taken to avoid breathing or swallowing it.

ALTHOUGH monocalcium arsenite preparation does not materially injure the principal apricot varieties or the Santa Rosa and Wickson plums, it injures all almonds and some prunes. Consequently less injurious eradicative fungicides have been sought. Of about 75 other compounds that were tested, the sodium salts of the chlorophenols (particularly pentachlorophenol) eliminated the conidia most effectively. Sodium pentachlorophenate is destructive to the conidia present on the twigs when it is applied but is not highly effective in preventing their further development. Being very soluble, moreover, it is sometimes washed from the twigs by rain before its maximum effect on the conidia has been exerted. Under proper conditions, however, it destroys much of the conidial inoculum. That in turn results in a significant decrease in the amount of blossom infection. Neither the eradicative nor the protective treatment alone satisfactorily controls the disease under all conditions. A combined eradicative-protective program is much more effective.

The protective fungicides most widely used against the disease in California are the copper-containing materials, bordeaux mixture and the fixed coppers. Sulfur fungicides, although relatively effective under favorable conditions, cannot be used on apricots because of the "sulfur sickness" they produce in the tree. The newer types of fungicides, many of which are complex organic compounds, are being tested. Some show promise, but further tests are needed to evaluate their effectiveness.

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Mr. Dunegan's discussion of peach brown rot appears on page 684.

Some Important Diseases of Coffee

Frederick L. Wellman

It has been commonly said that coffee (*Coffea arabica*) is a tree practically free from disease. Actually, the coffee plant is subject to more than 40 diseases—ailments due to lack of minor elements, virus troubles, mild bacterial infections of roots and fruits, and attacks by fungi and parasitic flowering plants. A century of effort has been expended on agronomic and horticultural problems in coffee, but only in the past 50 years has intensive work been done on its diseases.

In 1952 the Office of Foreign Agricultural Relations (now the Foreign Agricultural Service) of the Department of Agriculture sent a mission to study coffee diseases in all parts of the world. The mission was sponsored by the Point IV program and financed by the Institute of Inter-American Affairs. Information gathered on the trip has been incorporated into this chapter, which is based primarily on study and experience in Latin America.

COFFEE RUST, also called the oriental leaf disease, is by all odds the most serious disease of coffee. It does not occur in the Western Hemisphere, maybe just by pure luck. There are two species of rust: The classic *Hemileia vastatrix*, which is so destructive and is found in most of the coffee regions of Africa, the Near East, India, Asia, and the Pacific Islands, and *H. coffeicola*, an equally dangerous rust but still confined to the Cameroons of West

Africa and the nearby island of São Tomé. This discussion deals with the first species.

Ceylon, once one of the world's greatest coffee-producing countries, has had to become an exporter of tea when its coffee crops failed because of rust. The disease was first discovered in Ceylon in 1867. Between 1879 and 1893, after it had become well established, exports of coffee dropped to less than 7 percent of former shipments. In the Philippines in 1891 rust cut the harvest 35 percent. In Java, too, rust practically wiped out the coffee plantations, and the planters turned to hevea rubber as a substitute crop.

The first symptoms are small, yellowish, translucent, oily spots on the leaves. They expand into rather large, round spots and early show a powdery coating of spores on the under surface. As the spores mature, the spots gradually turn bright orange to red. With age the lesions become brown and surrounded with a yellow rusted band. Defoliation occurs to such an extent that many trees retain only two or three pairs of leaves on their branches where they might ordinarily have 15 or 20. Such affected trees are stunted, cannot produce, and usually die after a few years.

The disease was not present in 1953 in the Western Hemisphere. It was brought to Puerto Rico in 1903 but prompt and drastic action by O. W. Barrett, the horticulturist there who also dealt with pathology, destroyed all diseased material. He saved untold wealth for the coffee industry in the American Tropics and for centers of world trade.

In some eastern countries, notably the French Cameroon, Kenya, and Tanganyika in Africa, and in the states of Mysore and Coorg and in the Nilgiri Hills of southern India, growers control the rust by two or three annual spray applications of bordeaux mixture. The sprays are put on just before the heavy monsoon rains begin and again in the short dry spell that intervenes before the light monsoon rains fall. Sometimes a third spray is used after the light rains end. In countries that have extremely dry seasons, few rust spores are produced in these periods. Likewise little new leaf surface is developed by the coffee trees. When rains begin, both the parasite and the coffee take on new life, but by well-timed sprays the planters plan to keep about 70 percent of their coffee foliage free from rust infections.

