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About the Institute
The Hunt Institute for Botanical Documentation, a research division of Carnegie Mellon University, specializes in the history of botany and all aspects of plant science and serves the international scientific community through research and documentation. To this end, the Institute acquires and maintains authoritative collections of books, plant images, manuscripts, portraits and data files, and provides publications and other modes of information service. The Institute meets the reference needs of botanists, biologists, historians, conservationists, librarians, bibliographers and the public at large, especially those concerned with any aspect of the North American flora.

Hunt Institute was dedicated in 1961 as the Rachel McMasters Miller Hunt Botanical Library, an international center for bibliographical research and service in the interests of botany and horticulture, as well as a center for the study of all aspects of the history of the plant sciences. By 1971 the Library's activities had so diversified that the name was changed to Hunt Institute for Botanical Documentation. Growth in collections and research projects led to the establishment of four programmatic departments: Archives, Art, Bibliography and the Library.

THE GUAVAS, AND THEIR RELATIVES

The Myrtle family (Myrtaceae) includes many important economic plants, widely scattered over the world, among them being spices such as cloves and allspice. Pomologically, the guavas are the most important tropical members of the family, but there are many other fruits which are of minor interest. The rose-apple, Syzygium jambos, from the East Indies, has become naturalised in many parts of the tropics. It is a handsome tree with flowers made conspicuous by tufts of long stamens, but the round, yellow, rose-scented fruits, sometimes as much as two inches in diameter, are not highly esteemed. The Malay-apple, Syzygium malaccense, is another beautiful tree, strictly tropical in its requirements, the fruits of which are not good enough to merit serious horticultural attention, though they appear in the markets of the East Indies and occasionally in those of tropical America.

Brazil is the home of many genera and species, most of which are not commonly considered worthy of cultivation except by enthusiasts who like all sorts of rare or strange fruits. Some of them may eventually be improved through selection and vegetative propagation. The pitomba is perhaps one of the most promising. This handsome shrub, Eugenia luschnathiana, produces pear-shaped, orange-colored fruits an inch or more in length, by most people considered too pungent to be eaten out of hand. Early in this century the so-called pineapple guava, Feijoa sellowiana, attracted attention as a commercial possibility. It is a handsome shrub, hardier than the orange, which produces an abundance of yellowish green fruits the size of an egg, acidulous but lacking a pronounced flavor. In some regions it has not borne well, but has found popular acceptance as a hedge or border plant. Several named varieties have originated in California, but have not been exten-

sively planted.

THE COMMON GUAVA

This useful plant, Psidium guajava, is a native of tropical America, perhaps originally Brazil, the home of so many myrtaceous fruits, but wild or naturalised in many parts of the continent at the time of the Discovery. Carried to India at an early day, many thousands of acres are devoted to its cultivation in that country; in tropical America it sometimes becomes a pest in pasture lands. Never-the-less, there is room for its development on a horticultural basis, through selection and hybridization. ~~Excellent work has already been done along these lines, especially in Florida.~~

The common guava is an evergreen shrub or small tree, ~~commonly~~ 15 to 20 feet high. The fruits may be eaten out of hand, but more frequently ~~commonly~~ are used for making guava jelly, which has a flavor all it own and is highly popular. Eaten with cream cheese, it is a favorite dessert in many parts of tropical America. A somewhat similar product, guava paste, also is popular; guava shells, as they are called, are halved fruits cooked in heavy syrup after the seeds have been removed. Canned guava juice, to which sugar and water ~~are~~ have been added, is known as guava nectar. The vitamin C content of guavas is noteworthy, ranging in different seedling forms, or varieties, from the low value of 20 to the very high one of 1100 mg. in 100 grams. (Orange juice has about 50 mg. in 100 grams). Red-fleshed guava fruits may contain up to 5000 I.U. of vitamin A.

Climate and Soil

Like most tropical trees, guavas are easily damaged by frost, but sprout back readily from the roots. They thrive in warm, ~~rainy~~ moist climates, but endure drought and heat remarkably well. Fruiting is usually poor under arid conditions unless irrigation is provided. Elevations up to 3000 feet seem most suitable, but guavas can be grown successfully right up to the frost line. A wide range of soil types is satisfactory, including light sands and fairly compact clays. Even poor drainage is tolerated, though fruiting is less prolific on well drained soils. From these remarks it will

not seem strange that the common guava is so universally grown (and often naturalized) in the tropical and subtropical world, under many different climatic conditions and on a wide range of soils.

Varieties

Possibilities of selection are great because of the variation in fruit characters commonly shown by seedlings. Fruit size is commonly 2 to 3 ozs., but may range from 1 oz. to a pound; the shape may be round, oval, pyriform or oblate. Skin color of mature guavas ranges from pale green through light yellow; flesh color may be white, pink, salmon, orange, or red. Sugar content does not seem to vary greatly from 4 or 5%, while acidity ranges from 1/2 to 1-1/2% in selected seedlings. The vast majority of guava trees in the world are seedlings, though in recent years superior forms have been given names and propagated vegetatively in a few regions. Unfortunately, not many of these are offered by nurserymen, ~~due to lack of demand~~. Probably best known in tropical America (though not yet cultivated as widely as they deserve to be) are some of the selections made in Florida by George D. Ruehle, of which three are here described:

Red Indian. Fruit nearly round, weight 4 to 5 ozs., skin yellow, often with a faint pink tinge; flesh bright red, flavor sweet and mild, quality very good; odor intense. The seed cavity is rather large and not easily separated from the side walls, which are 3/8 in. or less in thickness. Vitamin C content about 200 mg. in 100 gms. Foliage rather subject to alga spotting.

Ruby. Fruit ovoid, usually 6 to 8 ozs., skin greenish yellow, often with faint pink blush. Flesh bright red, flavor sweet and mild, quality

very good. Odor intense. Seed cavity rather small, easily separated from the side walls, which are 1/2 inch thick. Foliage rather subject to alga spotting.

Supreme. Fruit ovoid to pyriform, usually 6 to 10 ozs. in weight, skin greenish to light yellow, flesh white, flavor subacid and mild, quality good, odor mild. Seed walls as in Ruby. Vitamin C content about 250 mg. in 100 gms. Foliage resistant to alga spotting.

Propagation

As noted above, most guava trees are seedlings, but the species is heterozygous and these may show great variation, ~~though not always so.~~ Up to recent years, vegetative propagation was considered difficult, since stem cuttings do not root easily and shield-budding was rarely successful. There are several methods of vegetative propagation, however, which have been found to give satisfactory results.

Marcottage (air-layering) is not difficult, and is recommended for securing a few plants of a clone, though it is too laborious if large numbers of plants are wanted. Veneer-grafting on pencil-size seedling stocks is one of the best nursery methods. Terminal growth flushes with bark still green, and well developed axillary buds, will often provide several scions. Frequently one of the buds at a node is better than the other. In this case only the stronger should be used, but if both are equally good, the twig can be split to make two scions. These may be 1-1/2 to 2 in. long. The completed graft is wrapped with plastic tape or rubber strips, leaving only the "eye" exposed. In about three weeks the stock should be lopped, to stimulate bud growth, and after another three weeks or so, the wrapping should be removed.

Patch-budding has also been used successfully, both the usual type and the modified Forkert, preferably on rootstocks about 1 inch in diameter. Scions should be of the same thickness. The seated patch of bud and bark is conveniently held in place by a somewhat larger patch of vinyl plastic, tied on with plastic strips.

