FEDERAL EXPERIMENT STATION IN PUERTO RICO
of the
UNITED STATES DEPARTMENT OF AGRICULTURE
MAYAGUEZ, PUERTO RICO

CIRCULAR NO. 33

GROWING AVOCADOS IN PUERTO RICO

By
EDWARD P. HUME
Horticulturist

Issued February 1951

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH ADMINISTRATION
OFFICE OF EXPERIMENT STATIONS

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Washington 25, D. C. - Price 20 cents

FEDERAL EXPERIMENT STATION IN PUERTO RICO

Mayaguez, P. R.

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[1] In cooperation with the Government of Puerto Rico.

ACKNOWLEDGMENT

The author, formerly with the Federal Experiment Station in Puerto Rico, is indebted to J. A. B. Nolla, plant pathologist, Central Igualdad, Mayaguez, for suggestions on the plant disease section; William Pennock, associate horticulturist, Insular Experiment Station, Río Piedras, for advice particularly on the propagation section; and Julio Simons (now deceased), assistant agronomist, Insular Experiment Station, Río Piedras, for information on Puerto Rican varietal selections. Narciso Almeyda, collaborating agronomist, Federal Experiment Station, prepared several drawings and charts. Assistant Dean Robert W. Hodgson, College of Agriculture, University of California, Berkeley, Calif., Vice Director George D. Ruehle, Subtropical Experiment Station, Homestead, Fla., and Dr. F. E. Gardner, Director, U. S. D. A. Subtropical Fruit Field Station, Orlando, Fla., have been kind enough to read the manuscript and make valuable suggestions.

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INTRODUCTION

Perhaps the most important fruit contribution of the New World to the human diet has been the avocado. Popenoe (*31, p. 10*)[1] says "An acre of land will yield a larger amount of food when planted to avocados than it will in any other tree crop known at present." This fruit was not only well distributed throughout most of Central America and northwestern South America before their discovery by Europeans, but was grown with a primitive culture by the Indians inhabiting these regions.

There is sufficient modification in the cultivated fruit to indicate that seed selection had been practiced for some time before Columbus' arrival in the West Indies. Popenoe (*32*), who has made an extensive study of the early distribution of the avocado, believes that in pre-Columbian times the fruits were grown from almost as far north as the Rio Grande in Mexico south to Ecuador and central Peru. His studies indicate that there were at least three and perhaps four or more separate primitive types in widely separated localities which through considerable modification have developed into the three, possibly four, distinct horticultural races now recognized. After the Spanish conquest the avocado was carried to other favorable sections

[1] Italic numbers in parenthesis refer to Literature Cited, p. 47.

of the Americas and Europe. Now the fruit is grown in almost all parts of the world where climatic conditions permit its culture.

In Central America, the West Indies, and northern South America the avocado has become a basic food constituent. In this area trees are commonly found growing singly or in small groups near homes and in the coffee fincas or farms. There is a wide variation in the quality of these seedling fruits and also between the fruits produced in various parts of this area. Collins (*10, p. 21*) reports finding the finest avocados on the Pacific coast of South America especially near Tamaco, Colombia. Popenoe (*32*) found many excellent seedlings in the limestone soils of Cuba, Jamaica, and Haiti, and near Santa Marta, Colombia, as well as Mexico's Yucatan Peninsula but he found few desirable types in the Lesser Antilles.

Avocado production in the Latin American countries is enormous. Although no exact figures are available on total production, the supply is generally sufficient to permit a much higher per capita consumption in the producing areas than in other parts of the world. Puerto Rico,

FIGURE 1.—Avocado production in Puerto Rico. Taken from United States Census for 1940. Each dot represents 100,000 fruits.

for instance, with about 2 million population, produces about 30 million fruits, or an average of 15 per person, whereas consumption in the continental United States is less than ½ pound per person (about 1 small avocado).

In Puerto Rico, as in other islands of the Greater Antilles, the avocado was probably introduced not long after the Spanish conquest of Central America but little is known of its early distribution within the island. It appears to have been grown for a considerable time since large trees are occasionally encountered even in inaccessible mountainous regions. The avocado is not grown as an orchard crop in Puerto Rico and the big majority of fruits produced are consumed close to their origin. Avocado production is carried on chiefly in the western half of the island, although some trees are found in almost all sections. The main centers of production are located in two bands running east and west across the western half of the island as shown in figure 1. The northern band extends from Aguadilla along the well-drained, limestone, ridge section, chiefly at elevations from 500 to 1,200 feet. It includes the western barrios of Aguadilla, the

northern barrios of Moca, San Sebastián, Lares, and Utuado, and the southern barrios of Isabela, Quebradillas, Camuy, Hatillo, and Arecibo. The soils of this region are well drained and tend toward a neutral or alkaline reaction. The rainfall for most of this area is between 70 and 100 inches and fairly well distributed. The southern band extends through the northern barrios of San Germán, Sabana Grande, Yauco, Guayanilla, Peñuelas, and Ponce, including the southern foothills of the central mountain range. This section has a lower rainfall with a long, well-defined dry period. It is also well drained, having either a limestone or porous subsoil. The production in Puerto Rico for a typical year is listed by municipalities in table 1.

TABLE 1.—*The number of trees and fruit produced on the island and in the principal avocado-growing municipalities of Puerto Rico, as reported in the 1940 census.*

Municipality	Trees in production	Fruits
Puerto Rico	279, 004	21, 655, 446
Adjuntas	7, 022	672, 795
Aguada	2, 400	285, 700
Aguadilla	5, 253	619, 021
Aguas Buenas	2, 707	425, 056
Añasco	4, 599	661, 379
Arecibo	9, 292	1, 320, 006
Cabo Rojo	3, 677	337, 246
Camuy	6, 521	938, 785
Guayanilla	6, 292	663, 469
Gurabo	1, 843	206, 873
Hatillo	8, 219	1, 001, 235
Isabela	11, 885	1, 113, 299
Lares	19, 445	2, 085, 766
Loíza	3, 620	348, 950
Mayaguez	3, 526	337, 508
Moca	10, 224	1, 193, 909
Morovis	3, 927	668, 070
Peñuelas	7, 791	1, 041, 901
Ponce	13, 632	1, 687, 430
Quebradillas	4, 065	429, 516
Rincón	2, 105	353, 875
Río Piedras	1, 300	149, 461
San Germán	8, 266	1, 041, 818
San Sebastián	10, 756	1, 113, 568
Utuado	8, 004	1, 010, 885
Yabucoa	4, 294	484, 570
Yauco	12, 762	1, 463, 355

In the continental United States the development of avocado growing as an industry began near the turn of the century in Florida and a few years later in California. It has been increased rapidly, particularly in recent years, when high prices for the fruits have spurred the planting of many new areas. The major part of the 40,000,000 to 60,000,000 pounds of fruit consumed annually in the United States is

FIGURE 2.—Avacado-growing sections of the United States; each dot represents 1,000 trees. Taken from 1940 census. Courtesy of Bureau of Agricultural Economics, U. S. Department of Agriculture.

produced in southern California, near the ocean (fig. 2). Florida's production is chiefly in the Miami area, with some in the central-ridge section.

Imports from Cuba except during World War II, when shipping facilities were not available, have exceeded Florida's production.

Botany.—The scientific name of the avocado is *Persea americana* Mill. It is a member of the laurel family or Lauraceae. The species is divided into three horticultural races one of which, the Mexican, is sufficiently distinctive botanically to stand as a variety, *Persea americana* var. *drymifolia*. This variety was formerly considered a separate species but the discovery of trees intermediate between the two has justified its reduction to varietal rank.

The differences and similarities between the characters of the three horticultural races are indicated in table 2. Trees of the West Indian races are adapted to low elevations in the Tropics and to subtropical areas with little frost. The Guatemalan race trees are found in their native home at medium and high elevations and are adapted to mountainous tropical regions with cooler weather. Members of this race tolerate moderate frost. Those of the Mexican race are tolerant of the greatest temperature range and are more frost-resistant than the Guatemalan.

The avocado has alternate leaves varying widely in shape and size between trees and to a certain extent even between leaves of a single flush on the same tree. The flowers are small, greenish yellow, with 6 petal-like members of the perianth or showy portion of the flower. There are 12 stamens in 3 whorls of 4 each with an additional central whorl of nonfunctioning stamens or staminodia. Nectar-secreting

TABLE 2.—*Similarity and differences between members of 3 avocado races in Puerto Rico*

Character	West Indian	Guatemalan	Mexican
Leaf odor	None	None	Anise-scented.
Usual leaf color	Light green	Dark green (new flushes reddish or reddish orange).	Medium to light green.
Usual fruit size	9 to 20 ounces	6 to 30 ounces	3 to 12 ounces.
Fruit color generally	Light to medium green	Dark green, purple, maroon	Medium green.
Fruit surface	Smooth to slightly pebbled	Usually pebbled to very rough	Smooth.
Skin thickness	1/16 inch, leathery	1/16 to 1/4 inch, often woody	1/32 inch, membranous.
Oil content	Low	High	High.
Flesh color	Cream to yellow, green near skin	Variable, often almost white	Yellowish.
Seed size	Medium to large	Medium to small	Large.
Seeds tight or loose in cavity	Often loose	Tight	Tight.
The 2 seed coats on opening	Usually separate	Adhere tightly together, remain on the seed if fruit is ripe.	Separate or adhere.
Seed surface	Rough	Smooth	Smooth.
Time of bloom in Puerto Rico	December–February	December–April	December–February, sometimes two distinct periods in same year.
Harvest	July–November	November–April	November–January.

glands at the base of each filament of the 2 inner series attract insects. The ovary, which develops into the fruit after fertilization, contains a single cell with only 1 seed therein.

The avocado fruits exhibit great variation in color, size, shape, surface texture, and other characters. The flesh varies from creamy white to deep yellow. Particularly in the West Indian race, a greenish tint in the flesh appears just below the skin. A system of fibers is embedded in the flesh. These fibers range in size from those that are objectionably thick and coarse to those that are almost imperceptible. The character of the seed is sufficiently variable to aid in distinguishing between races, as shown in table 2. It normally consists of two large cotyledons surrounded by two seed coats and contains a small embryo. Most seeds are tight within the seed cavity of the flesh, but in some varieties, particularly in the West Indian race, the cavity is larger than the seed at maturity, permitting some seed movement. The roots are devoid of root hairs (*8*).

