BULLETIN No. 25.

U. S. DEPARTMENT OF AGRICULTURE,

DIVISION OF BOTANY.

SHADE IN COFFEE CULTURE.

BY

O. F. COOK,

Special Agent for Tropical Agriculture.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1901.

COFFEE SHADED WITH BANANAS PLANTED WIDE APART, CORDOBA, MEXICO.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Botany,
Washington, D. C., December 19, 1900.

Sir: I have the honor to transmit herewith a manuscript entitled "Shade in Coffee Culture," by Mr. O. F. Cook, Special Agent for Tropical Agriculture, and to recommend its publication as a bulletin of the Division of Botany. The recent acquirement of tropical territory by the United States has brought conspicuously to the attention of the American people the question whether tropical agriculture does not furnish a promising field for the application of that ingenuity, energy, and intelligence which in the past century have revolutionized temperate agriculture. The accompanying report gives a partial answer to this question in the matter of coffee culture. It combines the results of personal observation and of a careful study of the literature relating to the much controverted question of the shading of the coffee tree. The hypothesis is here advanced that leguminous shade trees, in addition to the effects produced by shade trees in general in protecting the soil from erosion, drying, and heating, and in preventing the mechanical injury of the coffee plants by the wind, have the same beneficial effect on coffee as do clovers and other leguminous plants on the crops with which they are so commonly rotated, namely, that of adding nitrogen to the soil and thus, without expense, increasing the fertility and productiveness of a plantation. In some of the most prosperous coffee-growing districts of Central America this practice has been followed by the planters without an understanding of the real reasons of its success. It appears too, singularly enough, that this Central American system of shading coffee was adopted from the custom of the aborigines in the shading of cacao in prehistoric times, which is still practiced in many localities. It is confidently believed that a rational system of coffee culture in Porto Rico, based on the use of leguminous trees and plants for shade and fertilizer purposes, will revolutionize the coffee industry in that island and at least double the yield per acre.

Respectfully,

Frederick V. Coville,
Botanist.

Hon. James Wilson,
Secretary of Agriculture.

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INTRODUCTION.

The shading of coffee is one of the vexed questions of tropical agriculture, and the literature of the subject abounds in opinions of the most contradictory import. By some shade is condemned as always and everywhere hurtful, while others insist with equal emphasis that it is a necessity for the healthy growth and productiveness of the coffee tree. Some experts admit a limited use of shade at low altitudes and in regions subject to drought, while others insist that coffee can not be profitably cultivated where shade is necessary. A favorite argument for shade is the greater longevity of the trees, but this is answered by the assertion of greatly decreased productiveness. The occasion of the present bulletin is the attainment of the belief that the above arguments and others noticed in detail below are based, when they have any rational justification, on local conditions merely, and do not represent facts or principles of general application in the culture of coffee. To ascribe to the shade itself the effects of fertility imparted to the soil by the roots of leguminous shade trees is a natural and by no means unique error of judgment; but it is, nevertheless, somewhat surprising that this primary cause of so many contrary opinions should not have been apprehended long ago.

Testimony in favor of shade has come almost entirely from Central America, Venezuela, and Colombia, in which region the custom of planting leguminous trees with coffee is general; in Brazil and in the East Indies where experiments have been made with figs and other nonleguminous trees theory and practice have generally ignored or directly opposed the use of shade. To reconcile these contrary ideas it is necessary only to observe that the coffee and cacao planters of the Central American region have been practicing unconsciously a system of soil fertilizing. Like the clovers, vetches, and other fodder and soiling crops now extensively used and highly valued in the agriculture of temperate regions, the leguminous shrubs and trees are also able to avail themselves of the atmospheric nitrogen by means of their root tubercles and attendant bacteria. Although the planting of a leguminous soiling crop with coffee was suggested many years ago in Java, and although several writers who favored shade have mentioned the

increase of nitrogen among the incidental advantages possible under the shade system, this simple interpretation of the general problem seems never to have been made, and the practice of growing coffee under shade is still defended on grounds at once illogical and insufficient.

Without denying that shade may be a necessity in a few instances when coffee is grown in arid regions like parts of Arabia and Mexico, it is evident that the persistent and increasing use of shade in the moist tropics is irrational and unjustifiable on the basis of any existing theories. If the increased fertility of soil through leguminous trees be left out of account the adverse opinions of Dafert and other scientific investigators must be admitted as justified, and shade must be condemned as a cultural error of huge practical dimensions. If, on the other hand, the nitrogen fixed in the soil by the bacteria of the root tubercles of the leguminous shade trees be held as a factor of prime importance, to which other alleged advantages of shade are negative or merely incidental, estimates of the relative wisdom of existing systems of culture are entirely changed. New lessons from the past and new experiments for the future suggest themselves, and it becomes apparent that scientific coffee culture holds possibilities as unsuspected as they are unrealized.

The question of shade in coffee culture is fundamental, in the sense that from the clearing away of the forest to the harvesting of the crop the operations of the plantation are largely influenced or determined by the presence or absence of shade trees. The selection of suitable sites for plantations, whether the forest shall be completely destroyed or merely thinned out, which trees to leave for shade, or which to plant in advance of the coffee, how to lay out the plantation, the spacing of the trees, the drainage, cultivation, catch crops, soiling crops, weeding, fertilizers, and irrigation—none of these details can be intelligently dealt with until a decision has been reached in the matter of shade. Not that a general decision for or against shade is to be expected; shade is a cultural question which each planter must decide from the study of his local conditions. There are soils and climates where shade trees are unnecessary, or even harmful; there are others where leguminous shrubs or herbs can be utilized to much better advantage than trees, but in the broken and mountainous regions, where a large proportion of the world's coffee crop is grown, and in arid regions, where a great extension of the industry is possible, leguminous trees have, and will doubtless continue to have, enormous agricultural importance. To determine the true extent of the utility of shade trees and of the different kinds of trees adapted to this purpose is a scientific problem which should receive early experimental attention.

In many coffee-growing regions, such as Porto Rico, steep slopes and heavy rainfall forbid agricultural methods similar to those generally employed in temperate regions. The soil can not be stirred lest

COFFEE DISTRICT OF THE ADJUNTAS VALLEY, PORTO RICO; CLOSELY PLANTED SHADED COFFEE IN FOREGROUND.

it be washed away by the next rain, and the application of commercial fertilizers is for the same reason more or less impracticable. The use of leguminous annuals would also be attended with the difficulties of frequent replanting and the disposal of vegetable débris which often invites the danger of plantation fires. Leguminous trees, however, hold the soil in place, and seldom require replanting or other care; their shade discourages the growth of weeds, diminishes the cost of cultivation, and lessens the bad effects of drought. Rational shade culture thus renders it possible to utilize and maintain the fertility of extensive regions favorably located climatically, but too broken to be amenable to agriculture as practiced in temperate regions. In addition it has a most important bearing on coffee and many other tropical industries throughout their present extent and future expansion.

It could not have been expected that experimental investigation of the value of leguminous trees in coffee culture would have been made while all the benefits of their use were ascribed merely to the shade; indeed the popularity of Erythrina is commonly explained by reference to its rapid growth and to the belief that it furnishes water to the roots of the cacao trees, while Inga is said to have been selected for its umbrella-like top which is supposed to yield shade of a quality and quantity particularly grateful to the coffee. Moreover, experimental decision on the subject would have been obscured by the fact that shade, if ever directly beneficial, is seldom necessary for coffee, its good effects being generally limited to the protection of the soil and the superficial roots of the coffee. This consideration and others to be noted later have furnished the partisans of shade with real though insufficient arguments, while the generally obvious deterioration of coffee grown in heavily shaded situations has undoubtedly strengthened the conviction of the advocates of open culture. To determine experimentally the nature and extent of the injuries due to shade has naturally seemed superfluous to those who believed that its use was merely an ignorant superstition, while those who profited by the planting of leguminous trees have persisted in defiance of all assertions that shade is worthless or harmful, though they continued to plant leguminous trees, not because leguminous, but because they yielded a supposedly desirable kind of shade.

Admitting that sustained fertility of the soil and not perennial shade is the basis of the successful coffee culture of Central America and the northern countries of South America, it is possible to appreciate in new light many facts and opinions which were previously meaningless or quite contradictory. Shade may be detrimental, but leguminous trees may be advantageous; to adjust the balance to the profit of the planter is the problem to which experimental attention should now be addressed. To maintain the maximum of fertility with a minimum of shade, to lessen the labor of culture without decreasing the

crop, to waste no space but to lose nothing by overcrowding, to improve quality without diminishing quantity, to obtain timber or other secondary products of value—in the investigation of these and many similar questions of coffee culture the habits and characteristics of the various leguminous trees may furnish factors of the greatest importance, and the study of them will become a regular part of the investigations of tropical agriculture. Not only coffee, but cacao (chocolate) and coca (cocaine) are culturally connected in South America with leguminous trees, and even Guinea grass has been said to thrive best under the shade of *Pithecolobium saman*. It has accordingly seemed desirable, as a basis for further observation and experiment, to bring together some of the recorded information bearing upon the planting of leguminous trees with coffee.

Although direct historical evidence has not been found,[1] it seems not unreasonable to believe that the use of leguminous trees for shade purposes is a legacy from the prehistoric agriculture of the native races. Both cacao and coca were extensively cultivated before the advent of Europeans, and early accounts of the culture of the former make reference to recognized use of shade trees. Moreover, it is exactly in the cácao regions that the most uniform use of leguminous trees for shade has appeared.

THE DIRECT EFFECTS OF SHADE.

The various ways in which shade may affect the growth of such a plant as coffee may be grouped, for convenience of consideration, as direct and indirect. To maintain that shade is directly beneficial is but a converse of the proposition that sunlight is harmful, since reduced temperature and sustained humidity of the atmosphere and soil, and other similar and attendant results affect the coffee plant only indirectly and have been considered heretofore as merely incidental to the shade.

Although no writer of practical experience has maintained that shade is directly beneficial to coffee, many compiled and semipopular works repeat statements to the effect that dense shade is the "first essential to the life of the coffee bush," and some have taken the

[1] This deficiency has been supplied since the manuscript of the present report was sent to the printer. The following passage is from Acosta's account of cacao:

"The tree whereon this fruite growes is of reasonable bignesse, and well fashioned; it is so tender, that to keep it from the burning of the Sunne, they plante neere unto it a great tree, which serves only to shade it, and they call it the mother of Cacao. There are plantations where they are grown like to the vines and olive trees of Spaine. The province where there is greatest trade in cacao is Guatimala. There grows none in Peru, but this country yields Coca, respecting which there is another still greater superstition." "The Natural and Moral History of the Indies," 1590. Hakluyt Society edition, 1880, 1:245.

trouble to attempt a justification of this view by reference to the conditions under which coffee grows in the wild state.

NATURAL HABITAT OF COFFEE.

Like so many other members of the large natural order Rubiaceae, the numerous species of the genus Coffea are slender shrubs or small trees incapable of maintaining themselves in genuine forest growth, but seeking their opportunities for existence along water courses or in the somewhat open, partially wooded country which borders the many disconnected forest areas of Africa. Crowded among the greatest variety of similar vegetation, and finally overwhelmed by the trees of larger size, partial shade is a very general natural condition of such species. This fact has been interpreted by some writers as a reason for the belief that shade is a normal requirement of the coffee plant. It requires, however, but little observation in nature to realize that most of the plants having the same ecological relations as the coffee are not assisted by deficiency of light but will thrive much better and become more vigorous and productive when the competition of the masses of other vegetation is removed. In fact, many species which appear in nature and in works on systematic botany as "lax, trailing shrubs," will change their habit to one of strict upright growth when permitted to stand alone.

It is now generally admitted that the so-called Arabian coffee originated in the mountains of Abyssinia, whence it was introduced into Arabia in early Mohammedan times. Although there seem to be no very careful records of the natural habit and habitat of the Abyssinian coffee, the tendencies of the plant under cultivation and when neglected show its essential similarity to the other species, and indicate the improbability that there is any inherent or physiological reason why sunlight should be directly harmful.

To what extent *Coffea arabica* is confined in nature to high altitudes is by no means satisfactorily determined, so fragmentary is our knowledge of African botany, and so great are the chances of artificial introduction of the species to all the accessible parts of tropical Africa. Coffee considered not specifically distinct from *C. arabica* is noted by Warburg from several localities in the East African colonies of Germany and Great Britain, particularly in the lake region. The wild coffee reported by Welwitsch from the mountain forests of Angola as a tree attaining 20 feet in height and 6 to 18 inches in diameter is much larger than anything described from East Africa. This fact, in connection with the notably small size and inferior quality of the seeds, tends to throw doubt upon its identity with the genuine Arabian coffee. But even if considered specifically identical there are evidently considerable varietal differences, so that cultural reasoning could

scarcely be based on the Angolan natural conditions. But whatever the natural limits of the genuine species or variety, the fact that it has been found generally possible to grow it to maturity at sea level in moist tropical countries is an indication, from the vegetative standpoint, that the disadvantages suffered at low elevations are not necessarily serious, and there are also reasons for supposing that they may result from too much heat, too much dryness, or, in other cases, too much moisture. It would, in fact, be more logical to reverse the argument noticed above and to suggest that the Arabian coffee may suffer at low altitudes for lack of the powerful insolation[1] under which it reaches perfection in mountain districts.

The fact that coffee is sensitive to drought requires that for increased temperature the available moisture must also be increased and sustained. The difficulty with coffee at low altitudes when this requirement is met is not a failure to grow; on the contrary, the vegetative activity is too vigorous for practical results. Instead of flowering at a definite time, a succession of blossoms is put forth; the berries also ripen irregularly and often are not properly matured. The cost of culture and harvesting are increased and the quality of the product is inferior.

EFFECT OF SHADE ON YIELD.

The fact that shade by lowering the temperature and increasing the humidity may render it possible to produce coffee in regions so hot and so dry that none could be grown otherwise, has little bearing on the problem of ascertaining the value of shade in rational culture under conditions naturally favorable to the coffee plant. While there have been no scientifically conducted experiments to test the effect of shade upon yield, every consideration of vegetable physiology agrees with the frequent admission of planters that shade decreases the yield, especially where it assists in retaining excessive moisture either in the air or in the soil. That sunlight is necessary for the processes of plant assimilation, that the sugar content of vegetable tissues depends upon access to light, and that sugar is the material from which most of the alkaloids and other plant substances are elaborated, are well-known facts indicating the necessity of light for a maximum of functional activity. Even those who advocate the use of shade admit, as in Porto Rico, that the yield is diminished, though the existence of compensating advantages is maintained. It is true that in Porto Rico

[1] In connection with physiological and ecological studies of plants the word "insolation" means exposure to the radiant energy of the entire solar spectrum, and is also employed conversely in referring to the direct results of such exposure. In different sciences the energy radiated from the sun is considered with reference to its optical, thermal, actinic, electric, or other qualities, but in dealing with plants "insolation" involves possible effects from all parts of the spectrum, conditioned only by the properties of the intervening atmosphere.

COFFEE TREE GROWING NEAR SAN JUAN, P. R., IN SAND, AT SEA LEVEL, AND ENTIRELY WITHOUT SHADE.

the general reduction to one-third of a normal crop is caused by overcrowding, overshading, and the neglect of all cultural requirements. It is also true that large crops are produced in Central and South America under open shade culture with leguminous trees; the present point is that no reasons or facts have been advanced which indicate that under conditions favorable for coffee culture the direct effect of shade is other than detrimental to the yield.

In deciding upon the relative desirability of different conditions and methods of culture, it may be found necessary to distinguish carefully between the yield by areas and the yield by individual trees. Thus in some localities thick planting and small returns per tree may bring earlier and larger profits than could be secured by wide planting with the necessary postponement of the maximum yield. If the matter were to be decided entirely on the basis of the yield of individual trees testimony is well agreed that the most favorable conditions exist at elevations where a mild and equable climate renders shade entirely unnecessary, and a fertile soil sets no limits to growth. Thus in Java the largest trees are described as growing on terraced, carefully cultivated mountain sides with the slopes grassed over to prevent washing. The coffee is here planted 25 feet apart and permitted to grow to its full height, sometimes reaching 30 or 40 feet. These giant trees bore a crop which yielded 6 or 7 pounds of prepared coffee at a time when the general average for the Government plantations of Java was only half a pound per tree. On the rich volcanic soils of Central America similarly favorable conditions permit unusual size and yield to be attained without shade. Averages of 3 pounds per tree and upwards have been recorded for unshaded plantations, while individual trees have been reported as yielding 12, 20, and even 40[1] pounds of coffee. One writer who gave special attention to such exceptional cases in Mexico reports as follows:

> Coffee trees will grow and produce more or less fruit in almost any soil where the temperature is not too low, but in order to obtain the best results it is necessary to select a rich, light, and deep soil in a locality where it rains at brief intervals during the entire year; and yet too much moisture is not good for coffee. Much has been said and written about the altitude above the sea level. My own observation has convinced me that the importance of this point has been greatly overestimated, because I have seen abundant crops of excellent quality produced at a very insignificant elevation, and I have seen the same results obtained at a very considerable elevation above sea level. * * * It is a fact worthy of note that all the coffee trees which I have known to produce very large crops have been permitted to grow freely without pruning the roots or the tree beyond taking off the suckers or sprouts, and they have been so far from any other trees that their branches did not come in contact with them. Some of these very productive trees have received no attention whatever except the gathering of the fruit, but as far as I am able to observe they have been entirely free from contact with other trees. Some of them have grown always in the shade of other trees, others without any shade whatever from other

[1] Modern Mexico, March, 1899.

trees. It is very important in planting coffee trees that the roots should not be injured, although in many places it is customary to cut off the tap root at the length of 9 inches, and to cut off the top of the tree, but such treatment is sure to shorten the life of the tree, and hence the prevalence of the belief that the profitable life of a coffee tree does not exceed fifteen to twenty years. Yet I have seen trees heavily laden with fruit which were so old that no one in the vicinity knew when they had begun to bear fruit; but these trees had evidently been neglected.

It is therefore safe to assume the position that both elevation and shade are of importance in as far as they are required in order to secure conditions of sunlight,[1] temperature, moisture, and soil favorable to the growth of the coffee tree, but that neither altitude nor shadow is a primary requisite for normal development and productiveness.

EFFECT OF SHADE ON QUALITY.

It is very evident that the tendencies of such investigations as have been undertaken in coffee culture have been directed toward the question of securing productiveness rather than high quality, the latter concomitant being generally treated as a function of climatic and natural conditions over which the planter has no direct control. Obviously, however, it is more profitable to grow 200 pounds per acre of coffee which can be sold for 12 cents than 400 pounds, valued at 6 cents, the saving of half the labor of harvesting, preparing, and marketing being an important item. The relation of shade, as of other cultural considerations, to quality is thus an important one. The production without shade of Mocha coffee and the now equally prized Blue Mountain coffee of Jamaica, to say nothing of other high grades of East Indian and Brazilian coffees, shows that the claim that shade is a necessity to the production of coffee of good quality is not to be taken seriously. On the other hand, the assertion of an adverse effect of shade on quality is equally unsupported by experimental evidence, although the subject is one easily accessible to scientific investigation. Even the general question of the agency of sunlight in the formation of alkaloids and other special compounds has scarcely been taken up by the physiologists and chemists, but on theoretical grounds the indications are rather against shade. Fortunately two instructive cases of a parallel nature have received attention, those of quinine and cocaine. The investigations of Dr. Lotsy on cinchona trees cultivated in Java show that the distribution of the alkaloid is very definitely determined by sunlight, although the tree is one which, like the coffee, does not flourish at low altitudes. The second instance

[1] Investigations are needed to determine the actual thermal, actinic, and other conditions of plants growing at elevations in the tropics. Although the rarer atmosphere of higher altitudes permits the escape of heat radiated from the earth and thus remains relatively cool, this does not exclude the possibility that the soil and the tissues of plants, besides being more readily accessible to the influences of other parts of the solar spectrum, may absorb large amounts of heat.

HILLSIDE COFFEE PLANTATION, SHADED WITH BANANAS AND A VARIETY OF FRUIT AND FOREST TREES, BARRIO JUANA MATA, BETWEEN PONCE AND ADJUNTAS, P. R.

is even more pointedly of interest, since in the mountains of Bolivia the shade system in use for coffee is also applied in the cultivation of coca (*Erythroxylon coca*), from which the well-known alkaloid cocaine is extracted. As no direct investigations of the qualities of shade-grown and sun-grown coffee seem to have been recorded, the following note by Dr. H. H. Rusby on the effects of shade on coca is worthy of quotation:

> It is here generally believed that shade tends to the production of the best quality of leaves; so the cocales are planted thickly with a small broad-topped leguminous tree related to the St. John's bread, but whose name I can not at this moment recall. There is no doubt that this is a mistake. I have made repeated comparative assays of shade-grown and sun-grown leaves from adjoining plants, and invariably found the latter much richer in total alkaloids. I judge the custom to have arisen from two considerations. There is, as I have stated, a period of two or three months when the plants receive no rain, and then these trees afford a protection from the fierce heat; secondly, shade conduces to the production of a large, smooth, beautiful leaf, of elegant color, and thus adds to the appearance of the product.

It is further noteworthy that, as in the genus Coffea, the numerous lowland species of Erythroxylon are greatly inferior to *E. coca* in cocaine content, suggesting that in nature as in the shaded plantations examined by Dr. Rusby the alkaloids stand in a direct relation to the powerful insolation permitted by the transparent mountain atmosphere. But as the shade-grown coca leaves, although deficient in cocaine, appear to be acceptable to the coca-chewing Indians, it may be that other desirable qualities are not eliminated by shade growth,[1] though this seems improbable in view of the fact that the products of high altitudes are, as in the case of the coffee, considered superior, not merely on the account of the presence of more cocaine but of other substances grouped as "sweet alkaloids" which impart to the finest leaves their characteristic aromatic flavor. Dr. Rusby even supplies us with a physiological theory to account for the relations between quality and altitude.

> I have made a large number of assays tending towards elevations, soils, exposures, seasons, ages of plants and of leaves, different varieties, wild and domestic, different parts of the plant, and various modes of drying and packing. The results will be embodied in a future monograph, mere passing reference being made to them for the present. I have about concluded that the percentage of the sweet alkaloids varies inversely as the amount and continuousness of moisture that the plant receives. Thus, the Peruvian, Ecuadorian, and the Brazilian coca, which, as I have stated, is much more copiously and regularly watered than the Bolivian, is markedly inferior, so that Bolivia regularly exports about one-eighth of her crop to those countries. I am inclined to think that the greater breadth and thinness of the northern leaf may be partly due to the greater water supply and the consequent greater degree of evaporation. Again, the Indian always seeks the coca grown at the higher elevations, where the humidity is much less and more irregular than in the districts along the

[1] The failure to complete the changes necessary in forming the alkaloids might also leave undesirable substances in leaves or fruits grown in the shade.

rivers. We are thus obliged, for reasons to be elaborated in the future, to regard these alkaloids as preserving a sort of balance of moisture by which the plant stores up during the wet weather a concentrated supply of water which may be very slowly yielded up during a time of need.

This proposition appears to be entirely applicable to the culture of coffee grown at low elevations and with too much moisture. In connection with the previous quotation it also suggests that there may be physiological reasons why coffee produced in the shade or in humid situations can not contain a maximum of alkaloids and aromatic properties, though it is not, of course, certain that the parallel with coca will prove to be complete.

Coffee, like some other stimulating substances, is used for two reasons, (1) the pleasing flavor and (2) the subsequent physiological effects. The latter are now known to result from the alkaloid caffein, a nearly tasteless, slightly bitter substance, the presence or absence of which would probably change but little the flavor or the aroma of the coffee. These latter qualities are probably dependent upon a variety of essential oils and other organic compounds, the number and composition of which, as with the "sweet alkaloids" of coca, are not known. The character and amount of these may also have no direct connection with the caffein content, though the greater functional activity of sun-grown plants may be expected to result in larger amounts of the various special products, as in the above-described instance of the coca.

FERMENTATION OF COFFEE.

Investigations of the effect of shade on quality are likely to be complicated and hindered by our equally great ignorance of the influence of the various processes of curing and fermenting coffee. The importance of the changes now known to take place in the curing of tobacco, tea, cacao, vanilla, and other products depending for their value upon the development of an aromatic flavor indicates that the same question should not be neglected in the case of coffee. Doubtless the wrong methods of curing would cause deterioration in the very best natural product. It is easy to understand that the condition and composition of coffee which is picked as soon as the berries become red, run through a pulping machine and then dried as rapidly as possible in the sun or by artificial heat may be quite different from the condition of that which is allowed to become fully ripe on the tree, then falls to the ground, and there slowly completes the process of drying, as is said to be the case with the genuine Mocha coffee of Arabia. To further facilitate the rapid drying of the coffee it is customary on large estates to ferment the pulped coffee from forty to sixty hours for the avowed purpose of disintegrating the saccharine mucilaginous pulp which remains adherent to the outside of the parchment. What other changes may go on during this period is not known. Possibly the rapid fermen-

tation may be a substitute for the gradual process of drying in the pulp, which requires from three weeks to two months or more, depending upon the climate. It is not generally supposed that the berries dried in this way are ever fermented, not even Semler noting this point. Simmonds interprets the ordinary drying process as follows:

In curing or drying the coffee it is sometimes usual to expose the berries to the sun's rays in layers 5 or 6 inches deep on platforms or terraced floors, called barbecues. These paved barbecues are raised a little above the ground and inclosed with an upright stone ledge of 8 or 10 inches in height, and divided by transverse partitions, with four or more square compartments, that each may contain a day's gathering. During the first and second days the berries are turned often that the whole may be more exposed to the sun, but when they begin to dry they are frequently winnowed and laid on cloths to preserve them better from rains and dews, still exposing them to the sun daily and removing them under cover every evening until they are sufficiently dried. By this means the pulp ferments in a few days, and having thus thrown off a strong acidulous moisture dries gradually in about three weeks; the husks are afterwards separated from the seeds in a mill.