Guava trees already in production can be topworked to better varieties by the standard method of cleft-grafting, performed early in the season of most active growth. Another good method of top-working is to induce the development of many sprouts by pruning the trees heavily, then when the sprouts which develop have attained sufficient size (the diameter of a lead pencil or larger) they can be veneer-grafted, in the same manner as young seedling stocks. In all cases where guavas are topworked, many undesired shoots will develop below the graft and must be cut away promptly lest they outgrow the scions.

Seedlings, either for use as stocks or for planting in the field, are easily grown. Guava seeds remain viable for many months, but give decreasing percentages of germination with time, so that the sooner they are planted after removal from the fruit, the better. ~~The hard seed coats often do not absorb water readily, thus delaying germination for many weeks. While seeds sometimes germinate within three weeks, delay can be avoided by immersion in hot water for five minutes.~~ Seedlings ~~several months old~~ large plants are difficult to transplant from the open ground, hence ~~they~~ should be potted while still small and moved from time to time into larger containers until they are a year old. They are then ready for grafting, or for transplanting to the field.

Planting and Care

Guava trees are often set too closely together for best production. If the soil is fertile they should be spaced about ~~25~~ 20 feet apart, each way. Preparation of the land ~~planting~~ should be the same as for orange trees. Grafted guavas are usually set in the field about a year from the time of grafting, and should receive the usual watering and mulching after being planted.

Little research ~~has~~ been done on fertilizing guavas. In many tropical regions they thrive even when neglected, but of course they grow more rapidly when given proper cultural attention. On stony or sandy soils in Florida a fertilizer program suitable for oranges has given excellent results. The trees should begin to bear fruit in the third year.

Flowers are borne in the leaf axils of new shoots, ~~mostly in late spring~~. Fertilizing for vigorous vegetative development assures abundant bloom. In warm rainy climates flowers will be produced at intervals during the year, but in regions with marked wet and dry seasons blooming will all be in the rainy season, unless the trees ~~have been~~ are irrigated abundantly during the dry period.

Little or no pruning is usually given, but where fine large guavas sell at a premium, some pruning is desirable. Vigorous young shoots produce the largest fruits, hence moderate heading back and thinning of the top to develop such shoots is desirable. Root suckers and low-hanging branches should be removed.

Weed control is less important with guavas than with many other fruits because of the vigorous root system. Weeds or grass under the trees can be ~~mowed~~ cut several times during the harvesting season to facilitate collecting

fruits which fall to the ground. Yields of good varieties in well-managed orchards may reach an annual total of 10 to 15 tons per acre.

Harvesting

Fresh guavas are seldom shipped to distant markets; ~~the great bulk of~~ most commercial crops are utilized by nearby processing plants. Only fully ripe fruits are harvested for this purpose. The trees are sometimes shaken to cause the ripe fruits to fall to the ground; bruising is of little concern when the factory is close at hand. Guavas for home use or for local sale as fresh fruit must be picked and handled carefully to avoid bruising, and they should be nearly ripe for best quality. Mature but unripe fruit, well colored but not soft, may be sent to distant markets, remaining in good condition for a week or more, if kept at a temperature of about 45° F.

Pest Control

Guavas suffer from fewer pests than many other fruits, though there are a few which are quite troublesome. Spotting of leaves and fruits by an alga, Cephaleuros virescens, is quite common in areas of high rainfall, though varieties differ in their susceptibility to this pest. It may easily be controlled with copper sprays.

In India, a Fusarium wilt closely related to Panama disease of bananas has killed many guava trees. Growers in the American tropics where bananas are produced might well be on the watch for guava wilt. The common root-knot nematode also attacks the guava, especially on light sandy soils. Heavy organic mulching and applications of water and fertilizers to keep trees in vigorous condition will enable them to thrive in spite of nematodes.

Several insects are serious pests, especially the fruitflies which infest guava fruits to a notorious degree almost everywhere in tropical America. Harvesting fruits before they are ripe, and destroying all ripe fruits to prevent fruitflies from breeding in them, are helpful if there are no other fruits in the neighborhood which provide breeding grounds for this pernicious pest. Since fruitflies (mainly species of Anastrepha) attack many fruits in tropical America, ~~a certain amount of~~ much research has been devoted to their control, without very encouraging results to date, so far as practical methods are concerned.

The guava white-fly, Metaleurodicus cardini, is common in some regions. Attacks of this insect are followed by the development of sooty mold on leaves and fruits. Control can be effected by spraying with oil emulsions or malathion about two weeks after the insects are seen flying. The dosage should be the same as that used for oranges.

Various scales, aphids, thrips and other insects may cause injury at times and require appropriate control measures.

~~The Cattley Guava~~ THE CATTLEY GUAVA

Native to Brazil, the Cattley Guava (Psidium cattleianum) is more ornamental but much less valuable commercially than the species treated above. It is almost devoid of pests, and with its handsome foliage and attractive, tasty fruits, is excellent for home gardens. Jelly of pleasing flavor and appearance is made from the fruit, but yields per acre do not approach those of the common guava. Cattley guavas thrive wherever oranges do. They are most often seen as large shrubs, but with age may become small trees.

There are two seedling strains, one with red and the other with lemon-yellow fruits. Both of these usually come true to type when grown from seed.

The red-fruited form is often called "strawberry guava". Other than their fruit color, there is practically no difference between the two forms, though the yellow one is considered to have a slightly sweeter flavor. The fruits of both contain about 4 to 5% of sugar, and only 30 to 50 mg. per 100 grams of vitamin C.

~~The main crop matures in late summer from spring bloom;~~ The flowers are borne in the lower leaf axils of new shoots. ~~There may also be an autumn bloom with fruit maturing in late winter.~~ In ~~summer it takes about~~ the warmest part of the year it takes about three months, from the time of flowering, for fruit to mature. In cool weather it may take considerably longer. At best, the size of the fruit is small in comparison with that of the common guava - usually between 3/4 and 1-1/2 in. in diameter. Size is increased by moisture supply, and thinning of the crop can be helpful if large fruit is desired.

The plants are usually not too crowded at a spacing of 10 x 10 feet. Propagation is by seed. No special cultural practices seem to have been developed.

THE JABOTICABA
The Jaboticaba

This native Brazilian fruit (Myrciaria cauliflora, though some taxonomists recognize three species) has long been very popular at home, but has not yet been extensively planted elsewhere. The tree is a handsome one, with small, myrtle-like leaves and a well-rounded crown which under favorable conditions may eventually reach a height of 30 ~~or 40~~ feet or more. Such dimensions are only attained, however, after many years of growth in a favorable environment. This slow growth and the long time required for young trees to come into production are largely responsible for preventing the jaboticaba from becoming as popular elsewhere as it is in southern Brazil.