Among the 50-odd species in the genus *Persea* are some species of lesser importance. The coyo or shucta (*P. schiediana* Nees) is extensively grown in some sections of Guatemala. It ripens earlier than the avocado, but is usually inferior in quality. It has a brownish-white or pale-brown flesh with a coconut-like flavor. The redbay or bull bay of the eastern United States coast is *P. borbonia* Spreng., a handsome ornamental and timber tree (*5*). The laurel wreaths which were used to crown the athletic champions of ancient Greece were made from the sweetbay (*Laurus nobilis* L.), a member of the same family, as are also such well-known plants as camphor (*Cinnamomum camphora* Nees & Eberm), cassiabark-tree (*C. cassia* Blume), and cinnamon (*C. zeylanicum* Breyn).

Composition of the avocado flesh.—The percentage of flesh in ripe Puerto Rican avocado fruits is about 60 percent (*4*). Some of the varieties in Florida are over 77 percent edible pulp (*48, p. 43*). The composition of the fruit changes during its development. The oil content is particularly variable, being extremely low in the early stages and increasing rapidly with age until the fruits reach the stage where they can be picked and properly ripened in storage. After this stage, which is called physiological maturity, the oil content either stays the same or rises very slowly. Conditions under which the fruits are grown as well as inheritance strongly influence oil content. For example, fruits of a given variety have a higher oil content when grown in California, where they develop over a longer period, than when produced in Florida. The Florida fruits in turn are higher in oil than those grown in the West Indies (*42*). Varieties of the Mexican race generally have the highest oil content (12 to 15 percent in Florida), closely followed by the Guatemalan varieties (10 to 13 percent) (*48, p. 45*). The West Indian fruits are considerably lower and more variable than the other two races in their oil content, which ranges from 2 to 7 percent (*43, 48*).

The percentage of dry matter in the flesh varies with localities in the same manner as the oil content. The California avocados average almost 30 percent (*22*), whereas Florida's avocados are somewhat lower, 15 to 28 percent. The protein content of the fruit in Florida ranges from 0.85 to 1.70, and in California averages 2.1. The carbohydrate content of 1.5 to 2 percent in Florida is considerably below

the 4.5 percent average in California. The ash, or mineral salt, content in Florida varieties is 0.65 to 1.25 percent and averages 1.32 percent in California. The chemical characteristics of the avocado flesh have been calculated both in Puerto Rico (*4*) and in the continental United States (*24*). The results of two investigations are summarized in table 3.

TABLE 3.—*Characteristics of the liquid fraction of Puerto Rican avocado pulp oil*

	Puerto Rico (*4*)	California (*24*)
Specific gravity $\frac{25°}{25°}$	0. 9159	0. 9132
Refractive index 20°	1. 4692	1. 4700
Iodine number (Hanus)	70. 9	94. 4
Saponification number	197. 4	192. 6
Acid value	7. 4	2. 8
Acetyl value	7. 7	9. 2
Reichert-Meissl number	3. 0	1. 7
Polenske number	. 3	. 2
Unsaponifiable matter—percent	1. 1	1. 6
Soluble acids—do	3. 4	----------
Insoluble acids—do	87. 7	----------
Saturated acids (corrected)—do	26. 7	7. 2
Unsaturated acids (corrected)—do	65. 6	84. 3
Iodine number of unsaturated acids	97. 9	101. 2
Saponification number of unsaturated acids	201. 3	----------
Peroxide number, CC. 0.02N $Na_2S_2O_3$, gram of liquid fraction (1½ years at time of determination)	4. 8	----------

SUMMARY

Glyceride of—	Content in the oil	
	Percent	*Percent*
Linolenic acid	Trace	----------
Linolic acid	[1] 6. 0	10. 8
Oleic acid	[1] 62. 6	77. 3
Myristic acid	2. 1	Trace
Palmitic acid	25. 3	6. 9
Stearic acid	. 6	. 6
Unsaponifiable matter	1. 1	1. 6
Arachidic acid	----------	Trace

[1] Values calculated from the iodine number of the unsaturated acid fraction.

Dietetic value.—A comparison of the composition of the avocado flesh with that of other well-known fruits shows several features which indicate its value in human nutrition. The oil, which is the chief source of energy in avocados, has twice the energy value of carbohydrates. Since carbohydrates supply most of the energy in other fruits except the olive (*48, p. 48*), even the fruits of the West Indian race with their low oil content have considerable food energy value. However, the oil content has been shown to be independent of the eating

quality (*37*). The low carbohydrate content of avocados makes them particularly useful in diabetic diets. The work of Mattill (*28*) indicates that avocados are easily digested. The protein content of avocados is higher than most fruits. Its high mineral content is of particular dietary importance because of the unusually large proportions of iron (28 to 46 parts per million), copper (13 to 17 p. p. m.), and potassium (1.63 to 2.21 percent) (*18*).

The avocado flesh is particularly high in vitamins A and B (*45*) and also in vitamin D in high-oil-content fruits.

Because of its bland, nonirritating nature, avocado pulp is sometimes used in the treatment of surface irritations of the stomach and intestinal tract (*26*). It has laxative properties resulting from the combined effect of the roughage of the vascular tissue, organic acids, and oil—a combination of particular merit.

Uses.—The avocado is eaten in a number of ways. Probably the most common is in the form of a salad for which the pulp is sectioned or diced and served with salt. It is occasionally mixed with mayonnaise, catsup, nuts, fruits, and celery. In many Latin American countries the flesh is commonly added to soups just before serving. Varieties with medium or thick skins can be cut or broken in half, the seed removed, and the flesh spooned out of the half shell. In Brazil, particularly, the diced flesh is eaten as a breakfast fruit. In the West Indies the flesh is mixed with such staples as rice and beans.

Avocados are not suited for dehydration or sulfuring as a means of food preservation, but satisfactory frozen products can be prepared from them in two ways. The macerated flesh can be either mixed with sugar at the rate of one part sugar to three parts by weight, of pulp (*11*) or with one part vinegar to five parts fruit, frozen quickly, and kept at 15° F. or below. The flesh must be protected from the air by a tight seal to prevent browning. The sweetened, frozen pulp can be eaten directly or used in ice cream recipes. It should be completely thawed previous to mixing to prevent the formation of ice crystals during the freezing of the ice cream. The vinegar and pulp mixture makes a good sandwich spread alone or mixed with mayonnaise, pimento, and medium-ground pickles.

Cull fruits can be fed directly to pigs and chickens. When sufficient volume of fruit is available the fruit can be dehydrated and the oil extracted in several ways. If the dehydration is performed in the absence of oxygen, the resulting press cake is a superior concentrate for feed mixtures. The oil can be extracted by pressure, organic solvents, water flotation, or with the use of other chemicals, particularly lime (*27*). The oil is valuable in cosmetics because of its penetrating properties and the presence of phytosterol, a carrier of other constituents, and lecithin for its medicinal properties (*1*). It can also be used in the manufacture of specialty soaps.

The seed can be ground and, when profitable, the more valuable constituents chemically removed. Perseitol, a rare solid alcohol with seven hydroxyl groups, is one of the important constituents of the seed. Weatherby (*44*) found that the ground seed, either untreated or after treatment with solvents to remove these chemicals, could be used in rat diets up to 75 percent of the total without deleterious effects. The balance could be supplied from fresh press cake. More research is necessary to determine what percentage of ground seed

can be incorporated in cattle feed. A deep, indelible black juice can be extracted from the seed which is useful for marking linens (*7*).

Avocado wood is light reddish brown, beautifully figured, with poorly developed annual rings. It does not crack or check on drying. It is light weight, 40 pounds per cubic foot, and although brittle and not particularly strong, it has some limited uses because it is easily worked and finishes attractively.

Climate.—The climate of Puerto Rico is well adapted to avocado production except in regions of extremely high or low rainfall. In the low-rainfall areas water deficiencies can be met by supplying irrigation water. The humidity in the island is normally high, seldom if ever dropping so low as to cause actual damage, although this condition occurs in some other parts of the world.

Temperatures in Puerto Rico are adapted to avocado growing. Fruits could be produced during most of the year by growing West Indian varieties at the lower elevations, Guatemalan varieties at higher elevations where they are better adapted to the cooler temperatures, and interracial hybrids at intermediate height. Popenoe (*30*) calculated that in Guatemala, disregarding local conditions, the time of ripening of avocado was retarded at least 1 month for every 1,000-foot increase in elevation.

A comparison of the time of maturity of Guatemalan varieties in Guatemala, Florida, and California shows that for every 2° to 2½° increase in latitude there is a delay in maturity equivalent to the delay caused by a 1,000-foot increase in elevation. Thus, Guatemalan varieties growing at 5,000 feet and 15° north latitude would bear at approximately the same time as the same varieties in Puerto Rico at 18° north latitude near an elevation of 4,000 feet. Actually Guatemalan varieties are known to thrive in a relatively dry section in Puerto Rico at 1,500 to 2,500 feet, but poor growth has been encountered in one planting at 3,200 feet probably because of excess soil moisture.

PRODUCTION

Soil and water relations.—The avocado is adapted to a rather wide range of soil types. Good growth can be observed on stiff clays to almost pure sand or limestone, providing other requirements are satisfied.

Ryerson (*36*) recommends soil at least 4 feet deep for growing avocados in California. Hodgson (*22*) states that 3 feet is the minimum depth of soil on which satisfactory avocados can be grown. On the other hand, much of Florida's acreage is in areas with little or no soil other than sand or broken limestone, but in these areas the upper rock strata are sufficiently soft or broken to permit root penetration. The good growth on these limestone soils, even where shallow, indicates that a thick soil layer is not always necessary.

Haas (*19*) found by measuring the acidity of the soil at its field moisture content that a much greater acidity than commonly believed desirable was found in good orchards. However, Alvarez [2] found that the incidence of root rot in Puerto Rico was far lower on nearly neutral or slightly alkaline soils than on those with moderate or strong acidity.

[2] L. A. Alvarez, plant pathologist, Insular Experiment Station, Río Piedras, P. R., in conversation with the author.