On large estates, where the "wet process" or pulping of the recently gathered berries is practiced, a more or less extensive system of cisterns is arranged for the reception of the pulped coffee for storage during fermentation, and for washing subsequent to that process. Water prevents fermentation and, if wet weather interferes with drying, the coffee may be kept in the cisterns for several days if a stream of water be passed through. Lock also compares the two processes, and records facts which seem to indicate important changes in the chemistry of the cured product:

There are two ways of conducting fermentation—the dry and the wet. The former consists in allowing the pulped berries to lie without water, the bottom of the tank being perforated so as to drain off the liquid; by the latter the tank remains full of water. The dry system is the better as long as care is taken to turn the mass so that the fermentation shall be equal throughout; the presence of water equalizes the fermentation, but retards it, and slightly injures the quality of the coffee. When the fermentation is not sufficiently prolonged the beans will assume a yellowish color called "blanketty," will be difficult to dry, and liable to absorb moisture. When properly fermented the separation of the saccharine matters is easily effected in the washing tanks, to which the beans and a good supply of water are admitted.

To further hasten the process of drying, and avoid the danger of loss through bad weather, the Brazilian planters have resorted to a system of evaporation by artificial heat, which other countries have adopted to a slight extent. If, however, the curing process has any important influence on the flavor of the product, such a method of abridging or altogether omitting it is certainly most unwise. The probability that some such connection exists is considerably strengthened by the following inadvertent testimony from Hull's "Coffee Planting in Southern India and Ceylon:"

In Ceylon the rain sometimes falls for weeks in the middle of the crop season, and I remember on one occasion having between 3,000 and 4,000 bushels of wet parch-

ment lying piled up all over the barbecues which had accumulated before we could get a day's sunshine. Some of my neighbors had larger quantities still, and those of us who had no appliances for artificial drying had an anxious time of it. The only resource was to keep constantly turning over the wet coffee, night and day, to prevent fermentation and germination as far as possible; but in spite of all exertions, an alarming proportion of the beans had begun to throw out pedicles, indicating the commencement of the germinating process—much the same way as old potatoes will do in a damp cellar. Of course we all thought the coffee was ruined, but to our surprise and gratification it seemed to be thought rather better than usual by the brokers of Mincing Lane, judging by the prices realized.

The narrative is given by the author mentioned as showing the necessity of facilities for quick drying by means of artificial heat or at least the prevention of fermentation by constant aëration. It is not stated that the appearance of the crop unwillingly experimented with was good, and the probability that it was at least off color seems very strong. That the price was increased, notwithstanding the supposed deterioration, might have aroused a suspicion that some compensating improvement had taken place, but the incident passed without arousing curiosity or experimental interest. It is also remarkable that the famed superiority of the so-called "jackal coffee," consisting of seeds which have passed through the alimentary canal of wild animals, should not have led anybody to experiment upon the effects of temperature in the curing of coffee. Such facts as the above, though quite insufficient to serve as the basis of advice regarding methods of curing, at least warrant the suspicion that much coffee is badly fermented or cured; they indicate further that in solving the problem of producing high-grade coffee the effects of both shade and fermentation must be scientifically understood. The effects of shade on quality can not be learned from small samples subjected to special treatment in curing, a mistake which has probably vitiated many experiments and comparative tests of quality.

THE INDIRECT EFFECTS OF SHADE.

However untenable may be the position of those who argue that shade is directly beneficial to the coffee tree, the possibility is not excluded that shade in coffee plantations may often be indirectly beneficial by conserving soil moisture, keeping down the growth of weeds and grass, preventing erosion, protecting the coffee trees from the violence of the wind, and in other ways. These claims will now be examined.

PROTECTION AGAINST DROUGHT.

Like many tropical plants which in the wild state grow entangled with dense masses of other vegetation which shut out the sun and wind from the soil and keep it always moist, coffee is very susceptible to drought. Particularly is this the case while the plants are still too

small to have roots extending down to the level of permanent moisture, though even when full grown the largely superficial character of the root system justifies any precaution necessary to avoid the danger of drying out from overheating the upper layers of the soil. Thus shade has in some countries direct bearing upon the problem of irrigation as applied to coffee, a subject which has received the most meager attention in spite of the fact that the traditionally superlative coffee of Arabia is largely an irrigation product, and that in Mexico most promising results both as to quality and quantity have been reached by means of irrigation. Moreover it is claimed that with irrigation paying crops can be harvested after two years from the time the plants are set, instead of in five or six years, as is customary under ordinary conditions of open or shade culture.

SHADE FOR SEED BEDS AND TRANSPLANTED SEEDLINGS.

The seeds of coffee will not survive desiccation either before or after planting, so that the seedlings must be very carefully watered if planted in the dry season. The shading of seed beds is thus a necessity in many countries, since exposure during a few bright days may dry out and kill all the germinating plants, though even here the danger is from the dryness rather than from the light. In countries practicing the open culture of coffee, it is customary to cover seed-beds with lattice work, mats, leafy branches, or other temporary covering which can be removed gradually as soon as the plants are well established, since they may become spindling if shaded too long. Where the method of permanent shading is in use planters often neglect entirely the making of seed beds, and stock their plantations from the spindling chance-grown seedlings. But, as shown later, the failure of such seedlings when transplanted to unprotected situations is by no means a valid argument against open culture, although it has undoubtedly figured as one of the more important reasons for the use of shade. In countries subject to dry seasons of considerable severity, but where open culture is still practiced, considerable caution is advisable in removing shade from seed beds and nurseries, though it is in such localities the more necessary that the seedlings become accustomed to exposure to full sunlight before transplanting. Either the shade should be taken away very gradually or it should be removed during the rainy season, when harmful severity of heat or dryness is not to be expected.

SHADE AS A LOCAL NECESSITY.

The well-known inability of the coffee to withstand prolonged drought makes it readily possible to understand that in localities subject to a severe or prolonged dry season, coffee, if grown at all, must have irrigation or other protection from too great dryness. When

the conditions are too severe the growing of coffee becomes, of course, unprofitable; but there are undoubtedly localities where all other requirements being present shade or irrigation, or both, may be wisely considered by the planter. Thus the coffee of Arabia is produced under conditions apparently quite different from those of other coffee-growing countries. The climate is more or less arid and the coffee is mostly grown under irrigation on terraced hillsides, at an elevation of 3,000 feet or less, but only at the lower altitudes is it considered necessary to use shade trees, and even there the purpose of the shade is the maintenance of a moist atmosphere rather than the protection of the coffee from the sun.

In places much exposed to the south, they plant their coffee trees in regular lines, sheltered by a kind of poplar tree which extends its branches on every side to a great distance, and affords a very thick shade. Without such precaution they suppose the excessive heat of the sun would parch and dry the blossoms so that they would not be succeeded by any fruit.[1]

The destruction of the coffee crop through the withering of the flowers by a hot, dry day has occurred several times in Liberia, where the coffee is often brought suddenly into blossom by a rain near the end of the dry season.

Returning to Arabia, it is further to be noted that the dry climate makes it possible to permit the coffee to become thoroughly ripe on

[1] La Roque, as translated in Ellis's Historical Account of Coffee, London, 1774. This quotation is preceded by a quaintly interesting note on the Arab method of irrigating coffee:

He relates that the coffee tree is there raised from seed, which they sow in nurseries, and plant them out as they have occasion. They chuse for their plantations a moist, shady situation, on a small eminence, or at the foot of the mountains, and take great care to conduct from the mountains little rills of water, in small gutters or channels, to the roots of the trees; for it is absolutely necessary they should be constantly watered in order to produce and ripen the fruit. For that purpose, when they remove or transplant the tree, they make a trench of three feet wide and five feet deep, which they line or cover with stones, that the water may the more readily sink deep into the earth, with which the trench is filled, in order to preserve the moisture from evaporating. When they observe that there is a good deal of fruit upon the tree and that it is nearly ripe, they turn off the water from the roots, to lessen the succulency in the fruit, which too much water would occasion.

In view of the fact that the superiority of the genuine Mocha is still generally admitted, it is strange that no modern investigation of the Arabian conditions and methods of culture has been attempted, particularly in view of the fact that our imperfect accounts by no means agree. Thus another French traveler, Roland, as quoted by Shortt, gives a very different impression of the methods of irrigation and says nothing about shade:

In the interior of Arabia there are hill villages maintained solely by the produce of their coffee, which is grown on terraces, and planted so densely that the rays of the sun can hardly penetrate the groves. Although for the most part coffee in Arabia is not irrigated, but made dependent on the rains, in these parts some of the plantations are systematically watered by means of large reservoirs formed on the heights, in which spring as well as rain water is collected, and distributed over the terraces; and the coffee thus watered produces a second crop in the year, but the fruit only ripens well during the first crop, whilst that of the second is cast away in an immature state and is consequently always inferior to the first.

FIG. 1.—SUPERFICIAL ROOT SYSTEM OF COFFEE.

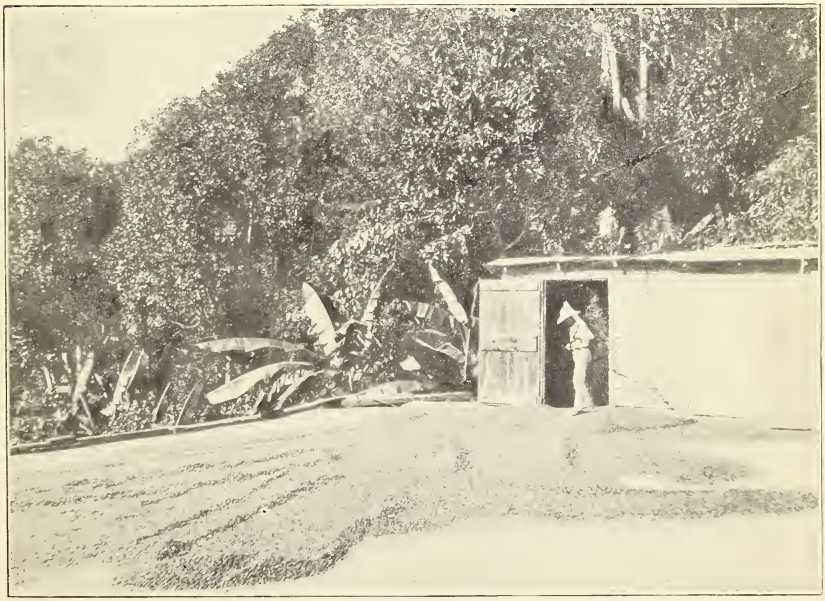


FIG. 2.—COFFEE-DRYING FLOOR, BETWEEN MAYAGUEZ AND MARIAS.

the trees. The drying is completed on mats after it has been shaken down upon cloths spread under the trees, an economical method of picking. The Arabs consider the dried pulp an acceptable addition to the beverage, only the parchment being winnowed out. Most authors admit that the method of curing may explain the excellence of Arabian coffee, but such a plan can not be followed except in a dry climate. Under ordinary tropical conditions the seed will germinate or rot soon after falling to the ground. Some writers contend, however, that the traditional superiority was not caused by differences in the crop or the methods of growing and handling it, but by the fact that when the Arabian coffee reached Europe it was already two or three years old, owing to slow circuitous routes of travel by way of India. That the Arabian conditions are not really favorable for the vigorous growth of the plant is indicated by the fact that a large proportion of the product is pea berry or caracolillo, the shape of which results from the ripening of but a single seed instead of two from each flower. The large proportion of pea berry in Porto Rican coffee is also an indication of degeneracy, but the cause is entirely different, namely, overshading under conditions of ample or excessive moisture.

The success of coffee culture in Mexico, another semiarid country where irrigation and shade are locally necessary, as in the State of Colima, is further evidence that while drought is often a real danger to the coffee planter, the amount of moisture necessary for productiveness and good quality has been overestimated. The great extension of the industry in the moist tropics has probably resulted in the neglect of some of the drier regions, such as the southern slopes of Porto Rico, where, by proper methods of cultivation, coffee could probably be made to grow as well, or better, than in the more moist areas to which it is now confined. Moreover, it is not improbable that any diminution in quantity would be more than compensated by superior quality.

Even in regions where the presence of shade trees has seemed to be necessary to the life of the coffee, it is entirely probable that the chief benefit results from the retention of moisture in the soil, so that shade is sometimes to be justified as a substitute for irrigation. Cases are on record of plantations which had thriven well for several years, but were then completely ruined by a single dry season of special severity. The interference of underlying rocks with the taproots of the trees has been alleged as the cause of damage, but it is far more reasonable to believe simply that the effects of drought were more severe on account of the shallowness of the soil,[1] since it is a well-known fact

[1] In the Kona district of Hawaii coffee is said to thrive and produce well entirely without shade, but droughts are prevented by a gentle daily shower at 2 o'clock. The total rainfall is, however, less than 100 inches at an elevation of 1,700 feet, while along the coast below no rain falls. At a similar altitude in the Olaa district the annual precipitation reaches 250 inches, though there are occasionally several days

that, when other conditions are favorable, coffee will thrive in the rockiest places, where the roots must be continually meeting obstructions. While it is, therefore, entirely possible that plantations in shallow soil have been destroyed which shade trees might have saved, this fact enforces merely the necessity of intelligence and caution in selecting suitable locations, and in making a proper use of shade trees or other means of protection against drought, but it does not warrant any general proposition regarding the necessity of shade or of irrigation.

In deep soils a large measure of protection against drought may be obtained by raising the coffee from seeds planted in the permanent location of the trees. In this way injury to the taproot is avoided, and the tree thus has much better access to the permanent moisture of the soil. In transplanting, the taproot is almost always broken or cut away and is seldom effectively renewed. The difficulty of starting seedlings in the regular plantation is, however, considerable, since in most countries they require to be shaded and carefully attended to during the first few months. A recent writer[1] advises the excavation of holes 18 or 20 inches square and nearly as deep, which are then filled up to within 3 or 4 inches with humus or loose surface soil on which eight or ten seeds are laid and lightly covered with decaying leaves and humus. These little seed beds are shaded with split cross-sticks raised from the ground by two thicker pieces of wood, one on each side of the hole. The weaker seedlings are gradually removed, one of the last two being taken away at the end of the first year. The shade is also gradually lessened, but not entirely removed except to permit the seedlings to grow through the slats. However advantageous the results of this method, it evidently involves much more labor and careful attention than the old system. Moreover, it seems not at all improbable that, even if permanent shade trees are not to be used, a judicious selection of catch crops, such as Indian corn and pigeon peas, might be made to assist in supplying the protection necessary in the early life of the seedlings, to say nothing of the value of

in succession when no rain falls. Possibly from this cause the coffee trees have remained unproductive, although they seem to grow and blossom normally. Some of the planters believe that the cause of failure is the lack of shade, which they are now supplying, while others ascribe it to the exhaustion of the shallow, porous soil underlaid by lava rock. Many plantations have been abandoned, while in others sugar cane is being substituted. These facts were brought to my attention by Dr. Henry Hayes, of Hilo, Hawaii.

Although it is not impossible that the few days of dry weather may affect the coffee, owing to the shallowness of the soil, it seems rather unlikely that this is the sole cause of the difficulty, which deserves careful investigation. The rain may wash away the pollen or prevent the visits of fertilizing insects, or the soil may prove to be deficient in some element requisite for the coffee, to say nothing of other possibilities.

[1] H. Rodatz, in *Der Tropenpflanzer*, October, 1900.

TYPICAL PORTO RICAN COFFEE PLANTATION, CAGUITAS, SHADED WITH INGA AND A VARIETY OF INDIGENOUS TREES.

the preliminary crop or of its aid in keeping down the weedy vegetation which constitutes so serious a difficulty for the tropical farmer.

Notwithstanding the proximity of what might be called the shade belt, much coffee is raised in Guatemala without shade, or at least without other shade than that cast by an occasional row of bananas, which, if they have any useful purpose, must serve as wind-breaks rather than as shade. The need of shade upon the ground rather than upon the coffee trees seems also to be appreciated according to the following quotation from a popular account of the Guatemala industry:

> Many planters allow but 10 feet between the trees, and others still less. There is a great diversity of opinion on this point, for several reasons. Some planters contend that trees placed 6 feet apart, the main stalk pruned to develop the trees horizontally, bear fuller crops, as the interlacing lateral branches shade the roots from the intense heat, and tend to conserve the moisture of the ground. Others, like our host, assert that trees should be planted 10 or 12 feet apart, and well pruned out, in order to increase the vigor of the remaining branches, as well as to permit the freest circulation of the air above the plants, and give each heavily burdened limb the fullest benefit of the sun's maturing influence.

SHADE FOR LIBERIAN COFFEE.

The Liberian coffee constitutes a botanical species, *Coffea liberica*, very distinct from *C. arabica*. The tree is of more erect and vigorous growth, and the leaves, flowers, and fruits are about twice the size of those of the Arabian coffee. Moreover, it is a native of thoroughly tropical coast districts of low elevation and flourishes in Liberia in cultivation without shade but a few yards away from the strand and but a few feet above the level of the sea. There can be no question of the ability of this species to withstand without injury full exposure to the sun. But while the shade temperature of the air in Liberia seldom rises far above 90 degrees, the upper layers of exposed soil become much hotter, and intelligent planters have found that the coffee is greatly advantaged by mulching. The simplest method of accomplishing this is to leave upon the ground the grass and weeds hoed up at the end of the rainy season, but some farmers consider it worth while to cut and distribute between the coffee rows large quantities of green brush, the leaves of which soon shrivel and drop off, though still furnishing considerable protection to the soil, and subsequently contributing to its fertility.

Although, like the Arabian coffee, the Liberian is very susceptible to injury from deficient drainage, the largest and most vigorous trees may often be observed in situations where permanent moisture is assured in the soil or where partial shade retards the drying process. Constant or heavy shade is, however, distinctly detrimental.

Thus at the borders of plantations, trees close to other growth are inferior to those in the open field, but it may also be noticed that a

few individual trees may show exceptional size and vigor when so situated that they can receive a mulch of leaves and slight shade, which tends to keep the ground from becoming overheated. Thus perhaps the finest plantations in Liberia are to be found in Grand Bassa County on rather loose and open soil, and with the trees planted at such distances that the ground is mostly shaded. It is, accordingly, not at all impossible that, even with Liberian coffee in its original home, the limited use of a carefully selected leguminous shade tree might be found advantageous. There are, of course, many native species, but most of them are either of slow growth or they have a dense, compact habit, so that the importation of desirable leguminous shade trees from other countries may prove to be advisable.

Whatever may be the facts regarding the ideal requirements of Arabian coffee in the way of sunshine and shade, there seems to be no room for doubt that with the Liberian species shade trees, if used at all, will be employed solely for their indirect or secondary effects, namely, to protect the superficial layers of the soil against heat and dryness, to provide for it a mulch of dead leaves, and to increase its fertility by means of root tubercles. Moreover, as there is in this case no possible question as to the ability of the coffee to withstand the sunlight, there is the greater warrant for believing that herbaceous or shrubby plants may be found preferable to trees for shading the soil and assisting in the formation of the mulch so useful in retaining moisture. If a leguminous plant can be found which, like the Florida beggar weed in the orange groves, will keep down the grass and add fertility to the soil, the culture of Liberian coffee, at least, will be revolutionized. It is also possible that the danger of fire, which menaces grass-grown plantations in the dry season would not be so serious in connection with leguminous vegetation.

PROTECTION AGAINST EROSION.

There can be no doubt that where coffee plantations occupy steep slopes the existence of large trees would, other things being equal, tend to keep the surface soil in place and maintain its fertility. If, in addition, the trees belong to the Leguminosae, and make a direct contribution to the nitrogenous content of the soil, the beneficial results sometimes ascribed to shade culture are no longer incomprehensible, even though it be still maintained that the direct effects of the shade itself must in many instances be negative. In Porto Rico the question of keeping the soil in place is a very important one, since many of the plantations occupy slopes of surprising steepness, much greater in fact than could exist with similar soil formations in temperate regions. Without being the least rocky, Porto Rican hillsides sometimes maintain themselves at angles of considerably more than 45 degrees from the horizontal. This is possible only because the red clay and underlying hardpan are extremely firm and tenacious, so that

when the surface is undisturbed the erosion is proportionally very small, and the mountain rivulets are often but slightly colored from the soil. If the cohesion of the soil particles were destroyed by frost or other agencies, the steep slopes would simply flow down into the valleys and cover the coast plain or go out to sea; but to a less extent this result must follow from any agricultural operations which stir the soil and permit it to be washed away by the torrential rains. Thus in some districts it is extremely doubtful whether the open culture of coffee would be at all practicable, not because the deficiency of shade would be hurtful, but because the hoeing and weeding or even the simple exposure of the soil to the direct action of winds and rains would undoubtedly result in a rapidly diminished fertility. Moreover, as the soil is relieved of its humus, it becomes the less able to retain moisture and the more liable to drought. To maintain the correct balance of moisture in the soil is, indeed, one of the more difficult problems of the culture of a plant which requires at once effective drainage and continuous humidity of soil. In heavy clays like those of Porto Rico special provisions for drainage may be necessary even on steep hillsides, particularly in localities where the rainfall is evenly distributed so that there is no danger of drought. Soil soaked full of water admits but little air, which is now known to be as necessary to the normal activities of the roots as to those of the leaves.

In planning drainage it is desirable to avoid as far as possible the erosion of the surface soil or the washing away of the vegetable débris from which humus is formed. Ditches are commonly dug across or oblique to the general slope. This decreases the fall and necessitates frequent cleaning, but the fine soil and vegetable matter deposited are eminently worth saving and serve instead of more expensive fertilizers.

In some districts of Central America a system of transverse pits or trenches is in use for preventing the loss of the loose soil and vegetable débris on steep hillsides. In the next rainy season these pits are filled by surface soil and other washings from above, and in the succeeding dry months other trenches are dug immediately above the preceding. As the coffee tree increases in size and the roots push farther out they meet a succession of these accumulations of rich soil which serve in lieu of commercial or other fertilizer. The application of this system in Porto Rico has been advocated by Mr. J. D. Sulsona, of Mayaguez, but it is not known that the suggestion has been acted on, even to an experimental extent. The practicability of the plan on many of the steeper slopes is not certain, but its value might be found to be increased if used in connection with a reasonable number of leguminous trees, which would help to break the force of the winds and torrents. Moreover, the roots would tend to prevent deep washing by heavy storms, and those cut away in digging the trenches would form with their tubercles a valuable contribution to the fertility imparted by the sediment caught by the trenches. In Venezuela similar transverse trenches

are dug, into which the fallen leaves are raked and covered. Another variation of the same idea is described in the Californian for November, 1892, as in use in Guatemala:

> On the Chocola plantation the holes, 6 feet square, are dug between the trees. They are 2 feet deep on the lower side and 1 foot deep on the side toward the top of the hill.
>
> When the heavy rains come the rich surface soil, instead of washing into the valleys and bottom lands below, is caught in these "traps," the water percolates through the roots of the trees and finds its way out without carrying away the nourishing properties of the soil and without exposing the roots of the trees. Each year the holes are dug in a different place so that the earth is kept cultivated as well as if a machine were run through it.

SHELTER FROM WINDS.

In elevated regions and exposed situations coffee is frequently injured by the wind. In some localities in Ceylon where open culture was practiced it was even customary to tie each tree to a stake to prevent it being "wind-wrung," or killed by being whipped about until the bark was bruised or worn away at the surface of the ground. To avoid this danger the planting of wind-breaks or the leaving of strips of the natural forest was found to be desirable and is now customary even where the danger from wind is, to say the most, not serious. In the Malay region, and particularly in Java, more and more emphasis seems to have been laid upon this question of shelter, the coffee having been found to do better in the neighborhood of protecting timber growth, particularly when composed largely of the dadap or other leguminous trees which are generally common in tropical forests. Gradually the planting of such trees, though very wide apart in the plantations, has come to be recognized as generally desirable, some explaining the good effects as an extension of the advantages of shelter, while others maintain that being shaded for an hour or two a day by the feathery leaves of a leguminous tree is really remarkably beneficial to the coffee. In the cacao and coffee culture of the French West Indies a similar idea of the desirability of protection against the wind has resulted in the custom of planting hedges or wind-breaks of Erythrina or Inga at distances of from 60 to 100 meters, in a direction transverse to that of the prevailing winds. Plantations are also divided into rectangles by other hedges running perpendicular to these, and 30 meters or more apart. Swietenia (mahogany) and Calophyllum are also planted, though the last is known to waste much land, and the popularity of the method probably rests to a considerable extent on the use of leguminous trees.