The small, white flowers are borne in clusters all along the trunk and woody branches. On old trees they may almost hide the lower part of the trunk. Three or four months after the appearance of the flowers the fruits mature; they are from 1/2 to 1-1/2 inches in diameter, round, dark reddish-purple in color, with tough skins and very short stems. Because they are produced mainly inside the canopy of foliage on the framework of the tree (a ~~habit~~ characteristic technically known as cauliflory) they may be almost invisible from a short distance away. The long time which it takes for a jaboticaba to come into bearing, and the small size which the tree attains in regions where environmental conditions are not too favorable, are somewhat offset by the fact that several crops are produced during the year. The juicy white pulp, somewhat like that of a grape, is sweet and somewhat acidulous, ~~and~~ It is liked by almost everyone. ~~It is usually eaten out of hand, but like several of the other myrtaceous fruits of Brazil, may be utilized in a number of ways.~~

The jaboticaba thrives in the tropics and warm subtropics; ~~but~~ it will withstand a few degrees of frost. In Central America it can be cultivated up to 3000 or 4000 feet. It likes a well-drained soil, preferably a sandy loam or clay loam. ~~The better the soil, the more rapid the growth and the greater the ultimate size of the tree.~~

Propagation by seed presents no problems, if the seed is not kept too long before planting. Named varieties, when they are developed through selection of seedlings, may be propagated by marcottage (air-layering) or by veneer-grafting on seedling stocks, though this species, like several others of the Myrtaceae, does not lend itself readily to asexual propagation. Not much information regarding varieties is to be found in the literature; it seems likely that most of the "varieties" known in Brazil are strains

propagated by seed. It has been shown that this genus, Myrciaria, is polyembryonic, as are a number of other fruits of its family. It is probable, therefore, that selected strains of the several species which are recognized by taxonomists can be perpetuated without marcottage, grafting, or budding.

THE PITANGA

~~The Pitanga~~

This interesting little fruit, sometimes called Surinam-cherry, has been planted widely in the tropical and subtropical parts of the world, more often, however, as an ornamental fruit-bearing shrub than as a species of economic importance. Botanically it is Eugenia uniflora. Besides producing handsome, ~~tasty~~, little fruits, a trifle too aromatic for some tastes, it is a favorite plant for hedges. Used in this way, it endures trimming admirably and can be maintained in fine condition for many years.

When not used as a hedge plant, the pitanga will grow to an ultimate height of some 15 feet, taking the form of a small tree. The ~~small~~, ovate leaves, an inch or two in length, are especially pretty in the young stage, when they are dark red in color and contrast nicely with the older green ones. Flowering takes place ~~in early spring~~ on new shoots, and is followed in a month or so by ripe fruits, oblate in form, about an inch or slightly more in diameter, and deeply 8-ribbed longitudinally. Often there is a second period of flowering and fruiting during the year. Even on hedges which are kept under control by severe pruning, many fruits are produced. They make delicious jellies, comparable to guava jelly in firm consistency and unique flavor. However, the pitanga is not just another of those jelly fruits. Excellent water-ices or sherbets are made from pitangas, not known everywhere but famous in Brazil for their bright color and sprightly, aromatic flavor. The sugar

content varies from 4 to 5%, with 1/2 to 1% of acid; the high pectin makes possible the excellent jelly above mentioned.

Pitangas have almost the same climatic requirements as the orange. They grow well on a wide range of soils, but fruit size and quality are greatly affected by availability of water and nutrients during development. With adequate soil moisture and fertilizers, (if the soil is not very good), the fruits are large, juicy, and pleasantly aromatic. Under environmental conditions which are unfavorable, they will be small, not very juicy, and somewhat resinous in taste.

There are two seedling races, distinguished only by fruit color: one is bright crimson-scarlet, the other dark maroon both on the surface and internally. These races come true from seed. No varieties have been selected for vegetative propagation. The large seeds - usually one to each fruit - retain their viability for several weeks and are easily germinated in any good medium. Very few pests of this plant have been observed.

Though not popular with everyone, because of the resinous taste which characterises poorly developed or slighly unripe fruits, the pitanga deserves wider cultivation than it enjoys at present.

THE GRUMICHAMA

The Grumichama

This is another small tree of Brazilian origin, not as well known, nor so widely planted as the pitanga. It is somewhat more tropical in its requirements and more difficult to grow, except under very favorable environmental conditions. Botanically known as Eugenia dombeyi, it has thick, glossy, dark green leaves, much larger than those of the pitanga, but unlike the latter does not lend itself to planting in hedge form. Rather it is a small tree, an ornament to any garden or dooryard.

The white flowers, which somewhat resemble, at long range, those of cherry trees of the temperate zone, are produced in great abundance, to be followed within a very few weeks by ripe fruits, much resembling northern cherries in appearance except for the large sepals protruding from the apex. Unfortunately, the flavor of these cherry-like fruits is rather simple, as the Spaniards put it; in other words, rather lacking both in acids and sugar. Letting them hang on the tree until ~~partially dried, like raisins,~~ overripe increases sweetness.

Propagation has been only by seeds, which should be planted within a few days after removal from the fruit. They germinate readily and develop rapidly into sturdy, shapely, young plants.

THE JAMBOLAN

The Jambolan

Native to India, Burma and Indomesia, the jambolan, (Syzygium cumini), sometimes called Java-plum, is a large or medium-sized evergreen tree. Its cultivation in India goes back at least 3000 years, but it has never attained commercial importance in that part of the world, nor in tropical America, where it is of relatively recent introduction.

The oblong, maroon-purple fruits, about an inch in length, are thin-skinned and contain a single large seed, to which the flesh adheres. The flavor is somewhat astringent, not too pleasant in spite of 10% of sugar and only 1% of acid. ~~The trees are tremendously productive, the ground beneath them being covered with fallen fruits during the season of ripening. This does not suggest a great popularity for the jambolan; in fact, it is useful mainly for the preparation of jellies and jams, and the world is pretty well provided with jam and jelly fruits.~~ The jambolan ~~It~~ is included in this

chapter primarily because it is a very handsome ornamental tree, will grow under adverse conditions of climate and soil, and produces tremendous crops of pretty, small, ~~little~~ fruits which are interesting though not of great value. There is considerable variation among the fruits of different seedling trees; perhaps some really good ones will show up eventually which will merit horticultural attention.

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Ruby. Fruit ovoid, usually 6 to 8 ozs., skin greenish yellow, often with faint pink blush. Flesh bright red, flavor sweet and mild, quality very good. Odor intense. Seed cavity rather small, easily separated from the side walls, which are ½ inch thick. Foliage rather subject to alga spotting.

Supreme. Fruit ovoid to pyriform, usually 6 to 10 ozs. in weight, skin greenish to light yellow, flesh white, flavor subacid and mild, quality good, odor mild. Seed walls as in Ruby. Vitamin C content about 250 mg. in 100 gms. Foliage resistant to alga spotting.

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Pest Control

Guavas suffer from fewer pests than many other fruits, though there are a few which are quite troublesome. Spotting of leaves and fruits by an alga, Cephaleuros virescens, is quite common in areas of high rainfall, though varieties differ in their susceptibility to this pest. It may easily be controlled with copper sprays.

In India, a Fusarium wilt closely related to Panama disease

of bananas has killed many guava trees. Growers in the American tropics where bananas are produced might well be on the watch for guava wilt. The common root-knot nematode also attacks the guava, especially on light sandy soils. Heavy organic mulching and applications of water and fertilizers to keep trees in vigorous condition will enable them to thrive in spite of nematodes.

Several insects are serious pests, especially the fruitflies which infest guava fruits to a notorious degree almost everywhere in tropical America. Harvesting fruits before they are ripe, and destroying all ripe fruits to prevent fruitflies from breeding in them, are helpful if there are no other fruits in the neighborhood which provide breeding grounds for this pernicious pest. Since fruitflies (mainly species of Anastrepha) attack many fruits in tropical America, much research has been devoted to their control, without very encouraging results to date, so far as practical methods are concerned.

The guava white-fly, Metaleurodicus cardini, is common in some regions. Attacks of this insect are followed by the development of sooty mold on leaves and fruits. Control can be effected by spraying with oil emulsions or malathion about two weeks after the insects are seen flying. The dosage should be the same as that used for oranges.