Excessive soil moisture is the most serious condition limiting avocado culture in Puerto Rico. Hodgson (*22*) states that the avocado is extremely sensitive to poor drainage and will not endure a saturated soil. Any practice which tends to increase the moisture content of the soil beyond field capacity is undesirable and conversely any practice which will eliminate excess soil moisture is desirable. In Puerto Rico, avocado trees occasionally are observed close to stream beds where it might be concluded they would not receive sufficient drainage. When these soils are examined, however, they are usually found to be extremely well drained. It has often been noted that older trees are rather scarce in Puerto Rico and occur only under conditions of very good drainage. The majority of Puerto Rican soils hold moisture too well to permit the best development of avocados.

The bad effect of excess soil moisture is increased by the presence of a soil fungus, *Phytophthora cinnamomi* Rands, which attacks the roots. This fungus can produce or intensify symptoms similar to those produced by a water-logged soil alone. In 80 percent of the California trees affected with decline disease the roots were infected with this fungus. A few trees not showing fungus symptoms were also found to have some infected roots. Apparently trees that are infected but vigorous can under conditions of good soil aeration continue to grow for a time at least without showing symptoms of the disease. Since the symptoms do not normally appear until after the trees come into bearing and since it is difficult if not impossible to cure a tree once it begins to show decline (*21*), all possible precautions should be taken to avoid this condition.

Nurseries and orchards should be located only on well-drained soils. "Cut off" ditches, which consist of shallow surface drains, can be located uphill from the trees to intercept surface water moving toward the trees from higher land. If the soil has sufficient natural drainage, no tile drains are needed, except possibly near the base of a hill where moisture accumulates. A drain laid below the last row of trees may be helpful, but it is safer not to plant too close to the bottom as the soil moisture content tends to be higher at the base of a hill. In planting avocado trees the ball should be set 1 to 3 inches above the surrounding grade to improve run-off.

Varieties.—The choice of varieties and the location of the trees in the orchard may be influenced by their flower behavior. The flowering of an avocado tree depends on its location, climate, and genetic constitution. Generally speaking, avocados flower in the winter and spring. However, in dry regions flowering may be delayed sometimes for several months because of insufficient rainfall. For this reason the avocados of the north coast of Puerto Rico, which experiences a more uniform rainfall than the rest of the island, flower normally somewhat earlier. In some years the difference between the extremes of flowering may be as much as 2 or even 3 months, whereas in other years there is little difference.

One of the most important factors to be considered in the development of a commercial avocado orchard is, "What kind of trees shall I plant?" The easiest answer is to plant any available seeds without consideration of the quality of fruit expected. However, the fruit produced from these seeds will be quite variable in size, shape, and other characters. The trees may be tall and slender which makes

them difficult to harvest and more subject to wind damage. They will not begin to bear until about the sixth year, and the fruits will all ripen at about the same time, usually at the time when avocado prices are lowest.

Budded or grafted plants are recommended as they will produce fruit which is the same shape and size range as the parent stock. These plants will be lower headed than seedling plants, which facilitates harvesting. They should begin to yield 2 to 3 years earlier than seedlings. By a careful choice of varieties for time of ripening and quality, the fruits obtained can be sold at top prices.

The selection of a variety or varieties for planting should be made carefully, considering especially—

1. Desirable fruit characters:

   Size—medium to large are desirable for local consumption, small to medium, for export; appearance, attractive, preferably dark green, smooth to slightly pebbled; skin, thick enough to protect flesh in transit but not objectionably thick or tough; flesh, almost fiberless, good quality; seed, tight in the flesh, small, seed coats adhering to the seed; time of ripening, at any season when West Indian fruits are not available; adaptability to shipping, long storage life, not easily bruised, tolerant of cold storage.

2. Desirable tree characters:

   Yield—heavy and regular, but not so heavy as to require thinning, or to cause dieback; tree form, low headed without excessive pruning. Resistant to diseases and insects.

No single variety possesses the ideal characteristics desired. Furthermore, in order to secure fruit during most of the year, it is necessary to have several varieties ripening at different seasons and mixed plantings to insure a satisfactory set of fruit. Investigations undertaken chiefly in Florida have shown that the avocado is more or less selfsterile because of the peculiar behavior of the flowers. The various varieties can be divided into two groups according to their time of opening and closing. The first, or A group, opens a set of flowers for the first time in the morning, when the stigmas are receptive to pollen but when no pollen is being produced, and usually closes by noon and remains closed until the afternoon of the following day when the flowers of this set reopen. The stigmas are then no longer receptive and the pollen is released. The other, or B group, opens a set of flowers in the afternoon for pollination of the stigmas and usually closes overnight. They reopen the following morning for pollen dispersal. Each day during the flowering season a new set of flowers opens on all avocados except under extreme weather conditions. During the morning the flowers of type-A trees are pollinated by pollen shed from the second opening of type-B trees, whereas type-B flowers are pollinated in the afternoon with pollen from type-A flowers which are opening for the second time (*40*).

In Florida a better set of fruits was obtained when orchards were planted with several varieties containing both the A and B types not more than three rows apart and flowering at the same season. In California no particular advantage from mixed plantings has been observed. Since the West Indian seedlings commonly grown in Puerto Rico are a mixture of the two types, there is seldom a pollination problem in that race. Where Guatemalan or hybrid types are grown it may be advisable to interplant several varieties representing

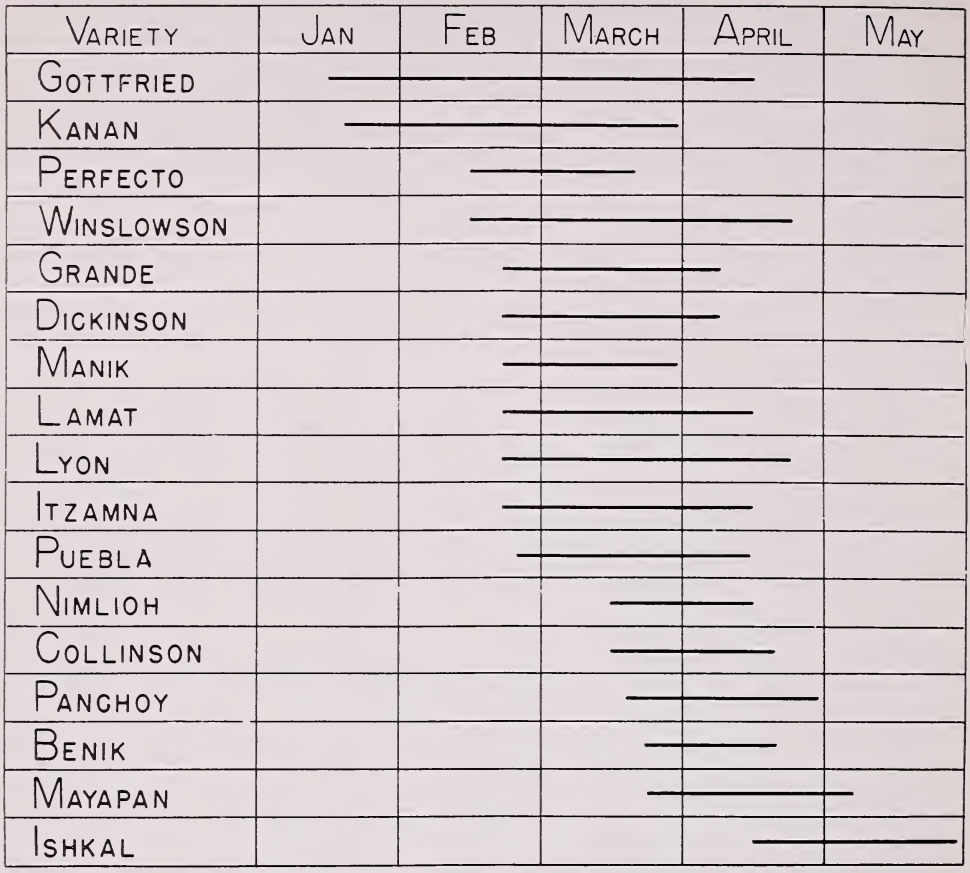

FIGURE 3.—Range in blooming period of avocado varieties near Guayanilla, P. R., based on monthly observations for three seasons. The actual flowering period during any one season usually covers about one-half the extreme range shown above.

both flowering types as their flowering is quite variable (fig. 3). Flowering of any one variety may not coincide with that of other trees in the neighborhood. No experimental evidence on the extent of self-pollination possible under Puerto Rico conditions is available on which to base any definite recommendations.

There are many seedling trees growing in Puerto Rico that have considerable merit. The College of Agriculture, the Insular Experiment Station, and the Extension Service of the University of Puerto Rico have been selecting and propagating from these, distributing the best to farmers of the island. There are doubtless many others worthy of further testing which should be reported to these agencies, and propagated by the owners for further trial.

Because of the lack of commercial orchards in Puerto Rico, it is very difficult to state what may be expected from the various varieties. The only sources of information on varietal performance are a few collections which are described in some detail. The newer Florida varieties remain untried in Puerto Rico and cannot be recommended at present although some have excellent possibilities.

The oldest collection of grafted avocados still growing in Puerto Rico is that of the Insular Experiment Station which is chiefly at

Trujillo Alto. Guatemalan varieties and several interracial hybrids have been grown by the Federal station in a cooperative planting near Guayanilla. The soil in this area is derived from limestone and receives about 50 inches of rainfall chiefly in the later summer and fall. While yields have not been satisfactory because of cultural difficulties and the low elevation (500 feet), the performance of these varieties is of value because of the lack of other comparative information on these races. There is another planting of mature Guatemalan race trees at an elevation of 1,600 to 2,200 feet near Villalba. The varietal identity of these trees has been lost, but their production appears to be considerably lower than the Guatemalan varieties at lower elevations.

Another young avocado collection of both Guatemalan and West Indian varieties has been planted near Mayaguez at 700 feet elevation on Nipe soil which is very well drained. The trees are 3 to 8 years old and many have made extraordinary growth.

The following varieties have proved superior under the conditions where they were tested in Puerto Rico.

West Indian Race:

ALZAMORA.—Selected from tree on finca Alzamora, Mayaguez. Fruit, pyriform, average weight, 18 ounces; skin, yellow-green, smooth, medium-thick; seed, loose; season, late August, early October. Growing in the finca of Oscar Castro, Mayaguez, where it has made good growth and produced fair crops.