Similar wind-breaks have been advocated in the East Indies to prevent the spread by air currents of the spores of the dreaded coffee disease, and in parts of British India, as explained elsewhere, coffee is actually planted in the forests to avoid this enemy.

But even in regions where no serious results are to be feared from

the movement caused by the wind, it is probable that considerable utility might be found in this idea of shelter planting. Thus at many points in Porto Rico the cultivation of coffee is confined to the lower slopes of hills and the sides of narrow ravines, the land above not being utilized, doubtless because too dry to permit a successful beginning with coffee under the prevalent methods of culture. Perhaps it would not be possible to cover all such ridges and higher slopes with coffee, but if they were planted with leguminous trees or even occupied by ordinary forest growth there can be no doubt that the coffee area could be carried far upward and that the fertility of the plantations would be greatly increased by the materials accumulated above and washed down in readily available solutions. Such tracts of forest, even though of limited extent, also exert an appreciable benefit in retaining water in the soil, so that the advantage commonly ascribed to shade may be secured even from trees planted a considerable distance above. It is not known that the actual value of such an arrangement has been experimentally determined, but when one has opportunity to note the differences between coffee planted below forest and that on entirely denuded ridges or slopes, no doubt of the wisdom of such an arrangement will be entertained.

FALLEN LEAVES AS FERTILIZER.

Saving in the cost of cultivation through the fact that shade trees discourage the growth of weeds is often advanced as one of the arguments for shade culture, notwithstanding the equally obvious fact that shade sufficiently dense to affect the weeds would as certainly impede the development of the coffee. But notwithstanding this disadvantage, an arrangement under which something may be taken out where nothing is put in would continue to recommend shade culture to those who have no lack of land or of time, and who are satisfied with small returns.

Shade culture of a more rational character does, however, offer an indirect protection against weeds, in that the fallen leaves often cover the ground and largely prevent the lodgment and successful germination of weed seeds. When the slopes are not too steep and the dead leaves lie undisturbed such a leafy covering, or mulch, of the soil may be complete, and unless it becomes so dense as to smother the roots of the coffee the effect may be wholly beneficial, since, as shown by Dr. Delgado[1] the fallen leaves of Erythrina (bucare) and Inga (guama)

[1] *Contribución al Estudio del Café in Venezuela*, por Dr. G. Delgado Palacios, Caracas, 1895, pp. 93. This author, while defending the use of shade as such, seems to have been the first to realize that the good effects come largely from the fertility imparted to the soil, though he ascribes this result largely to the fallen leaves. The special utility of leguminous trees is emphasized and explained on the ground that, though having superficial roots for the fixation of free nitrogen, they draw nourishment only from the deeper strata of the soil, and thus do not come into harmful competition with the coffee.

contain a large amount of fertilizing material. Similar facts have been established by M. Grandeau with the leaves of *Albizzia lebbek*. The decaying leaves are incorporated with the soil in the processes of cultivation, and undoubtedly make a considerable addition to its fertility, and also improve its mechanical condition. The addition of lime is supposed to add greatly to the value of this leaf manure by neutralizing the acids formed in the decay of the vegetable tissues, and by liberating free nitrogen or soluble nitrogenous compounds. There is, however, a belief in Venezuela that the use of lime in coffee plantations is dangerous, for, although the immediate benefit is admitted, the ultimate result is said to be the rapid impoverishment of the soil. According to Dr. Delgado, this erroneous view is based only on the excessive use of lime beyond the amount required for the utilization of the vegetable food materials already available; but if employed with reasonable moderation lime is held by him to be of great and permanent value. How far the alleged benefit attaches in reality to the effect of lime upon the humus, and how far we are dealing with the now well-established fact that many of the tubercle-forming bacteria require lime for functional activity with leguminous plants, are matters which can be determined only by careful experiment.

It is of further interest to note Dr. Delgado's insistence upon the fertilizing value of a stirring of the soil, quite outside of what may be necessary in the removal of weeds. The regular use of the creole plow between the rows of coffee is advised as extremely beneficial, and the injury to the superficial roots of the coffee is said to be more than compensated by the efficiency of the new ones put forth in the newly stirred and aerated soil. But here again the possible effects of stimulating the activity of the roots of the leguminous shade trees, as well as the fertilizing value of the detached tubercles, are to be taken into account in scientific experiments for determining the lines of rational culture.

A further suggestion from Venezula, of possible utility in Porto Rico, is that for the utilization of the fallen leaves of shade trees on slopes so steep that they are washed away in the rainy season. The leaves are raked into windrows placed a little above the middle of every second space. Just below the windrow a trench is dug 2 or 3 feet wide and more than half as deep. The leaves are sprinkled with lime, and the surface soil from the trench is also thrown over them, after which they are pulled into the trench with a hoe, and the earth taken from the trench is thrown back upon them. This plan is evidently a modification of the system of open pits in use in Central America, and already discussed under the subject of erosion.

NITRIFICATION THROUGH SHADE.

In the Boletin de Agricultura Tropical for September, 1899, an ingenious explanation of the value of shade in the coffee culture of

COFFEE OVERSHADED AND DWARFED BY BANANAS, AS COMMONLY PLANTED IN PORTO RICO.

COFFEE FROM HEAVILY SHADED PLANTATION, PORTO RICO.

[Natural size.]

Costa Rica is offered by Mr. Julio E. Van der Laat. In urging the use of commercial fertilizers, particularly nitrate of potash, this writer propounds the theory that a process of nitrification in the soil is necessary in rendering the fertilizer available for the coffee trees. This is thought to be brought about, or at least favored, in two ways: (1) By spreading in the plantations fine earth taken from ditches and pools and (2) by shading. It is declared that the alluvial matter is not a manure, and that its good effects are due to its "richness in nitrifying organisms." The completion of the process of nitrification also requires humidity, and shade is said to have "no other effect or utility than that of maintaining this humidity in the soil and in the atmosphere during the dry season." While thus admitting that the benefits of shade are entirely indirect, this writer betrays no doubt of its importance:

> The want of shade brings two evils: The soil cracks and injures the smaller roots of the coffee, and, what is still worse, nitrification ceases or is diminished, and the tree is thus deprived more or less completely of its nitrogenous nourishment, and the remainder of the fertilizer fails of its proper effects.
>
> Shade is, then, an essential condition for the production of large crops; but it should be lofty, to allow free circulation of air, and not excessive, so as not to cause injury during the winter.
>
> The shade trees should have deep roots, of a kind to draw their nourishment from a stratum of soil different from that in which are spread the roots of the coffee tree.

This theory of the function of shade probably owes its existence to the more or less conscious realization of the fact that the results of the shade culture practiced in Costa Rica required other explanation than that of direct benefits which could be ascribed to a diminution of sunlight. It is by no means impossible that the soil bacteria may be found to play an important rôle with coffee, as well as in other departments of agriculture, but our knowledge of these organisms is still too slight to furnish more than ground for speculation, while the demonstrated utility of leguminous soiling crops gives great strength to the analogous explanation of the value of the arboreal types of the same family. The idea that the leguminous shade trees do not impoverish the soil because they are "deeper rooted" is of course another assumption made in support of a method for which the real justification remained hidden.

Similar ideas appear in Cameron's account of the coffee industry of Coorg district of British India:

> Where the initial mistake has been made of removing the indigenous deep-rooted shade—and it is pretty universal—replanting has been compulsory, as no one now thinks of growing coffee successfully without shade.
>
> But in addition to losing much valuable time in secondary planting it will be felt that the land is called upon to do double service. This, however, is not the only disadvantage arising from the sudden exposure of forest soil long nurtured under shade. Such treatment causes a revulsion in the chemical action of the soil, and under strong sunlight the valuable process of nitrification is arrested. Possibly this may account for the infertility of long-abandoned coffee lands. It is therefore clearly

to the planter's interest not to bare the land entirely, but rather by careful selection to retain and make use of the forest trees already in possession. The finest shade, with the least exhaustion to the soil, is provided by deep-rooted umbrageous trees growing at 60, 80, and even 100 feet apart. Specimens of this description are sufficiently abundant in the virgin forest, and planters should always utilize them when making new clearings. It is under shade of this sort, with perhaps a little secondary planting here and there to fill up gaps, where one sees the finest coffee.

It is true that most saplings will soon establish their leading roots in the subsoil at depths far beyond the reach of the coffee bush, and as they increase in size this tendency to draw nourishment from the substratum increases until in many fully developed forest trees surface rooting is reduced to a minimum. All other conditions being favorable, it is deep-rooting trees of this class that should be preferred to shade coffee. The only exceptions would be in the case of fig trees, which (probably from their quasi-parasitic nature) do not appear to exhaust the soil to the same extent as other shaders, and leguminous trees, which assist nitrification in the surface soil.

Of course it is hardly to be supposed that the shade of leguminous trees is more "nitrifying" than the shadows cast by any other objects; but that the positive contribution of the leguminous trees to the fertility of the soil was not appreciated, is evidenced by the fact that the author's investigations resulted in the approval of the current method of mixed shade, over twenty trees being listed as in use. But as eight of these, including those most commonly used, are leguminous it is evident that the facts will bear a different interpretation, and that in the East Indies theory and practice are still a stage behind Venezuela and Colombia, where only leguminous trees are recommended for shade.

But whatever be the cultural possibilities of "nitrification" either by genuine soil organisms or by those symbiotic with leguminous plants, it seems probable that such agencies are to be considered merely as the most effective means of maintaining the fertility of the soil, coffee not being necessarily dependent on organic products or remains. Like many other plants, coffee makes extremely vigorous growth on soil from which the humus has been burned away by the method of clearing by fire usual in heavily forested tropical countries. The fertility of such soil for the first two or three years is commonly ascribed to the ashes, but it seems not unlikely that larger quantities of plant foods may have been liberated and rendered soluble in the soil calcined by the fierce heat developed in the combustion of the large masses of dry vegetation. The belief is general among the natives of West Africa that the success of the subsequent agricultural operations depends upon the size and thoroughness of the conflagration. Thus they open new farms each year in the dense forest, and submit to the hard labor of cutting the large timber rather than avail themselves of areas which could be much more easily cleared, and state, as an explanation of this preference, that the former will "burn better."

Crops planted immediately after the burning shoot up at once into vigorous growth, presumably long before soil organisms would have

time to become reestablished and exert an appreciable effect. The fertility, however, is not sustained, and generally decreases measurably after the first season, probably more because the soluble materials are washed rapidly away than because of exhaustion by the year's crops. How much virtue may lie in the baking of the earth, and how far such a fact could be utilized with coffee or other cultures remains to be determined, but in opening new plantations in mountainous regions the desirability of clearing the lower slopes first is worthy of consideration, since to the fertility derivable from the drainage of forest areas would be added that from the tracts subsequently cleared and burned.

SHADE AND FUNGOUS DISEASES.

While by no means confined to shaded plantations, it is now admitted that the leaf-rust of coffee, due to a parasitic fungus (*Hemileia vastatrix*), is especially virulent on shaded trees, and it has even been claimed that the comparative immunity of Liberian coffee is due to the fact that it has been grown without shade. Investigation of the disease has also shown that the spores germinate only in water, and that they are killed by exposure to sunshine. The desirability of more open planting in situations affording a good circulation of air has been realized in Java, and this is also in accordance with the general proposition that vigorous, healthy vegetation is less liable to parasitic and other diseases than that improperly nourished or otherwise debilitated. It happens, however, that, with reference to the present disease, what might appear to be exactly the contrary method has also been found of use. In the Coorg coffee district, on the west side of the peninsula of southern India, it has been sought to avoid the ravages of the Hemileia by planting the coffee in forests which have been thinned by the removal of the trees supposed to exert a harmful competition with the coffee. A leguminous species, *Dalbergia latifolia*, is the favorite of those retained, though two species of Artocarpus and several others, leguminous and nonleguminous, are also considered desirable. The coffee is thus grown under permanent shade from the first, but the theory of protection from the disease is quite different from that followed in Java. The forest is intended to serve as a wind-break, which prevents the spores of the fungus being carried to the coffee by currents of air, and thus hinders the distribution of the fungus. A recent letter from Mr. Oliver Moll, of Ubero, Oaxaca, Mexico, states that coffee is also planted in that vicinity in natural forest, which has been "thinned out sufficiently to permit enough sun on the young plants." The experiment of planting rubber alternately with the coffee is also being tried, and the forest conditions may be chosen on that account, though the results of the arrangement are not yet apparent.

In Venezuela and Colombia heavily shaded plantations, or those

shaded in elevated localities where the moisture is already ample and the temperature sufficiently low, have been found to be especially susceptible to *mancha de hierro* and other diseases due to parasitic fungi, and even a shade tree (*Inga laurina*) has been similarly attacked. Thus, from the present as from other standpoints, it may be said that the use of shade is warranted only under conditions and to the extent of contributing to normal vigor and healthful growth of the coffee; no general principle can be laid down.

THE EFFECTS OF UNWONTED EXPOSURE.

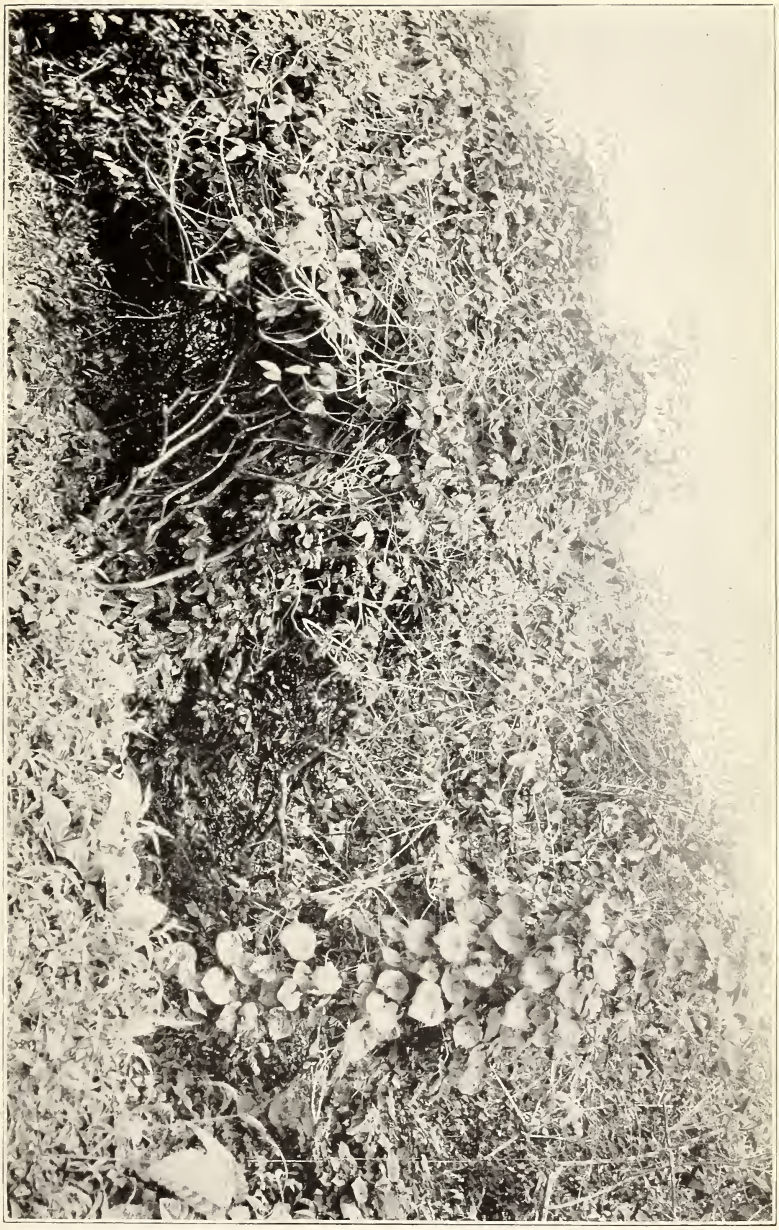
In addition to reasons drawn from the preceding facts regarding the local, incidental, and indirect advantages of the use of shade, other arguments require notice. These may be grouped under the present heading because they have reference to the general fact that coffee plants nurtured in the shade are at a disadvantage when the protection is removed, though it appears, even in such instances, that the coffee suffers because of an exaggeration of its normal susceptibility to drought rather than from injuries due directly to increased sunlight.

In countries where, as in Porto Rico, the shade method is carried to an unreasonable and suicidal extreme, it is obvious that the general impression in favor of shade is not based on any experimental realization of the possibilities of open or at least of more open culture. Custom and tradition influence the majority of the planters, but those who are sufficiently thoughtful and intelligent to seek a reason for a cultural method not in use in some of the principal coffee-growing countries, are often misled through failure to realize that the effects of sudden and unwonted exposure in plantations which have grown up under heavy shade furnish no criterion applicable to plantations subjected from the first to rational methods of culture.

THE USE OF VOLUNTEER SEEDLINGS.

There can be little doubt that the overshading practiced in Porto Rico, and probably also in some districts of Central and South America is partly the result of the habit of transplanting chance-sown seedlings instead of raising new plants in special seed beds or nurseries. In countries where rain is prevalent during the ripening season, or where heavy shading is in vogue, the berries which are accidentally dropped by the pickers or which fall from overripeness, germinate readily and produce quantities of young plants. The use of these precludes, of course, anything like the selection of good seed, and often tends in the contrary direction, since the berries which are unripe at the time of the harvest or those sparingly produced by unhealthy or unfruitful trees are much more likely to have the opportunity of germinating than good and seasonably-ripened seeds. The indefinite repetition of this process of reversed selection can bring about only a deterioration

PORTO RICAN COFFEE PLANTATION, OVERSHADED BEFORE THE HURRICANE, NOW CHOKED BY GRASS AND DENUDED BY THE LEAF-MINER.



NEGLECTED COFFEE IN PORTO RICO, GROWN WITHOUT SHADE, BUT VIGOROUS AND LEAFY.

in vigor, fruitfulness, and uniformity of ripening, a fact which makes plain the necessity of the introduction of new stock in all countries where, as in Porto Rico, this objectionable method of propagation has been followed.

Returning to the question of the bearing of this evil practice upon the apparent desirability of shade, it may readily be understood that the more heavily the old plantations are shaded the more spindling will be the growth of the seedlings, and the greater the necessity of continuing the shade after transplanting. One meets in Porto Rico, for instance, densely crowded fields of bananas, the planting of which for any other purpose than their own fruits would never be suspected if special attention were not directed to the spindling, whip-like coffee seedlings 2 or 3 feet high, but with few branches and scarcely any leaves. Properly grown, stocky seedlings would, of course be ruined by this treatment, but on the other hand it would be quite impracticable to use for open culture the plants already deformed and debilitated by unfavorable initial conditions of growth. Although transplanting is usually undertaken only in the rainy season, it often happens that vigorous and stocky seedlings are injured if unexpected fair weather occurs shortly after. In some countries the use of artificial covering or of quick-growing plants like castor oil or indian corn is considered necessary to avoid this temporary danger. But the taller and more spindling the seedling the greater harm from exposure, and the greater necessity for adequate protection after transplanting, until, as in Porto Rico, the custom of setting out bananas in advance of the coffee has come into regular use.

OVERSHADING.

Whatever be the possibilities of the rational use of leguminous trees for maintaining the fertility of the soil of coffee plantations, there can be no doubt that the use of shade trees can be carried to hurtful excess. Too much shade, even with leguminous trees, may easily be worse than none. The coffee culture of Porto Rico furnishes a good example of overshading, though others can in all probability be found in Venezuela, Colombia, and Central America. A newspaper writer who visited Porto Rico during the recent war records the following interesting impression of the coffee industry of that island:

> A Porto Rican coffee plantation does not present any very marked difference in appearance from the rest of the country. The bush or shrub, growing to some 8 or 10 feet in height, is set out on no apparent system, and grows mixed with bananas and forest timber. Until one knows what it is, one might easily pass a whole plantation and believe that he had seen nothing but a somewhat scattered forest with its usual undergrowth of scrub and thicket.

The description is certainly of very general applicability (see Pls. II, IV, and VI), and though occasional plantations showing somewhat

better methods were seen, particularly in the neighborhood of Mayaguez, coffee is almost universally grown as a half-wild culture, either under heavy shade or so badly crowded with other vegetation that properly developed trees are seldom to be found. It can scarcely be charged that the Porto Rican method of coffee culture is entirely the result of carelessness and lack of knowledge, since it had an apparent advantage in the fact that it formerly produced returns with a minimum expenditure for labor, and made no other demand on the planter's purse. The deeper the shade the less the growth of grass, weeds, or underbrush, and the less necessity even of cleaning with a cutlass; but this discouragement of growth affects the coffee as well as other vegetation, so that few plantations yield more than a third of what would be an ordinary crop under open culture, although an attempt has been made to counteract by close planting the evil effects of too much shade. Trees are set without regularity, often within a few inches of each other. Sometimes two seedlings are put in the same hole, but the weaker is not cut out, and both are left to crowd each other and their neighbors four or five feet away. The tendencies of other countries practicing open culture have generally been in the direction of wider and wider planting, from 4 to 6 meters being the prevailing distance in Brazil.

When it is remembered that the chemical activity and resulting productiveness of a plant is conditioned directly on the amount of its leaf surface, it will be understood that the shade habit of growth is incompatible with good agriculture or a maximum yield. Under heavy shade the tendency is always in the direction of the formation of a single layer, so to speak, of leaves, below which little or nothing grows. The limbs and smaller branches of the tree, instead of being lined with rows of large and healthy leaves, are bare nearly to the tips, and the berries are borne singly or in small clusters instead of crowded in bunches of a dozen or more (Pl. VIII).

REMOVAL OF SHADE

It is a well-known fact that, even with plants which grow normally exposed to full sunlight, seedlings, sprouts, or cuttings which have been stored or shipped in the dark are often seriously injured or killed outright by being placed in an open situation without having an opportunity to become gradually accustomed to the light. Thus it is entirely possible that coffee trees accustomed to dense shade like that customary in Porto Rico would be disastrously affected by sudden exposure like that afforded by the hurricane of August 8, 1899, which in many plantations left few of the larger shade trees standing. As generally happens when a forest is cut away, the exposed undergrowth ceases to thrive, and even large trees left standing as individuals often die, although belonging to species which grow well when

planted in the open. Although the leaves might be directly affected, another possible source of injury lies in the delicate texture of the bark, which has been protected from the sun which now scalds, and from the wind which now strains it. Many instances were observed in Porto Rico where the removal of the shade had no evil effects upon the coffee in cases where the leaves were thick enough to shade the branches and trunks. But while this shows that exposure was not directly injurious, which was already apparent from the vigorous condition of many trees which had grown up in open places (Pl. X), it leaves the intervening causes still in doubt, since, when there were enough leaves to shade the trees, the ground was also shaded. A sufficient cause of the debility of trees which have had their accustomed shade removed is perhaps to be found in the fact that in every case where the symptoms were severe the ground had already been covered with a dense growth of grass, the evil effects of which are well known in countries where open culture is customary.

Thus does overshading produce and continually strengthen the arguments for its own continuance, the effects of unwonted exposure being interpreted as indications of the normal requirements of the coffee tree. While it is undoubtedly true that the destruction of the shade trees by the hurricane had a disastrous effect on many plantations, it is equally true that there are many others which would receive great benefit by the gradual withdrawal of a large part of the shade which now discourages growth and productiveness.

It is improbable that the shade-grown coffee could be made to succeed under open culture, but if immediately after the hurricane the old spindling trees had been sawed off near the ground, the sprouts which would have arisen from the stumps could have been brought into bearing under open or a reasonable shade culture much earlier than newly transplanted seedlings, and thus made to yield an advantage of several years of productiveness without the initial expense and delay incident to new plantations.

In connection with this advice there should, however, be mentioned the fact, brought forward by Dr. Delgado, that in Venezuela the roots of coffee trees grown under shade are almost entirely superficial, the taproot and its branches being relatively atrophied, perhaps because it has been unnecessary for the tree to seek either moisture or plant food deep in the soil, This renders plantations started under shade culture specially liable to injury from drought, and makes it easier to understand why the disastrous effects of sudden exposure in heavily shaded plantations is no criterion for judging the possibilities of more open culture. Whether such a change is feasible depends very largely upon the local conditions of climate and soil, and upon the methods used in making the transformation. It has been reported that in the State of Colima, Mexico, the shade trees are cut down after the coffee has

attained to full growth, but according to Dr. Edward Palmer this is accomplished by a process of gradual thinning.

SHADE AND THE COFFEE LEAF-MINER.