Various scales, aphids, thrips and other insects may cause injury at times and require appropriate control measures.

THE CATTLEY GUAVA

Native to Brazil, the Cattley Guava (Psidium cattleianum) is more ornamental but much less valuable commercially than the species treated above. It is almost devoid of pests, and with its

handsome foliage and attractive, tasty fruits, is excellent for home gardens. Jelly of pleasing flavor and appearance is made from the fruit, but yields per acre do not approach those of the common guava. Cattley guavas thrive wherever oranges do. They are most often seen as large shrubs, but with age may become small trees.

There are two seedling strains, one with red and the other with lemon-yellow fruits. Both of these usually come true to type when grown from seed. The red-fruited form is often called "strawberry guava". Other than their fruit color, there is practically no difference between the two forms, though the yellow one is considered to have a slightly sweeter flavor. The fruits of both contain about 4 to 5% of sugar, and only 30 to 50 mg. per 100 grams of vitamin C.

The flowers are borne in the lower leaf axils of new shoots. In the warmest part of the year it takes about three months, from the time of flowering, for fruit to mature. In cool weather it may take considerably longer. At best, the size of the fruit is small in comparison with that of the common guava - usually between 3/4 and 1½ in. in diameter. Size is increased by moisture supply, and thinning of the crop can be helpful if large fruit is desired.

The plants are usually not too crowded at a spacing of 10 x 10 feet. Propagation is by seed. No special cultural practices seem to have been developed.

THE JABOTICABA

This native Brazilian fruit (Myrciaria cauliflora, though some taxonomists recognize three species) has long been very popular at home, but has not yet been extensively planted elsewhere. The tree is a handsome one, with small, myrtle-like leaves and a well-rounded

crown which under favorable conditions may eventually reach a height of 30 feet or more. Such dimensions are only attained, however, after many years of growth in a favorable environment. This slow growth and the long time required for young trees to come into production are largely responsible for preventing the jaboticaba from becoming as popular elsewhere as it is in southern Brazil.

The small, white flowers are borne in clusters all along the trunk and woody branches. On old trees they may almost hide the lower part of the trunk. Three or four months after the appearance of the flowers the fruits mature; they are from ½ to 1½ inches in diameter, round, dark reddish-purple in color, with tough skins and very short stems. Because they are produced mainly inside the canopy of foliage on the framework of the tree (a characteristic technically known as cauliflory) they may be almost invisible from a short distance away. The long time which it takes for a jaboticaba to come into bearing, and the small size which the tree attains in regions where environmental conditions are not too favorable, are somewhat offset by the fact that several crops are produced during the year. The juicy white pulp, somewhat like that of a grape, is sweet and somewhat acidulous. It is liked by almost everyone.

The jaboticaba thrives in the tropics and warm subtropics; it will withstand a few degrees of frost. In Central America it can be cultivated up to 3000 or 4000 feet. It likes a well-drained soil, preferably a sandy loam or clay loam.

Propagation by seed presents no problems, if the seed is not kept too long before planting. Named varieties, when they are developed through selection of seedlings, may be propagated by marcottage (air-layering) or by veneer-grafting on seedling stocks, though this species, like several others of the Myrtaceae, does not lend itself readily to asexual propagation. Not much information

regarding varieties is to be found in the literature; it seems likely that most of the "varities" known in Brazil are strains propagated by seed. It has been shown that this genus, Myrciaria, is polyembryonic, as are a number of other fruits of its family. It is probable, therefore, that selected strains of the several species which are recognized by taxonomists can be perpetuated without marcottage, grafting, or budding.

THE PITANGA

This interesting little fruit, sometimes called Surinam-cherry, has been planted widely in the tropical and subtropical parts of the world, more often, however, as an ornamental fruit-bearing shrub than as a species of economic importance. Botanically it is Eugenia uniflora. Besides producing handsome little fruits, a trifle too aromatic for some tastes, it is a favorite plant for hedges. Used in this way, it endures trimming admirably and can be maintained in fine condition for many years.

When not used as a hedge plant, the pitanga will grow to an ultimate height of some 15 feet, taking the form of a small tree. The ovate leaves, an inch or two in length, are especially pretty in the young stage, when they are dark red in color and contrast nicely with the older green ones. Flowering takes place on new shoots, and is followed in a month or so by ripe fruits, oblate in form, about an inch or slightly more in diameter, and deeply 8-ribbed longitudinally. Often there is a second period of flowering and fruiting during the year. Even on hedges which are kept under control by severe pruning, many fruits are produced. They make delicious jellies, comparable to guava jelly in firm consistency and unique flavor. However, the pitanga is not just another of those jelly fruits. Excellent water-ices or sherbets are made from

pitangas, not known everywhere but famous in Brazil for their bright color and sprightly, aromatic flavor. The sugar content varies from 4 to 5%, with ½ to 1% of acid; the high pectin makes possible the excellent jelly above mentioned.

Pitangas have almost the same climatic requirements as the orange. They grow well on a wide range of soils. With adequate soil moisture and fertilizers (if the soil is not very good), the fruits are large, juicy, and pleasantly aromatic. Under environmental conditions which are unfavorable, they will be small, not very juicy, and somewhat resinous in taste.

There are two ~~seedling~~ races, distinguished only by fruit color: one is bright crimson-scarlet, the other dark maroon both on the surface and internally. These races come true from seed. No varieties have been selected for vegetative propagation. The large seeds - usually one to each fruit - retain their viability for several weeks and are easily germinated in any good medium. Very few pests of this plant have been observed.

Though not popular with everyone, because of the resinous taste which characterises poorly developed or slightly unripe fruits, the pitanga deserves wider cultivation than it enjoys at present.

THE GRUMICHAMA

This is another small tree of Brazilian origin, not as well known, nor so widely planted as the pitanga. It is somewhat more tropical in its requirements and more difficult to grow, except under very favorable environmental conditions. Botanically known as Eugenia dombeyi, it has thick, glossy, dark green leaves, much larger than those of the pitanga, but unlike the latter does not lend itself to planting in hedge form. Rather it is a small tree, an ornament to any garden or dooryard.

The white flowers, which somewhat resemble, at long range, those of cherry trees of the temperate zone, are produced in great abundance, to be followed within a very few weeks by ripe fruits, much resembling northern cherries in appearance except for the large sepals protruding from the apex. Unfortunately, the flavor of these cherry-like fruits is rather simple, as the Spaniards put it; in other words, rather lacking both in acids and sugar. Letting them hang on the tree until overripe increases sweetness.

Propagation has been only by seeds, which should be planted within a few days after removal from the fruit. They germinate readily and develop rapidly into sturdy, shapely young plants.

THE JAMBOLAN

Native to India, Burma and Indonesia, the jambolan, (Syzygium cumini), sometimes called Java-plum, is a large or medium-sized evergreen tree. Its cultivation in India goes back at least 3000 years, but it has never attained commercial importance in that part of the world, nor in tropical America, where it is of relatively recent introduction.

The oblong, maroon-purple fruits, about an inch in length, are thin-skinned and contain a single large seed, to which the flesh adheres. The flavor is somewhat astringent, not too pleasant in spite of 10% of sugar and only 1% of acid. The jambolan is included in this chapter primarily because it is a very handsome ornamental tree, will grow under adverse conditions of climate and soil, and produces tremendous crops of small, pretty fruits which are interesting though not of great value. There is considerable variation among the fruits of different seedling trees; perhaps some really good ones will show up eventually which will merit horticultural attention.