AVILA.—Originated in Quebradillas in 1934, finca of Joaquín Avila. Fruit, pyriform; weight, 16–25 ounces; skin, light green, smooth; flesh, deep yellow; flavor, excellent; seed, medium to large. Has performed exceptionally well at Río Piedras and distributed in some quantity throughout the island. Matures July to September.

BUTLER.—Originated as seedling in U. S. Department of Agriculture, Plant Introduction Garden, Coconut Grove, Fla. Formerly propagated to a limited extent in Florida, but now obsolete there. Fruit, pyriform; weight, 16 to 24 ounces; skin, light green, smooth; flesh, thick, almost fiberless, deep yellow with green zone underlying the skin; flavor, excellent; seed, medium, tight, seed coats adhere to skin.

FARIA.—Selection from a tree on Faria's finca, Lajas; fruit, rounded; weight, 14–25 ounces; skin, medium green, shiny, very smooth; flesh, deep yellow; flavor, very good; seed, medium size, sometimes loose; season, late June to early September. A superior variety at Río Piedras.

GARCÍA.—Selected from a tree growing near Trujillo Alto; fruit, short-necked, pyriform; weight, 8 to 16 ounces; skin, yellow-green, flecked with brown, smooth; flesh, very deep yellow; flavor, good; seed, medium, loose; season, late September to November. Recommended on basis of tests at Río Piedras.

HERNÁNDEZ.—Selected from a tree near Carolina; fruit, pyriform; weight, 10–16 ounces; skin, medium green, smooth; flesh, yellow; seed, fairly tight; season July to September. A good variety in trials at Río Piedras.

ST. JUST.—Selected from a tree in Barrio St. Just, Trujillo. Fruit, pyriform; weight, 10–20 ounces; skin, brownish yellow with red blotches, maturing a wine color, smooth; flesh, deep yellow; flavor, good; seed, medium size, tight; season, September to November. Next to Avila, the most widely distributed of the Puerto Rican selections.

Selections in Puerto Rico other than true West Indian:

AMADOR.—Source unknown. Fruit, oblong, spherical, flattened at the base; weight, 18–25 ounces; skin, dark brown, pebbled, 3/16 inch thick; flesh, deep yellow; flavor, good; seed, small and tight; season, October to early December; growing at Isabela. Has performed well at Río Piedras.

GALO.—Found near Ponce. Weight, 16–20 ounces; skin, dark green, dull, rough, 3/16 inch; flesh, pale yellow; season, December to January. Grows well near Mayaguez and on the south coast; a light but consistent bearer.

GIMÉNEZ.—Selected from the finca of Nicasio Giménez. Barrio Guatemala, San Sebastián. Fruit, pyriform, very short-necked; weight, 12–20 ounces; skin, green, smooth; flesh, medium yellow, superior quality; seed, medium, tight; season, late November to early January. Recommended chiefly for late season of maturity.

TORRES.—Selected from the finca of Angel Torres, Adjuntas. Fruit, obovate; weight, 12–20 ounces; skin, dull green, fairly smooth, 1/16 inch; flesh, deep yellow, very good quality; seed, small, tight; season, January to April. Of special interest because of growth at high elevation and of its late season maturity.

TRUJILLO.—Selected from the finca of Teófilo Mercado near the "leprocomio," Trujillo Alto; fruit, pyriform, long, thin neck; weight, 12–22 ounces; skin, deep green, smooth, 1/8 inch; flesh, reddish; flavor, excellent; seed, medium, tight; season, September to November. Recommended on the basis of performance at Río Piedras.

Guatemalan-West Indian Hybrids:

COLLINSON.—(Fig. 4, *C*). Originated in Florida. Fruit, broadly obovoid to elliptic; weight, 18–30 ounces; skin, leathery, 1/16 inch, nearly smooth, glossy; flesh, creamy yellow; flavor, excellent; seed, medium size, loose or tight; season, December and January at Guayanilla, P. R., where it has proved a slow grower but heavy producer and rated one of the best in this collection. It does not produce pollen so must be interplanted with other varieties.

WINSLOWSON.—(Fig. 4, *D*). Originated in Florida. Fruit, roundish oblate; weight, 20–40 ounces; skin, dull, light green, smooth; flesh, pale yellow; flavor, excellent; seed, medium, loose; season on south coast, December and January. Recommended as superior to most Guatemalan varieties; closer to the West Indian type and therefore more acceptable on local market, also large fruit size. Trees not as large as other nearby varieties in this planting indicating a possibility of closer spacing; not adapted for export.

Guatemalan Race Varieties:

DICKINSON.—Originally cultivated in California. Fruit, oval; weight, 9–16 ounces; skin, very thick, rough, dark purple; flesh, medium yellow; flavor, good; seed, small, tight; season, January to February. A good variety at Guayanilla, yielding moderate but consistent crops. Upright tendency of growth.

GRANDE.—(Fig. 4, *A*). A California variety originally from Mexico. Fruit, pyriform; weight, 20–32 ounces; skin, rough, dark green; flesh, yellow; seed, medium, tight; season, December to January. Not recommended on south coast, but trees, apparently of this variety, growing near Mayaguez have produced excellent crops. The large size desirable for local consumption.

ITZAMNA.—An introduction of the U. S. Department of Agriculture by F. W. Popenoe. Fruit, oblong pyriform, stem insertion offset from middle of smaller end; weight, 14–18 ounces; skin, rough-pebbled, dark shiny green; flesh, yellow; flavor, very good; seed, small, tight; season on south coast, February to early April. A consistent high yielder in the collection near Guayanilla. Desirable also for late season of maturity. The long fruit stems may expose fruit to sunburn.

NIMLIOH.—(Fig. 4, *F*). An introduction of the U. S. Department of Agriculture. Fruit, elliptical, large; weight, 20–40 ounces; skin, slightly rough, dark dull green; flesh, rich yellow; flavor, excellent; seed, fairly small, tight; season, January and February. At Guayanilla on the south coast, the tree grows slowly and bears moderate yields of large-sized fruit.

PANCHOY.—(Fig. 4, *B*). An introduction from Guatemala by the U. S. Department of Agriculture. Fruit, pyriform to nearly elliptic; weight, 16–28 ounces; skin, glossy green, roughly pebbled; flesh, light yellow, nutty; seed, medium, tight. Season, March to early April. Heavy yielder on the south coast but susceptible to "dieback." Fruits have undesirably thick skin.

FIGURE 4.—Fruits of various avocado varieties. *A*, Grande; *B*, Panchoy; *C*, Collinson; *D*, Winslowson; *E*, Manik; *F*, Nimlioh.

None of the varieties containing Mexican inheritance has proved desirable in the plantings observed by the author in Puerto Rico. These include the Fuerte, Puebla, and Gottfried.

Check list of avocado varieties which have been recommended at one time or reported as satisfactory in Puerto Rico:

Amador.—See list of superior Puerto Rican selections.
Avila.—See list of superior Puerto Rican selections.
Benik.—A Guatemalan making fair growth at Guayanilla.
Butler.—See list of superior Puerto Rican selections.
Collinson.—See list of superior Guatemalan-West Indian hybrids.
Dickinson.—See list of superior Guatemalan varieties.
Dulce.—Origin unknown, growing vigorously at the College of Agriculture, University of Puerto Rico, Mayaguez.
Faria.—See list of superior Puerto Rican selections.
Fuerte.—A vigorous grower recommended in former years before dieback became serious.

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Galo.—See list of Puerto Rican selections.
García.—See list of Puerto Rican selections.
Giménez.—See list of Puerto Rican selections.
Grande.—See list of superior Guatemalan varieties.
Guatemala.—A selection from Barrio, Guatemala, San Sebastián, for its late season of maturity.
Hernández.—See list of superior Puerto Rican selections.
Ishkal.—A fair grower but poor yielder at Guayanilla.
Itzamna.—See list of superior Guatemalan varieties.
Kanan.—A fair producer at Guayanilla and Mayaguez, upright tendency of growth makes culture and harvest difficult.
Knight.—A fair grower but poor yielder at Guayanilla.
Lamat.—Irregular bearer at Guayanilla.
Manik.—(Fig. 4, *E*). A Guatemalan variety worthy of further testing because fruit holds well into the spring.
Monje.—A high quality West Indian fruit bearing early in the season for this race.
Nabal.—Recommended in former years at Río Piedras.
Nimlioh.—See list of superior Guatemalan varieties.
Panchoy.—See list of superior Guatemalan varieties.
St. Just.—See list of superior Puerto Rican selections.
Tumin.—A desirable variety for home use because of the smooth, shiny, attractive fruit, a poor yielder at Guayanilla.
Winslowson.—See list of superior hybrids.

The following varieties are not recommended at present: Dorothea, Fuerte, Gottfried, Kanola, Mayapan, Puebla, and Tertoh.

The following varieties have been named but not sufficiently tested to evaluate: Archilla, Capacete, Cristina, Dick, Escalera, Fajardo, $40, January, Mercado, Q2, Q3, Q5, Q7, Redo 2, Silva, Tocón, and Torres.

Nursery management.—Grafted trees are not easily produced because of the care required at all stages in their development. In regions where commercial orchards are planted with grafted trees, their production is usually carried on by a few specialized nurserymen who sell them to the grove owners. Since at present there are no commercial sources of grafted avocado trees in Puerto Rico, it will be necessary in most cases for each grower to graft his own trees.

The site selected for the nursery should be close to the center of operations where water is available. Raised beds are preferred to improve the drainage. A sandy soil with some well-decomposed organic matter permits good root development. The larger seeds germinate rapidly and produce bigger trees (*23*). Guatemalan race seeds produced in proximity to West Indian trees are perhaps best because of the possibility of hybrid vigor in the stock. Crossing seldom occurs in the reverse combination. However, both Guatemalan and West Indian stocks can be used for scions of either of these races. One local grower feels that he has less decline on trees with Guatemalan stock.

Early planting is advised since seeds lose their ability to germinate within a few weeks after removal from the fruit. Removal of the seed coat has given earlier and more uniform germination at this station. Seeds can be sprouted in special containers or directly in the nursery bed. The latter method avoids a check in growth but does not permit seedling selection for a more uniform stand. The seeds are planted point up and protruding from the soil but covered by a light mulch of organic matter.