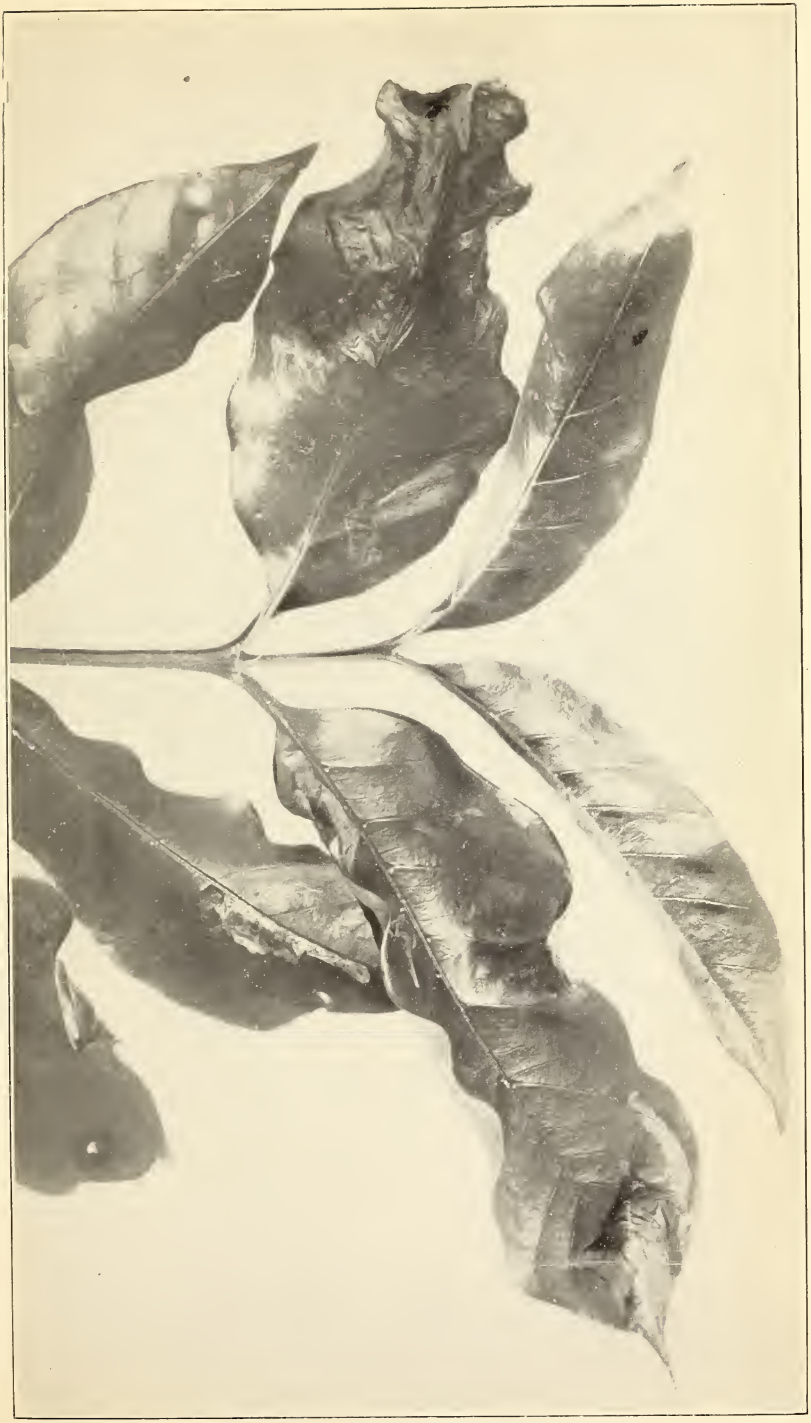
The coffee leaf-miner, *Cemiostoma coffeellum*, the larva of a small lepidopterous insect related to the clothes-moth, has appeared to furnish an argument for the direct benefit of shade, but observations recently made in Porto Rico seem to indicate that this question may be properly discussed among the effects of unwonted exposure.

The leaf-miner burrows in the middle layer or soft tissue of the leaf, leaving the upper and lower surfaces uninjured, except that the cells die and form large, irregular brown spots, having exactly the appearance of vegetation scorched and shriveled by heat (Pl. XI). In Porto Rico, and doubtless in other countries, these brown spots are commonly interpreted as the results of exposure to the sun, and there can be but little doubt that the ravages of this insect pest have had an important influence in strengthening the opinions of those who advocate heavy shading. Probably they are at least partially responsible for many unwarranted statements by writers making pretensions to scientific accuracy, to the general effect that coffee "can not endure the intense direct radiation of the tropical sun." The insect is very small and would never be seen unless carefully searched for, while the scorched spot is, to the general public, indisputable evidence that the coffee has been injured by the sunlight.

The ravages of the coffee leaf-miner have been investigated in Brazil[1] and elsewhere, and the opinion is held that the damage is greatest at low elevations and in trees exposed to the sun.[2] In Porto Rico the latter idea seemed to apply well to the recently exposed trees, but those which had never been shaded were often quite free from injury, and were nowhere noticed to be seriously affected. It is true that trees in very heavy shade do not suffer from the leaf-miner, but in regions where the insect is abundant the shaded trees are not entirely immune, although the burrows seem to remain smaller than in debili-

[1] Mann's report of his investigations of the coffee moth (American Naturalist, 1872, 6: 332–341; 596–607) in Brazil is almost exclusively entomological, and, beyond the statement that the larvæ are said to attack the new leaves in early spring, nothing is recorded regarding predisposing causes. It was estimated that the injury amounted to about one-fifth of the coffee crop of Brazil, but no remedy was found other than that of picking off and burning the affected leaves before the escape of the larvæ, and although this process would be expensive, it was estimated that the gain in yield would more than compensate. The insect probably came originally from the East Indies, but was introduced into Brazil from the Antilles. Every precaution should be taken to keep it from any coffee regions where it has not yet appeared.

[2] The depredations of this insect are now known to be avoidable by planting Liberian coffee, which is much more hardy than the Arabian at low elevations, and also much more resistant to fungous and insect diseases.



COFFEE. LEAVES INJURED BY LEAF-MINER; FROM PLANTATION SHOWN IN PLATE IX.

[Natural size.]

tated trees. On otherwise healthy trees the leaves attacked by the miner do not appear to be injured except at the spot where the tissue has been eaten away, but on those already weakened by adverse circumstances the leaves fall rapidly, leaving the branches quite bare except for a few young leaves at the tips, and these seemed to fall before they reached full size.

At Quebrada Arenas, between Caguas and Cayey, the writer found a coffee farm occupying the sides of a ravine running east and west. Large trees which must have furnished heavy shade had fallen, doubtless at the time of the hurricane, leaving the coffee exposed. On the north side of the ravine the trees had nearly all lost a large proportion of their leaves and most of those which remained were of a noticeably lighter yellowish color. With few exceptions they showed the work of the leaf-miner, and most of them were undersized or deformed, indicating that the insect had begun its attack before the leaves had been fully expanded. That the leaves fell solely on account of the ravages of the miner seems, however, improbable in view of the obvious debility of the trees from other causes; but it seems entirely probable that the insect was hastening the deterioration of this part of the plantation. A sufficient cause of the unhealthy condition of the trees existed, however, in the fact that the ground under the exposed trees was covered with a dense growth of grass, to say nothing of the possibility of the direct injury by the sun on the thin bark of the slender and fully exposed trunks and branches of the spindling trees.

On the south side of the ravine where most of the shade trees were still standing the coffee leaves had preserved a more healthy, dark-green color, and, while the leaf-miner was also frequent, it seemed to make less progress and many of the leaves were uninjured. While the contrast in this case was very marked and might on superficial inspection appear to have warranted the opinion that the difference in exposure determines the severity of the leaf-miner and the resulting unhealthfulness of the coffee, this view seems to be negatived by the fact that similarly ill-conditioned trees showed the lighter color and lost their leaves, though perhaps with less rapidity, in places where there were few, if any, leaf-miners, but where the ground was covered with grass or where drainage was obviously defective. These facts appear to warrant the conclusion that an unhealthful condition which gives the coffee leaves a yellowish color also invites the attacks of the coffee miner. This opinion seemed to be further justified by many instances where the removal of the shade trees had worked no appreciable damage when the foliage of the coffee was thick enough to protect the trunks and keep the grass from growing underneath. Special notice was also taken of trees which through some accident or neglect had been allowed to grow up in exposed places. Where the conditions

were at all favorable these were often unusually vigorous and healthy. It was also observed that the trees along the roadside like those shown in Plate X were much larger and more leafy than those farther back in the plantations.

The Philippines also furnish an example of bad effects from a removal of shade. A serious disease due to a longicorn beetle has ravaged the coffee plantations, and the insects are found to be especially numerous in plantations shaded by *Gliricidia maculata*, but during the season when the leaves are wanting and the coffee is exposed to the full sunlight. Although the report of Señor Sanchez indicates that the damage is due to the fact that the beetles prefer the sunlight, it seems by no means impossible that the change from dense shade to open sun may affect the trees in such a way as to invite the attacks of the insect. Coffee shaded by *Erythrina indica* and *E. ovalifolia* is said to suffer to a much smaller extent, though these trees normally permit more light to enter.

METHODS OF APPLYING SHADE.

The use of shade in coffee culture offers all the stages intermediate between leaving of belts of forest or scattering trees as protection against the wind and the provision of a succession of dense coverings of bananas and other vegetation described as overshading. In some localities of dry countries like Mexico shade or irrigation may be necessary to enable the coffee to withstand the long dry season. Where shade is thus indispensable the source of it may not appear to be a matter of serious importance, and in Mexico coffee is often planted under almost any trees already existing in gardens or cultivated grounds. Dr. Edward Palmer reports having seen at Tampico in 1880 a considerable area of coffee shaded, not by trees at all, but by arbors latticed with small sticks and brush. According to the same traveler, shade and irrigation are used together in the State of Colima, and even at Tepic, at the highest elevation where coffee is grown in Mexico, shade is still employed. There seems to be no special discrimination in favor of any single species, though the *guaymochil* (*Pithecolobium dulce*) is used as often as any. This is a large leguminous tree commonly cultivated in Mexico for its edible fruit.

In southern Mexico (Oaxaca and Chiapas), as well as in Central America, there are many coffee-growing districts where shade is not used, being considered quite unnecessary from the standpoint of normal requirements of heat or moisture. This region also includes some of the finest coffee soils in the world, loose volcanic débris, the disintegration of which is believed to set free phosphoric acid and other plant foods in quantities sufficient to maintain for decades the vigorous growth and productiveness of the coffee. There are numerous accounts of plantations averaging 3 pounds and upward per tree

entirely without shade. Patriarchal coffee trees are reported which remain fruitful after nearly a century of production; also giant trees which are asserted to have borne 12, 15, 20, and even 40 pounds of coffee in one season. It has also been noted that these exceptional individuals generally stand quite exposed, out of reach of the shadow or the roots of other trees of any kind. The possibilities of these unusual natural conditions do not, however, affect the question of the desirability of shade in less favorable surroundings. Maximum results are possible without shade trees, but this by no means detracts from the utility of the latter when needed.

To what extent the coffee culture of Central America has been influenced by that of Brazil and the East Indies is not known. It is a curious fact, at least, that in Central America, where much coffee is grown without shade, cacao is planted with shade, while in Colombia the open culture of cacao is in vogue, though coffee is regularly shaded. In Venezuela shade seems to be habitually used for both coffee and cacao. This variety of method is supported by equally diverse opinions on the part of the planters of the different localities, a fact which well demonstrates the lack of definite experimental knowledge or establishd principles of general application. The coffee culture of Venezuela and Colombia may be said to have taken a step in advance of that of other countries in that there is definite allegiance to the proposition that only leguminous trees should be planted for shade. Furthermore, the idea has also dawned that the leguminous shade trees influence the relative fertility of the soil, though this notion, for the lack of a satisfactory explanation, has received thus far no wide credence or sympathy.[1]

[1]Shortly before the completion of this paper two references have been found which might appear to vitiate the claim that the question of coffee shade is universally misapprehended through failure to recognize the fact that the good results are largely ascribable to the fertility rather than to the shade supplied by the trees. In reality, however, these statements strengthen the above position, since they demonstrate that even though the possibility of such effect came before the mind the strength of traditional opinion was such that it received but the most casual notice. Thus in the Journal für Landwirtschaft, 1897, **45**: 18, Dr. M. Fesca, of Berlin, offers the following opinions:

> The coffee trees grow wild only in the semidarkness of forests; they can not endure the intense direct radiation of the tropical sun. * * * For purposes of shade individual trees are accordingly left when the original forest is cleared away, and for wind-breaks narrow strips of forest are also left on the borders of the plantation. Commonly special shade trees are also planted, and for this purpose leguminous trees are particularly adapted, since their feathery leaves furnish a light shade and permit an adequate circulation of the air, and, moreover, they bring about the fixation of the free nitrogen of the atmosphere through the production of bacterial tubercles on their roots, and thus directly enrich the soil with nitrogen.

With reference to cacao a similar possibility had been noted in a similarly casual manner three years before by Mr. J. H. Hart, superintendent of the Royal Botanical Gardens of Trinidad. In reporting the introduction into Trinidad of a species of *Lonchocarpus* used in Nicaragua for shading cacao, he says:

> The tree belongs to the order Leguminosae, to which the "Bois Immortel" (*Erythrina umbrosa*) also belongs. The common name for the "Immortel" in Trinidad

Apparently the most intelligent and authoritative statement regarding coffee culture in the United States of Colombia is that of Mr. Robert Thompson, published in the reports of the British Foreign Office for 1895. In that country coffee culture has been greatly extended within the last decade, even in districts from 600 to 800 miles from the coast, necessitating heavy transportation expenses before the crop can reach export markets. But notwithstanding an outlay of this kind, often amounting to 2 or 3 cents a pound, production was considered extremely profitable until the general fall in prices occurred. Land at $5 to $8 per acre is cheaper than in Porto Rico, but labor is nearly as expensive, and would perhaps be more costly were it not for the depreciation of the currency. Mr. Thompson was also familiar with the coffee industry of Jamaica, and his statement contains comparative figures likely to be of interest in Porto Rico, in addition to an account of a very interesting series of leguminous trees planted with coffee at different elevations:

The number of coffee trees planted per hectare (2½ acres) in Colombia averages about 1,500. The general average yield per tree per annum on well-kept plantations is 1½ pounds, or 2,250 pounds per hectare (900 pounds per acre). On many other plantations the average yearly crop does not exceed 1 pound per tree (600 pounds per acre). Thus the number of trees planted per acre in this country strikingly contrasts with the number planted in British colonies, where twice as many are planted per acre; notwithstanding heavier crops are secured in Colombia. In the palmy days of coffee cultivation in Ceylon the average production was 5 cwt. per acre.

One of the chief elements of success appertaining to this cultivation in Colombia must be assigned to the systematic interplanting of shade trees with the coffee. At altitudes ranging from 3,000 to 5,000 feet more densely foliaged shade trees are employed than is the case on plantations between 5,000 and 6,000 feet, where a slender shade is afforded by a species of Cassia. The shade trees utilized on plantations situated between 3,000 and 5,000 feet are a species of Erythrina and another leguminous tree, a species of Inga, which latter is becoming very generally adopted by planters. I would strongly recommend this Inga for adoption by British colonial coffee planters, as it is most admirably adapted for the purpose. It grows rapidly, and the large compound leaves fall abundantly at the season in which the plantation requires the least degree of shade, whilst the abundance of fallen leaves from this tree check in a very marked manner the irrepressible growth of weeds. Moreover, the general result of the beneficial influence of this congenial shade reduces to a minimum all cultural expenses; indeed, it may be safely computed that the good offices of this tree curtail the cost of actual cultivation to the extent of some 50 per cent as compared with coffee devoid of shade. It is a remarkable fact that British colonial coffee planters have in the main ignored the application of shade to the coffee tree. Without shade the tree certainly flourishes, but its full exposure to the sun, at any rate as the sun is

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and on the mainland is "Madre de Cacao," and the belief exists that it furnishes moisture to the roots of the cacao.

It has been determined by scientists that all trees belonging to this order have the power of supplying nitrogen to the soil or making it available for other crops, and it is quite possible that in this capacity the tree acts as a real Madre de Cacao.

I do not wish, however, to enter into a discussion as to the value of either the "Madera" or the "Bois Immortel" any further than to state that I believe the former is well worthy of trial by our cacao planters, and as it will be distributed free of cost I hope to procure a good record of the trials.

wont to shine here, is detrimental in the long run to its most congenial state of productiveness. However, near the upper limit of this cultivation, namely, from 5,000 to 6,000 feet, shade is not to be recommended.

As I am well acquainted with the productive resources of Jamaica, England's tropical American colony par excellence for coffee, it may not be amiss to give the following particulars touching coffee cultivation in that colony in comparison with the cultivation in Colombia: The total coffee production in Jamaica, about 10,000,000 pounds, represents what is cultivated on an area of 11,000 acres in Colombia, but in Jamaica 22,476 acres are under cultivation. Thus, were the Jamaica plantations yielding to the same extent as those of Colombia, the value of the output would be increased from £336,840 to double that amount yearly. Moreover, the general average quality of the Colombian article is superior to that of Jamaica, though that island contains several plantations at high altitudes the produce of which is the finest in the world. There can be no doubt that the coffee industry of Jamaica would be greatly benefited by the adoption of the more advanced practical methods pursued in Colombia.

In a recent number of the Kew Bulletin reference is made to the slow development of the coffee enterprise in Jamaica and other British colonies. What that paper suggests in order to encourage the enterprise in Jamaica is the opening up of the roads to facilitate transport, but Jamaica is already well provided with splendid roads; besides, the most eligible sites for plantations are nowhere situated more than some 20 miles from the sea, and seaports surround the island. I have already described how remarkably different are the conditions of transport in Colombia, and how this, the most important commercial plant of tropical America, can be turned to better account in the colonies.

Understanding that the benefits ascribed to shade may prove to be largely due to the fertility imparted by the leguminous trees, it is possible to reconcile these interesting statements with others of a contradictory import. That there are, however, rational limits to the use of even leguminous shade trees is indicated by the fact that although species of Erythrina and Inga have been introduced into Porto Rico the average yield is as low or lower than that of Jamaica. Supposing that the natural conditions are equally favorable with those of Colombia, overshading and neglect are apparently responsible in Porto Rico for the loss of more than half of the possible crop. Although Mr. Thompson does not state the amount of shade used, it is evident that great moderation exists in comparison with the general custom in Porto Rico, notwithstanding the probability that the continental conditions and greater seasonal extremes of heat and dryness justify the use of shade for its own sake to a far greater degree than in Porto Rico. It is quite possible that shade would be desirable at some places in Jamaica, although the fact that the island produces a very high grade of coffee without shade is also significant.

In the most extensive coffee region of the world, Brazil, shade is not in use, a fact which has doubtless had great influence upon general opinion and has stood in the way of an appreciation of the problems of this and related branches of tropical agriculture. The Brazilian practice of excluding shade trees has been justified by many experts acquainted only with the coffee industry of that country and has also

been favored even by some who approved the use of shade in Java or elsewhere, because the Brazilian coffee region lies near the limit of tropical conditions and suffers from low temperatures in the winter season. This might render shade at that season undesirable, but such a difficulty could be avoided by the use of deciduous trees, so that other reasons will be needed if the failure to plant leguminous trees is to be rationally explained in the districts where coffee is known to suffer from heat and drought, to say nothing of the possibilities of soil improvement. The climatic or other conditions may forbid the use of the shade trees popular in other countries, but there is every probability that species able to meet the local requirements could be secured.

As noted elsewhere, the earlier writers on the coffee culture of the East Indies are silent upon the subject of shade, and in the extensive industry formerly existing in Ceylon open culture was the rule. Gradually, however, and more especially in Java, the good effects of proximity to forest areas or to individual leguminous trees became appreciated by planters. The benefit was ascribed, however, to shelter from winds, and the leaving of belts of the natural forest and the planting of hedges or wind-breaks came into favor. Latterly the opinion has gained ground that a slight open shade, such as that cast by an occasional tree of the open habit and finely divided foliage of some of the leguminous species, was extremely beneficial to the coffee. Thus a reason was found for the planting of leguminous shade trees, the advantage of which has gained increasingly wide appreciation and is now general in the British as well as in the Dutch colonies. The failure to realize what is here taken to be the true function and chief value of leguminous trees is, however, shown in the fact that even in Java frequent attempts are still made with nonleguminous species. On a recent visit to Java, Mr. David G. Fairchild, agricultural explorer of this Department, saw plantations in the vicinity of Buitenzorg shaded with the kapok or silk-cotton tree (*Ceiba pentandra*), which is mentioned as eligible for this purpose in a paper published during the present year.[1] Planters who use this species will probably conclude that their land is not suitable for coffee and console themselves with the cotton crop. The silk-cotton tree would be of little use where shade is really needed, and in any situation may be expected to discourage the growth of anything else within reach of its enormous superficial roots.

But by approaching the problem from a different standpoint the planters of Java have avoided the errors of overcrowding and overshading which have often brought the shade method into disrepute in America. But notwithstanding more intelligent observations and more scientific study of other phases of coffee culture, there has been no

[1] Beihefte zum Tropenpflanzer 1: 68.

realization of the importance of an experimental determination of the cultural functions and relative utility of the numerous species of shade trees. The introduction to the East Indies of the more valuable of the American leguminous shade trees has not been attempted, to say nothing of a general canvass of the tropical arboreal flora of this family, a botanical undertaking now most desirable if the culture of coffee and other agricultural crops of the Tropics is to receive the assistance which this branch of science might be able to furnish. No mere catalogues of species or systematic studies in the ordinary sense of the words will, however, suffice for this purpose. Trees which give promise of eligibility should be thoroughly investigated in their native countries with reference to soils, altitudes, and climatic conditions, size, habits, and rates of growth, immunity from disease, quality and value of wood, fruits or other products, facility of propagation, and all other facts bearing upon their availability in agriculture. Such preliminary knowledge will be of great value in avoiding expense and delay in the experiments necessary in selecting the best species for different regions and climates. Many tropical leguminous trees are deciduous; in some countries species deciduous in the dry season will probably be best, in others those which lose their leaves in the rains. One species, *Adenanthera pavonina*, drops its leaves both at the beginning and at the end of the rainy season. Many close their leaflets at night, and thus permit more thorough ventilation. The quick-growing species are short lived; there is, however, no reason why, as with cacao, two or three species of shade trees might not be planted with coffee, some to be cut away when they had reached the limit of usefulness, the more desirable and longer-lived species to remain as permanent shade.

It is not desirable at this point to attempt a discussion of the uses and products of leguminous trees which might be used for shade, although this is a subject likely to prove of much importance, since trees yielding edible or otherwise useful fruits may occupy no more space and require no more attention than those yielding no direct returns. The appended list of species which have been planted with coffee either as shade trees or as catch crops includes the available information on the above point. This information is of necessity fragmentary, but it may prove of use for the practical planter as well as for those who may be interested in the increase of knowledge likely to have so important a bearing upon the development of tropical agriculture.

CONCLUSIONS.

A canvass of the subject of shade in coffee culture shows that there is no basis in reason or in observed fact for the belief that shade is a general necessity for the coffee plant, even when grown at low eleva-

tions. On the contrary, it is extremely probable that the beneficial effects resulting from shade are quite apart from the shadow cast upon the coffee tree.

The beneficial effects connected with shade arise from the protection afforded against drought, erosion, and winds. The planting of shade trees for these purposes is accordingly determined by local conditions of climate and soil, and furnishes no reason for the general planting of shade trees.

In regions not affected by injurious climatic extremes the planting of shade trees is justified from the cultural standpoint only by the increased fertility imparted to the soil by means of the nitrogen-fixing root tubercles of leguminous species. This view has not been made the subject of experimental demonstration, but it seems to accord with all the facts thus far ascertained.

The benefits of leguminous fertilizing are quite apart from the shading of the coffee, and under suitable cultural conditions are also to be secured from shrubs and herbs belonging to the same natural family.

The relative utility and availability of the various shade trees and soiling crops is a subject of vast importance in coffee culture and in other agricultural industries of the Tropics.

The combinations of such cultures as coffee and cacao with leguminous trees and plants of maximum cultural and commercial value afford many complex, scientific, and practical problems bearing upon the rise of mixed farming in the Tropics, and are thus worthy of serious experimental attention.

LIST OF COFFEE SHADE TREES.

Some of the cacao and coffee shade trees of South America have been introduced into Trinidad, Porto Rico, and other West Indian islands, and one of the favorite species in Java came from the Moluccas, but there has been no serious attempt at bringing together even the more prominent American and Asiatic species, much less any systematic effort at investigating the possibilities of the multitudes of arboreous legumes to be found throughout the Tropics. If experiments shall demonstrate that the roots and not the leaves are the parts of the tree which are of primary importance, the selection of leguminous trees for agricultural uses must be approached from a new standpoint, and the results it is impossible to foresee. But in addition to such considerations the further possibility of using for shade leguminous trees which furnish valuable wood, fruits, gums, or other products must not be overlooked, since additional returns from such a source would be in the nature of clear profits to the coffee planter.

As a preliminary to the study of shade trees available for use with coffee and other similar cultures, a collation of the species thus far recorded as having been used for this purpose seems desirable, and a

beginning is accordingly made with the present list. Although the chief interest will undoubtedly center upon the Leguminosae, species of other orders are also included for the sake of historical interest and completeness, and also because it is by no means impossible that other types of vegetation may have a practical bearing upon the subject, since members of several families outside the Leguminosae are now known to profit by symbiotic relations with lower organisms, either fungi or bacteria.