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DEPARTMENT OF PLANT PATHOLOGY

RIVERSIDE, CALIFORNIA 92502

February 7, 1966

Air Mail

Dr. Wilson Popenoe
1722 N.W. 2nd Avenue
Gainesville, Florida

Dear Wilson:

I was very glad to receive your letter of January 24, and to hear of your good progress on your book. In general the write-up on avocado root rot looks very good; I have made a few suggestions on the copy regarding a few minor points. Our recent work on this soil fungicide, Dexon, looks quite good in the field plots in San Diego County, but I hesitate to suggest that you add this because of the expense and, under tropical conditions without irrigation, the difficulty of treating trees.

I stopped at your house in Antigua the week before last and was sorry to find from Maria that you were in Florida. I was on a brief trip to Costa Rica, Guatemala and Mexico, on some avocado and coffee disease work, but more on this trip on cacao. We have a projection on Phytophthora palmivora on cacao with the American Cocoa Research Institute and have been doing quite a bit with this fungus recently--I got some 50 different isolates of it in Australia and the South Pacific, on everything from cacao to papaya, rubber, pepper, coconut, etc.

With best regards. Let me know if there is anything more I can do.

Very sincerely yours,

George

GAZ:hb

George A. Zentmyer
Professor of Plant Pathology

In many countries, the worst enemy of the avocado tree is "root rot", caused by the fungus Phytophthora cinnamomi. This parasite works in the soil, attacking and destroying the root system. The eventual result - and this may take some time - is the withering and dying of the leaves, then of branches from the tips downwards. Once this process has commenced, no means have been found to check it. In its destructiveness and difficulty of control root rot is reminiscent of Panama disease of bananas, caused by another soil-borne organism.

In recent years root rot has destroyed thousands of avocado trees in California orchards, and it is becoming serious in Florida. It has had a devastating effect in various parts of Mexico, around Lake Valencia in Venezuela, and in many other regions. It is most destructive on compact, wet clay soils; not so bad on loams and friable, well-aerated clays. In Cuba, for example, avocados do well on the friable clays of Matanzas and Habana and Pinar del Rio provinces, but are conspicuous by their absence on the vast stiff clay sugar lands of Camagüey and Oriente. In Jamaica and Puerto Rico healthy, mature avocado trees are rarely seen on the compact clay soils of the littoral, but wholly successful on limestone soils on the hillsides. On the other hand, this disease has not been a problem, up to now, on the sandy volcanic loams and clay loams of the Central American highlands, nor even on the coastal lowlands where the same soils are present.

In recent years, control of root rot has been the subject of much technical investigation, especially at the hands of Dr George Zentmyer of the University of California, who has not confined his studies to that State but has worked in Latin America and the principal avocado-growing regions of several other parts of the world. Little progress

has been made toward controlling the disease through soil treatments. On a large scale, they would be too expensive, even if effective. Consequently, attention has been devoted to securing a resistant rootstock. Many forms and varieties of the avocado have been tested, as well as other species of Persea, whether or not they looked promising. A hprticultural variety of the Mexican race, Duke, which originated as a seedling in northern California, has shown a degree of resistance to root rot, but not sufficient to recommend it for commercial plantings. All of the wild species of Persea have either proved incompatible, or, as in the case of P.schiedeans, have proved unsatisfactory from some angle. The wild species that are compatible generally have little resistance to root rot. There is still hope of finding a good resistant rootstock, but in the meantime, the best advice which can be given prospective planters is to avoid compact wet clays, even sandy clays unless their structure is such as to provide good aeration and drainage. Any soil in which drainage is restricted should be avoided. The provisions of adequate drainage, through planting on slopes or through using ditches, does not seem to be the answer. At least this has been the case in Honduras, where experiments along this line have been conducted for some 25 years.

A number of food plants are resistant to the avocado root rot fungus and can safely be used to replant areas where the disease is severe. These include mango, citrus, macadamia nut, cherimoya, guava, berries, most types of vegetable crops.

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PHYTOPHTHORA CANKER OF CACAO IN THE CAROLINE ISLANDS

D. Zaiger and G. A. Zentmyer[1]

Abstract

The first reported outbreak of an epidemic of bark canker of Criollo cacao, caused by Phytophthora palmivora in the Caroline Islands, Western Pacific is described. The disease is characterized by trunk girdling cankers which kill large trees in 30 to 60 days. Prior to succumbing, affected trees burst into flower. Calonectria rigidiuscula is present as a secondary in affected bark. The proven pathogen is apparently a different strain of P. palmivora from those common in Central America. Effective control measures include the roguing and burning of badly diseased trees, using sterilized pruning tools, covering pruning wounds with coal tar and excising the cankers.

INTRODUCTION

Bark canker was first noted on a single Criollo cacao tree in late 1961 on an islet in the lagoon of Ponape, Eastern Caroline Islands. Six months later a dozen trees adjacent to this first diseased tree and a few trees in a planting about 3 miles away were observed to be harboring the disease. Suddenly, in the fall of 1962, nearly all of the trees of these two plantings, about

[1]Plant Pathologist, Trust Territory of the Pacific Islands and Professor of Plant Pathology, University of California, Riverside, respectively.

FIGURE 1. Typical Phytophthora cacao bark canker. This 7-year-old tree with a trunk measuring about 6 inches in diameter was entirely free of disease 2 months prior to the taking of this photograph.

FIGURE 2. Phytophthora palmivora pathogenicity test. The 3-month-old Criollo cacao seedling on the left wilted on the eleventh day after inoculation. A healthy Criollo seedling is shown at right.

1200 trees, became diseased. The disease spread along one side of the island (about 20 miles) from similiar such loci of infestation, destroying in this outbreak about 2000 trees. Practically all of the trees attacked were of the Criollo variety, although a few were hybrid types.

SYMPTOMS

The disease is characterized by a brown band of necrosed bark spreading around the trunk, usually beginning from the site of a pruning or other wound or at the bark suture in the main jorquette. By inserting bits of diseased bark under the bark of healthy trees 4 to 6 inches in diameter, cankers were produced which completely encircled the trunks in 30 to 60 days. When the bark is pared back (Fig. 1) the affected cambium is seen to be watery to gummy and of a dull brownish-gray color, which often, but not always, assumes a claret hue on exposure. The necrosis does not extend into the wood beyond the cambial layer.

When the canker is large, or has nearly encircled the trunk, the tree typically sheds the major portion of its leaves and a new flush of smaller leaves is put forth. Concurrently, the tree bursts into bloom with an enormous number of flowers, often literally covering the branches. Large numbers of cherelles develop but fail to mature before the tree succumbs.

ISOLATION OF THE PATHOGEN

Interior bits of necrotic bark from the margins of active lesions consistently yielded the conidial stage of Calonectria rigidiuscula (Berk. & Br.) Sacc. when plated out on PDA. The asci and ascospores of this fungus are readily observed on the bark of trees killed by the disease.

As the disease syndrome exactly parallels a brown bark rot of cacao reported from the Philippine Islands (3, 4), attributed to Calonectria rigidiuscula, pure cultures were tested for pathogenicity on seedlings and adult trees by a variety of inoculation techniques. All tests

failed to reproduce the disease. The fungus made only superficial penetration into healthy bark, which invasion was later walled off by callus tissue. These results confirm the findings of S. H. Crowdy (1).