To permit easy grafting, a spacing of 14 to 18 inches in rows 2 to 2½ feet apart is recommended. The best success obtained at Mayaguez

was under a lath shade which screened 40 to 60 percent of the light. Relatively frequent, light waterings maintain the soil moisture near optimum.

In sandy soils, such as occur in Florida, the seedlings are planted directly in soil contained in deep wooden boxes, in gallon cans, or in tar-paper cylinders where they remain during grafting and until planted in the field. For home gardens the plants are sometimes shifted to 5-gallon cans and sold at a considerably higher price.

Propagation.—The age and vigor of the stock have an important bearing on the percentage of successful "takes" obtained in propagating. Young seedlings with only a few expanded leaves still have considerable food reserves in the seed to draw on. Moreover, the stem is still succulent and capable of uniting quickly with the scion without the necessity of carefully matched cambium lines. The percentage take drops with the increasing age of the stock until the trees are old enough to have considerable stored food reserves.

The selection of the proper budwood is important for success in budding. Some propagators prefer to defoliate the branches about 2 weeks before cutting to permit the petiole bases to mature and fall before the bud is utilized; others use the buds from older sections of the stem where the leaves have already fallen in order to have a healed bud scar. On the other hand, the base of the petiole can serve as a convenient handle when inserting the buds and reduces the chances of contaminating the interior surface from handling. The petioles can then be cut off flush with the bark to avoid difficulties in wrapping. Some growers girdle the stem several weeks before taking the budwood in order to permit food reserves to accumulate. There is no experimental evidence to recommend these systems.

Although very young stock is particularly desirable for grafting, as mentioned later, a somewhat older stock is preferred for budding. The bark of very young seedlings is so thin that it is easily torn in the process of inserting the bud.

The position and condition of buds in relation to their suitability for use in propagation have received attention by many workers (*22; 29; 31, p. 40; 46, p. 30; 47*). The opinion of the majority is that the bud sticks should be well developed, 4 to 6 months old, and preferably from the last flush. Higgins and his associates (*20*) found wood from the next-to-last flush superior. The lowest buds of a flush should be discarded as they are difficult to start into growth, and the soft, tip growth should either be discarded or used in grafting as these buds drop the eyes too easily.

Work at the Federal station indicates that from the third or fourth bud below the terminal cluster to the eighth or ninth there is no appreciable difference in the end results. Buds near the center start more rapidly but the others are not far behind after 4 months. Experiments in Puerto Rico have also indicated that if the wood is taken just as the flower buds are first beginning to swell, greater success can be obtained.

Budwood can be kept up to 2 months by packing in slightly dampened sphagnum, peat, sand, or in sealed jars, and storing in a cool, dark place (*22*).

The shield bud method is the one most commonly used for budding avocados. The name is derived from the shape of the piece of bark

taken with the bud. This shield is cut with a very sharp, thin-bladed knife which is drawn under the bud for a distance of 1 to 1½ inches. The knife handle is held as nearly parallel with the bud stick as possible in order to make the cut surface nearly flat. Success is largely dependent on securing a smooth, flat surface on the underside of the shield which will make good contact with the stock. The bud is slipped without delay under the bark through a T or inverted T-shaped cut (fig. 5). It should be handled as little as possible, particular care

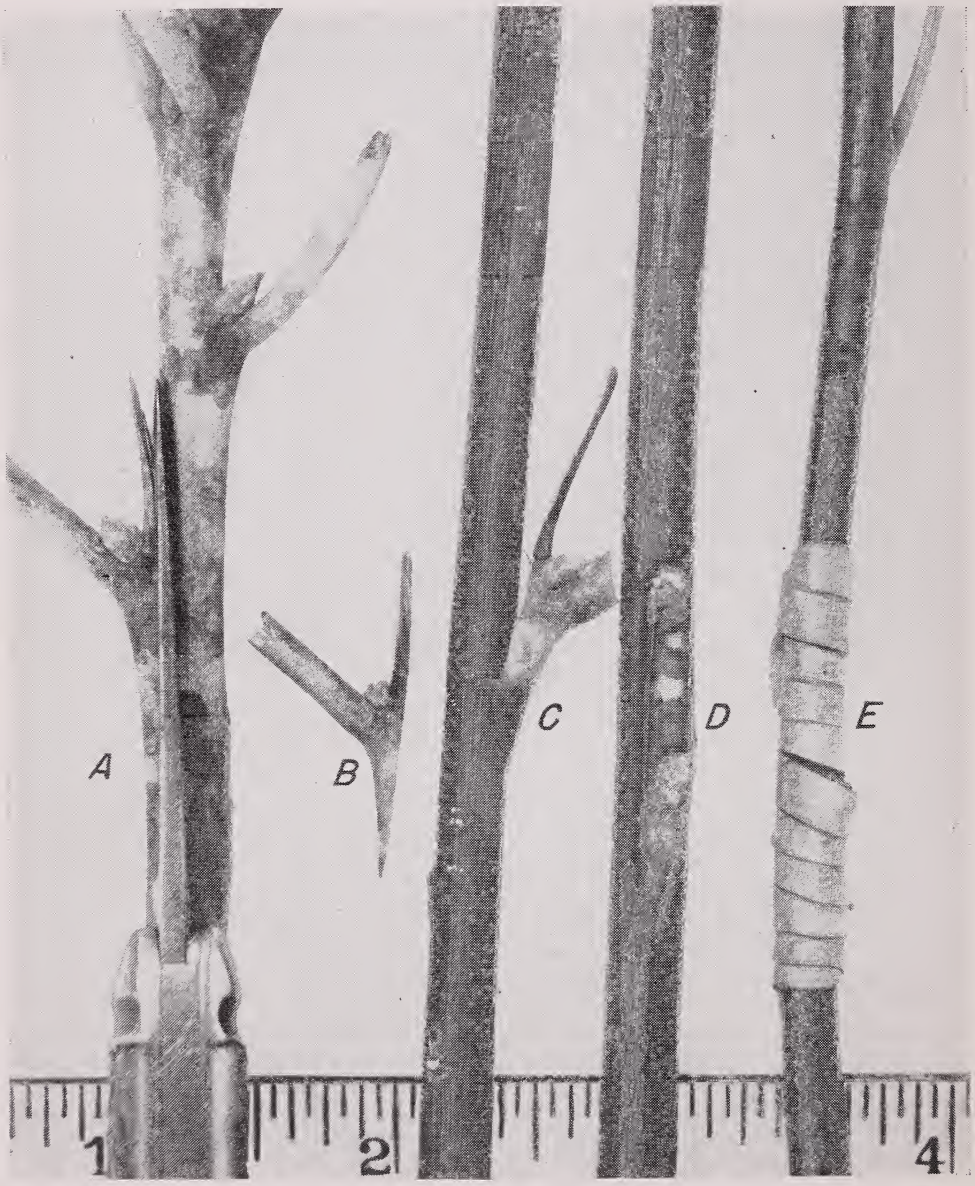

FIGURE 5.—Shield budding consists of forcing buds of the desired variety, which have been removed with a thin section of the surrounding bark, under the bark of the stock through a T-shaped opening. The bud is cut holding the knife closely in line with the bud stick (*A*) for a smooth flat shield (*B*). It is pushed under the bark at the intersection of the T-cuts (*C*) and (*D*). A rubber grafting band (*E*) holds it in place during union.

being taken to avoid touching the lower or uniting surfaces. The knife or razor used to cut the buds should be maintained in optimum condition by sharpening on a leather strap at frequent intervals. Sharpening after 25 to 30 buds is recommended (*48*). The thickness of the bud is also important. Buds that are cut too thin are difficult to force under the bark, whereas excessively thick buds are bound to be gouged and are too stiff to fit the curved surface of the stock. The best shield is one that is just thick enough not to bend or wrinkle when inserted under the bark of the stock.

The bud shield must be tied in place until the union takes. Rubber bands or strips are particularly satisfactory, and, if not wrapped tightly, do not require loosening as the stem thickens. Cotton string, waxed cloth bandages, or raffia have proved equally satisfactory but require loosening in 3 to 5 weeks. All bindings should be removed when the scars are healed. The bud may be further protected by wrapping with wax-impregnated cloth bandages or by an umbrella of waxed paper tied above the bud to prevent the entrance of moisture. Forcing the bud to grow into a shoot is often a difficult job particularly in older stock. This is another reason for budding at the earliest possible stage. The tops of the stock plants can be headed back as soon as union is completed, but several leaves should be left above the bud to prevent dieback until the new shoot is well established. Girdling the stem above the bud except for a small section on the side opposite the bud is recommended in Hawaii (*20*). When the new stem from the bud reaches 4 to 6 inches it is desirable to pull and tie it toward the stock to encourage upright growth, and to protect it against strong winds (fig. 6). The union is easily broken, so strong pressure should be avoided. The stock should not be completely cut back until the bud shoot is well established and growing vigorously and at least two new flushes have developed. The final cut should be made close to the shoot and sharply slanting to avoid dieback. Wound painting is desirable to prevent infection.

Grafting is now used almost entirely in Florida because the time necessary to produce a tree ready for field planting by this method is less than that required by budding. Suitable scion wood is also easier to obtain because its condition is not as important. When propagating material is scarce, however, budding is desirable because many more plants can be budded than can be grafted from an equal quantity of wood. The best time to graft is in the cool winter months (*48, p. 50*). The leaves in the grafting area of the stock are cut off flush with the stem.

In Florida the most successful and the most commonly used graft in very young stock is a simple side graft (fig. 7, *B*). When this graft is used a slanting cut is made into the stock stem a few inches above the ground penetrating downward about 2 inches and about half way or less through the stem. The scions are cut from the tips of branches 2 to 3 inches long. The leaves are cut off through the petiole close to the stem, and the base is cut to a slender wedge by tapering the cuts on each side. The wedge is inserted in the opening in the side of the stem so that no cut surfaces are exposed, and is held firmly by wrapping with rubber strips. String, raffia, and other nonelastic binding materials are cut away in 2 to 3 weeks to avoid girdling. When

FIGURE 6.—The young growth from buds or scions should be tied to the stock or to a stake for wind protection and to encourage upright growth. The unions are still weak and will break if pulled too tightly.

the grafted surfaces have united, a new tie may be made for support. At this stage the stock top is headed back and subsequent treatments are the same as for budded plants.