Where the seasons are not so well defined, such as in Ceylon, Java, Malaya, and the Philippines, weekly or monthly sprayings are needed to control rust. They increase tremendously the cost of growing coffee. Some plantations in some of those countries have been moved to high altitudes, where cool temperatures reduce the inherent producing capacity of the coffee tree but do permit it to grow with less trouble from the rust.

Spores of the rust are long-lived, withstand drying and other vicissitudes, and may be easily transported on live plants or as invisible dust from one country to another. Quarantines have been instituted, and many research workers in the western Tropics have repeated warnings of the danger. All varieties of coffee grown commercially in the Americas are highly susceptible to *Hemileia*. Increasing transportation between East and West by air as well as by sea multiply the hazards of reintroducing the disease and establishing it this time on western shores.

For more than a half century it has been known that highly tolerant and rust-resistant types of coffee exist. Those better strains, one after another, have been brought to afflicted areas in the Orient. There, at first, they were grown with success, only to succumb later to the rust. Beginning some 30 years ago intensive study was devoted to the phenomenon in India. It was learned that the rust, like others, had biologic races, which attacked new coffee varieties that had been selected for their resistance to the old populations of rust. Moreover, the races were prob-

ably the result of mutations, as no one has ever been able to discover an alternate host relationship, which ordinarily is fruitful in producing new races of rust.

Coffee breeders have been able to secure trees with enough resistance in them to be—in time—the basis for developing improved and acceptable coffee types that will grow well in the presence of rust. Through the work of the mission that studied the rust in the Eastern Hemisphere, seeds from all the rust-resistant coffees, and many more, have been obtained for growing in the Americas. After careful disinfection and other prophylactic measures to assure freedom from all diseases and insects, these new coffees are now growing in the Western Hemisphere. They are insurance against the time that the rust comes to this part of the world—if it does.

THE AMERICAN LEAF SPOT is recognized as the most serious disease of coffee in the Occident. It was discovered and studied by N. Saenz in Colombia in 1876. He sent herbarium species from Colombia and Costa Rica to Europe for identification. The causal fungus, *Mycena citricolor* (*Omphalia flavida*), is an inhabitant of wet mountains and woodlands and has a phenomenally wide range of wild hosts, from which it has spread to coffee. Its attack has been particularly severe because coffee culture has been concentrated in cool, moist mountain regions. It may cause losses of 75 percent or more of the crop in some districts. In Costa Rica it takes an annual toll of about 20 percent of the crop. It occurs in all leading coffee countries of the Americas.

The first symptom is a small, dark area on a leaf. In the center of the spot is a yellow infection body. The tiny lesion grows into a round, grayish spot. On the spot are produced a number of fine, yellowish, hairlike stalks, which at one time are tipped with a large, pear-shaped fruiting body. The infection body is not always present in field material but is large enough to be seen with the unaided eye. It is readily detached by water and carried by splashing droplets of rain—practically the only means of distribution. The disease progresses slowly in coffee plantations. Wide roadways, rows of closely set banana plants, thick hedges of old shade trees, and narrow fields of annual crops are barriers against its movement. Rarely in nature does the fungus produce the characteristic brilliant-yellow, miniature mushrooms. They bear few spores. Some bear none at all.

The large infection bodies carry the disease from plant to plant. They cause excessive defoliation and fruit drop. They also attack flowers and green stems and produce lesions on fruits. The trees finally die if serious infection continues. Because the fungus has a comparatively narrow temperature range, the disease is more severe in cool highland areas and does not occur in warm places at low altitudes. It grows fairly well under conditions as cool as 54° F.; well at 61° to 75°, reaching an optimum at 75°; and poorly at 83°. At 86° to 90° it stops growing.

The disease thus far is confined to the Americas. With care it can probably be kept from spreading to the oriental Tropics. The disease can be restrained somewhat in countries of its origin if the coffee is grown at warm, low altitudes, and if the dense protecting shade trees are thinned by severe pruning.

Spraying with bordeaux mixture has been recommended. Tests of other fungicides have been started. It is ordinarily considered that costs of materials, employment of untrained labor, and difficulties of terrain make adequate and regular spray applications practically impossible.