As the Criollo plantings in Ceylon and Java were decimated at the turn of the century by a canker disease caused by Phytophthora palmivora Butl. (5), and Phytophthora canker has been reported in other cacao-growing areas, sections of cacao branches containing cankers were sent to the co-author at the University of California, Riverside. Using the selective medium of Eckert and Tsao (2), which employs three antibiotics to inhibit bacteria and non-phycomycetes, he readily obtained P. palmivora from the lesions. Subsequently, numerous isolations made at Ponape by the same technique yielded P. palmivora. These isolants proved to be virulent pathogens. They killed Criollo seedlings in 11 days (Fig. 2) and produced cankers that girdled trees of 4 inches or more in diameter in 18 days. The Ponape isolates are slightly different in cultural appearance from two cacao isolates of P. palmivora from Central America, and did not form oospores when paired with either CR 1, from Costa Rica (A_1 type) or 4002, from Mexico (A_2 type isolated by S. Romero). Apparently the strain from Ponape differs in mating type from either of those from Central America. No previous report of an outbreak of cacao bark canker, caused by P. palmivora, from the Caroline Islands is found in the literature.

CONTROL

Field experiments showed the disease to be easily transmitted by mechanical means. Pruning knives contaminated by cutting through diseased bark were used to prune chupons or small branches of healthy trees. Nearly all became infected. Contaminated pruning knives were rendered innocuous by rinsing them in a .5% solution of sodium hypochlorite. All wounds made on healthy trees with sterilized tools and covered with tar healed, whereas 8% of wounds so inflicted but left uncovered developed cankers.

In consideration of these findings, an intensive eradication and sanitation program was launched in early 1963. All diseased trees were rogued by burning and farmers were instructed to sterilize pruning tools and to cover the wounds with coal tar. Losses from bark canker were reduced ten-fold, from more than 2000 newly diseased trees in 1962 to 185 in 1963. The number of cacao trees developing canker in 1964 was 65. The total population of Criollo cacao on Ponape is estimated at about 150,000 plants.

During 1963 a therapy technique was developed for trees with cankers in an early stage, or extending less than half-way around the trunks. It consists of paring away diseased bark, flooding the resulting wound with a .5% sodium hypochlorite solution, and covering it with coal tar. More than 90% of such treated trees recovered.

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PLANT PATHOLOGY LABORATORY, TRUST TERRITORY OF THE PACIFIC ISLANDS, PONAPE, EASTERN CAROLINE ISLANDS

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Testing for Resistance of Avocado to Phytophthora in Nutrient Solution

G. A. Zentmyer and S. M. Mircetich

Professor and Laboratory Technician II, respectively, Department of Plant Pathology, University of California, Riverside.

Determination of resistance to plant pathogenic organisms presents many problems, with particular respect to reproducibility of results and to simplicity and rapidity of testing. Many methods have been developed and used to varying extent over the past 30 or 40 years. This paper concerns development of a simple rapid method in which results have been consistently similar over several years of testing; the disease involved is *Phytophthora* root rot of avocado (*Persea americana* Mill.).

Methods used in testing resistance to root-rotting organisms, especially *Phytophthora* and *Pythium*, include: growing plants in naturally infested soil (15); artificially infesting soil or sand by adding ground mycelia (11), spore suspensions, or grain or other media on which the pathogen is growing (10); dipping roots in spore or mycelial suspensions (8); growing plants under sterile conditions and adding the pathogen by various means (12); inoculating wounded roots or stems (9); and growing the plants in water culture or nutrient solution and adding the pathogen in one of several forms (2, 5).

The method described in this paper involves the latter procedure and essentially is an expansion of the method described by Bingham and Zentmyer (2) in which three to six avocado seedlings were grown in ceramic cylinders containing aerated nutrient solutions; inoculum of *Phytophthora cinnamomi* Rands was suspended in the solution in a small cheesecloth bag. This method was an adaptation of the mist-chamber inoculation method used by Klotz for inoculating citrus and avocado seedlings (7).

Resistance testing method—Fungi in the genera *Phytophthora, Pythium,* and *Aphanomyces,* which produce zoospores, are well adapted to infection in nutrient or water culture. Several investigators have reported various types of tests using water culture for studying resistance and the response of pathogens to varying nutritional or other factors (1, 4).

After the nutrient solution method was found to be useful for studying the effect of factors on infection of avocado seedlings by *Phytophthora cinnamomi* (2, 3, 6, 14), the method was adapted on a small scale to test seedlings or cuttings for resistance to this pathogen. Since relatively few plants could be tested at any one time, uniform temperatures were used to increase reproducibility of results.

The method is now as follows: avocado seeds are allowed to germinate in flats containing steam-sterilized sand; approximately 480 seedlings (3-4 inches tall) are transplanted to each tank (Fig. 1-A) containing a complete nutrient solution as previously described (2);

Fig. 1. A) Temperature-controlled tanks with avocado seedlings growing in aerated nutrient solution. The seedlings are supported by the rack shown in the middle tank. **B)** Healthy roots of avocado seedlings prior to inoculation. Note the cheesecloth bags with the inoculum.

the solution is adjusted to pH 4.5 and held at a constant temperature of 24 C. The seedlings are supported on a rack (Fig. 1-A) on the surface of the nutrient solution so that only the roots are immersed. The pH of the nutrient solution is raised to 6.5 prior to inoculation of roots.

The tanks employed are ESCO milk coolers, type UPS4, manufactured by ESCO Cabinet Company, West Chester, Pa. Contamination of the nutrient solution with traces of heavy metals is prevented by lining the inner walls of the tanks with either stainless steel or heavy polyethylene sheets. The tanks are 1.05 m square with a 425-liter capacity. Each tank is cooled by a ¾ hp compressor, and the nutrient solution is heated with a vinyl-jacketed heating cable set, 26 feet long. The temperature of the nutrient solution is controlled by a system that includes the "Metastatic" mercury thermoregulator. The nutrient solution is aerated by passing compressed air through four glass tubes with sintered glass tips; the tubes are laid on the bottom of each tank and spaced so that the entire tank is evenly aerated.

When new roots are well developed, 7-10 days after

the plants are transplanted into the nutrient solution (Fig. 1-B), inoculum of *P. cinnamomi* is placed in the tanks. The fungus is grown on potato-dextrose agar (made from fresh potatoes) in petri dishes in the laboratory for 7-10 days. The agar and mycelia are removed from the dishes, wrapped in cheesecloth, and suspended in the nutrient solutions. Eight bags containing the inoculum from four petri dish cultures are placed in each tank.

Sporangia of the fungus form abundantly on the suspended cultures and release a great number of zoospores into the nutrient solution. These zoospores encyst and germinate on the avocado roots, and numerous infections occur on the susceptible roots (Fig. 2-A, B). At

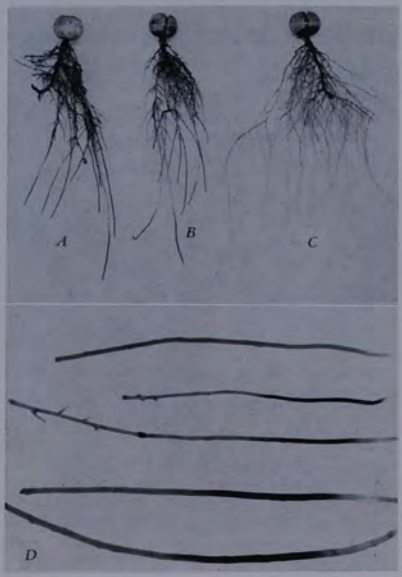

Fig. 2. A, B) Numerous infections produced by *Phytophthora cinnamomi* on roots of avocado seedlings (Mexicola variety) in the inoculated nutrient solution. **C)** Noninoculated. **D)** Early infection of avocado feeder roots. Note discoloration at the elongation zone and white apical meristem. Healthy, noninoculated root on the top.

