying that shade may be a necessity in a few instances where coffee is grown in arid regions like parts of Arabia and Mexico, it is irrational and unjustifiable to say that it is needed in the moist tropics. Ukres (174) on the other hand, states that coffee requires shade when it is growing on low lying land, but that it grows well without it on elevated land.

Andrad (4) reports an experiment in Brazil where shade improved the quality of coffee and increased the yield of fruit. By placing thermometers on branches of shaded coffee and on branches of unshaded coffee he found that the temperature of the shaded coffee was very stable, whereas the temperature of the unshaded coffee varied considerably. He explains that this variability in temperature probably accounts in large part for the less perfect ripening of the berry and the lower percentage of fruiting on the unshaded trees. Andrad

found that coffee harvested where shade prevailed produced a less number of bad fruits, a larger fruit, and a lower percentage of "escolha".

McClelland (137) in Porto Rico, using artificial shade and young plants of the same age and more or less of the same height and conformation, found pronounced differences between the shaded and the unshaded plants. The difference between the heavily shaded and the lightly shaded plants was not marked. In spite of a gradual transition from shade to full sun exposure the unshaded plants were much yellower and less healthy in appearance than were the shaded plants several months after the differentiation in treatment was begun. At the outset of the experiment the unshaded group of plants had a slight advantage in height and in trunk diameter. At the end of a year the trees in the shade had increased in height twice as much as those receiving full sun-exposure. This difference in increase in height was due principally to differences in internodal length. On correspondingly located portions of the main stem a section of five internodal lengths averaged, per plant, 22 cm. for plants receiving full sun-exposure and 42 cm. for the shaded plants. The internodes on the lateral branches showed similar response to the differences in lighting, the average length for correspondingly located internodes being 4.5 and 7.3 cm. for the unshaded and shaded plants, respectively. Leaf counts at the beginning of the experiment

showed all plants to be quite uniform in respect to the amount of foliage, averaging 69, 73, and 67 leaves per tree for the unshaded, lightly shaded, and heavily shaded plants, respectively. Leaf counts a year later showed averages of 530, 812, and 569 leaves per tree for the same plants. The size of the leaves was found to be in reverse proportion to the amount of light received.

Trench (84) also reports an experiment carried out with artificial shade in which he obtained an increase in yield from a few cwts. to about three-fourths of a ton per acre by the use of shade. The experiment was conducted in the field and the shade was obtained by placing maize stalks, grass, branches, etc. on strands of plain wire supported on posts.

It has been suggested (61) that the ideal type of tree to provide shade in coffee plantings is one which is deep rooted, grows rapidly, has a prolonged life period, branches abundantly, with branches such that when they fall they go directly to the ground and seldom remain hanging from the coffee bush, belonging to the legume family (capable of fixing nitrogen), and if possible bearing edible fruit.

Holland (61) states that shade trees for coffee Arabica should be planted 10 to 15 feet apart in avenues with about 20 to 25 feet between the avenues. The avenues should run from east to west to insure a lateral shade being cast on the coffee from south to north. He recommends planting dif-

ferent kinds of trees in the same plantation stating that this will help to conserve soil fertility and aid in controlling insect and disease pests.

Cook (36), in his very extensive discussion of "Shade in Coffee Culture", names over 100 different species of trees that have been used for shade. In Java (51) Erythrina lithosperma and Pitheoclobum saman have been found to be the best shade trees for coffee. In Brazil and in some of the Central American countries, Igna supria, Igna ursi and various other species of this genera are used quite extensively.

In Porto Rico (128), after the hurricane of 1928, it was observed that the regions most severely damaged were those where the large trees of Igna vera were thrown over. The broken Erythrina bertervana trees developed leaves within a few weeks after the storm, thus showing their superiority over the Igna trees which were practically worthless as shade. Gliucida sepium also showed decided wind resistance as compared to the Igna trees. This tree has been found (129) to be abundantly supplied with nodules of the nitrogen fixing bacteria.

Fertilizers for Coffee

In Porto Rico (117), nitrogen as ammonium sulphate, phosphorus as superphosphate, and potassium as potassium sulphate, were applied singly and in combination to coffee trees of the Padang variety. Records for an eight year period show that potassium alone, or in combination with nitrogen, was effective in increasing growth and yield. Nitrogen alone, when applied in amounts of four pounds to the tree, was found to affect growth and fruiting, but the same amount applied in combination with potassium at the same rate gave the highest yield of all combinations tested. Phosphate applied to coffee trees did not give a profitable response. I

In Mysore the results from a one year test showed that nitrogen and phosphorus in combination gave higher yields than combinations of potassium and nitrogen or than phosphorus and potassium, but less than when all three were used together. Of the nitrogeneous fertilizers tested, Floranid and ammonium sulphate gave the highest yields with nitrate of soda and groundnut cake following. Of the phosphoric manures tested basic slag and superphosphate ranked first in yield while potassium sulphate was superior to potassium chloride in a comparison of potassium carriers.