In the absence of comparative experiments with even the better-known shade trees, it is impossible at this time to determine which species are really to be preferred, if indeed species still untried are not to be found more desirable than those now in use. Moreover, if the leguminous trees follow the analogy of the herbaceous fodder and soiling crops, they will be found to have definite adaptations to soil and climate, so that in a perfected agriculture not one but many trees will need to be considered. The best that appears to be possible at present is to bring together all that has been ascertained regarding shade trees and catch crops for coffee. The present compilation makes no claim to completeness, but may be of use as furnishing suggestions for planters and experimenters, and as a basis for further accumulations of knowledge. In canvassing the available literature attention has been directed especially to the practical details and methods of propagation, rapidity of growth, size, habit, value of wood and other products bearing upon the desirability of the different species.

For the guidance of those new to the subject it may be said that the favorite leguminous shade trees of the East Indies belong to the genera Albizzia and Erythrina, while in the American Tropics other species of Erythrina are used, though members of the genus Inga seem to be more popular. Of better promise, perhaps, than any of the above are the two species of Pithecolobium, the rain tree (Pl. XVI), guango, or saman of the West Indies, and the guaymochil or Manila tamarind of Mexico and the Philippines. In addition to the shade, fruit, timber, rubber, and other trees which have been considered for planting with coffee, herbaceous plants used for temporary shade and catch crops raised with coffee for soiling and fodder purposes have been included. Of course it would be possible to grow almost anything between the rows of young coffee trees, but some plants and cultures will be more useful or less injurious than others; and some, such as the banana, castor bean, indian corn, and pigeon pea have a regular place in the shade cultures of some coffee-growing countries. For regions where intensive culture is practicable and the use of shade unnecessary or undesirable, the most eligible of herbaceous soiling crops for coffee is, perhaps, the peanut, though the velvet bean, phasemy, beggar weed, and numerous other tropical leguminous plants should be made the subjects of early experiments.

For the sake of ready reference all the common names used for shade trees and crops grown with coffee in the various coffee regions have been introduced in the form of an alphabetical index.

Acacia albicans.

COMMON NAME.—Huizache (Mexico).

This species is said to be desirable because it produces a moderate shade, "with its small leaves and elevated top." Gomez objects to it, however, on the ground that it stains the leaves of the coffee tree, though the extent and nature of the injury are not explained.

Acacia angico. (See *Piptadenia colubrina.*)

Acacia julibrissin. (See *Albizzia julibrissin.*)

Acacia montana.

A tree native in the mountains of Java; recommended for coffee shade according to van Gorkam.

Acacia virginalis. (See *Piptadenia colubrina.*)

Acajou. (See *Anacardium occidentale.*)

Acajou amer (Guadeloupe). (See *Cedrela odorata.*)

Acajou de Saint Domingue (Guadeloupe). (See *Swietenia mahagoni*).

Acajou du pays (Guadeloupe). (See *Cedrela odorata.*)

Achiote (Spanish America). (See *Bixa orellana.*)

Acrocarpus fraxinifolius.

COMMON NAME.—Howlige (Coorg, India).

A leguminous forest tree left standing for shade in coffee plantations. (Cameron.)

Acupa (Colombia). (See *Hura crepitans.*)

Adenanthera pavonina.

According to Morren this species, though little known for coffee shade, has several very desirable qualities. The leaves are dropped twice in the year, at the beginning and at the end of the rainy season, but the new foliage appears in a few days. The leaves close at night like those of *Pithecolobium saman*, permitting access of air and dew; the roots are deep; the wood is hard, of beautiful color, and suitable for cabinet-work. It is not stated, however, that the present species excels in rapid growth. To insure prompt germination the seeds need to have the outer shell cut or filed through and to be soaked in water from six to twelve hours.

Agati grandiflora.

SYNONYM.—*Sesbania grandiflora.*

COMMON NAMES.—Baculo (Porto Rico); Gallito (Porto Rico).

This beautiful leguminous ornamental, though growing to a height of from 10 to 20 feet and becoming a small tree in size and form, is scarcely more than herbaceous in structure and lives but a year or two. In India the bark is used as an astringent medicine, while the leaves, flowers, and fruit are used as a vegetable or as an ingredient of curries. The leaves and shoots are also eaten by cattle. The bark also yields a fiber and the trunks serve for firewood and as a substitute for bamboo. From the

coffee-shade standpoint this species is of possible interest on account of its extremely rapid growth, which may render it useful for temporary shade. Belonging to the Leguminosae, it is probably preferable for this purpose to the banana, castor-bean, or indian corn.

Aguacate (Mexico). (See *Persea gratissima.*)

Alada (Coorg, India). (See *Ficus bengalensis.*)

Albizzia elata. (See *Albizzia procera.*)

Albizzia julibrissin.

SYNONYM.—*Acacia julibrissin.*

Acacia julibrissin is mentioned by Lock as though synonymous with *Albizzia moluccana.* In reality the two species are held by botanists to be quite distinct, though both are now referred to the genus Albizzia.

Albizzia lebbek.

COMMON NAMES.—Bois à friture; Bois noir (French West Indies); Siris (British India).

This species is in favor for coffee shade in the French islands of the East and West Indies. The wood is harder and more valuable than that of *A. moluccana* and *A. stipulata*, and the growth slower, though still quite rapid. A further disadvantage is in the large spreading superficial roots and in the fact that the tree ultimately attains great size. There is said, however, to be a smaller variety in Reunion and the West Indies, the leaves of which furnish an excellent fodder for cattle. That they are also a valuable nitrogenous manure is indicated by the following analysis credited by Professor Lecomte to M. Grandeau. The table is based on 1,000 kilograms of dry leaves:

	Kilograms.
Nitrogen	18.79
Phosphoric acid	1.40
Potash	3.18
Lime	37.00
Magnesia	2.50

From the trunk may be obtained a gum similar to gum arabic, and the wood is hard, close-grained, veined with pink and red, and darkening with age.

This small variety seems to be very different, in habit, at least, from the large form which is extensively planted for shade in Egypt and India. To judge from the specimen photographed in Porto Rico, it is much smaller, of a much more horizontal and spreading habit, and has a rough, almost shaggy, bark. Such differences seem to indicate specific rather than merely varietal distinctness.

Albizzia moluccana.

COMMON NAME.—Djeundjing laut (Java); Poon sikat (Banda); Sengoon laoot (Malay).

As the specific name indicates, this tree is a native of the Moluccas, but is now extensively planted in Java for coffee shade, and has also been introduced into British India for the same purpose. It is noted for its extremely rapid growth. In a single year it sometimes exceeds 15 feet, and in six years, according to Dr. Fesca, it may attain over 80 feet (25 meters). The open, thin shade of this species is currently believed to be peculiarly grateful to the coffee, and the fact that the leaflets are closed at night is looked upon as a further advantage in permitting a freer circulation of air, though the importance of these considerations in a country where the shade trees are planted as far apart as in Java is scarcely to be taken seriously.

In view of the fact that the roots of *Albizzia moluccana* are known to abound in large tubercles, it is much easier to believe that the benefits ascribed to the slight shade are in reality the result of the exceptional activity of the tubercle-forming bacteria as indicated by the very rapid growth of the tree.

The disadvantages of the present species are the worthlessness of the soft, brittle wood, together with the fact that the trees are badly damaged by wind and that the falling limbs often break down the coffee trees. The liability of such injuries is further increased by the fact that the soft wood of the tree is frequently riddled by the larvæ of a beetle.

According to Raoul, the seeds should be sown from six to nine months before the coffee is planted, in the places where the trees are to stand, at distances of from 13 to 15 meters in both directions. Fesca states, on the other hand, that it is customary to plant the shade trees in seed beds like those used for coffee, from which they are subsequently transferred to the plantation.

Albizzia odoratissima.

Common name.—Bilvara (Coorg, India).

A leguminous forest tree left standing for shade in coffee plantations. (Cameron.)

Albizzia procera.

Synonym.—*Albizzia elata.*

Common name.—Medeloa (Burma).

Recommended for shading Liberian coffee in the Tavoy district of Burma. The timber is of excellent quality.

Albizzia stipulata.

Common names.—Sengon (Java); Sau (Ceylon); Sengon yora (Malay).

A Java species similar to *A. moluccana*, but having tougher wood, which would be an important advantage. Another desirable feature is the deciduous character of the leaves, which have been thought on this account to make a large contribution to the fertility of the soil, though the real advantage, if any, probably lies in the further reduction of the shade. The chief objection to this species is that growth is, as far known, much slower than in *A. moluccana*. If, however, quick-growing varieties could be found or obtained by selection, it is thought that the present species would largely supplant the other, though Lecompte objects that the foliage is too dense and that the masses of fallen leaves interfere with the necessary aëration of the roots.

Alfalfa. (See *Medicago sativus.*)

Algarrobo. (See *Pithecolobium saman.*)

Alligator pear. (See *Persea gratissima.*)

Ama-sisa (Peru). (See *Erythrina poeppigiana.*)

Anacardium occidentale. Cashew.

Common names.—Acajou; Cajou (French Antilles).

This well-known tropical fruit tree is sometimes planted in hedges as a wind-break in the West Indies, according to Raoul.

Anal (Philippine Islands). (See *Erythrina ovalifolia.*)

Ananas sativus. Pineapple.

Common name.—Pina (Spanish).

Pineapples are said to be grown as a side crop with coffee in some parts of Mexico. The experience of the Florida pineapple growers has demonstrated that the par-

tial shade afforded by the latticework sheds erected for protection against frost is highly beneficial to the size and quality of the fruit and as a protection against sun scald. The improvement is in fact so important that, even far below the frost line, thousands of dollars are being spent on sheds for shade alone. It is by no means impossible that this requirement could be as successfully and much more cheaply met by means of leguminous shade trees. Moreover, it is not impossible that the culture of pineapples and coffee could be advantageously combined in Porto Rico, since the two crops would require their principal amount of attention at different seasons, the pineapple ripening before the coffee.

Ananassa sativa. (See *Ananas sativus.*)

Anatto. (See *Bixa orellana.*)

Anauca (Trinidad). (See *Erythrina umbrosa.*)

Andira inermis.

Common names.—Cabbage bark tree, or cabbage tree (Jamaica); Moca (Porto Rico).

A leguminous tree called "cabbage tree" or "cabbage bark tree," on account of its disagreeable odor, resembling that of the well-known vegetable. It is generally distributed in Porto Rico and is sometimes used for coffee shade, but is considered inferior to the two species of Inga on account of its slow growth. The bark, in the form of a powder or a decoction, is said in Jamaica to have value as a cathartic and vermifuge, but large doses are dangerous, causing vomiting, delirium, and even death. The wood is said to be hard and durable, having a specific gravity of 0.88, and is susceptible of a high polish. The pods are fleshy, about the size of a horse-chestnut, and contain but a single seed. The floors of the caves at Aguas Buenas, Porto Rico, are in places covered with the seeds of this species, which are carried in by the bats for the sake of the inclosing pulp. The seeds germinate in the caves, sending up slender white sprouts 2 or 3 feet high.

Andropogon sorghum. Sorghum.

Common names:—Kaffir corn; Milho (Portuguese); Millo (Spanish).

In Brazil a form of sorghum or millo maize is one of the crops planted on a small scale with young coffee.

Angico (Brazil). (See *Piptadenia colubrina.*)

Antiaris toxicaria. Upas tree.

This belongs to the family Moraceae. It is enumerated by Cameron among the forest trees left standing for shade in coffee plantations of the Coorg district of British India.

Apio (Venezuela). (See *Arracacia esculenta.*)

Arachis hypogaea. Peanut.

Common names:—Goober; Kratok (Java); Mani (Porto Rico); Pinaar; Roway (Java).

Mentioned by van Gorkam as a luxuriant species of Arachis which was recommended as a soiling crop for coffee plantations. It covers the ground with a dense mat of vegetation and enriches the soil by means of the nitrogen fixed in the root tubercles. It would seem that the peanut would make one of the best secondary crops for use with coffee. In addition to the green manure and the peanuts the vine would also have a value as forage. The vigorous dense growth of the plants would keep down weeds, retain moisture in the soil, and prevent its becoming overheated.

Successful experiments with the peanut as a green manure for coffee are mentioned by Lecomte, but not described in detail, though he recommends that the plants be cut and used as a mulch in their green state before fruiting. On large plantations favorably situated for the growth of peanuts it might, however, be found advisable to harvest the crop and extract the oil, instead of shipping the seeds in the pods. It would then be possible to utilize the shells and oil cake as fertilizer, to say nothing of the possibilities of finding advantageous local markets for the oil.

Arbol de pan (Porto Rico). (See *Artocarpus incisa*).

Arracacha. (See *Arracacia esculenta*).

Arracacia esculenta. ARRACACHA.

COMMON NAME.—Apio (Venezuela).

A plant related to the carrot and parsnip, extensively cultivated in the mountains of Venezuela and Colombia for its fleshy roots, which somewhat resemble those of the vegetables mentioned, but are said to be superior to either. The arracacha requires a very equable climate and a rather low temperature. It is sometimes planted between the rows of young coffee in Colombia (Saenz), and might be found of use as a cultivated catch-crop elsewhere at sufficient elevations.

Artocarpus hirsuta.

COMMON NAMES.—Wild jak; Kad halasu (Coorg, India).

Mentioned by Raoul and Cameron with *Dalbergia latifolia* as one of the deciduous native trees allowed to remain in the forest planting of coffee as practiced in the Coorg district of western Hindustan.

Artocarpus incisa. BREADFRUIT.

COMMON NAMES.—Arbol de pan, and Castaño (Porto Rico); Chataignier (French West Indies).

The breadfruit is said to be sparingly used for coffee shade in the French Antilles. Where the fruit is an object it might not be unwise to set parts of coffee plantations with breadfruit. Purely as a shade tree, however, it could scarcely rank high, being easily broken by the wind.

Artocarpus integrifolia. JACK-FRUIT.

COMMON NAMES.—Halasu (Coorg, India); Jak (British India).

An East Indian tree with entire leaves and a fruit much larger than the breadfruit. This is generally considered inferior to the breadfruit, but some writers represent it as preferred in some parts of India. Hull strongly recommends the jack-fruit as coffee shade:

> I am strongly in favor of the jack as the tree best suited for providing shade for fields of coffee. In the first place its presence, so far from being prejudicial, seems to be actually beneficial to the coffee plant; next, it is a subsoil feeder; then it produces a fruit much valued as food by the natives; its timber is also valuable, whether for cabinetmaking or building purposes; and, finally, it flourishes best precisely in those conditions where its shade is most required. Known to botanists as the *Artocarpus integrifolia*, the jack grows to a large size; it resembles and belongs to the same family as the breadfruit tree. The timber, when newly cut, is of a light-yellow color, possesses a beautiful grain, and is capable of a high polish, not greatly inferior to that of the mahogany or satinwood, both of which it also resembles to a certain extent in grain and color, after having been polished. The fruit is as large as a pumpkin, and weighs from 20 to 30 pounds, containing from 200 to 300 seeds, which, though somewhat unpleasant in smell when raw, are converted by being roasted or boiled into a wholesome and agreeable farinaceous food, always much appreciated by the coolies.
>
> The jack is said to bear transplanting badly, and it will therefore be necessary to deposit two or three of the seeds a couple of inches below the surface, wherever a tree is desired to grow. The most healthy of the plants can afterwards be selected.

The jack-fruit is also mentioned by Raoul as one of the forest trees preserved in the forest planting of coffee in the Coorg province of southern India. Here also it is favored because not supposed to exert harmful competition with the coffee. This suggests the possibility that there may be some undiscovered peculiarity in the ecology of this tree, which should be carefully investigated.

It is not known that the present species has been used for shade in America, but Saenz, writing on the coffee industry of Colombia, recommends it for planting at distances of 15 meters in localities having a temperature maximum of 21° C., or at 10 meters where the heat is greater.

The present may, however, prove to be one of the cases where bad advice has been industriously repeated. At least the following communication printed in the Tropical Agriculturist for 1882 indicates that the favorable opinion is not uniformly held:

> Meanwhile I submit, with all deference, my opinion of this tree, viz, that it does far more harm than good on a coffee estate. Has any one known coffee to bear heavily, or even fairly well, when under the influence of the artocarpaceous foliage? I have not. This I will say, that where jaks are encouraged coffee will fail.
>
> Years ago I remember being struck with the luxuriant *foliage* of some coffee (Arabian) which was growing beneath these trees, but *crop* there was none. The constantly falling leaves, too, choke up drains and litter the ground for a considerable space around.

Atti (Coorg, India). (See *Ficus glomerata.*)

Avilla (Porto Rico). (See *Hura crepitans.*)

Avocado pear. (See *Persea gratissima.*)

Baculo (Porto Rico). (See *Agati grandiflora.*)

Balicbalic (Philippine Islands.) (See *Pongamia glabra.*)

Banana. (See *Musa.*)

Bastard cedar (Jamaica). (See *Guazuma tomentosa.*)

Bean. (See *Phaseolus.*)

Beggar-weed. (See *Meibomia tortuosa.*)

Bili basuri (Coorg, India). (See *Ficus tsiela.*)

Bilvara. (See *Albizzia odoratissima.*)

Biti (Coorg, India). (See *Dalbergia latifolia.*)

Bixa orellana. ANATTO.

COMMON NAMES.—Achiote (Spanish America); Roucou (Carib).

This tree is planted in wind-breaks with *Morus indica* and a malvaceous tree called waroë, as described by Lecomte for Java. The achiote or anatto is a small tree of handsome appearance, with large, clean, cordate leaves and numerous pink flowers, followed by burr-like pods, at first green, but changing to deep red and becoming an inch in diameter. These contain the seeds, the arillus or fleshy covering of which is bright orange in color and constitutes the anatto of commerce. On drying, the arillus becomes dull orange. Quantities of dried seeds are to be found in the Porto Rican markets for domestic use in soups, and in coloring rice and other dishes yellow. In the English colonies the coloring matter is removed from the seeds while fresh, and then dried and compacted into cakes, in which form it is exported to the United States for manufacture into butter color. Supposedly for this purpose, 726,269 pounds were imported into the United States in 1899, valued at $34,827, but recent analyses of butter colors show that they consist very largely of aniline dyes.

Black plum (British India). (See *Eugenia jambolana.*)

Blackwood (British India). (See *Dalbergia latifolia.*)

Bocare (Trinidad). (See *Erythrina velutina.*)

Bois à friture. (See *Albizzia lebbek.*)

Bois Immortel. (See *Erythrina umbrosa*, also *Erythrina poeppigiana.*)

Bois noir (French West Indies). (See *Albizzia lebbek.*)

Breadfruit. (See *Artocarpus incisa.*)

Bread-nut. (See *Brosimum alicastrum.*)

Broad-leaf. (See *Terminalia latifolia.*)

Brosimum alicastrum. BREAD-NUT.

A West Indian tree recommended by Morris for sheltering plantations from the wind.

Bucare (Porto Rico, Venezuela). (See *Erythrina poeppigiana*, also *Erythrina umbrosa.*)

Butter-pear. (See *Persea gratissima.*)

Byrsonima spicata.

COMMON NAME.—Moricypre (French West Indies).

Reported by Raoul as used for coffee shade in the British West Indies, though English writers make little or no reference to it in this connection. It is said to have the advantage of open foliage, hardiness, and rapid growth; it also serves as a protection against the wind and does not attain an undesirably large size.

Cabbage bark tree (Jamaica). (See *Andira inermis.*)

Cabbage tree (Jamaica). (See *Andira inermis.*)

Cacao. (See *Theobroma cacao.*)

Caesalpinia arborea.

Has been recommended as a shade tree in Java, but is smaller and grows less rapidly than *Caesalpinia dasyrachis.*

Caesalpinia dasyrachis.

COMMON NAMES.—Pepetar (Sumatra); Petah-petah (Java); Petah (Sumatra); Petar (Sumatra).

Resists windstorms better than Albizzia and grows with considerable rapidity even at an elevation of 1,000 meters. Experiments in the Lampongs province of Sumatra are said to have been successful. A tree at Buitenzorg, Java, is noted by Dr. Fesca as 5 meters high at an age of 2½ years, while an old specimen was 17 meters high, with a diameter of over 2 feet. According to the *Index Kewensis* this species should be called *Peltophorum dasyrachis*, and is a native of Malacca.

Cajanus indicus. PIGEON PEA. (See Pl. XII.)

SYNONYMS.—*Cajanus bicolor; Cajanus flavus.*

COMMON NAMES.—Congo pea; Dhal (British India); Ganduli; Guando (Brazil); No-eye pea.

A somewhat shrubby leguminous plant with an upright bushy habit, attaining a height of 5 or 6 feet, and sometimes living for several seasons. The fruit resembles

THE PIGEON PEA OR GANDULI (CAJANUS), A LEGUMINOUS CATCH CROP FOR COFFEE.

[Natural size.]

beans and the seeds are shelled and used in the same way. It is extensively cultivated throughout British India, even at elevations of 6,000 feet, and has also been introduced throughout the Tropics. In India it is usually planted as a mixed crop with cotton and other products, though sometimes planted alone. There are several varieties differing greatly in size, earliness, and other qualities. By some authors *Cajanus bicolor* and *C. flavus* are treated as distinct species.

The pigeon pea is said to be used in Brazil for planting with coffee to shade the ground and prevent washing, and has also been recommended in India for the same purpose. It is also thought to have value as a fertilizer and to be rich in potash. As a leguminous plant of such a size as to afford shade to young coffee trees, the value of this crop as an adjunct to coffee culture seems worthy of careful investigation.

Cajanus bicolor. (See *Cajanus indicus.*)

Cajanus flavus. (See *Cajanus indicus.*)

Cajou (French Antilles). (See *Anacardium occidentale.*)

Caladium esculentum. (See *Colocasia esculenta.*)

Calophyllum calaba.

Common name.—Galba (Guadeloupe).

This tree belongs to the family Clusiaceae. It is a large, quick-growing tree, and has been found very useful for large hedges or windbreaks in the coffee plantations of the islands of Guadeloupe and Martinique, but has the serious objection of not permitting anything to grow within 7 or 8 meters of its trunk.

Cambulo.

Recommended by Saenz for coffee shade in Colombia at low elevation where the temperature exceeds 21° C. The trees are set at distances of 10 meters.

Carica papaya.

Common names.—Papaw; Papaya (Spanish America).

Mentioned by Yorba among the trees principally planted for coffee shade in Mexico.

Carrisso (Nicaragua). (See *Clibadium.*)

Cashew. (See *Anacardium occidentale.*)

Cassava (West Indies). (See *Manihot utilissimum.*)

Cassia florida.

Common names.—Djuas (Java); Djohar (Malay).

Fesca states that this species has the advantage of resisting drought well, but is of slow and irregular growth. According to Raoul, it grows very rapidly and has hard and useful wood. The shade is considered too dense for use with coffee, with which the large roots also interfere.

Castano (Porto Rico). (See *Artocarpus incisa.*)

Castilloa elastica.

Common names.—Hule (Mexico); Ule (Mexico).

The planting of the rubber tree of Mexico and Central America as a shade tree for cacao and coffee has been advocated in recent years by several writers on the agricultural possibilities of those regions. While there may be localities in which it would be possible to carry on profitably a mixed culture of this kind, the chances are that in places adapted to rubber the wide planting necessary to permit the coffee

or cacao to be cultivated would be very detrimental to the rubber, while elsewhere the rubber would be a drawback to the other crop, without furnishing any compensating advantage. The present trend of opinion is that the Castilloa rubber can be looked upon only as a tree requiring essentially tropical forest conditions, outside of which it may sometimes thrive, but refuses to produce rubber in quantities sufficient to make its culture profitable. The reason why trees standing apart in orchard form are not productive has not yet been demonstrated, though several suggestions have been made. It is well known that the bark of trees standing in the open is of quite different texture from that which grows on the same species in the forest, where the air is constantly moist and winds and sunlight are excluded. The bark of Castilloa is said to become much thicker and more corky in exposed trees, and it has been thought that this might interfere with the flow of milk when the trees are tapped. It is easy to see how this might be the case with a small cut, but from the large gashes usually employed the flow would scarcely be impeded by the nature of the outside layers of the bark. A more probable cause of difficulty in securing rubber from cultivated trees is the fact that in the forest the trunk of Castilloa becomes tall and columnar, being much larger in proportion to the top than when grown in the open. This may easily affect the pressure relations of the inclosed liquids, and may forbid the employment of other than forest culture while the present methods of harvesting the rubber are in use. A third possibility is that the milk of exposed trees is really thicker and less fluid than in the forest. Finally, the drier atmosphere of open orchards may have an influence in causing coagulation and impeding the flow of the milk.

In the State of Oaxaca plantations are now being set out in which rubber is alternated with coffee, as already noted. In this instance the rubber is not, however, being used to shade the coffee, but both rubber and coffee are planted in the thinned out natural forest. Unless the circumstances are exceptional this method is likely to offer many difficulties, in that seedlings and sprouts from the stumps and roots of the forest species will make rapid and repeated growth and require frequent cleaning. The coffee and rubber, on the other hand, may grow much more slowly than in open, thoroughly cultivated land. The advantages of the arrangement are thus not obvious, though local conditions may be found to justify it.