24 C and pH 6.5, brown lesions begin to appear on the elongation zone of the roots within 72 hr, whereas the apical meristems of roots remain white (Fig. 2-D). Within 10-12 days the fungus kills 90 to 100% of the roots of susceptible seedlings.

In our standard screening test, final disease readings are taken 12 days after the inoculum is placed in the tanks. Seedlings are classified into 10 groups: 0-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, and 91-100% of the roots rotted. Plants in the last two groups are discarded and those in the other groups are transplanted into soil in 1-gal cans for further observation and propagation.

Using this nutrient solution method, we have tested more than 20,000 seedlings and cuttings of many species of *Persea* and related genera and many varieties of avocados collected throughout the world (13). In this very severe test, most of the plants are in the classes above 80% at the end of the infection period. Of the few plants in classes below 80%, most are in the 70-80% group. A very few plants, with the exception of several small-fruited *Persea* spp. and the avocado cuttings, have an infection percentage less than 70.

Correlation between the nutrient solution tests and the tests in infested soil in the greenhouse, and with field performance, is good. Two varieties of Mexican avocado seedlings, Duke and Topa Topa (the latter a standard susceptible control), were resistant and susceptible, respectively, in all types of tests. Species such as *P. caerulea* Mez, *P. skutchii* Allen, etc., which are highly resistant in the nutrient solution tests, grow very well in infested soil in the field.

The method described in this paper has greatly expedited our screening program in the search for a *Phytophthora*-resistant avocado rootstock, and the method should be useful for similar work with other crops involving similar pathogens with motile spores.

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Bacterial Stimulation of Sporangium Production in Phytophthora cinnamomi

Abstract. *Bacteria, notably* Chromobacterium violaceum, *stimulate initiation of production of sporangia by* Phytophthora cinnamomi, *a plant pathogen which does not produce this asexual stage in ordinary agar or liquid culture.*

Reproduction in fungi and in other microorganisms is affected in various ways by a number of environmental and nutritional factors. This report concerns asexual reproduction by sporangia in *Phytophthora cinnamomi* Rands, a cosmopolitan plant pathogen with a large host range (*1*), and in two other species of the genus. *Phytophthora cinnamomi* does not produce either sporangia or oospores in ordinary agar or liquid culture.

In 1935 Mehrlich (*2*) stimulated sporangium production in *P. cinnamomi* with a nonsterile soil extract. The basis for the effect was not elaborated beyond presentation of evidence that heating the extract to 121°C for 20 minutes destroyed the stimulatory principle.

In connection with studies of *P. cinnamomi* as the casual agent of a serious root rot of avocado trees in California and Latin America, a modification of Mehrlich's method has been used in our laboratory as follows. Ten grams of moist soil are added to 1000 ml of deionized water; and the mixture is shaken vigorously and filtered through Whatman No. 42 filter paper in a Buchner funnel under a slight vacuum. The filtered extract may then be stored in a dark bottle at room temperature; under such conditions, the extract has retained activity over 1-year storage periods. To test sporangium production, disks of mycelium and agar from the margin of a culture on V-8 juice agar are placed in the soil extract in petri dishes.

Formation of sporangia was reported in 1959 (*3*), and I presented further data on stimulation in 1962 (*4*).

Data reported in 1959 and from subsequent experiments with nonsterile soil extract indicated the involvement of a microbial agent in asexual sporulation. Sterilization of the extract by autoclaving [15 lb (7 kg) for 20 minutes] or filtration (Seitz or Berkefeld filters) removed the stimulatory factor. This factor was thermolabile; it was eliminated from the soil extract by incubation at 45°C for 5 days or at 50°C for 10 minutes, but not by freezing. Results with dilution and dialysis also supported the microbial theory.

The nonsterile soil extract has also stimulated formation of sporangia in the opposite (A_1) mating type of *P. cinnamomi* (*5*) and increased production of sporangia in *P. citrophthora* and *P. palmivora*.

Subsequently many soil bacteria were isolated and tested for influence on sporangium development by *P. cinnamomi* in sterile extract. Stimulation was obtained in Australia in the spring of 1964 in a number of tests with a purple-pigmented bacterium identified as *Chromobacterium violaceum* (Schroeter) Bergonzini (*6*). This bacterium was first isolated from South Australian soils by the soil-dilution plate method in 1964–65. This organism was also isolated from soil in South Australia by the rice-grain method (*7*); it produced a deeply pigmented culture, the pigment was not soluble in water, the bacterium did not grow at 37°C, and no endospores were produced.

When *C. violaceum* was added to soil extract sterilized by autoclaving, sporangium production in *Phytophthora cinnamomi* ranged from 5 to 40 percent of that in the nonsterile soil extract. Usually the bacteria were suspended in sterile distilled water; then 0.05 to 0.10 ml of this suspension was pipetted into 8 ml of sterile soil extract in a small petri dish. Stimulation of sporulation was more consistent and of higher magnitude when a culture of *Chromobacterium violaceum* which had been recently isolated from soil, or recently transferred, was used. No stimulation occurred in several tests with bacterial cultures several weeks old, including an isolate of *C. violaceum* from California soils (*8*). The *C. violaceum* freshly isolated on rice grains from California soils was effective in inducing formation of sporangia. Corpe (*9*) reported considerable variation in this group. Soils from different areas varied considerably in stimulation of sporangium production; this could reflect differences in bacterial population.

Several other bacteria and combinations of bacteria have given occasional stimulation of sporangium production in *Phytophthora cinnamomi*, in tests in California and in Australia. Washings from dilution plates containing a number of different bacteria, when added to sterile soil extract containing disks of mycelium of *P. cinnamomi*, have consistently caused sporangia to be produced. Thus, *Chromobacterium violaceum* is not the only microorganism involved in the phenomenon. This is indicated also by reports on the stimulation of sporulation in *Phytophthora cinnamomi* by bacteria or diffusates from nonsterile soil extract (*10, 11*); in one case "aseptic" sporangia were reported on the side of Millipore membranes opposite a soil extract (*11*).

Chromobacterium violaceum, although not readily isolated from soil, is a common inhabitant of many soils throughout the world, and it also is commonly found in water. Thus this organism could well be one of the important biotic agents providing the stimulus for production of this essential spore stage by *Phytophthora cinnamomi* and other species of the genus.

That several tests of spring water and other water sources for stimulation of sporangium production have given positive results further substantiates the probable importance of an organism such as *Chromobacterium violaceum*. Another link in the involvement of this bacterium in sporulation is provided by the data on inactivation of the factor or agent at temperatures of 45° to 50°C. This correlates with the fact that *C. violaceum* does not grow at 37°C and does not produce spores.

There are indications that the substance or substances influencing pro-

duction of sporangia are intimately associated with the bacterial cell, for removal of bacteria from the soil extract by filtration through a Millipore filter (0.45-micron pore size) also prevented development of sporangia. Filtration of the extract through Millipore filters with pore sizes of 3.0 or 1.2 microns did not remove bacteria; these filtrates stimulated production of sporangia. Undoubtedly *C. violaceum* and other microorganisms in the soil are producing some metabolite or metabolites that are essential for triggering sporangium production in *Phytophthora*.