If the side graft fails the stem may be cut off 2 to 3 inches above the soil and the butt split through the center. A scion prepared as in the

FIGURE 7.—Two simple forms of grafting. *A*, Cleft grafting on young seedling stock. From left to right: Decapitated stock cleft to take scion; scion with slender taper on both sides; scion in place; and scion bound with rubber grafting band. *B*, Side grafting. Left to right: Scion wood as prepared after removal from the tree; scion in place; a scion tapered ready for insertion; and graft bound with rubber grafting band.

side graft is forced into the split or cleft until the cut surfaces are in contact (fig. 7, *A*). The graft is covered with grafting bandages, or tied with raffia, soft string, or rubber strips. Some method of waterproofing is required where the grafts are exposed to rains. Grafting wax may be painted over the area, or waterproof paper may be tied over the graft. This method was reported highly successful at the Mayaguez station some years ago with very young stock.

In the open, the cleft graft has not been as successful as either side grafting or budding in recent years. For slightly older stock, side-tongue grafts were more successful. This type of graft increases the area of cambium contact and helps to hold the scion in place. The side-tongue graft is prepared similarly to the side graft except that a second cut is made in the stock, starting from the same point but penetrating deeper into the stem, and the scion is split back through the tip of the tapered base a distance equal to the length of the cuts in the stock (fig. 8, *A*). The scion is placed in position by forcing the wedge between the two cuts in the stock into the split in the base of the scion. It is necessary to have the cambium, or the part of the stem between wood and bark, in close contact with similar tissue in the scion. The best success is obtained where stock and scion are the same diameter. Where the stock and scion are quite different in size it is possible to get contact on one side only. Whip, or top-tongue grafts (fig. 8, *B*), are slightly easier to accomplish, but they require time for the development of a new top if the graft fails.

A more cumbersome but surer way is inarching. A thin strip is cut from the stem of a potted stock seedling and firmly bound to a similarly cut section of the stock tree. The pots may require tying to a tree or the construction of a frame support under large trees. After union the scion is cut off from the tree (fig. 9).

Older trees can be top-worked by cutting back branches to within a foot or two of the trunk and inserting scions in these butts. The scions should be taken from somewhat older wood than that used for young seedlings. In top-bark grafting the scions are cut with a single smooth sloping cut at the base and inserted between the bark and the wood at the exposed ends of the old branches, with the cut surface facing inward. Two to four scions are inserted in each stub, depending on its size, and are nailed in place.

The cut ends of the old branches can also be cleft grafted, in the same manner as with very young stock, but preferably during the winter when the trees are dormant. In mature trees, the opening must be forced apart with a wedge to prevent damage to the scions, even when taken from older wood, and in very heavy stems a part of the wedge must be left in place to avoid crushing the scions. Two scions tapered on both sides are placed in the opening thus formed, so as to match the cambium lines at both ends of the cleft. The cuts for tapering the scion base are made not quite parallel, and the thicker end is placed on the outside of the cleft for close cambium contact. As the tree bark is much wider than that of the scion, the scion must be inlayed sufficiently to match the cambium lines. A somewhat better fit can be obtained if the V-shape necessary for the scion wedge is sawed out and the surface smoothed with a knife.

In California a method called saw kerf is recommended in which shallow notches are sawed out of the tip of the butt and are smoothed with a knife.

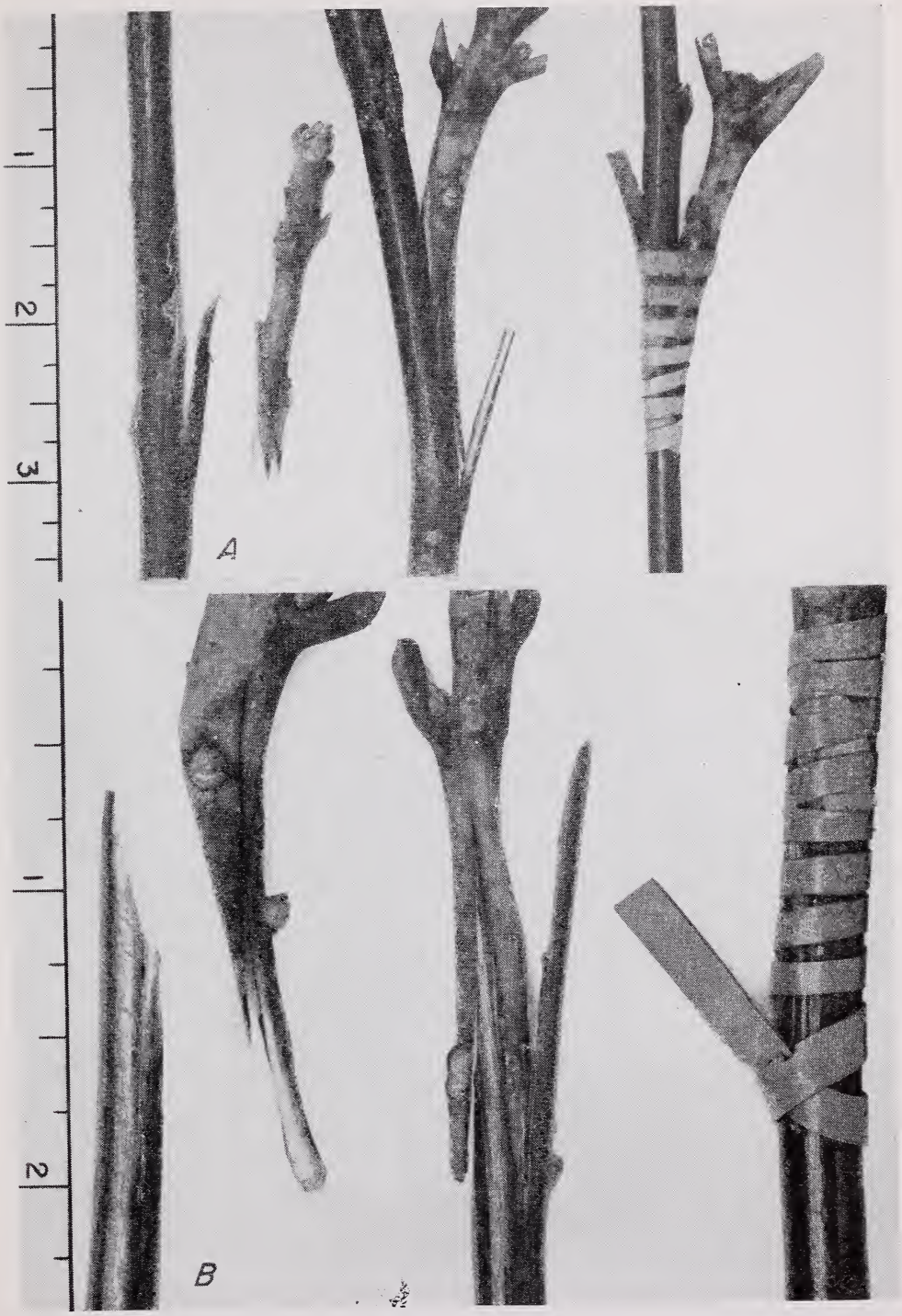

FIGURE 8.—Tonnage grafting. *A*, Side tongue grafting. Left to right: Stock cut preparatory to grafting; scion similarly cut; scion in place ready for budding; graft bound with rubber grafting band. *B*, Top tongue or whip grafting in the same order.

It is essential to give complete protection to prevent drying out of the tender tissues exposed in the grafting operation, to avoid wood rot fungi, and to prevent the entrance of water. For this purpose all

the exposed surfaces should be thoroughly coated with a suitable grafting compound. The upper portion of the scions should be protected against drying by wrapping a piece of roofing paper around the stump end of the branches. The cylinder thus formed should extend beyond

FIGURE 9.—Avocado propagation by inarching consists of binding the cut surfaces of seedlings against stems of similar size of the desired variety until the two are united. The scion is then cut below the union.

the tips of the scions. It is then filled with moist peat and watered if necessary until new growth develops. Another method of protecting the upper end of scions consists of forcing a small section of banana leaf stem over each scion and leaving it in place until union is complete.

When the treetop is cut off the bark is exposed to the sun. Whitewashing will prevent sunscald or high-temperature injury. Top-working a tree is far more difficult and time consuming than grafting a small seedling. It also requires regular inspections and follow-up work to keep the unions in good shape and to develop a well-formed head. Generally, only one branch is allowed to develop from each stump branch even when more than one scion takes; but the others are not destroyed completely as they help to heal the exposed stump.

A more simple method of top working consists of side-bark grafting. In this method two parallel vertical cuts are made in the main branches or, in smaller trees, directly in the trunk as wide as the scion to be inserted. A horizontal cut across the top of the two vertical ones permits a flap of bark to be pulled away. The scion should be inserted far enough so that the bark above does not interfere with the direct contact between exposed cambial surfaces. The scion, tapered to a slender wedge by smooth cuts on both sides of the base, is inserted and held fast by a nail through the flap. The cut surfaces are protected by grafting compounds. After the graft has taken and the new growth started, the branch or trunk can be headed back and finally cut off with care to avoid damage to the new shoot. In addition to its simplicity, this method has these advantages—production from the tree need not be stopped until a successful graft is obtained and the trunk is shaded at all times, thus eliminating the necessity of whitewashing. The bark graft can also be used on young stocks; in this case the scion is forced into a T-cut in the bark as in shield budding.

A number of special forms of grafting such as the seed graft, in which the scion is inserted in the seed with the tip of the wedge in contact with the embryo, are adapted for special purposes. These methods are not in general use and are therefore not considered in this circular.

Another method is to plant seedlings in the orchard at the spacing desired for the trees. After 3 years these are grafted to the desired varieties. This method avoids any possible loss of grafted trees in transplanting and delays decision with regard to the scion varieties to be used. The additional 2 years' performance record of possible scion varieties in other plantings may change the decision as to what varieties to use.