According to Martinez, the use of the hule as shade for cacao was abandoned in the State of Tabasco, Mexico, because the young trees were found to be delicate and to require the same care as the young cacao.

Castor bean. (See *Ricinus communis.*)

Casuarina equisetifolia.

Common name.—Pina de Santo Domingo (Porto Rico).

Suggested by Morris for windbreaks for cacao plantations in Jamaica because of its rapid growth, resistance to wind, and useful timber. Its loose and open habit and slender branches afford, however, but the slightest resistance to the wind. As is the case with Eucalyptus, nothing grows under Casuarina.

Cay vong nem (Philippine Is.). (See *Erythrina indica.*)

Ceara rubber. (See *Manihot glaziovii.*)

Cedrela microcarpa.

This species is said to be used with *C. toona* in the Coorg district of western Hindustan.

Cedrela odorata. West Indian Cedar.

Common names.—Acajou amer and Acajou du pays (Guadeloupe); Spanish Cedar; West Indian Cedar.

Family Meliaceae. A fine tree, native in the West Indies. It has been planted as a shade tree for cacao in Guadeloupe, where it is said to resist parasites better than

Erythrina, and where the wood becomes valuable at an age of 30 or 40 years. The leaves are also said to be deciduous at the season when the sunlight is an advantage to the cacao.

Cedrela serrulata.

COMMON NAME.—Surian (Java).

Family Meliaceae. A native of Sumatra congeneric with *C. odorata*, the West Indian or Spanish Cedar, from which the wood is obtained which is used in making cigar boxes. The planting of this tree for shade has been advised in Java because the wood is of value, but its use will probably be found impracticable if fertility and not shade is the primary consideration. Moreover it is of rather slow growth and when planted in the open does not tend to become tall, a specimen at Buitenzorg 15 years old being but 13 meters (40 feet) tall, with a circumference of somewhat over 2 feet. This rate of growth is only about half that recorded for the West Indian species, the cultivation of which seems likely to prove profitable for its own sake, though planting with coffee would not give conditions favorable to the production of marketable timber.

Cedrela toona.

COMMON NAMES.—Red cedar (British India); Noge (Coorg, India).

This species has been planted for shade and shelter in the Coorg district of India, but is considered objectionable by Raoul on account of the fact that while young the trees are subject to the attacks of numerous parasites, and subsequently they attain such size that the coffee plantation is in a few years seriously injured by overshading. It is also among the trees permitted to stand when the forests are only partly cleared away.

Ceiba casearia. (See *Ceiba pentandra.*)

Ceiba pentandra. SILK COTTON TREE.

SYNONYMS.—*Ceiba casearia; Eriodendrum anfractuosum.*

COMMON NAME—Kapok (Java).

Used for coffee shade in East Africa (Ettling) and also in Java. Mr. David G. Fairchild, agricultural explorer of this Department, reports that in the neighborhood of Buitenzorg plantations are shaded with this tree, the use of which has probably been taken up because of the diseases and other disadvantages of the dadap (*Erythrina lithosperma*). According to Lecomte a sort of oil cake made from the seeds of this tree is used as a fertilizer for coffee in Java.

It seems hardly possible that the Ceiba can exert any beneficial influence on the coffee, though the planters who use it will possibly ascribe poor results to other causes, since the shade cast by this tree is generally of the thin, open character supposed by the planters of Java to be peculiarly grateful to the coffee.

Challa.

A plant used for cacao shade in the State of Tabasco, Mexico. (See discussion under *Madre chontal.*)

Charcoal tree (British India). (See *Trema orientalis.*)

Chataignier (French West Indies). (See *Artocarpus incisa.*)

China tree. (See *Melia azedarach.*)

Chontal. (See *Madre chontal.*)

Cinchona succirubra. CINCHONA.

Family Rubiaceae. Cameron mentions Cinchona among the shade trees of the coffee plantations of the Coorg district of British India, but states that it is "not

classed as shade," for which purpose it would probably have no use, because even less able than the coffee to endure hot, dry weather.

Citrus aurantium. ORANGE.

Used in Mexico for coffee shade.

Clibadium.

COMMON NAME.—Carrisso (Nicaragua).

A composite shrub used in Nicaragua as primary shade for cacao is reported by Hart and doubtfully referred to the genus Clibadium.

Cochin.

This is the preferred coffee-shade tree of Guatemala, according to Morren. It is an indigenous species of rapid growth, and reaches a height of 25 to 30 feet. The author mentioned considers the foliage too thick for best results. The leaves are deciduous at the beginning of the rainy season, but new growth is soon put forth. The dadap and sengon (*Albizzia moluccana*) are said to have been introduced into Guatemala, but are not used for coffee shade.

Coco (Jamaica). (See *Colocasia esculenta.*)

Cocoanut. (See *Cocos nucifera.*)

Cocohite.

A tree used for cacao shade in the State of Tabasco, Mexico. (See discussion under *Madre chontal.*)

Cocos nucifera. COCOANUT.

Lock mentions a record of coffee as having done well in Ceylon under the shade of cocoanut palms, and, as the latter are said to have flourished, the experiment was probably made at a low elevation.

Coffea liberica. LIBERIAN COFFEE.

It is by no means impossible that at low altitudes the planting of Liberian coffee in alternation with Arabian might prove to be an advantageous arrangement. The more vigorous growth of the Liberian would shade and protect the ground sooner than would be the case with the Arabian planted alone. The latter might ultimately be cut away when the Liberian trees were large enough to need all the space, but not before several crops had been harvested.

Colocasia antiquorum. (See *Colocasia esculenta.*)

Colocasia esculenta. TARO.

SYNONYMS.—*Caladium esculentum; Colocasia antiquorum.*

COMMON NAMES.—Coco (Jamaica); Eddo; Elephant's Ear; Oto (Panama); Tannia (French West Indies); Tannier (Trinidad); Taro (Polynesia); Tayaux (Santo Domingo); Yautia (Porto Rico).

This well-known and much-named plant is recommended by Morris for shading young seedlings of cacao and is sometimes used similarly with coffee. The following reference is supposed to pertain to the same plant:

I have seen the young trees successfully sheltered by rows of *tayaux* planted between the rows, or every second row. But the roots must not be dug out, and the largest leaves must be cut at the weedings. This seems in appearance to keep back the trees, but in proportion as the growth of the top is slower, the trunk and roots gain force, and when the tayaux are destroyed (which is done in the end of the second year by cutting them close and choking the sprouts by leaves heaped upon the stocks) the coffee trees resist the wind and grow with redoubled vigor.—Laborie, The Coffee Planter of Saint Domingo, 1845, p. 118.

Congo-pea. (See *Cajanus indicus.*)

Coral tree. (See *Erythrina umbrosa*, also *Erythrina poeppigiana.*)

Cotton. (See *Gossypium.*)

Cowpea. (See *Vigna catjang.*)

Dadap (Java). (See *Erythrina subumbrans*, also *E. lithosperma.*)

Dadap djangoen. (See *Erythrina lithosperma.*)

Dadap minjak (Java). (See *Erythrina lithosperma.*)

Dadap serap (Malay). (See *Erythrina indica.*)

Dapap solo (Java). (See *Erythrina indica.*)

Dalbergia latifolia.

Common names.—Biti (Coorg, India); Blackwood (British India); Rosewood (British India.)

In the Coorg district of western Hindustan the planting of coffee under forest conditions has been undertaken to avoid the attacks of the parasitic fungus Hemileia. The native trees which are thought to compete to the detriment of the coffee are cut away; the others, and particularly the deciduous species, are left for protection. Among these Dalbergia is the favorite, perhaps because of its valuable wood, but also probably on account of the fact that, as a member of the Leguminosae, it assists in maintaining the fertility of the soil.

According to Cameron, some Coorg planters reject this in favor of the Australian tree *Grevillea robusta*, but the custom of planting or permitting the growth of a large variety of shade trees seems to be general, and there are no accounts of experiments to determine their relative value.

Dalbergia sissoo.

A native of British India recommended by Cameron for shading coffee in stony land, and said to flourish in the vicinity of Bangalore.

Desmodium. (See *Meibomia.*)

Dhal. (See *Cajanus indicus.*)

Dioscorea. Yam.

The tropical yam, of which there are numerous species, has been planted as a catch crop with coffee, but would seem to be very poorly adapted to the purpose, although the vines of the varieties not trained upon poles might cover the ground and serve as a protection against drought.

Dissochaeta cyanocarpa.

Family Melastomataceae. A tree native in the Malay region; enumerated by Raoul among those which have been recommended for coffee shade. It has also been used for forest planting. According to the *Index Kewensis*, this species is a synonym of *Anplectrum glaucum.*

Djeundjing laut (Java). (See *Albizzia moluccana.*)

Djohar (Malay). (See *Cassia florida.*)

Djuas (Java). (See *Cassia florida.*)

Dobera.

Species of this genus of Salvadoraceae are used, according to Lecomte, for shading coffee in Arabia.

Dori.

According to Lock, a name applied in Java to a variety of the dadap (Erythrina).

Eddo. (See *Colocasia esculenta.*)

Ehretia.

Species of this genus of Borraginaceae are used, according to Lecomte, for shading coffee in Arabia.

Elephant's ear. (See *Colocasia esculenta.*)

Emmajagua (Porto Rico). (See *Paritium tiliaceum.*)

English walnut. (See *Juglans regia.*)

Eriobotrya japonica. Loquat.

The loquat tree is planted along the roadsides on many of the estates in the Wynaad and elsewhere, and coffee appears to thrive well under it; but, so far as I am aware, the wood is not of any value, which at once places it at a disadvantage in competing with the jak. The loquat yields a pleasant fruit, in size and appearance much like the yellow plum.—Hull.

Eriodendrum anfractuosum. (See *Ceiba pentandra.*)

Erythrina amasisa. (See *Erythrina poeppigiana.*)

Erythrina hypaphorus. (See *Erythrina lithosperma.*)

Erythrina indica.

Common names.—Cay vong nem (Philippine Islands); Dadap serep (Malay); Dadap solo (Java); Palwan (Coorg, India).

Planted instead of the dadap in central Java (Fesca). This species is also said to be readily propagated from large pieces of the branches, and is for that reason used for the shade and support of *Piper nigrum*, the true pepper. This species has also been introduced into the West Indies as an ornamental and shade tree, and is reported by Guerin as used for shading cacao plantations in Guadeloupe. It has also been distributed by the Botanical Gardens of Trinidad in connection with an attempt at encouraging the cultivation of pepper.

This species is enumerated by Cameron among the indigenous forest trees which are left standing for shade in the coffee plantations of the Coorg district of British India.

In the Philippines it is now considered much preferable to *Gliricidia maculata*, under which the coffee has received serious injury from a longicorn beetle during the months while the trees are bare of leaves. The present species retains its leaves, has elevated horizontal branches, and an evenly distributed, though not dense, foliage.

Erythrina lithosperma.

Synonyms.—*Erythrina hypaphorus; Hypaphorus subumbrans.*

Common names.—*Dadap djangoen.* Dadap minjak (Java); Dedap.

In Java this species is the chief rival of *Albizzia moluccana* for the distinction of being considered the best shade tree for coffee. As an exception among leguminous trees, propagation by cuttings is advocated, and this method has the further advantage, as in the orange, of eradicating the spines which are normally present in trees grown from seedlings. The susceptibility of the dadap to epiphytes and parasites may be mentioned as a disadvantage; also, according to Dr. Fesca, this tree "makes greater demands upon the soil than the species of Albizzia," which probably means that the activity of the symbiotic root bacteria may be less, an important considera-

BASES OF LEAFLETS OF THE BUCARE OR MADRE DE CACAO (ERYTHRINA POEPPIGIANA), THE BEST-KNOWN COFFEE SHADE TREE OF THE WEST INDIES; THE CHARACTERISTIC EXTRA-FLORAL NECTARIES SHOWN AT THE BASES OF THE LOWER LEAFLETS.

[Natural size.]

tion from our present standpoint. Raoul considers the use of the dadap unwise on several accounts—too dense shade, the leaflets not closing at night, liability to attacks of parasites, and shortness of life.

According to van Gorkam, the dadap was originally the favorite shade tree of the coffee planters of Java, many of whom were led to discard it in favor of Albizzia because of a disease which proved to be extensively destructive to the dadap. The Albizzia has proved objectionable, however, on account of the brittleness of its wood, so that an ideally desirable shade tree is still a desideratum in Java. The dadap is also said to have been seriously injured by a disease in Ceylon, which led to the substitution of Grevillea. Recently, however, it has been introduced into the Coorg district of British India.

In the propagation of this and related species from cuttings, several precautions have been found desirable by the planters of Java. Smooth, healthy branches about 2 years old are selected from trees 5 to 8 years old. These are cut up in pieces 75 to 90 centimeters long, and should have a diameter of from 5 to 8 centimeters. The ends are trimmed off smoothly and obliquely, but so as to keep them in a manner parallel. Pieces bearing twigs or having any diseased spots are rejected. The cuttings are set obliquely in the ground at an angle of about 60 degrees, and pointing in the direction of the heaviest winds, or against the slope if planted on hillsides. The sticks are buried in the ground to a depth of 20 to 30 centimeters, and the earth is smoothed and trodden firm about them; otherwise they will not send out shoots. A leaf is tied over the cut end to prevent the pith being dried out by the sun or rotted by rain.

Erythrina micropteryx. (See *Erythrina poeppigiana.*)

Erythrina ovalifolia.

Common name.—Anal (Philippine Islands).

According to Sanchez, this species and *E. indica* are preferable to *Gliricidia maculata*, under which the coffee is seriously injured by a longicorn beetle during the season when the leaves are off.

Erythrina poeppigiana. Bucare. (See Plate XIII.)

Synonyms.—*Micropteryx poeppigiana; Erythrina micropteryx; Erythrina amasisa.*
Common names.—Ama-sisa (Peru); Bois immortel; Bucare (Porto Rico); Coral tree; Erythrine de Cayenne (Martinique); Immortel jaune (Guadeloupe); Madre de cacao; Palo de boyo (Porto Rico); Peñon (Cuba).

This species has often been confused with *Erythrina umbrosa*, especially in the West Indies. As the latter species was described by Humboldt as used for shading of cacao in Venezuela, the general impression has prevailed that the same species had been introduced and used in Trinidad and in the other West Indies. Recently Professor Urban, of Berlin, declared that all the West Indian specimens studied by him from Cuba, Porto Rico, Martinique, and Trinidad belong to *Erythrina micropteryx*, the correct name of which seems to be *E. poeppigiana*. And yet it seems scarcely possible that *Erythrina amasisa*, the "handsomest" tree, described by Spruce as growing 100 feet high in the forests of the eastern slopes of the Peruvian Andes, can be the same as the Porto Rican bucare, of which 15 or 20 meters is considered the limit of growth. Moreover, it seems improbable that the Andine tree has reached the West Indies without gaining a footing in the adjacent coffee regions of the South American Continent. According to Hart, *E. umbrosa* is taller and more open in habit than *E. velutina*, and is preferred for the higher elevations in the cacao plantations of Trinidad. For coffee, at least, these species seem objectionable on account of the too dense shade. The wood is not only too soft and water-logged to be of any use, even for fuel, but it is also extremely brittle and will not withstand windstorms. After the hurricane of August, 1899, scarcely a tree of Erythrina was to be found in Porto Rico which had not had the limbs carried away well down to

the trunk. Morris objects to it even for shading cacao in Trinidad and Jamaica because the leaves are deciduous, and are absent from January to May, at the end of the dry season, when the cacao most needs the shade. It is also said to be a surface feeder, and to send out long superficial roots, which impede cultural operations in the plantations. In Trinidad there has also been a movement set on foot by Superintendent Hart, of the British Gardens, to supplant Erythrina with a species of Lonchocarpus introduced from Nicaragua. Many planters are also said to have substituted *Hura crepitans*, the sand-box tree, the advantage of which, if any, probably lies in the more open habit, an indication that the use of Erythrina resulted in overshading.

According to Lecomte, *Erythrina amasisa* is sparingly planted for coffee shade in the French West Indies.

Erythrina subumbrans. Dadap.

Synonym.—*Hypaphorus subumbrans.*

Common name.—Dadap (Java).

According to Lecomte, this species is the true Dadap, and distinct from *E. lithosperma* (*Dadap djangoen*), to which *Hypaphorus subumbrans* is usually referred as a synonym.

Erythrina umbrosa.

Common names.—Anauca (Trinidad); Bucare (Venezuela); Coral tree; Immortel; Madre de cacao.

This species was originally described from trees planted for cacao shade between La Guaira and Caracas, Venezuela, and has probably on that account been taken to be the species cultivated for the same purpose on several of the West Indian Islands. As noted under *E. poeppigiana* this is not now thought to be the case, and all the West Indian references to *E. umbrosa* may need to be transferred to the former species, under which this question is discussed.

Erythrina velutina.

Common name.—Bocare (Trinidad).

According to Hart, this species is planted in Trinidad in cacao plantations of low elevation and casts a denser shade than *E. umbrosa*, which is used higher up.

Erythrine de Cayenne (Martinique). (See *Erythrina poeppigiana.*)

Eugenia jambolana.

Common names.—Black plum (British India); Jambolan; Java plum.

A tree native in British India and extensively planted for its subacid edible fruit. The bark is used in dyeing and tanning and is valued as an astringent. The leaves, fruit, and seed are also supposed to have medicinal properties. The tree attains moderate size and is enumerated by Lecomte among those used for coffee shade.

Eugenia jambos. (See *Jambosa jambos.*)

Eugenia zeylanica.

Enumerated by Lecomte as a coffee-shade tree. According to Watt, this is a small tree noted only as yielding wood used for building purposes and for field tools.

Ficus asperrima.

Common name.—Gargatti (Coorg, India).

An indigenous forest tree left standing in coffee plantations for shade, but said to be of inferior value for this purpose. (Cameron.)

Ficus bengalensis.

COMMON NAME.—Alada (Coorg, India).

A native forest tree left standing for shade in coffee plantations. (Cameron.)

Ficus carica.

COMMON NAME.—Fig.

Mentioned by Yorba among trees planted for coffee shade in Mexico.

Ficus glomerata.

COMMON NAME.—Atti (Coorg, India).

A native forest tree left standing for shade in coffee plantations.

This East Indian fig is also mentioned as a coffee-shade tree by Raoul, and is said to have the advantage of dropping its leaves during the dry season. This could be counted a desirable feature, however, only where there is no danger of drought or where the dry season is also cool. A peculiar method of handling the seeds may also apply to those of other species which are not always easy to keep or to germinate successfully. They are mixed with fresh cow dung, which is rolled into balls, allowed to dry, and is subsequently powdered before sowing.

Ficus mysorensis.

COMMON NAME.—Goni (Coorg, India).

An indigenous forest tree left standing for shade in coffee plantations. (Cameron.)

Ficus pseudosycomorus.

According to Lecomte, this species is used for shading coffee in Arabia.

Ficus tjakela.

COMMON NAME—Kap basuri (Coorg, India).

An indigenous forest tree left standing for shade in coffee plantations. (Cameron.)

Ficus tsiela.

COMMON NAME—Bili basuri (Coorg, India).

An indigenous forest tree left standing for shade in coffee plantations. (Cameron.)

Ficus tuberculata.

A native forest tree left standing for shade in coffee plantations in the Coorg district of British India.

Fig. (See *Ficus carica.*)

Fraxinus pistaciaefolia.

Reported by Dr. Edward Palmer as used for shading coffee at Tepic, Mexico.

Fustic. (See *Maclura tinctoria.*)

Galba (Guadeloupe). (See *Calophyllum calaba.*)

Galedupa maculata. (See *Pongamia glabra.*)

Galedupa pungam.

COMMON NAME.—Madrecacao (Philippine Islands).

According to the report of the first Philippine commission this tree is usually planted for coffee shade in the Philippines. It is probably the same as *Gliricidia maculata*, introduced from Guatemala.

Gallito (Porto Rico). (See *Agati grandiflora.*)

Ganduli. (See *Cajanus indicus.*)

Gargatti (Coorg, India). (See *Ficus asperrima.*)

Geno. (See *Lonchocarpus.*)

Gliricidia maculata.

COMMON NAME.—Madre cacao.

A tree described from Guatemala and used for shading cacao and coffee in the Philippines. In the Revue Indo-Chinois, 1899, M. Lemarie describes, on the basis of a report by Señor Sanchez, a serious disease of coffee in the Philippines, due to a longicorn beetle the larva of which burrows in the wood. This pest is said to be especially abundant in plantations shaded with the present species, while with *Erythrina ovalifolia* and *E. indica* it is much less serious. The beetles are said to be favored by open culture and exposure to sunlight. The present species is therefore considered undesirable, because it is bare of leaves for several months, but impedes the circulation of the air when the leaves come out. Its growth is said to be very rapid, but the above objections should be considered before advising an extension of its distribution.

Goni (Coorg, India). (See *Ficus mysorensis.*)

Goober. (See *Arachis hypogaea.*)

Gossypium. COTTON.

Cotton is one of the several crops sometimes grown in Mexico and other parts of tropical America between the coffee rows while the trees are still young; there is no record of the success of this method on a large scale.

Grevillea robusta.

Family Proteaceae. A native of Australia, introduced into Ceylon and Coorg as shade for coffee. Doubtless recommended because of its valuable wood. According to van Gorkam, this tree is thought to serve as protection against the coffee-leaf disease.

Grewia columnaris.

Family Tiliaceae. A tree supposed to be native in the Malay region and in tropical Africa. It has been recommended for coffee shade on account of its rapid growth, but is said by Raoul to have serious disadvantages, which he does not specify.

Guaba (Porto Rico). (See *Inga vera.*)

Guacima (Porto Rico). (See *Guazuma tomentosa.*)

Guama (Venezuela, Porto Rico). (See *Inga laurina.*)

Guamo. (See *Inga laurina.*)

Guando (Brazil). (See *Cajanus indicus.*)

Guango (Jamaica). (See *Pithecolobium saman.*)

Guava (Porto Rico). (See *Inga vera.*)

Guaymochil (Mexico). (See *Pithecolobium dulce.*)

Guazuma tomentosa.

COMMON NAMES.—Bastard cedar (Jamaica); Guacima (Porto Rico).

Recommended in Jamaica for windbreaks about cacao plantations by Dr. Morris. The foliage is said to be of use as food for cattle. This species is common on the southern coast of Porto Rico.

Habilla. (See *Hura crepitans.*)

Halasu (Coorg, India). (See *Artocarpus integrifolia.*)

Hevea brasiliensis. PARA RUBBER.

The planting of the Para and other rubber as shade for cacao and coffee naturally suggested itself to many while the belief held that mere shade was a desideratum in these cultures. It is barely possible that cacao or coffee might be grown as a sort of catch crop between rubber trees, but if the permanent use of the land for the latter purpose has been decided upon, it will probably be found to be much better policy to plant the rubber thick enough to soon shade all the ground, insure permanent moisture, and prevent the growth of other vegetation requiring expense for its removal. In other words, it is possible that neither the rubber nor the other crops would be as productive as soon or as extensively as if planted alone, and any such combinations as the present would need to be justified by special and local reasons.

The planting of Para rubber trees with coffee and other crops was attempted some years ago in British India, but without conspicuous success from the financial standpoint. The coffee districts are too dry and too elevated for the Hevea to become productive, although it may appear to thrive and maintain its vegetative vigor. The former plantings of Hevea in India have yielded returns only from the sale of seed, though better results are now expected from forest plantings in low, overflowed regions. Other species of Hevea may be found better adapted to high-land culture, but the present indications are that closer planting to secure true forest conditions will be desirable in this genus, as in Castilloa.

Heynea sumatrana.

Family Meliaceae. A tree mentioned by Raoul as used for coffee shade and reforestation in the Malay region.

Hibiscus tiliaceus. (See *Paritium tiliaceum.*)

Higuerilla (Mexico). (See *Ricinus communis.*)

Hog-plum. (See *Spondias lutea.*)

Honne (Coorg, India). (See *Pterocarpus marsupium.*)

Howlige (Coorg, India). (See *Acrocarpus fraxinifolius.*)

Huamuchil (Mexico). (See *Pithecolobium dulce.*)

Huizache (Mexico). (See *Acacia albicans.*)

Hule (Mexico). (See *Castilloa elastica.*)

Hura crepitans. SAND-BOX TREE.

COMMON NAMES.—Acupa (Colombia); Avilla (Porto Rico); Habilla; Javilla (Panama); Monkey's dinner bell; Sand-box tree.

A peculiar American tree considered by botanists to belong to the Euphorbiaceae or spurge family, but very different from the other members of that group. The common name alludes to the biscuit-shaped fruit which explodes when dry with a loud report. It grows with great rapidity, and has an open, spreading habit, features which have probably suggested its use as cacao shade in Trinidad, where, according to Morris, it has on some of the best estates supplanted the madre de cacao (Erythrina). The shade of the latter is too dense and the wood is so brittle that the limbs are frequently blown down, to the injury of the cacao. It is easy to understand that Hura may be superior in these respects, but that it will compare in desirability with the better class of leguminous shade trees is scarcely to be believed

without further demonstration, particularly in view of the fact that the Euphorbiaceous trees are generally known to make serious demands upon the soil and to permit little or nothing to grow under them. The indications are rather that the plantations had been too heavily shaded under Erythrina and appeared at first to profit by the change.