Several years of research under Point IV in cooperative stations by the Office of Foreign Agricultural Relations have resulted in developing a control that does not employ spray methods but is accomplished by removing leaves. During the first 2 weeks of the rainy season, diseased trees are stripped of

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all leaves, flowers, and fruits, which fall to the ground, carrying the inoculum with them. There the fungus is destroyed by natural means—by insects, slugs, and bacterial action—before the 6 weeks elapse that are required for new leaves to appear on the denuded trees. The current crop is sacrificed, of course, but the larger harvests in the following years compensate for the destruction of the one poor crop. If careful watch is maintained and reinfected trees are defoliated as soon as they are found in the old treated area, the disease apparently may be kept in check indefinitely.

DIEBACK, or anthracnose, caused by the fungus *Colletotrichum coffeanum*, is common in all countries where coffee is grown. It apparently causes injuries at irregular times to seedlings in the seedbed and nursery, to old bearing trees, and to new supplies transplanted in the field. In the places where it has been studied, the fungus has been found to be present on all trees. Losses are hard to measure, because the disease is still not well understood, but the trouble doubtless cuts substantially into profits year after year.

First symptoms of anthracnose are the dark lesions, usually large, which appear on seedling leaves. On weakened or older plants leaf lesions of anthracnose often spread into the stem tissues to which the leaves are attached. Those parts are killed, and the blackened dieback spreads down into branches and stems. When conditions of moisture and temperature favor the disease, it produces profuse masses of sticky spores. The spores are spread by rains, insects, and other means. A variable interval elapses between the period of inoculation with fungus spores and the visible appearance of disease symptoms. Latent infections, which involve the presence of the organism in apparently healthy plants, may therefore occur. Intensive dieback of stems often is found that is unrelated to *Colletotrichum* infection under conditions adverse to tree growth. In Africa and India dieback is often due to plant exhaustion, following heavy crops. That is true also to some extent in tropical America. Instances are encountered in which the condition known as dieback results as a complex of both widespread infection by the causal fungus and from unfavorable growth conditions or physiological disturbances of infected plants.

The infective dieback disease appears to be more common during the warm, dry season, for the optimum temperature for growth of the *Colletotrichum* is about 83° F. It grows at temperatures up to 90° but is inhibited at 97°. Fair development occurs at a temperature as low as 61°.

Anthracnose alone or with accompanying dieback apparently may occur in all regions where coffee can grow. No wholly satisfactory control is known for it. The fact that dead branches are replaced by new growth tends to allay the fears of growers or pathologists and means that interest lags in developing intensive control measures.

Disease-resistant strains are badly needed. Varieties of coffee have been found in east and central Africa that are highly tolerant to anthracnose dieback. They are being tested in Africa and have been introduced into Latin America for further study. It seems that the use of resistant plants is a promising way to combat it.

Cooperative projects have been started to study spray treatments in Costa Rica. Of several fungicides tested, Fermate was found to be best to keep seedbed and nursery plants free from anthracnose. It also keeps young field transplants free from infective dieback until they are well established in the plantation.

THE COFFEE BERRY DISEASE is a comparatively new disease of coffee. It has been found in Africa, the Belgian Congo, and Kenya. It has apparently increased in severity in the past few years. It is due to a specialized race of the anthracnose organism, *Colletotrichum coffeanum* var. *virulans*, that is pecu-

liarly adapted to infecting fruits. The first symptoms are small, brownish spots, which become glazed, enlarge, and finally get a pinkish color. It is common on coffee grown at higher elevations, where as much as 50 percent of a crop may be destroyed. Its life history is not wholly understood.

Considerable work has been done on methods of control since 1950. The use of sprays has been studied but has given no results of practical value. Some varieties are more resistant than others. Research workers hope to breed varieties of higher degrees of resistance and to introduce that resistance into the regular commercial lines of coffee in the severely diseased regions.

THE THREAD BLIGHT DISEASE, also known as black rot in the Orient is reported in many countries in both hemispheres. Often it is localized in occurrence, but it can cause considerable losses. This is especially true in parts of south India, central Costa Rica, and like regions. It weakens trees and intensifies colletotrichum dieback.

This tropical fungus—*Pellicularia koleroga*—occurs in moist regions and is one of a typical group of thread producers. It occurs in part as thick, traveling threads, tightly glued along the under sides of branches. A thread that reaches a leaf petiole sends out a side shoot to follow it. A broad, tissuelike pellicle is formed on the under side of the leaf by fanlike growths of the fungus hyphae. During this period of apparently superficial attack, the fungus can be torn from the host surfaces, but affected leaves darken, wither, and die.