Establishing an orchard.—By proper planning, it is possible to avoid many of the troubles that are difficult to overcome in later stages of orchard development. The discussion of soil and moisture relations should be carefully considered in connection with any proposed orchard site. Wind protection is another factor of importance in locating an orchard. The drying effect of even moderate winds is much greater than most people realize. In fact, at times moisture may be lost from the leaves at an even greater rate than the roots and stem can supply. Although citrus leaves, for instance, wilt soon after this condition occurs, the stiffer avocado leaves may not show loss of moisture until the leaf tips die or the fruits begin to fall prematurely. Wind movement may cause mechanical damage by branches rubbing against the fruits which mars their appearance and may serve as an entry way for fruit rot organisms. A well-protected location is therefore a great asset.

More exposed sites may be utilized if satisfactory windbreaks are developed. The only satisfactory permanent windbreaks are trees. They should be planted before the fruit trees, or at the same time if temporary windbreaks are also used. Temporary-type windbreaks include screens covered with burlap or similar mechanical structures, rows of tall, quick-growing crops such as pigeonpeas or "gandules" (*Cajanus cajan* (L.) Millsp.), bananas, tall-growing Crotalarias, and "vara blanca" (*Desmodium nicaraguensis* Oerst). Several species of *Casuarina* are the most commonly recommended windbreak trees, but their roots spread from 50 to 75 feet from the trunk and compete with adjacent crop tree roots unless controlled by cut-off ditches. In Florida the Australian silk-oak (*Grevillea robusta* Cunn.) and the jambolan (*Eugenia jambolana* Lam.) are recommended. The rose apple (*E. jambos* L.) grows wild in Puerto Rico and can also serve as a windbreak.

Windbreak trees can be reduced or eliminated if the avocados are grown in mixed plantings with more wind-tolerant, tall trees such as coconuts (*Cocos nucifera* L.), breadfruit (*Artocarpus communis* Forst.), mango (*Mangifera indica* L.), and shade trees for coffee such as *Inga vera* Willd. or *I. laurina* (Sw.) Willd.

In cleared land that is not too steeply sloping, the holes for planting can be laid out geometrically in the staggered row system, so that every tree is equidistant from its neighbors. A spacing of 30 to 35 feet is recommended for grafted trees on fertile soil. If the land slope permits, a wider space should be left every 6 to 8 rows as a road to facilitate harvesting and orchard management.

Many areas are already planted to coffee and other economic crops. Farmers are reluctant to clear all the land for a crop which will not yield for 4 years or more. The existing vegetation will supply both shade and wind protection to young avocado trees, if properly opened. The problem here is not a question of clearing the land and cultivating by mechanical means, but of locating the points for planting so that the trees will have approximately the desired spacing. Some variation in spacing is sometimes necessary to avoid planting directly under trees with heavy shade, but irregularities in spacing will reduce the ultimate yield.

In digging the holes the topsoil should first be removed and piled. Then the subsoil should be removed and discarded as only topsoil should be used to fill around the tree balls. The holes should be somewhat wider than the tree balls but no deeper than necessary to avoid later settling.

When the new growth from the scion or bud has developed into a bushy head as a result of heading back (fig. 10,*A*), and after the orchard location has been prepared and the holes dug, the trees can be prepared for moving. This consists of digging the soil away from the roots until a cylinder 7 to 8 inches in diameter and 10 to 12 inches deep of undisturbed soil containing most of the roots is left (fig. 10,*B*). Burlap is then placed over this cylinder, leaving 4 to 5 inches extra at the base. The burlap is drawn firmly around the soil cylinder by sewing with strong cord using a coarse lock stitch, starting from the stem and continuing down the side (fig. 10,*C*). The cylinder is then cut away from the soil below and the base similarly sewed (fig. 10,*D*).

FIGURE 10.—Avocado transplanting. *A*, A grafted avocado in the nursery, ready for transplanting. *B*, The soil cylinder containing most of the roots. *C*, Burlap sewed firmly around top and down the side with enough to cover the bottom after the cylinder is cut off. *D*, The "ball" ready for moving; the burlap sewed firmly over the bottom.

These balled and burlaped trees must be handled with extreme care to avoid breaking the fine rootlets in the soil. The plants should always be handled by the ball. A deep cushion of freshly cut mulch should be placed under the balls when they are to be transported over rough roads.

The burlap can be cut away when the ball is in place if the ball of soil is still firm. Otherwise, it may be left in place as it will rot before it seriously impairs new root growth. One of the most important steps in planting is to replace the soil in close contact with the ball to avoid large air spaces. The soil used should be pulverized and packed in thin layers, unless it is wet. This packing should be done on the filled earth. Care should be exercised not to hit the soil in the ball. The newly set plants should be given an immediate, thorough watering to aid in compacting the new fill. Subsequent waterings should be given whenever the rains are not uniform or sufficient.

Trees may be left in the nursery until they are quite large to reduce the time until the orchard begins to bear, but small trees are easier to transplant as they require smaller balls of soil and are less checked in growth as a result of moving.

Orchard management.—If the area between trees is not already utilized for other crops, it should be planted to help carry the expense of the orchard, as an aid in cultivation, and as a soil-conservation measure. Almost any crop which can be planted in such a way as to avoid excessive shading of the avocados and not to damage the roots in harvesting, can be utilized. It should be kept in mind that the spread of roots will exceed that of the tops within a year or two of planting; hence no root crop should be planted closer than twice the spread of the tops. Pigeonpeas or "gandules" are particularly good as these plants are fairly tall, quick growing, do not cast dense shade, and at the same time build up the nitrogenous content of the soil through action of root nodule bacteria. They should not be seeded closer than 5 feet to the trees as they may reach a height of 10 to 12 feet. Bananas and plantains are desirable at a greater distance for their wind protection and because the crop returns justify fertilization, some of which benefits the avocados also (fig. 11). Cover crops such as *Crotalaria*, velvetbeans (*Stizolobium* spp.), and tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.), are desirable for soil improvement or as a source of cut forage.

Unless the soil is mulched, cultivation may be necessary, particularly in the early years, until the avocados are old enough to shade the surrounding ground. The chief purpose of cultivation is to discourage competing weeds, particularly vines, which can be accomplished by frequent "macheting." A more lasting control can be obtained by shallow cultivation, ½ to 1½ inches deep. Deeper cultivation is not desirable as this practice cuts off the tree roots in the upper soil layer where they are most active.

Pasturing animals in avocado orchards is almost always undesirable. Chickens and hogs disturb the soil and thus destroy the feeding roots. Larger animals tend to compact moist soils, which aggravates excessive soil moisture conditions where they exist. Furthermore, avocado foliage has been shown to be poisonous to and may even kill rabbits (*3*) and probably other animals, if consumed in sufficient quantities. If an animal is tethered to a tree, cankers may develop on the tree trunk where the rope was tied.

Fertilization of avocado orchards has never been studied under Puerto Rican conditions. Consequently any recommendation is of little value. The subject can best be approached from a review of fertilizer practices in other parts of the world. Hodgson (*22*) rec-

FIGURE 11.—Young avocados with banana intercrops.

ommends from 125 to 200 pounds of nitrogen per acre per year in the bearing orchard in California. This amount is equivalent to the nitrogen in 1,250 to 2,000 pounds per acre of a complete fertilizer carrying 10 units of nitrogen or 625 to 1,000 pounds of ammonium sulfate. Additional applications may be required if a heavy crop is set. For young trees the desirability of any fertilization in fertile soil is open to question. Since most California soils are relatively well supplied with phosphorus and potash, the use of these fertilizers is not recommended aside from that carried by organic matter, or where deficiencies can be shown by improved growth of test trees.

In Florida where the avocado-growing soils are either sandy or broken limestone, the nutrients are leached more rapidly and the orchards require frequent applications of fertilizer. Wolfe et al. (*48*) recommend that the nitrogen for young trees should be chiefly from

organic sources. Avocado plantings should receive a mixed fertilizer, high in phosphate, every 60 days for 2 years. A rough guide to the amount required annually as recommended in Florida but adjusted to fit the nearest approved formula for Puerto Rico is 1 pound of a 12–8–5 fertilizer per tree for every year of its age for the older trees. This annual amount is divided into three equal applications. Neither California nor Florida has comparable soils to those of Puerto Rico. The chief point in common from the above recommendations is the benefit from nitrogenous fertilizer in bearing orchards. A moderate application of nitrogenous and perhaps complete fertilizer appears advantageous for bearing trees in Puerto Rico.

The use of mulches in avocado growing has many advantages. Weed control is simplified and the physical condition of the soil is improved. The roots can grow closer to the surface since soil under a mulch is less susceptible to drying out. Soil erosion and fertilizer runoff are reduced to a minimum. Falling fruits are less apt to be injured because of the cushioning effect of the soft mulch.

The mulch may consist of leaves, grass, or other suitable organic matter, particularly legumes, and should be applied at least 6 inches thick, preferably deeper. A mulch decomposes fairly rapidly in a warm climate and will require replenishing at the beginning of each dry season. It should not be placed in direct contact with the tree trunk. For a bearing tree the mulch need not be applied closer than 2 feet from the trunk, but it should extend beyond the spread of the branches where many of the feeding roots are found. Fertilizer may be applied to the surface of the mulch as an aid in decomposing it and to prolong the period of availability to the roots. Mulching normally increases the moisture content of the soil and should not be used where there is any question of adequate drainage in order to avoid possible root rot infection. In high rainfall areas the use of mulch during the period of heavy rains may be questioned.

Mulches are particularly beneficial to trees that are not otherwise fertilized; they are even more important on steep slopes where soil erosion is severe and where it is difficult to use mechanical means of cultivation. Mulches seldom if ever constitute a fire hazard under the usual conditions of high humidity.

The avocado usually requires little pruning. Pruning should be done only when necessary for a particular purpose such as in heading back trees to facilitate harvest and to decrease wind damage (fig. 12, *C*). Any necessary pruning should be done yearly to avoid the severe checks in growth and large wounds when pruning is delayed. Branches which lie on the ground should be removed. When the branches are spaced too close together, they should be thinned out to secure a strong framework of evenly spaced branches (fig. 12, *D*).

Other pruning recommendations call for removal of cross branches and suckers (fig. 12, *A*) and thinning the head to improve the development of fruit in the center of the tree (*13*). If dieback develops (fig. 12, *B*) the affected branch should be cut off several inches below the infection and burned. In pruning, clean smooth cuts should be left at the point where the branch originated or flush with a side branch so that no stubs remain to die and serve as an entrance for wood rot fungi or termites. In cutting main branches it is desirable to first cut to a stub about 3 feet from the main trunk to relieve the weight on the final cut and reduce the danger of splitting.