The sand-box tree is commonly planted for shade along the highways in Porto Rico. The hurricane of August, 1899, injured it badly, though not to the same extent as the Erythrinas.

The trunk suggests that of the Ceiba, having prominent roots, large stout spines, and a similar light-gray color. The habit of the branches is different, however, and the leaves are simple and cordate instead of palmately compound. They are also peculiar in having unusually numerous white veins.

The slightly milky juice is acrid and irritant, while the seeds are sometimes used as a purgative. An oil expressed from them is said to be less nauseous than castor oil, and to be effective in smaller doses. The fruits of the Porto Rico trees were much less prominently ribbed than those figured in botanical works; possibly it represents a distinct species.

Hypaphorus subumbrans. (See *Erythrina lithosperma*, also *Erythrina subumbrans.*)

Immortel. (See *Erythrina umbrosa.*)

Immortel jaune (Guadeloupe). (See *Erythrina poeppigiana.*)

Indian corn. (See *Zea mays.*)

Indian mulberry. (See *Morus indica.*)

Indian nettle tree (British India). (See *Trema orientalis.*)

Indigo. (See *Indigofera.*)

Indigofera. INDIGO.

The planting of indigo as a soiling crop with coffee is suggested by Lecomte.

Inga dulcis.

COMMON NAME.—Pois doux (French Antilles).

Raoul reports the use of this species as a windbreak in the West Indies; according to Guerin, who gives the same common name, *I. laurina* is used for the same purpose in Guadeloupe. The *Index Kewensis* gives *Inga dulcis* as a synonym of *Pithecolobium dulce*, but this can hardly apply to the present instance.

Inga inicuil.

SYNONYM.—*Inga jiniquil.*

COMMON NAMES.—Inicuil; Jinicuile.

According to Mr. O. W. Barrett, the iniquil is preferred for coffee shade in the region of Vera Cruz, Mexico. In the Biologia Centrali Americanae this species is said to be both indigenous and cultivated about Jalapa. It is also mentioned by Herrera as considered desirable for coffee shade in the region of Cordoba, Mexico.

Inga jiniquil. (See *Inga inicuil.*)

Inga laurina. (See Pl. XIV.)

COMMON NAMES.—Guamo, or Guama (Venezuela, Porto Rico); Pois doux (Guadeloupe).

According to Guerin, this tree is one of those employed in the cacao culture of Guadeloupe in making hedges or windbreaks which are planted across the direction

LEAVES AND PODS OF GUAMA (INGA LAURINA), A FAVORITE SHADE TREE FOR COFFEE IN VENEZUELA AND PORTO RICO.

YOUNG SHOOT OF GUAVA (INGA VERA), PLANTED FOR COFFEE SHADE, CAYEY, P. R.

[Slightly reduced.]

of the prevailing winds at distances of 100 meters. Such hedges are used at elevations where permanent shade is thought not to be required but where protection from the wind is necessary. In Venezuela and Colombia this is one of the favorite species for coffee shade. It has also been imported and extensively used for the same purpose in Porto Rico. As a possible objection to it may be noted the report that it is susceptible to the disease called "mancha de hierro," or "iron rust," which has been very destructive to coffee, especially in overshaded plantations.

In Colombia Saenz recommends the planting of this species at 15 meters where the temperature does not exceed 21° C.; in hotter regions a distance of 10 meters is advised.

Inga saman. (See *Pithecolobium saman.*)

Inga vera. (See Pl. XV.)

Common name.—Guava (Porto Rico).

This species seems to be the favorite species in Porto Rico, with the related *Inga laurina*, or guama, second. Both grow much less rapidly than the bucare (Erythrina), but are less liable to injury by hurricanes. In well-kept plantations the lower branches are trimmed out and the upper form an even layer of rather open foliage. But even where this amount of care is taken the shade is usually still too thick for the coffee to make normally vigorous growth, and the crop would probably be improved by the removal of alternate trees, so as to increase the distances to 30 or 40 feet.

The name of this tree is likely to be confused by the visitor with that of *Psidium guajava*, the well-known tropical fruit called guava in English, but which the Porto Ricans more correctly term guayava.

Inicuil. (See *Inga inicuil.*)

Irvingia bararteri. Irvingia barteri.

Planted for shade in the recently established coffee plantations of the German colony of Kamerun. (Froehner.)

Jack-fruit. (See *Artocarpus integrifolia.*)

Jak. (See *Artocarpus integrifolia.*)

Jambolan. (See *Eugenia jambolana.*)

Jambosa jambos. Rose-apple.

Synonyms.—*Jambosa vulgaris; Eugenia jambos.*

Common names.—Pomme-rose (French Islands); Pomarosa (Spanish America).

Planted in the French Antilles in hedges for protecting coffee plantations against the wind, and recommended in Jamaica for the same purpose with cacao. A myrtaceous shrub or small tree, native in the Malay region, but now introduced in all parts of the Tropics and escaped from cultivation in many countries. In Porto Rico it is abundant in thickets in waste places, and furnishes the material from which most of the larger baskets are made. Considerable amounts are also used for hoops of the large sugar casks. It yields also an edible fruit which has a pleasant odor like roses, whence the name. The leaves are long and narrow and resemble those of the peach and oleander.

Jambosa vulgaris. (See *Jambosa jambos.*)

Jatropha multifida (?).

Common name.—Quelita (Nicaragua).

A tree used as secondary shade for cacao in Nicaragua is reported by Hart as "a Jatropha, near to *Jatropha multifida.*"

Java plum. (See *Eugenia jambolana.*)

Javilla (Panama). (See *Hura crepitans.*)

Jinicuile. (See *Inga inicuil.*)

Jobo. (See *Spondias lutea.*)

Juga.

A tree mentioned by Herrera as desirable for coffee shade in the region of Cordoba, Mexico.

Juglans regia. ENGLISH WALNUT.

Mentioned by Yorba among trees planted for coffee shade in Mexico.

Kad halasu (Coorg, India). (See *Artocarpus hirsuta.*)

Kaffir corn. (See *Andropogon sorghum.*)

Kap basuri (Coorg, India). (See *Ficus tjakela.*)

Kapok (Java). (See *Ceiba pentandra.*)

Kratok (Java). (See *Arachis hypogaea.*)

Lagerstroemia lanceolata.

COMMON NAME.—Mandi (Coorg, India).

Family Lythraceae. A forest tree left standing for shade in coffee plantations. (Cameron.)

Liberian coffee. (See *Coffea liberica.*)

Lonchocarpus sp.

COMMON NAMES.—Madera (Nicaragua); Savonette (Trinidad).

A species of Lonchocarpus used in Nicaragua for shading cacao plantations was introduced into Trinidad by Superintendent Hart, of the Botanical Gardens, and a distribution of seedlings was announced in January, 1895. A species of Lonchocarpus native in Porto Rico has recently been described by Urban as *Lonchocarpus glaucifolius*, for which the common name is said to be *geno.*

Loquat. (See *Eriobotrya japonica.*)

Maclura tinctoria. FUSTIC.

A tree belonging to the Moraceae or mulberry family and to the same genus as the Osage orange. The yellow wood furnishes a yellow dye, also used for brown and green shades. Fustic to the value of $121,665 was imported in 1899, according to the Treasury reports. Fustic is recommended in Jamaica for windbreaks about cacao plantations.

Madera (Nicaragua). (See *Lonchocarpus.*)

Madre blanca.

A tree used for cacao shade in the State of Tabasco, Mexico. (See discussion under *Madre chontal.*)

Madre cacao. (See *Erythrina poeppigiana* and *E. umbrosa;* also *Gliricidia maculata*, *Galedupa pungam*, and *Pongamia glabra.*)

Madre chontal.

A system of mixed shade for cacao is described by Martinez as practiced from time immemorial in the State of Tabasco, Mexico. The trees used are called madre

chontal, madre prieta, madre blanca or serrana, cocohite, and challa, the latter being employed as temporary shade, "chichihuas" or "wet-nurses," and cut away after the "madres" or "mothers" are sufficiently grown to shade the entire area. The detailed plan advocated by Martinez shows the cacao planted at equal distances in rows which alternate, or "break joints." In each alternate row the madre chontal and cocohite are set in alternate spaces between the cacao, while the chichihuas are placed close to the young cacao trees, one on each side. In some localities the latter are omitted entirely and the cocohite is cut away between the eighth and twelfth years of the plantation.

The Madre chontal is propagated by stakes a meter or a meter and a half long, taken from the trees in the winter when the leaves are off. The other "madres" also lose their leaves in the winter when the extra heat of the sun is not unwelcome in the plantations. This ancient culture seems not unworthy of investigation, with reference both to cacao and to coffee. Unfortunately the scientific names of the shade trees are not given.

Madre de cacao. (See *Erythrina umbrosa*, also *Erythrina poeppigiana*.)

Madre prieta and

Madre serrana.

Trees used for cacao shade in the State of Tabasco, Mexico. (See discussion under *Madre chontal*.)

Mahoe (Jamaica). (See *Paritium tiliaceum*.)

Mahogany. (See *Swietenia mahagoni*.)

Mais (Spanish). (See *Zea mays*.)

Maize. (See *Zea mays*.)

Majagua (Porto Rico). (See *Paritium tiliaceum*.)

Malanga. (See *Xanthosoma sagittifolium*.)

Mamey. (See *Mammea americana*.)

Mammea americana.

Common name—Mamey (Mexico).

Mentioned by Yorba among trees mostly used in Mexico for shade.

Mammet.

Dampier is quoted as saying with reference to the island of Tobago, in the Bay of Panama:

Among the cocoa trees grows the mammet, a straight tree without knot or branch, 70 feet in height, and with a tufted and interlaced head. This seems to serve as a parasol to the cocoa tree, which is injured by the burning rays of the sun.

This may have reference to the mammee-apple, *Mammea americana*.

Mandi (Coorg, India). (See *Lagerstroemia lanceolata*.)

Mandioca (Brazil). (See *Manihot utilissimum*.)

Mangifera indica. Mango.

The mango tree has a very compact habit and dense foliage. It affords excellent protection from both sun and rain, and little or nothing will grow directly under it. Thus while coffee is often planted near it in yards or gardens and the black pepper is sometimes trained on its trunk, the mango has never been considered as a shade

tree in the proper sense of the word. Hedges of mango are, however, reported by Hart in the cacao plantations of Nicaragua. The mangoes are planted in rows at short intervals, and are trimmed to form a compact mass of vegetation sometimes 60 feet high, which doubtless serves admirably the intended purpose of forming a windbreak. There are doubtless many localities where such protection would be desirable in coffee culture, so that the suggestion may not be without value, though in general leguminous trees should be preferred, even in planting for shelter, particularly where the washings of the soil are to percolate through the coffee plantation.

Mango. (See *Mangifera indica.*)

Mani (Porto Rico). (See *Arachis hypogaea.*)

Manihot glaziovii. CEARA RUBBER.

In British India experiments have been made with this rubber tree as shade for coffee plantations. The results were unfavorable, and the Manihot has in many places been rooted out as worthless. Coffee requires soil and climate too wet for the success of Manihot, which, in addition, rapidly exhausts the land and permits little or nothing to grow under it. Moreover, little expectation is now cherished that this species has any agricultural value except for hopelessly waste and barren regions, subject to a long dry reason like its native home in northeastern Brazil. The cost of collecting the rubber of this species is also too great for profitable handling in culture.

Manihot utilissimum. CASSAVA.

COMMON NAMES.—Cassava (West Indies); Mandioca, or Manioc (Brazil); Yuca (Spanish America.)

In Brazil cassava is planted between the rows of young coffee and has the advantage of living three or four years. Roots are available for use within a year or less, but if left in the ground they continue to grow and others are formed. Cassava is propagated from cuttings which make very rapid growth, and might thus be useful for shading newly planted coffee in regions of low elevation.

Manila tamarind (India). (See *Pithecolobium dulce.*)

Manioc (Brazil). (See *Manihot utilissimum.*)

Mataraton.

Mentioned by Yorba among the trees mostly used in Mexico for coffee-shade.

Medeloa (Burma). (See *Albizzia procera.*)

Medicago sativus. ALFALFA.

Alfalfa is not known to have been tried with coffee, but is one of the fodder and soiling plants to which the farmer from temperate regions would naturally turn. It is accordingly proper to state that in the moist tropics alfalfa has not been found a success. Experiments in British Guayana have resulted in recommending phasemy (*Phaseolus semierectus*) as the best available substitute.

Meibomia polycarpa.

German colonists in Samoa have recently found that this species gives great promise of value as a fodder and soiling crop. It is expected to replace *Monerma repens* and *Mimosa pudica* with which experiments were already in progress. (See Reineke, Die Flora der Samoa-Inseln, Engler's Bot. Jahrb., 1898, 25: 640.)

Meibomia tortuosa. BEGGAR-WEED.

SYNONYM.—*Desmodium tortuosum.*

A leguminous shrubby herb which has latterly been found to be a valuable adjunct to the orange culture of Florida and also as a forage and soiling crop in the general

agriculture of that State. The growth of the beggar-weed in the orange groves is found to increase the yield and especially the quality of the fruit. The same fact has also been remarked in Porto Rico, though it has not been utilized in any regular cultural industry. In coffee the same species would in all probability be found useful, though for different altitudes and soils other plants might be found preferable.

Melia arguta.

Common name.—Mindie.

Recommended by Ettling for coffee shade in German East Africa. The seed germinates well and the young plants make very rapid growth, becoming in a year's time a "beautiful tall tree." Lecomte states that it loses its leaves during the last two months of the east monsoon, but the Javan plantations where it is used are said not to suffer from the exposure to the sun.

Melia azedarach. China tree.

Common name.—Mindi (Java).

This well-known species has been used in parts of Java as shade for Liberian coffee, and is considered by Dr. Fesca preferable to *Cedrela serrulata*. The wood is also said to be valuable for cabinetwork and in the manufacture of wind instruments.

Melia composita. (See *Melia dubia.*)

Melia dubia.

Synonym.—*Melia composita.*

An Indian tree mentioned by Raoul as of extremely rapid growth, but said to be objectionable to most planters on other accounts.

Micropteryx poeppigiana. (See *Erythrina poeppigiana.*)

Milho (Portuguese). (See *Andropogon sorghum.*)

Millo (Spanish). (See *Andropogon sorghum.*)

Mindi (Java). (See *Melia azedarach.*)

Mindie. (See *Melia arguta.*)

Moca (Porto Rico). (See *Andira inermis.*)

Monkey's dinner bell. (See *Hura crepitans.*)

Moricypre (French West Indies). (See *Byrsonima spicata.*)

Morus indica. Indian mulberry.

Used in Java with *Bixa orellana*, according to Lecomte, for filling in wind breaks of waroë when the trees have grown so large as to leave openings below.

Muche.

A tree used for coffee shade in Colombia. It casts a very open shadow and is used for the higher elevations, where it is planted wide (25 meters) apart. According to Saenz, no shade is necessary where the temperature varies only between 17° and 19° C., and only the above is permissible. Lower down, where the temperature reaches 21°, the muche may be set at 10 meters or the jack or guamo at 15 meters. Lower still, the guamo, saman, jack, or cambulo are used at 10 meters.

Mucuna utilis. Velvet-bean.

Common name.—Pois mascate (French colonies).

The planting of this species as a green manure for coffee is suggested by Lecomte. The recently acquired popularity of this species in the Southern States makes it easy

to secure seed through the regular trade, and careful experiments in Porto Rico and Hawaii are to be expected. *Mucuna pruriens*, supposed to be the original wild form of this plant, is native and grows luxuriantly in the American tropics.

Mulberry (India). (See *Morus indica*.)

Musa. Banana. (See Pl. I.)

Bananas and plantains are planted very generally with coffee. In some regions they are employed for the temporary protection of the young plants while the permanent shade trees are still small, but it is also customary in parts of Mexico and Central America to maintain bananas throughout the life of the coffee, with or without other shade. In the extremely rich and deep volcanic soils of Central America this system may be permissible, but under ordinary conditions it is probable that the banana is not a desirable shade plant, and many intelligent writers emphatically condemn it as exerting a distinctly harmful competition with the coffee. Analyses in Venezuela, reported by Dr. Delgado, indicate that from a given area planted to bananas or plantains the fertilizing materials annually drawn from the soil are nearly twenty times those required for coffee in full bearing, and it is accordingly claimed that secondary shade by means of bananas should not be employed, even for a few years, since it hinders the growth of the young trees and induces a debility from which they never fully recover. In Porto Rico many plantations are smothered with bananas to an extent obviously harmful, the young seedlings having opportunities for only the most spindling and weakly existence and requiring many years to attain even to the meager fertility with which their owners seem to be satisfied.

The popularity of bananas for coffee is probably largely due to the value of the fruits, which, even though produced incidentally and not exported, furnish an important part of the food of the laboring population in Porto Rico and other coffee-producing regions.

In such regions many peasants and small farmers derive a large part of their subsistence from the bananas, while the small amount of coffee obtainable is still sufficient to supply their slender needs in the way of imported articles. The culture may be a success from their standpoint, but this is no indication that the method is adapted to commercial production which will yield a profit after the expenses of hired labor and management have been covered.

It may be added that as a shade tree the banana is also objectionable because, unless planted so thickly as to smother the coffee, a part of the latter is exposed while the remainder is too densely shaded. The tall varieties are also liable to be blown down in heavy winds and often fall upon and injure the coffee trees. The large leaves may also keep the rain off some trees while pouring torrents upon others.

In Porto Rico bananas are often planted indiscriminately among the coffee, though some planters arrange them in alternate rows. This is altogether too close to permit a normal growth of the coffee, which never attains proper stature or productiveness. In Mexico and Central America it is customary to run from two to six rows of coffee between the rows of bananas. The middle rows of coffee under this arrangement are but little shaded, and the trees are larger and more fertile than those which stand nearer to the bananas, showing that the effects of the latter, if not negative entirely, are confined to the general protection against wind and drought.

If for any reason the planting of bananas with or near coffee is found to be desirable, the utility of the dead stems and leaves as manure should not be overlooked. These may be used as a mulch. The so-called "trunk" is in reality a bundle of the sheating bases of the succulent, herbaceous leaves, and retains its moisture for a long time, usually until thoroughly decomposed. According to Gomez, it is customary to bury the stems and leaves of the banana about coffee trees in the vicinity of Urua-

pan, in the State of Michoacan, Mexico. These may also be collected and allowed to decompose in trenches or piles, and with proper handling are said to yield a manure rich in nitrogen, potash, lime, and phosphoric acid, and thus particularly valuable for coffee.

Nicotiana tabacum. TOBACCO.

Tobacco is sometimes grown in young coffee plantations in Mexico.

No-eye pea. (See *Cajanus indicus.*)

Noge (Coorg, India). (See *Cedrela toona.*)

Orange. (See *Citrus aurantium.*)

Oryza sativa. RICE.

A Queensland experimenter claims good results from the planting of rice for shading the young coffee and protecting it from the wind. The rice paid nearly all the expenses of preparing the land and planting the coffee. After removing the grain the straw was used as a mulch and the coffee is said not to have suffered, but to have been advantaged by the rice, the growing of which also helps to keep down the weeds.

Otaheite apple. (See *Spondias dulcis.*)

Oto (Panama). (See *Colocasia esculenta.*)

Pachyrhizus trilobus. YAM BEAN.

A bean-like plant formerly widely cultivated for its large fleshy root; native in America but introduced in prehistoric times in Polynesia and in the East Indies. According to Graeffe the inhabitants of the island of Tongatabu, though not cultivating this species, welcomed it in their fallow clearings because they believed that it rendered the land more quickly suitable for the resumption of yam-growing.

Palma Christi. (See *Ricinus communis.*)

Palo de Boyo (Porto Rico). (See *Erythrina poeppigiana.*)

Palwan (Coorg, India). (See *Erythrina indica.*)

Papaw. (See *Carica papaya.*)

Papaya (Spanish America). (See *Carica papaya.*)

Para rubber. (See *Hevea brasiliensis.*)

Paritium tiliaceum.

SYNONYM. —*Hibiscus tiliaceus.*

COMMON NAME.—Mahoe (Jamaica); Majagua, or Emmajagua (Porto Rico).

Recommended in Jamaica by Dr. Morris for windbreaks about cacao plantations. A handsome shrub or small tree of 10 to 20 feet, bearing considerable general resemblance to the cotton plant, for which travelers have sometimes mistaken it. In Porto Rico it is often planted for hedges along roadsides and is very abundant in waste places near the sea. It was already widely distributed in America in prehistoric times and has now been introduced throughout the Tropics.

It is valued for its very strong bast fiber, which has much similarity to jute but differs in the peculiar property of maintaining or even increasing its strength after long maceration in water. The extraction of the fiber for the manufacture of cordage and other purposes offers no special difficulties. It has also been recommended for

paper making. At present it is utilized in Porto Rico for domestic purposes only, all the homemade ropes being twisted from it. The conditions are, however, very favorable for the cultivation of emmajagua on a large scale should more extensive industrial uses be found for it.

Parota.

Mentioned by Yorba as one of the principal coffee-shade trees of Mexico.

Peanut. (See *Arachis hypogaea.*)

Peltophorum dasyrachis. (See *Caesalpinia dasyrachis.*)

Peñon (Cuba). (See *Erythrina poeppigiana.*)

Pepetar (Sumatra). (See *Caesalpinia dasyrachis.*)

Persea gratissima.

Common names.—Aguacate (Mexico); Alligator pear; Avocado pear; Butter pear.

This well-known fruit of the Tropics has the external appearance of a large pear, but on being cut open is found to have a large central seed, which separates readily from the rather firm, somewhat buttery outer pulp, which is the part eaten. The "butter pear," as it is sometimes called, is a salad fruit, if such a term may be used, being eaten with salt, vinegar, pepper, and other condiments. The pulp is scraped away from the outer hard skin with a spoon. Opinions differ greatly as to the value of this fruit. Some are extremely fond of it, while others consider it quite insipid, as it undoubtedly is, without seasoning. Properly seasoned, it blends finely with dressings, and has recently been used as an ingredient of rich and elaborate salads. Treated with oil, salt, and tarragon vinegar, it has also been recommended, cut in slices and served as a relish, or the "butter" mashed up with such a dressing may be applied to sandwiches. At present but a small quantity of this fruit is marketed in New York, but the prices are good, 20 cents apiece being an average figure, at which the business would certainly be very profitable. According to Semler, an oil extracted from the alligator pear is used in large quantities in America in soap manufacture, but the seat of the oil industry is not stated.

There are numerous varieties, the ordinary green sort being the prevailing, if not the only type in Porto Rico, but in other countries purple and nearly black kinds are known. Some varieties are also said to be more hardy than others. It is very desirable that a collection of these be made in order to determine which should be propagated in large quantities for export.

It is not impossible that the culture of the avoçado pear on a large scale might be advantageously combined with that of coffee, especially in localities where shelter is desirable. It is enumerated by Yorba among "trees mostly used in Mexico for shade."

Petah (Sumatra). (See *Caesalpinia dasyrachis.*)

Petah-petah (Java). (See *Caesalpinia dasyrachis.*)

Petar (Sumatra). (See *Caesalpinia dasyrachis.*)

Phasemy. (See *Phaseolus semierectus.*)

Phaseolus. Bean.

Various species of Phaseolus and other beans are planted as catch crops with coffee in Brazil and elsewhere.

Phaseolus semierectus. Phasemy.

Experiments at the Botanic Gardens of British Guayana have demonstrated that this species is there much more vigorous and prolific than alfalfa, and this will probably be true for other moist tropical countries.

Pigeon-pea. (See *Cajanus indicus.*)

Piña (Spanish). (See *Ananas sativus.*)

Pina de Santo Domingo (Porto Rico). (See *Casuarina equisetifolia*).

Pindar. (See *Arachis hypogaea.*)

Pineapple. (See *Ananas sativus.*)

Piptadenia colubrina.

Synonyms.—*Acacia virginalis; Acacia angico.*
Common name.—Angico (Brazil).

A leguminous tree used in some parts of Brazil where coffee is cultivated in the lowlands. Most of the Brazilian coffee is, however, grown without shade. The synonyms are those given by Van Delden Laërne and by Raoul; *Acacia virginalis* does not appear in the Index Kewensis, while *Acacia angico* is referred to *Piptadenia rigida.*

According to Van Delden Laërne, experiments in shading coffee with this tree were made in the Sierra Abaixo of Brazil, in plantations situated at an elevation of less than 300 meters. The plan was never carried out, whether from accident or unfavorable results is not known. With this exception the author mentioned states that "trees yielding shade are unknown in Brazil." Open culture is commended on the ground that the berries ripen in the dry winter season when low temperatures prevail, thus decreasing the injury from drought. That the policy of open culture may have been carried too far in Brazil is indicated, however, by the fact that even windbreaks are not used, although many trees are said to be injured by exposure.

Piptadenia rigida. (See *Piptadenia colubrina.*)

Pithecolobium dulce.