At the Lamo Agricultural Experiment Station, P.I. (185,186) several mixtures of fertilizers were tested on Excelsa coffee with the following results: For the first two years a combination of guano, potassium sulphate, and bone meal in the proportion of 2-1-2, respectively, gave the highest yield. In the third year, a combination of ammonium sulphate, potassium sulphate, and superphosphate, in the proportion of 1-2-½, respectively, yielded highest. In the fourth year ammonium sulphate, potassium sulphate, and superphosphate in the proportion of 1-2-3, respectively, gave the highest yield.

Youngberg (186) in a test to ascertain the relative effectiveness of methods of applying fertilizers to coffee trees, found that trees fertilized by broadcasting the fertilizer around the tree gave an average yield of 2.33 kilos of clean coffee per tree. Those fertilized by burying the fertilizer in trenches yielded an average of 1.83 kilos, while those in which the fertilizer was forked in gave a yield of 1.66 kilos.

Experiments in Porto Rico (117) showed no beneficial effect from the use of lime applied to coffee trees.

McClelland (118) determined the amount of nitrogen, phosphoric acid, and potash contained in every 100 pounds of market coffee. He found that by returning the pulp to the land more than one-fourth of the total phosphoric acid, nearly half of the total potash, and considerably more than

one-fourth of the total nitrogen removed from the plant in the fruit could be returned to the ground. His results were as follows:

Nitrogen, phosphoric acid, and potash removed from soil for every 100 pounds of market coffee. (McClelland, Porto Rico.)

	Entire Cherry	Market Coffee	Parchment and pulp
Phosphoric acid	.40 lbs.	.29 lbs.	.11 lbs.
Potash	2.87 "	1.44 "	1.43 "
Nitrogen	2.39 "	1.68 "	.70 "

Diseases

There are a very considerable number of diseases which attack coffee. The more important of these are discussed briefly.

Rust or leaf disease (Hemileia vastatrix B and Br)

This disease attacks the under surface of the leaves producing small, orange-yellow spots of about a millimeter or two in diameter. The disease is very prevalent in Java, Sumatra, India, Ceylon and other countries of the orient. It has not, as yet, been reported from any country on the western hemisphere. The disease appears to attack coffee only (106). It is more prevalent in humid areas. However, in India and Kenya severe cases have been reported as developing in the dry season (134). Experiments and observations in Mysore (106) have shown that the fungus passes the dry season in the infested leaves that drop to the ground. As a means of control McDonald (134) recommends clean cultivation. Downson (45) has found common strength Bordeaux mixture a good preventive for the disease. Africa (2) reports that Bordeaux applications for the control of this disease should not be less than 25 per cent of 3:5:50 stock solution. David (40), in the Philippines, found Liberica coffee to be the most re-

sistant and Arabica the most susceptible to the fungus. Mayen (106) notes that Hemileia is more common in unshaded places and recommends the use of shade as a preventive measure.

"Gotera" or "Mancha de la Hoja" (Omphalia (Stilbella flavida) (Cook) Maubl. and Rang.)

This disease, according to Tucker (172), is the worst disease affecting coffee in the New World. The fungus produces grayish spots on the leaves. The spots are generally circular in form and measure about 16 millimeters in diameter. The infected tissue generally drops out leaving a hole in the leaf, hence the name of "gotera". In severe cases the fungus attacks also the stem and the fruit, producing discolorized areas. Fawcett (48) has found the disease to attack such unrelated plants as the orange, mango, begonia, various ferns, and guava. As a preventive treatment to the disease, it is recommended in Colombia (111) to control the humidity of the plantation by controlling the shade. The fungus has been found not to affect leaves that are not moist at the time of the attack (134). Anything making for drier conditions should be unfavorable to the fungus. Fawcett (48) found Bordeaux mixture very effective as a preventive and recommends it as a check for the disease when spreading to healthy plantations. In Porto Rico (171) the varieties Arabica and Columnaries

were found to be very susceptible to the fungus. Liberica and Abeocuta were found to be very resistant.