If the fungus is left undisturbed, petioles of diseased leaves are loosened from branches but are held attached by fungus strings, which permit the leaves to hang swinging in the air like small, black rags. When moist weather comes, the surface of the fungus pellicle on under parts of leaves becomes powdery with spore-bearing bodies.

No thorough study has been made of the temperatures at which sporulation occurs, but vegetative growth of the fungus is good at temperatures ranging from 75° F. to 90°, with greatest development at 83°. It grows poorly at 54° and is completely inhibited at 97°. Much research remains to be done on this parasite and its life history.

Different changes in plantation culture have been tried in order to combat the disease. Clean culture, fertilizing, variations in shade, and defoliation methods have had little effect. It was quickly eliminated in Africa and eastern lands where bordeaux spray was applied to control rust. After many years without black rot, as rust-resistant varieties have been introduced in parts of India and coffee has not been sprayed for rust control, thread blight has again returned with serious consequences. Spraying of individual trees with bordeaux mixture in Central America has given good results. The newer copper sprays have been found to be of equal value. The copper compounds often are injurious to coffee foliage, but that disadvantage is outweighed by the effectiveness of the compound against thread blight.

FRUIT SPOT, or brown eye leaf spot, is a bothersome, common, fruit- and leaf-spotting disease. Its causal organism was named *Cercospora coffeicola* in 1881. It is found on coffee the world over but is not severe in much of the Orient. It is of greater economic importance in Latin America than is ordinarily admitted. Defoliation actually is one of its worst effects. It produces severe decay on the fruit.

Fruit infections result in a characteristic black dry rot. The pathogen is seed-borne. The leaf spots are large; usually only a few occur on a leaf, although one on a leaf is often enough to cause it to drop. The spots have been confused with the American leaf spot, but they are quite different. Cercospora spots have wide brown edges and a light center, with black specks. The disease seems to occur under a wide range of conditions and may be especially severe in nurseries. It grows

fairly well even at temperatures less than 54° F. and is relatively good in growth from 61° to 90°. The greatest growth is at 75° to 83°. It grows weakly at 97°. The disease is more severe in coffee exposed to the sun than in well-shaded coffee.

A common and sound way of reducing the disease is to develop a canopy of shade over the plantation. Proper attention to soil protection and adequate moisture content seem to have good effects. No effective fungicide has been found.

ROSELLINIA ROOT ROT is one of several root rots to which coffee is susceptible. The fungus that causes the most trouble is *Rosellinia bunodes*, which is found in both hemispheres. Compared with some of the serious leaf parasites, this disease causes almost negligible losses, but the death of occasional trees may cause so much concern among growers that they attach greater importance to the disease than actual economic losses justify.

The planter first notices a diseased tree by its slightly yellowed and grayish-green leaves, which soon wilt and turn black when the tree dies. The base of the trunk of such a tree usually has bark that is slightly roughened just above the ground and is tightly appressed to the wood below. Dead roots that have been dead long enough are dark, with a hairy, black growth under the bark—a condition that extends up the tree trunk. The bark in those parts has black spots and streaks in the wood. Usually when one tree dies the one next to it will succumb somewhat later.

The cause is an apparently weak-growing fungus, whose growth habits provide a key to control measures. Diseased areas may be isolated by digging a trench around them and throwing the soil that is dug from the trench in towards the disease center. Some planters do not follow this practice but simply replant. Replanting is done even in trenched-in areas. As trees die, it is best to dig them immediately and remove all large roots from the soil. A wide, deep hole should be left open for 6 or 12 months. Afterwards it may be filled in and replanted with a healthy seedling, which often grows without contracting the disease. At times, however, that treatment fails, and digging must be repeated, with a longer interval between removal of the diseased seedling and replanting with a new seedling. In regions where the disease is believed to be common, jungle land is cleared for coffee with unusual care to remove stumps and large roots of wild trees. Corn or another crop is grown on the land for 2 years before it is made into coffee plantings. The practice seems to help against early infections of rosellinia root rot.

THERE ARE several other root-attacking fungi—other species of *Rosellinia* and species of *Fomes*, *Pellicularia*, and *Ganoderma*. They all cause much the same symptoms as described for *Rosellinia bunodes*. Another root rot, *Armillaria mellea*, as it occurs in Tanganyika causes a curious splitting of roots, trunks, and larger stems, and leaves the bark hanging more or less loose in strips. All root rots are handled as *Rosellinia* is.

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