Native names.—Huamuchil, or Guaymochil (Mexico); Manila Tamarind (India).

This species seems to be the favorite for coffee shade in the subarid regions of Mexico, as far as preferences have been expressed in the undiscriminating literature of the subject. The indications are, moreover, that the tree is worthy of general consideration, at least for the drier of the coffee-growing regions, since in addition to vigorous growth and ability to withstand drought it affords a valued edible fruit; the bark is used for dyeing and tanning and the wood is of good quality.

The origin of this tree is a matter of uncertainty, for though it is generally thought to be a native of Mexico it is not known to occur wild in that country, and its name seems not to be recognizable in the extensive lists of aboriginal plants known to Hernandez. Moreover it seems not to be closely related to the American Pithecolobiums, and, like many other economic species, may have been introduced at an early date from the Philippines. It was originally described from specimens introduced from the Philippines into India, where it is extensively planted as a shade tree along roads, for hedges, and in waste places for firewood or for charcoal. In the drier regions of the western slope of Mexico the guaymochil is also extensively planted, and is said to maintain itself well even in localities with but 2 inches of annual rainfall. The fruits are here the first consideration, and are an article of commercial importance. According to Dr. Edward Palmer:

The fruit of the tree is much sought after as food. It is very prolific, and the white manna-like substance which adheres to the black seed is a favorite food with all classes, especially those who have consumption, who eat it with the strong conviction of obtaining relief. In Colima it is so abundant that it is sold for 1 cent a kilo. In Acapulco there is an ample supply of this fruit, and in spite of all the tropical fruits on the market it is a great favorite. It is surprising the quantity of fruit a tree growing in a desert region with not more than 2 inches of rain a season will produce, and it grows from the Tropics to the region where there is ice.

Dr. J. N. Rose has also described the fruit and its uses:

The fruits ripen toward the close of the dry season. At Guaymas and Mazatlan they ripen the last of May. The boys and men gather the pods by the basketful and sell them in the streets as bananas are sold in our own cities. The pods and seeds are largely sold in the markets. The latter are often put up in little cone-shaped wrappers, which with their contents are sold for a cent apiece. An old tree will produce many bushels of fruit, which is valued at the rate of $25 a tree. The pods are about 10 to 15 cm. long; when mature somewhat reddish or flesh-colored and irregularly swollen. After the seeds have fallen, the valves usually become strongly coiled. The part which is eaten is not the seed proper, but the large, fleshy aril, which almost completely surrounds and hides it, measuring 30 mm. (15 lines) long by 15 mm. (7 lines) thick. The aril is usually white, sometimes reddish, very crisp, sweetish, and very palatable.

The tree grows to a large size, reaching a height of 50 feet, with long, spreading branches and a trunk from 1 to 4 feet in diameter. The leaves are rather small and leathery and of a light-green color, and at the base of each leaf is a pair of spines. The flowers are yellow and resemble those of Acacia; when in blossom the tree is said to be a very attractive object. Both Dr. Palmer and Mr. Walter T. Swingle, who studied this tree in the neighborhood of Guaymas, have recommended it strongly for shade and ornamental purposes in southern California and similar places which, like the south side of Porto Rico, are deficient in moisture. That the fruits would be as highly valued among more civilized populations as in Mexico can scarcely be asserted, but it seems certain that they would find a use in any tropical country.

Pithecolobium montanum.

A tree native in the mountains of Java; according to van Gorkom this species has been recommended for coffee shade.

Pithecolobium polycephalum.

This species is recorded (Tropical Agriculturist, 1899, p. 134) as growing more rapidly than *Albizzia moluccana* in British India, and is therefore considered very promising as a coffee-shade tree. According to Index Kewensis, it is a native of the American tropics.

Pithecolobium saman. Saman. (See Pl. XVI.)

Synonym.—*Inga saman.*

Common names.—Algarrobo; Guango (Jamaica); Rain tree; Regen boom (Dutch Colonies); Saman (Trinidad and Spanish America); Zaman.

A large spreading tree, 15 to 20 meters high, planted for shade in yards and public grounds. The tree is inclined to be short and thick, while the branches are horizontal and extremely long. According to Stahl, the wood is not very hard, with the heart of a handsome red color, but on account of its lack of durability it is very little used. Lecomte, on the other hand, claims that the wood is hard and adapted to a variety of uses. The flowers appear in spring and summer; all the growing parts are slightly hairy.

This tree is sparingly introduced into Porto Rico, but, if the accounts of it are correct, it is worthy of much more general planting, as advised for Trinidad by Superintendent Hart, of the Royal Botanic Gardens of that island:

Probably there are few tropical trees which are so useful for a variety of purposes as the saman or zaman of Central America. In Jamaica this tree is known as the "guango;" in Trinidad, by its Spanish name of "zaman" or its corruption "saman." This tree is a native of Central America, from Nicaragua southward to Brazil. It is a large umbrageous tree belonging to the order Leguminosae or the pea family, many of which are noted for the property of accumulating or storing nitrogen in the soil. In Jamaica it is well known, and is grown for shading "Guinea-grass" fields. In Trinidad it has not the same good reputation for shade purposes, as its place is, in a manner, usurped by the quicker growing "*bois immortel.*"

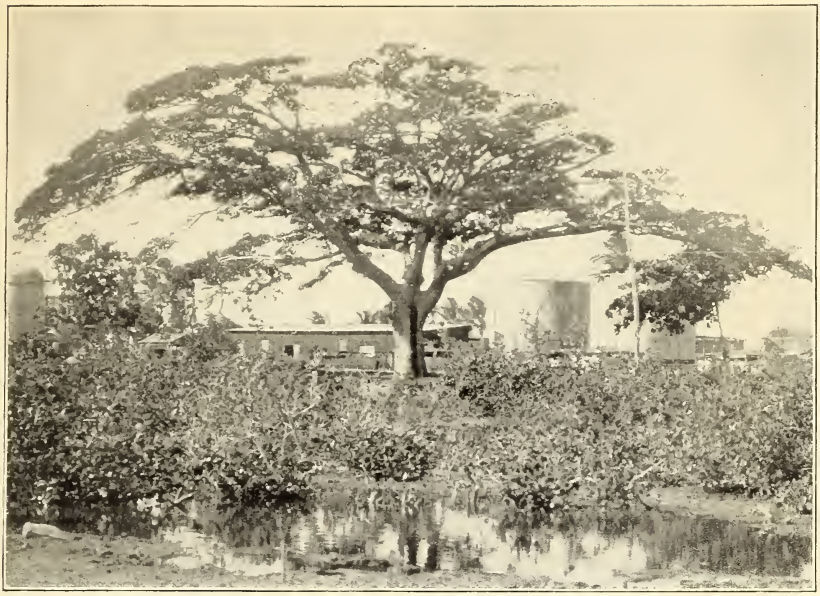

FIG. 1.—RAIN TREE (PITHECOLOBIUM SAMAN), ONE OF THE MOST DESIRABLE SHADE TREES.

FIG. 2.—LEAFLETS AND FLOWERS OF THE RAIN TREE.

[Natural size.]

There is some reason to doubt, however, the superiority of the latter over the former, and personally I am inclined to the belief that the claims of the saman are much higher from every standpoint. The tree can be seen in the botanic gardens shading nutmegs, cacao, coffee, tea, and other products to the greatest advantage; it is, besides, a tree less liable to fall and injure the plantation than the *bois immortel*, and being of the same family it possesses the power of becoming a real madre de cacao just as well as the *bois immortel* or *Erythrina*. For Guinea-grass pastures the tree gives a fine shade, and it is also an excellent one for planting in ordinary "low-bite" pasture, both for the benefit of the herbage and also as a shade for the cattle.

In Nicaragua the wood of this tree is used to make wheels for ox carts, solid sections being sawn through the trunk for the purpose. It gives a splendid dark-colored wood with excellent grain, which takes a fine polish. The legumes, or beans, as they fall from the tree are greedily eaten by cows and horses, although they are apt to give internal troubles of a minor character to the latter. Professor Harrison, of Demerara, who analyzed the pods, observed that the beans have about the same average composition as "carob" beans obtained from *Ceratonia siliqua*, but as the seeds of the saman invariably pass through the stomach of a cow without being digested, the food value of the seed must be eliminated to obtain the true value of the legume as a cattle food. I understand that Professor Harrison, who published the original analysis, will shortly complete it by a separate examination of the seed. Whatever may be the result, it is certain that the pods or beans are a very suitable food for milch cows, as is shown by the character of the milk afforded by animals fed regularly upon them. In some places *Pithecolobium saman* has obtained the name of "rain tree"—for what reason is not clearly apparent—but it is certain that much larger crops of Guinea grass can be grown under its shade than in the open. It is one of those trees in which, like some of the Mimosas, its leaflets are possessed of the power of movement and close together at sundown, thus allowing the dew to fall upon the crops beneath, while when the sun is high the foliage is spread out in a form which securely screens off its rays and protects the ground beneath from excessive evaporation. In the gardens we have large examples of these trees, planted, it is supposed, between the years 1818 and 1824, so that they are over seventy years of age, and are probably the finest in the West Indies. The spread of the branches of several of them reaches a diameter of considerably over 140 feet. For all purposes of shade, so necessary in a moist tropical climate, the saman is certainly an excellent tree, and it grows at a rate which would satisfy any but the most impatient. A tree with a trunk of 12 inches diameter can be grown in good soil in about ten years, and large enough to shade cacao and other shrubby trees in from four to five years.

In islands subject to cyclonic storms the tree suffers considerably owing to the great weight and size of the branches, but in Trinidad our trees have never suffered in this way, as we are fortunately outside the common cyclone or hurricane area.

The Porto Rican specimen shown in Pl. XVI stands near the oil refinery behind Cataño. The leaves are much smoother than those of another specimen collected by Sintenis between Manati and Arecibo, but the latter was in flower while ours had half-grown pods and the leaves may have become smoother with age. In any case our specimen seems to be exactly the same as another from St. Croix supposed to be saman. The pods are quite straight in both cases, and it is difficult to understand how a flat pod could become curved, as stated by Grisebach to be sometimes the case.

The present species has, according to Watt's Dictionary, been introduced in the neighborhood of Calcutta and in other parts of British India as an ornamental shade tree of quick growth. It is also in use in the Coorg district as shade for coffee plantations, for which purpose it has been especially recommended by Thwaites.

In Colombia, Saenz mentions the saman among the trees recommended for planting in coffee plantations at low elevations. The distance suggested is 10 meters, but the long horizontal branches would cover a much larger space. Alternate trees of this or some other species would need to be removed. Very recently further commendation for this species has come from the Philippine Islands, where it is considered by Señor Sanchez to be superior to *Gliricidia maculata*, *Erythrina ovalifolia*, and *E. indica*, the first of these being especially objectionable, the coffee apparently suffering by being alternately heavily shaded and then exposed to full sunlight and rendered specially liable to the attacks of a longicorn beetle. The following good points of *Pithecolobium saman* are enumerated: Rapid growth, attaining 15 meters in eight or nine years; horizontal branches 7 meters or more long; leaves evenly dis-

tributed, closing as soon as the sunshine disappears, which permits ventilation and the deposition of dew. A distance of 10 meters apart is also suggested by Sanchez.

Plantain. (See *Musa.*)

Pois doux (French Antilles). (See *Inga dulcis.*)

Pois doux (Guadeloupe). (See *Inga laurina.*)

Pois mascate. (See *Mucuna utilis.*)

Pomarosa (Spanish America). (See *Jambosa jambos.*)

Pomme-rose (French Islands). (See *Jambosa jambos.*)

Pongamia glabra.

SYNONYM.—*Galedupa maculata.*

COMMON NAME.—Balicbalic (Philippine Islands); Madrecacao (Philippine Islands).

Blanco does not state that this tree is planted for shade. Possibly it may have been called madrecacao because of its similarity to *Gliricidia maculata* (*Galedupa pungam*).

Poon sikat (Banda). (See *Albizzia moluccana.*)

Pito.

Mentioned by Yorba among the principal trees planted for coffee shade in Mexico.

Podocarpus.

A genus of coniferous trees with species native in the mountains of the American tropics, the Pacific islands, and the Malay region. Experiments made by Professor Nobbe (Die Landwirtschaftlichen Versuchsstationen, 51, 1898–99, p. 241) show that at least one of these, *P. chinensis*, is able to assimilate nitrogen by the aid of a symbiotic filamentous fungus affecting the roots. It is accordingly not impossible that this genus is worthy of attention in connection with coffee culture, particularly in regions where it is native.

Poplar.

According to the quotation given on page 18, a "poplar tree" is used for coffee shade in Arabia. Later writers have not referred to it.

Poro blanco.

Mentioned in a special bulletin on "Coffee in America," published by the Bureau of the American Republics, as a quick-growing tree planted for coffee shade in Costa Rica.

Pterocarpus marsupium.

COMMON NAME.—Honne (Coorg, India).

A leguminous forest tree left standing for shade in coffee plantations. (Cameron.)

Quelita (Nicaragua). (See *Jatropha multifida.*)

Rain tree. (See *Pithecolobium saman.*)

Rammon. (See *Trophis americana.*)

Red Cedar (British India). (See *Cedrela toona.*)

Regen boom (Dutch Colonies). (See *Pithecolobium saman.*)

Rice. (See *Oryza sativa.*)

Ricinus communis. CASTOR BEAN.

COMMON NAMES.—Higuerilla (Mexico); Palma Christi.

Used in Mexico as temporary shade, and generally replaced by woody trees as soon as these have had time to grow. It is generally considered less desirable than the banana, and is also thought to exhaust the soil rapidly. If its use is desirable at all, it is likely to prove valuable only in dry regions where shade is a necessity and where slow-growing leguminous trees are to be employed. The marketing of the beans and the local extraction of the oil are also to be considered in connection with any extensive enterprise. In Brazil some of the larger plantations are equipped with facilities for making from castor beans illuminating gas for lighting the buildings in which the coffee is dried and prepared for market. The apparatus for distilling the beans, together with the pipes and other equipment for 50 burners, was given in 1885 as about $1,600.

Rose-apple. (See *Jambosa jambos.*)

Rosewood (British India). (See *Dalbergia latifolia.*)

Roucou (Carib). (See *Bixa orellana.*)

Roway (Java). (See *Arachis hypogaea.*)

Rubber (Ceara). (See *Manihot glaziovii.*)

Rubber (Central America). (See *Castilloa elastica.*)

Rubber (Para). (See *Hevea brasiliensis.*)

Saccharum officinarum. SUGAR CANE.

Sugar cane is sometimes planted in Mexico between the newly set coffee seedlings. It doubtless furnishes shade in the same way as maize, but further advantages of the arrangement are not evident and it is not known that it is used on a large scale.

Saman (Spanish America). (See *Pithecolobium saman.*)

Sand-box tree. (See *Hura crepitans.*)

Sau (Ceylon). (See *Albizzia stipulata.*)

Savonette (Trinidad). (See *Lonchocarpus.*)

Schizolobium excelsum.

A Brazilian leguminous tree mentioned by Raoul as used for forest planting in the East Indies; also recommended for coffee shade. It is capable of extremely rapid growth, becoming a tree of considerable size in eighteen months. This extraordinary development is said to take place, however, only in soils to which it is particularly adapted, which may mean that it must be planted where the tubercle-forming bacteria are present under conditions favorable to them.

Sengon (Java). (See *Albizzia stipulata.*)

Sengoon laoot (Malay). (See *Albizzia moluccana.*)

Sengon yora (Malay). (See *Albizzia stipulata.*)

Serap.

According to Lock, a name applied in Java to a variety of the dadap (Erythrina).

Serrana. (See *Madre serrana.*)

Sesbania grandiflora. (See *Agati grandiflora.*)

Silk cotton tree. (See *Ceiba pentandra.*)

Siris (British India). (See *Albizzia lebbek.*)

Soja (or Soy) bean. (See *Soja hispida.*)

Soja hispida. SOJA BEAN OR SOY BEAN.

The planting of the soja bean as a green manure for coffee is suggested by Lecomte.

Sorghum. (See *Andropogon sorghum.*)

Spanish Cedar. (See *Cedrela odorata.*)

Spondias dulcis. OTAHEITE APPLE.

A tree native in Polynesia, bearing an edible fruit having the flavor of pineapple. It is now cultivated in many tropical countries and is among those recommended by Morris for planting as windbreaks for cacao plantations in Jamaica.

Spondias graveolens. (See *Spondius lutea.*)

Spondias lutea.

SYNONYM.—*Spondias graveolens.*

COMMON NAMES.—Hog-plum; Jobo.

Family Anacardiaceae. One of the most common trees in Porto Rico, planted extensively for shade and for the sake of its edible fruits. It grows readily from large cuttings, and, with *Bursera simaruba*, the "almacigo," is preferred for stakes and fence posts, which are permanent because they take root and remain alive. This would render very easy the planting of shade trees by cuttings. The fruits are oval and attain a length of 1½ inches. The skin is very thin and incloses a pleasantly acid pulp surrounding a nut-like seed. The tree attains a height of 40 feet or more and a diameter of from 1 to 2 feet, but the wood is light and soft (specific gravity 0.457), and is very little used except in the way explained above. The fruits of this species are yellow and are said to be inferior to those of *Spondias purpurea.* "Hog-plum" is a Jamaica name and does not, as might appear, involve any reflection on the quality of the fruit, but refers to the fact that hogs are extremely fond of the "plums," on which they fatten rapidly.

The use of this tree for shade in cacao plantations in Jamaica was suggested by Dr. Morris, but it is not known whether the experiment has proved successful. It is used for coffee shade in the recently established plantations of the German colony of Kamerun. (Froehner.)

Sponia wightii. (See *Trema orientalis.*)

Sugar cane. (See *Saccharum officinarum.*)

Surian (Java). (See *Cedrela odorata.*)

Swietenia mahagoni. MAHOGANY.

COMMON NAMES.—Acajou de Saint Domingue (Guadeloupe); Mahogani (Guadeloupe).

Family Meliaceae. This is the tree yielding the original West Indian or Spanish mahogany, as well as that of the mainland of Central and South America. It has been used for shade in cacao plantations in the island of Guadeloupe, and according to Guerin is preferable to *Erythrina indica*, since it resists parasites, and the wood is valuable after thirty or forty years. In Trinidad the planting of mahogany under forest conditions has been advocated by Superintendent Hart, of the Botanical Gardens, who finds that under favorable conditions the annual average increase of thick-

ness in the trunk is about 1 inch, and even in trees 60 years old or over is about nine-tenths of an inch.

The planting of mahogany with cacao or coffee is, however, of doubtful advisability, since for best results in timber the mahogany trees should be planted close enough together to cover the ground from an early period, 10 feet apart, to be thinned later to 40 feet, being the suggested figures. Otherwise growth will be slow, particularly in height, so that if set far enough apart to enable coffee to be cultivated to advantage the value of the timber would not be great. Morris recommends mahogany for windbreaks for cacao plantations in Jamaica.

Tamarind. (See *Tamarindus indica.*)

Tamarindus indica. TAMARIND.

The tamarind is given by Lecomte as one of the trees used for shading coffee in Arabia. Being a member of the Leguminosae, it may be worthy of consideration, particularly if proper methods of utilizing the fruit can be worked out. As a shade tree for general purposes the tamarind will probably not be found desirable. The foliage, though fine and delicate, is too dense, and the shadow too dark. Moreover, little or nothing in the way of minor vegetation is usually to be found under tamarind trees, and in some countries they are thought to give off unwholesome acid exhalations injurious to those who may sleep under them, or even to the cloth of tents pitched in their vicinity. The tamarind is planted very commonly in Porto Rico and other tropical countries for the sake of the fleshy edible pods, which have a pleasant, decidedly sour taste, due to the presence of several vegetable acids, including citric and tartaric. According to the Treasury of Botany, the tamarinds of the East differ from those of Porto Rico and the other West Indies in that the pods have a brittle brown shell and contain from 6 to 12 seeds instead of from 1 to 4. Considerable quantities of tamarinds are imported into Europe and America, either dried or preserved in sirup. They are largely used in the preparation of acid cooling drinks, and are believed to have a beneficial laxative effect. In British India and elsewhere a large variety of other medicinal qualities are claimed for the tamarind as an ingredient of preserves, confections, and popular remedies, proprietary and otherwise, but these claims do not seem to have been either verified or refuted by investigation.

Tannia (French West Indies). (See *Colocasia esculenta.*)

Tannier (Trinidad). (*Colocasia esculenta.*)

Tare (Coorg, India). (See *Terminalia belerica.*)

Taro (Polynesia). (See *Colocasia esculenta.*)

Tayaux. (See *Colocasia esculenta.*)

Teak. (See *Tectona grandis.*)

Tectona grandis. TEAK.

Family Verbenaceae. According to Raoul, this tree has the same disadvantage as *Cedrela toona.*

Terminalia belerica.

COMMON NAME.—Tare (Coorg, India).

Family Combretaceae. A forest tree left standing for shade in coffee plantations. (Cameron.)

Terminalia latifolia.

COMMON NAME.—Broad-leaf.

Recommended in Jamaica for windbreaks about cacao plantations.

Theobroma cacao. Cacao.

Cacao is recorded by Lock as having been planted for coffee shade in Ceylon, though evidently in plantations already started, since the coffee is said to have shaded the cacao at first and to have been shaded in turn after the cacao had grown large. Outside the assistance rendered by the cacao in keeping down the weeds, the mutual benefit, if any, is probably to be explained by the more complete shading of the ground desirable at the low elevation at which cacao would flourish. With this fact in mind it is apparently not impossible that a mixed culture like the present would succeed better than thick planting of one crop, particularly if the two plants differed in what they required from the soil.

Tobacco. (See *Nicotiana tabacum.*)

Trema orientalis.

Synonym.—*Sponia wightii.*

Common names.—Charcoal tree (British India); Indian nettle tree (British India).

Much used in India for coffee shade, but said by Raoul to be objectionable in many ways not specified. A quick-growing, small tree yielding a bast fiber used for cordage and even for coarse cloth. The wood is soft and is preferred for charcoal which is to be used in gunpowder. The species occurs abundantly from the Himalayas to Ceylon and Singapore, and frequently appears spontaneously in forest clearings. It was formerly thought to belong to the Urtdicaceae or nettle family, but is now reckoned as a member of the Ulmaceae or elm family.

Trophis americana.

Common name.—Ramoon.

Recommended in Jamaica by Dr. Morris for windbreaks about cacao plantations. The foliage is said to be of use as food for cattle.

Ule (Mexico). (See *Castilloa elastica.*)

Upas tree. (See *Antiaris toxicaria*).

Vanilla.

The combination of the culture of vanilla with that of coffee is one of the more or less impracticable propositions often advanced by those who are anxious to enlarge the apparent possibilities of tropical agriculture. Even if the cultural requirements of the plants did not conflict, the climatic necessities would render it unwise to attempt to bring the Arabian coffee and vanilla together, since the latter requires an extremely warm and much more humid atmosphere than coffee will bear with advantage. The coffee trees are also not at all suitable for support for the vanilla. The latter might possibly be grown to advantage on the shade trees of low-lying plantations. The practicability of combining vanilla culture with that of Liberian coffee might also be worth while to investigate.

Velvet bean. (See *Mucuna utilis.*)

Vigna catjang. Cowpea.

The cowpea might be found useful in some coffee regions, though in truly tropical conditions it will probably be found that, as in our Gulf States, the velvet bean is preferable.

Voandzeia subterranea.

A leguminous plant closely similar to the peanut and often confused with it; recommended by Lecomte as a soiling crop with coffee.

Walnut (English). (See *Juglans regia.*)

Waroë.

A malvaceous tree mentioned by Lecomte as preferred in Java for windbreaks.

Warŭ.

According to Lock, a name applied in Java to a variety of the Dadap (Erythrina).

West Indian Cedar. (See *Cedrela odorata.*)

Wild jak. (See *Artocarpus hirsuta.*)

Xanthosoma sagittifolium.

COMMON NAME.—Malanga.

A large aroid cultivated in the French West Indies and occasionally used for shading young coffee trees.

Yam. (See *Dioscorea.*)

Yam bean. (See *Pachyrhizus.*)

Yautia (Porto Rico). (See *Colocasia esculenta.*)

Yuca (Spanish America). (See *Manihot utilissimum.*)

Zaman. (See *Pithecolobium saman.*)

Zea mays. MAIZE.

COMMON NAMES.—Indian corn; Mais (Spanish).

Indian corn is often planted with coffee or shortly before the seedlings are transplanted. Its rapid growth enables it to furnish shade even before the newly set banana plants can put forth leaves. The bananas are also planted between the rows of corn, which they replace when the latter is harvested. If, as generally believed, the corn does not compete to the disadvantage of the coffee, this suggestion may be of value in some localities where transplanting is not done in a rainy season of sufficiently constant humidity to make temporary protection unnecessary.

In Natal corn has proved to be a very satisfactory catch crop when "planted thinly in rows, three rows, 18 inches apart, between the rows of coffee, and two plants in the coffee rows between each pair of coffee plants." The cultivation necessary for the corn is beneficial to the young coffee, which reduces but little the size of the corn crop. The fertility taken from the soil by the corn should, however, be returned in the form of manure.

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