Brown Eye Spot (Cercospera coffeicola B and Cke)

This disease attacks the leaves and the fruit, producing round or semioval spots. On the leaves the spots are reddish brown with a gray center. On the fruit the spots are dark brown and form sunken, dry areas on the pulp. The disease has been reported from South and Central America, Porto Rico, Cuba, Trinidad, and Santo Domingo (172). In Kenya it appears to be negligible in field plantings but sometimes is decidedly injurious in the nurseries (134). In Colombia the disease is said to be more prevalent where shade is limited. Proper shading is recommended as a control measure. Fawcett (48), in Porto Rico, found sufficient shade to improve the conditions of the berries when badly infected with the fungus. Downson (45) in East Africa, and Wells (192) in the Philippines found the fungus to yield readily to Bordeaux misture. Tucker (172) found coffee Arabica typica and Columnaris very very susceptible and Liberica and Abeocuta very resistant to the fungus.

Black blight or Sooty mold (Capnodium Brasilense Puttem)

This disease manifests itself in two ways; (a) in the form of black spots on the surface of the leaves and (b) in

the form of agglomerative masses on the branches and at the base of flowers and fruit. The infected leaves have the appearance of being covered with soot, hence the name "sooty mold." Investigations (134) have shown that the mold does not derive nourishment from the plant. Its food is the honey dew produced by certain insects, notably scales. The fungus damages the plant by excluding from the leaves light and air needed for photosynthesis. The disease is controlled by controlling the insects which provide food for the fungus.

Koleroga (Corticium (Pellicularia) Koleroga (Cook) Hohn.)

This is mainly a disease of the leaves. The leaves when attacked turn first to a reddish brown color and then black. The leaf when dead drops off and is usually held suspended by the mycelium of the fungus which, upon careful examination, can be seen extending along the stem and branches and between the leaves. The disease sometimes also attacks the fruit, causing it to turn black (48) (111) (171). The disease is found to be more common at the lower altitudes. The fungus is known to be parasitic to many other plants. Fawcett (48) found no very satisfactory method of control. Mayne (107) found that Bordeaux was effective in the early stages of the disease. Good ventilation and light have been recommended as helpful in checking the fungus.

Esclorosis (Schlerotium coffeicollum Stahel)

It is reported that this disease attacks only the Liberian type of coffee (111) (171). The Arabian appears to be immune. The fungus attacks the berries producing dark green spots about five millimeters in diameter. It lives on the fleshy part of the fruit and does not affect the grain. Fruits attacked usually mature imperfectly. In humid regions the fungus forms compact, sclerotic masses on the leaves and fruit. These masses are dark green outside and white inside. They are usually very abundant on fruit that has fallen to the ground. In Surinam the disease has been fought with Bordeaux mixture with good results (171).

Black root rot (Rusellina bunodes Berk. and Br.)

This disease attacks the root of the plant causing the leaves to yellow and the root anchorage of the trunk of the tree to become insecure (51). In advance stages the disease may be identified by the presence of a black substance (the hyphae of the fungus) between the cortex and the woody tissue, as well as by the presence of small dots in a cross section of the infected wood (171). The fungus is known to be saprophitic. Tucker (171) states that infected trees seldom recover and that to insure protection, the infected plants should be dug up, the roots burned, and a trench deep enough

to extend below the organic matter level made around the infected area. The disease has been reported (171) also to attack seedlings, which, when infected, look wilty rather than yellowish, as the trees do.

White root rot (Armillaria mellea Quel)

This disease has symptoms very similar to black root rot and differs from the latter mainly in that the infecting fungus is white instead of black. The same treatment as for black root rot is recommended.

Brown root rot (Fomes lamaoensis Mun.)

This disease, as reported from the Philippines, attacks young trees. The disease is detected by the presence of a soil crust which forms around the affected roots and does not fall away readily on removal of the bush from the soil. The crust sometimes appears on trees above the surface of the soil and black fungus strands may be discovered on it. In advance stages of the disease the leaves lose their color, the branches die back, and the tree may suddenly topple over (51). The same control treatment as for black root rot is recommended (51).

"Cancer" or "Llaga del tronco y la raiz" (Necteria tropica)

This disease is reported from Colombia (111) as attacking coffee during the wet season, causing the tree to lose its

vigor. The disease is present in the form of orange colored areas along the trunk and root where an injury or wound has been made. In mature trees the disease spreads longitudinally along the edge of the wound, but in young trees the fungus spreads all over the woody cylinder. The disease is controlled by scraping off the infected area and disinfecting it with a concentrated solution of iron sulfate.

Brown blight (Collectotrichum coffeanum Noack)

The fungus causing this disease is believed responsible for four different diseases of coffee; one on the leaves, two on the fruit, and one on the twigs. McDonald (134) believes these four diseases not to be caused exactly by the same fungus, but claims the differences are not sufficiently different to distinguish the forms as species.