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PROGRESS ON CHEMICAL CONTROL OF PHYTOPHTHORA ROOT ROT

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Research on control of Phytophthora root rot of avocado at the University of California, Riverside, has covered many aspects. One of these has been the search for a fungicide with low toxicity to the avocado tree that could be applied in the irrigation water or by some similar, simple means of application. With this objective in mind a greenhouse screening program was developed six years ago, in an attempt to find such a fungicide by testing many chemicals on avocado seedlings. A number of effective chemical fumigants are known that will kill soil fungi when applied after plants have been removed from the soil, or as pre-plant treatments, but there has been relatively little information on chemicals that could be applied to living plants.

This paper describes greenhouse results and intitial field results with one fungicide that has been relatively effective in controlling **Phytophthora cinnamomi**, and not damaging avocado seedlings or trees. This chemical is known commercially as Dexon; chemically it is p-dimethyl-amino-benzenediazo sodium sulfate. It has been found particularly effective against fungi in the genera **Phytophthora** and **Pythium**. Appreciation is expressed to the Chemagro Corporation, Kansas City, Missouri, for supplying liberal amounts of Dexon for our experimental tests.

Laboratory Tests.—Dexon has not been a highly effective fungicide against Phytophthora when tested against this fungus alone in laboratory studies in agar and in vials containing soil. Dexon does not kill the fungus even at high concentrations, but it does prevent or retard it from growing. Even 3200 ppm of Dexon did not kill the avocado root rot fungus in the standard laboratory tests in soil.

Greenhouse Tests.—For most greenhouse tests field soil naturally infested with **Phytophthora cinnamomi** was used, although in some cases the soil was artificially infested by adding laboratory cultures of the fungus. Topa Topa seedlings were grown in greenhouse soil in 4-inch pots, then were transplanted to 6-inch clay pots or 1-gallon cans containing the infested soil. As soon as the seedlings were transplanted they were watered with either Dexon or with water alone; three dosages of Dexon were used in most experiments: 10, 20, and 40 ppm of the chemical on a soil weight basis. Treatments were replicated five times, and were applied once a week for 12 weeks.

Periodic evaluation of the condition of the tops of the plants were made throughout the 12-week experimental period. At the end of this period the plants were harvested, roots and tops were weighed, percentages of healthy roots were estimated, roots were cultured to detect the presence of the root-rot fungus, and the soil was tested for presence of the

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fungus, using the fruit-test method. This method involved placing a firm, mature green avocado fruit in a waxed container with the soil to be tested, flooding the surface of the soil with water, incubating for from 4 to 6 days, and observing the fruit for development of typical Phytophthora spots (see Univ. of Calif. Circular 511).

In several greenhouse experiments control of Phytophthora root rot was striking with 10 and 20 ppm Dexon; the 40 ppm treatment was somewhat toxic to the avocado seedlings. Another experimental soil fungicide, Shell SD-4741 (0,0,0-trimethyl phosphorothioate) gave good control of the disease in several greenhouse tests, but dosages of 50 and 100 ppm were required; this chemical is not available on a commercial scale, and field trials with it have not been as successful as with Dexon.

Results of one of the greenhouse tests with Dexon are summarized in Table 1. These data show that avocado seedlings grew exceedingly well in soil heavily infested with root rot fungus which received weekly drenches of Dexon. Even though the plants in several dosages are healthy, the fungus was recovered from the treated soil, showing that the chemical does not kill **Phytophthora cinnamomi** in the soil, but retards disease development. In a few cases, prolonged treatments with 40 ppm of Dexon greatly reduced the fungus population.

Table 1. Control of Phytophthora root rot of avocado seedlings in the greenhouse by drenching the soil with Dexon.

Treatment	Dosage ppm	Mean Wt. of Roots (grams)	Mean Wt. of Tops (grams)	Mean Per Cent Healthy Roots	Recovery of Phytophthora cinnamomi
None	—	3.5	12.8	0	+
Dexon	10	23.4	20.4	75	+
Dexon	20	26.8	30.2	94	+
Dexon	40*	12.4	25.3	58	+

* This dosage injured the avocado seedlings.
Treatments applied once a week for 12 weeks.

Another series of tests was designed to determine how frequently Dexon would have to be applied to avocado seedlings, under greenhouse conditions, to obtain good disease control. Dosages of 10 and 20 ppm were used; different series of plants were treated once a week, once every two weeks, and once every four weeks. Figure 1 shows that, when a dosage of 10-ppm Dexon was used, treatment had to be applied once a week to obtain adequate control. When the 20-ppm dosage was used, good control was obtained by applying the fungicide once a week or once every two weeks, but once every four weeks did not give control.

Field Tests.—Following the good results with Dexon in greenhouse trials, the material was applied to large avocado trees (Hass and Fuerte varieties) in San Diego County. Two methods were used: 1) concentrated solutions were applied evenly to the soil surface using sprinkling cans, then the chemical was watered in immediately by using low sprinklers; 2) concentrated solutions were placed in an applicator (similar to a Prizer fertilizer applicator) attached to the irrigation system, which metered the chemical into the irrigation water so that Dexon was applied to the trees by means of sprinklers set under each tree. Trees were treated at monthly intervals, using several dosages of Dexon.

Figure 1. Treatment with Dexon over a 12-week period in naturally-infested soil (October, 1961).

1) Check plant
2) Dexon 10 ppm once a week
3) Dexon 10 ppm every 2 weeks
4) Dexon 10 ppm every 4 weeks
5) Dexon 20 ppm every week
6) Dexon 20 ppm every 2 weeks
7) Dexon 20 ppm every 4 weeks

Four plots have been established over the past four years. Three of these have shown benefit from applications of Dexon, in regarding disease symptoms and maintaining treated trees in better condition than untreated ones. In two of these the results have been striking.

The oldest plot involved 12 trees (12-14 years old) that were treated monthly; four of these received Dexon, four received SD-4741, and four received only water. After four years, all four of the Dexon-treated trees are still alive, three of the four trees treated with SD-4741 developed severe root rot and had to be removed, and three of the four untreated trees died. Three of the Dexon-treated trees are still in good condition, even though the root rot fungus has been present in the root zone for over four years.

In a larger, more recently established plot, involving 24 trees, Dexon applications of 100 ppm are appreciably retarding the progress of root rot and are permitting good tree growth in most of the replicates. Trees treated with a dosage of 50 ppm are slightly, but not significantly, better than the untreated trees. In this plot we are applying 94 grams of Dexon (70 per cent wettable powder) to each tree and using one gallon of water per square foot to dilute the chemical. The material is applied in a split application, with 47 grams of chemical followed by one-half of the total amount of water, after which the second 47 grams of chemical is followed by the remainder of the water.

Fruit of both the Fuerte and Hass varieties from trees treated with Dexon have been analyzed for residues in our chemical laboratory by Mr.

J. Hara, and by the Chemagro Corporation chemists. No Dexon residues have been found in any of the fruit from treated trees. The chemical has recently been registered for use on avocados.

The chemical Dexon shows promise of retarding root rot development and maintaining trees in healthy condition in the initial field trials; thus it may help to serve as a stop-gap until the ideal ressistant rootstock is available.

Even though the results look very promising to date, it should be emphasized that field trials with this new fungicide are still in the experimental and exploratory stage, so that the chemical is not yet recommended for general use. Different types of application are being investigated, as well as different dosages and intervals of application. A new granular formulation of Dexon will soon be available; this may simplify application problems for treating a small number of trees.