The disease of the leaves is characterized by the appearance of brown spots, up to about an inch in diameter, on both sides of the leaves. The spots when on the margin of the leaf are usually elongated; elsewhere on the leaf they are approximately circular. As the spots become older they turn gray at the center and black, minute points develop - the fruiting bodies. The spots caused by brown blight are often confused with those caused by the grub of the leaf miner moth. McDonald (134) points out that they may be distinguished, however, by the fact that the spots caused by the white grub tend to split up into flakes when suddenly bent and the grub itself can be found frequently in the tissue.

The two berry diseases attributed to this fungus are known as brown blight of the fruit and black berry disease. The first one is characterized by the appearance of dark brown, somewhat sunken areas on the pulp of the berry. The fungus may penetrate to the bean causing a brown discoloration on it. The disease is more prevalent on unshaded than in shaded trees. It frequently attacks the berries on the more exposed side, where it gains entrance into tissues damaged by the sun or injured by hail.

The second berry disease attacks the green fruit at any stage of development and at any point on the fruit. The first indication of attack is a small, brown, slightly sunken spot which rapidly enlarges until the whole pulp is involved. The berries so attacked are of a uniform brown to black color, hard to brittle, and collapse easily under pressure. The stalk of the berry is also attacked and becomes brown, dry and shrivelled. The fungus does not attack the leaves or twigs, and except for the fruit and their stalks, the branches remain green to the tips (134).

The disease of the twigs caused by this fungus and called anthracnose, attacks branches here and there in the tree at a point more or less distant from the tip. The tissue in the diseased region becomes blackened and the adjoining leaves dry up and fall. The fruitification of the fungus to which the disease is attributed, appear as numerous, minute points on the blackened area.

For the control of this fungus clean cultivation, proper shading, careful pruning, and the picking and burning of the infested twigs and berries are recommended (134). McDonald has found that spraying with Bordeaux and carbide mixtures has given good results in the control of the fungus.

Nursery disease (Rizocotonia solani Kuhn)

This disease as reported by McDonald (134), attacks the stem of young seedlings at or just above the soil level, producing a water-soaked area of a dark brown coloration. The seedlings are generally attacked before the first leaves have expanded. Overcrowding, overwatering, and overshading are factors which favor the disease. Affected plantlets should be removed from the nursery and burned. No control method as yet has been found effective.

Mealy bug root disease

This disease, so called because of its association with Pseudococcus citri Risso., the coffee root mealy bug, which is different from Pseudococcus lilacinus Ckel., the common mealy bug, has been reported from Uganda and Kenya (134). The roots of the tree when attacked by this disease become covered with a dirty-white coating, having a watery appearance, within which the insect lives. The latest experience with this form of root disease in Uganda indicates that it is caused by the

fungus Microphomia phaseoli. Thus far not enough work has been done with the disease to ascertain reliable methods of control.

"Mal de tinta"

A disease affecting the base of the trunk and the upper parts of the root of trees of all ages has been reported from Colombia (111). The name "mal de tinta" has been given to the disease because of the ink-like color which the infected wood develops. From the exterior the disease can be identified by the abnormal development of the part of the trunk attacked. The disease appears to be more prevalent in areas followed by water currents, indicating that the fungus is carried by water and that this probably is the most important method of distribution. The active fungus is thought to be a Blepharospora, although not enough work has been done as yet to ascertain this definitely.

Dieback

Several diseases attributed to physiological causes have been reported from different coffee growing countries. Dieback is one of these diseases. It is very common in Kenya, Tanganyika, and Uganda. The trouble is characterized by the dying of the primary branches which become blackened and dried-up from the tips downwards. The leaves from such affected

trees fall and the fruit ceases to develop and turns brown. There are several types of dieback, but the most common is that in which the young primaries in the region just below the top of the bush die completely, while the very youngest branches at the apex which have not yet reached the bearing stage and the older ones below, remain green. Over-bearing has been credited as the cause of dieback. It is believed that the strain due to the effort of the tree to mature an excessive crop is felt most severely by the young primaries near the top of the bush, which not having established a system of secondary branches to assist in the process, succumb more rapidly than either the younger apical branches, not yet bearing, or the fully developed branches towards the base of the tree. The problem of combating or preventing dieback is identical with that of promoting a healthy vigorous growth. Good cultivation to insure soil aeration and conservation of moisture during the dry periods, as well as a proper system of pruning are important factors in combating dieback (134).

Black tip

This is another trouble attributed to physiological causes. Reports from Kenya state that Black tip is more common at higher altitudes (6000 feet upwards) than at lower altitudes. The trouble affects the extremity of the branches which die and turn black. An increase in the branching of

the secondary and tertiary branches usually occurs. This probably is due to the profuse growth which generally follows the death of the apical growing points. Two factors are believed to be concerned with the trouble. These are sunburn and too great fluctuations in temperature. The provision of suitable shade therefore is recommended as a remedy.

Chlorosis

In Kenya two types of chlorosis affecting coffee are known. One is general all over the leaf and gives a sickly yellowish appearance to the foliage. In the other the areas between the main veins become yellow or almost white, but the veins themselves remain green. The trouble is not of economic importance and the cause is not known.

Insects

The insects attacking coffee are numerous and a detailed consideration of them would be beyond the scope of the present work. In the table below are presented some of the most destructive insects attacking the plant with the recommended methods of control.

Insect	Damage	Control
1. Broca (*Stephanoders hampei*)	Larva feeds on inside of grain.	Destroy all infected berries. Clean cultivation. Biological control, *Propos nasuta*.
2. "La palomilla" (*Ceroputo antioquensis*)	Adult sucks juice at crown of root	Destroy weeds near infected area. Spraying with paradichlorobenzene has helped.
3. Leaf miner (*Leucoptera coffeella*)	Larva eats the foliage.	Pull and destroy infected leaves.
4. "Mion del cafe"- (*Clastoptera Isabelae*)	Nymph sucks juice from leaves and stem.	Spray with nicotine sulphate.
5. Root borer (*Hammoderus granulosus*)	Bores tunnels in the root.	Mixed lead arsenate (4 lbs) and barnyard manure (100 lbs) applied to ground around tree has helped.
6. Green scale (*Coccus viridis*	Sucks juice from leaves and twigs.	Spray with nicotine sulphate.
7. "Toy-beetle" (*Leucopholis irrorata*)	Larva eats root of seedling when in nursery.	Destroy weeds in vicinity of seedbed. Carbon bisulphide applied to ground has helped.
8. Cuspid bug. (*Lygus simonyi*)	Injures flower bud causing it to develop abnormally.	Spraying with kerosene emulsion has helped.
9. Aphids or plant lice.	Suck juice of plant.	Spray with soap solution or kerosene emulsion.
10. Thrips.	Suck juice of plant.	Spray with soap solution or nicotine sulphate.

HARVESTING THE CROP AND PREPARATION FOR MARKETING

Observations made in several countries, and particularly in Colombia, indicate that the best way to harvest coffee is to pick the berries one by one, by hand. This, though it may seem a slower and more expensive method than the one commonly practiced in which the berries are picked en masse by pulling them from the branches, has been shown (111) to be more profitable in the long run. The advantage of picking the individual berries lies in the fact that the plant is damaged less and a better grade of coffee is obtained, since the method makes possible careful separation of the ripe from the unripe berries.

It has been pointed out (111) that when picking the coffee care should be observed not to leave dried or dead berries on the plant as they seem to have a toxic effect on the plant.

If the berries are left unpulped for over six hours after picking they undergo a fermentation which damages the quality and appearance of the grain. For this reason the berries must be pulped soon after they are picked.

It is a well known fact that the quality of the coffee may be seriously affected while the beans are being fermented to remove the "saccharine matter" that covers them.

To avoid unsatisfactory results from the fermentation process the following points have been suggested as important: (1) The tank in which the coffee is to be fermented must be thoroughly clean before it is used and if possible white-washed once a week; (2) The tank must not contain water during the process; (3) In order to allow circulation of air through the coffee the coffee in the tank should not be covered; and (4) The fermenting process should not be allowed to continue for over 12 to 15 hours depending upon the temperature; the warmer the shorter the period allowed.

Much dispute is found in the literature as to the causal agent that breaks down the "saccharine matter" during the fermentation process. Beckley (12) believes the agent is an enzyme produced by the "saccharine matter" itself. Von Lilienterfld (182) believes that it is lactic acid produced by several bacteria. Many believe the destructive agent is acetic acid while others claim it is alcohol.

Of the two systems used in washing the fermented "saccharine matter" from the grain, the so-called "by hand in channels" is thought to be superior to the mechanical methods available.

The drying of the grain, once it has been cleaned, is done by spreading it on cement in "yards" or by placing it in ovens. Results (111) obtained indicate that drying in the oven, where

the temperature can be controlled, gives better coloring of the grain but the difference usually is not sufficient to justify the difference in cost.

The coffee, before it is sacked for shipment, should be classified as to size and the broken and discolored grains removed. Sixty kilos bags are becoming the accepted standard size for shipping coffee.

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