FIGURE 12.—Pruning and tree form. *A*, Sucker growth close to the trunk is normally undesirable and should be removed. *B*, Poorly shaped, weak avocado tree showing some dieback; too far developed to improve form by pruning. *C*, Well-shaped avocado with low head for easy harvesting, with intercrops of pineapple (*a*) and pigeonpeas (*b*). *D*, A wide angle of branching desirable for strong framework.

Avocado trees should be encouraged to develop either one of two generally desirable forms. In the central leader type the main trunk is well developed and all other branches are more or less perpendicular to it; whereas in the modified leader type two to five of the lower side branches are well developed and turn upward, serving as secondary trunks. The latter form (fig. 12, *C*) is easier to handle as the tops are lower but under such pruning the tree is not so strong as under other types of pruning. Double or multiple leader trees branching at very narrow angles are undesirable because the crotches of such trees are easily split.

Thinning of fruit when a very heavy crop is set is seldom practiced in Puerto Rico. The usual purpose of this operation is to overcome alternate bearing or the tendency of some varieties to yield heavy

crops every other year. This tendency is more pronounced in the Guatemalan race where the fruit remains on the trees for 10 to 15 months thus affecting more seriously the flowering and set of the succeeding crop. In Puerto Rico the majority of the trees show irregular yield rather than any definite periodicity. The chief benefit to be gained from thinning in Puerto Rico is the prevention of excessive weakening of the trees from overproduction. A number of cases of severe dieback or even death of the trees occurred the year following the development of an extra large crop.

The grower is naturally adverse, however, to removing fruit that is already growing on his trees and that represents potential profit with the objective of obtaining possible increases in future years. Furthermore, a considerable amount of natural self-pruning takes place at all stages of fruit development. However, the earlier the excess fruits are removed the sooner the heavy drain on the food reserves of the tree can be eliminated and the more effective the operation will be. Early thinning also tends to increase the size of the remaining fruit.

In thinning, the smallest, diseased, or malformed fruit should always be removed first, usually when the fruits reach a length of 1 inch (*48, p. 75*).

Harvesting.—As the avocado fruit grows it changes in size, shape, and color as well as in chemical and physical conditions. If picked too early, the subsequent changes are not normal and the resulting fruit is inferior or worthless. Since the fruits should be picked before they soften in order to insure greater storage life and less liability of damage in transit, it is necessary to know the stage of development that permits normal ripening of the fruits off the tree. This stage, called physiological maturity, is easily detected in the fruits which change color at maturity. In green fruits this stage is more difficult to determine because no easily detected color change serves as a guide. Several criteria have been developed to indicate the time of maturity. That most widely used is the determination of the oil content of the flesh which increases rapidly during the early development of the fruit but changes very little or not at all once maturity is reached. This method is used almost exclusively in California where analytical equipment is installed for rapid sampling at the packing houses.

Since such service is not available in Puerto Rico and the oil content of the West Indian fruit is much lower than that of the Californian, this method is not practical for Puerto Rican growers. Because the time between picking and softening diminishes as the fruit matures, samples of fruit can be picked every few days near the time of maturity and the number of days to softening determined. If the quality and number of days it takes for a series of samples to soften is recorded every few days as they reach maturity and this information is set up in the form of a chart for each variety, it can be used by the grower in subsequent years to determine the earliest possible time of harvesting good quality fruit. Obviously, when a sample ripens normally, the bigger fruit are all sufficiently ripe to pick.

Stahl (*37*) has found that for West Indian fruit a specific gravity of 0.98 is a fairly reliable indication of maturity. However, this criteria varies somewhat with seed size, cavity size, and skin thickness and is apparently not as well adapted to the Guatemalan varieties.

The brightness of the avocado skin is reduced slightly at maturity. The stems also acquire a slightly more yellowish-green color (*6*). Careful observation and experience is required to detect accurately the point of maturity.

Since the avocado fruit usually hangs on the tree for several weeks after reaching maturity, it is better to delay the first harvest until the fruits are definitely mature unless higher prices justify earlier picking.

The common practice in Puerto Rico of knocking down the fruit with a stick or shaking the branches should be discouraged. Fruit thus harvested is bound to be scarred and likely to have the stem pulled out of the flesh making an easy entrance for disease. The use of a picking stick by a few growers in Puerto Rico, by which the fruit is twisted off and caught in a sack attached to the pole, is a better harvesting method. Authorities (*6*, *9*, *14*, *20*) agree that the fruit should be cut off with blunt-nosed clippers rather than pulled; the fruit stem is cut ¼ to ½ inch from the fruit. The clippers are mounted on long poles which should be fitted with a bag or bucket to catch the fruit. A cloth funnel, whose lower end is tied loosely to the operator's waist, permits the fruits to drop without harm to within easy reach of the harvester without the pole being lowered. The protruding end of the fruit stem should be cut again flush with the skin to avoid damage to other fruit. Ladders may be needed to reach the upper fruit on tall trees. Although ladders can be leaned against citrus trees apparently without damage to the tree, the avocado wood is too brittle to permit this practice. Ladders with three legs can usually be adjusted even on steep hillsides to put the harvester within pole length of the fruit (*6*).

Since all the fruit on the trees do not mature at the same time, several pickings are desirable in order to remove the largest fruit first. Heavily loaded branches should be picked first, removing all but the smallest fruit at the first harvest to avoid dieback later (*48*, *p. 77*).

Harvest is the time to determine the value of the trees. Since it requires at least 3 bearing years to satisfactorily judge the performance of a tree (*16*), each tree's production should be recorded at harvesttime every year. The extra time and effort involved will be more than repaid as the poor trees thus detected can be removed or top-worked.

Yields.—Grafted fruit trees normally come into bearing within a year or two of planting in the orchard but may vary up to 6 years (*20*, *p. 26*). Seedling trees are usually 1 to 3 years later in producing the first fruits. With early-bearing trees, the first year's crop should be removed or heavily thinned as young trees are particularly susceptible to dieback. Popenoe (*31*, *p. 53*) suggests leaving only 6 fruit of the second crop and 30 to 40 from the third. The yield of mature seedling trees will vary widely and even grafted trees of the same variety will show considerable variation. Higgins and others (*20*) report an average yield of 500 fruits per tree in Hawaii with better trees ranging from 800 to 1,200 fruits per tree. Trees in Guatemala are reported (*30*) to average 200 to 250 fruits per tree, with large trees bearing 1,000 to 3,000; the larger figure is for small-sized (6- to 8-ounce) fruit. A similar variability is reported from Florida

(*48*) where a general average of 50 pounds is expected, although yields up to 500 pounds per tree are not uncommon. Puerto Rico's average, in the neighborhood of 100 fruits per tree, is well below the general average of world production based on available figures.

Theft.—The loss of fruit by theft is a serious handicap to avocado growing in many regions of the world. While signs and fences are useful in protecting the orchard, fruit growers, when organized, can also push legislation to increase the penalties for fruit stealing and to insist on prompt and thorough investigation of all fruit thefts. A system started in California consists of marking sample fruits on the tree with a pattern of minute dots before maturity. Only a small proportion of the fruit need be marked as the presence of only one or two fruits thus marked in a suspected lot of fruit is convincing evidence of its origin. The marks are made by inserting fine wires in a desired pattern in a thick piece of leather, extending out just far enough so that they puncture only the surface of the skin when pressed against the fruit. The pattern can be assigned to individual farmers by a cooperative organization or by the Government. It functions in the same manner as a cattle brand.

Fruit handling.—The literature on avocados indicates that the fruit should be handled gently in the field, packed in shallow boxes surrounded by wood wool or other material to take up the shock, and generally handled with the utmost care, particularly the thin-skinned varieties. In Puerto Rico where fruit has a skin thickness seldom exceeding $\frac{1}{16}$ inch, the fruit is usually knocked to the ground, dumped into large bags, carried to trucks, and transported to market in bulk over rough country roads, and still arrives in a salable, if not good condition. In view of this fact, it is small wonder that few growers are willing to undertake the extra effort and expense of careful handling. The fruit under these circumstances has lost its identity and is sold chiefly on the basis of its size. However, careful handling and packing will be necessary if an export trade is to be developed as competing fruit from California is normally carefully handled. Grading, packaging, and careful handling have "paid off" in California and should, at least to a limited extent, do likewise in Puerto Rico.

According to recommended methods for commercial packing (*6*) the fruit should be placed directly in padded field crates when harvested, and never permitted to touch the ground. Soil and small stones serve to mar the appearance and may facilitate the entrance of fruit rot organisms by scarring the surface of the skin (*6*). Even abrasions too small to be noticed may permit the entrance of disease.

Packing and storage.—In California packing houses, fruits are first dry-cleaned by soft brushes to remove dirt and to polish the surface. After careful hand-grading each fruit is stamped by machine according to its grade as it passes on conveyors to the automatic scales and counters which separate the fruit according to size and weight (*22*).

Graded fruit is usually packed in single-layer "flats" made of thin wood or cardboard with excelsior or other suitable padding on all sides and between the fruit. Light, cardboard flats are gaining in popularity for shipment of Cuban fruit by air to the continental United States (*12*).

All early trials with wrapping or coating avocados to prolong their storage life were discouraging. However, in the last few years several types of wrapping have become available which permit sufficient gas exchange to prevent fruit damage and increase the storage life up to twice that of unwrapped fruits at room temperature (*38, p. 57*). These wrapping materials not only improve the storage life of the fruit but make them more attractive, and usually justify the additional expense. Pliofilm, cellophane, or Lumarith are products which have proved successful (*17*). The fruit should be wrapped as soon as possible after harvesting because the effectiveness of the wrapping decreases as the fruits ripen. The fruits are usually wrapped individually and sealed in 1-foot squares of these materials, a process which can be carried out very rapidly by machine.

The storage life of avocado fruits may be increased by low temperature storage. Experimental work in Trinidad (*43*) has shown that West Indian race fruits are very variable in respect to the amount of cooling they can stand. Most fruits tested showed chilling injury at 45° F. It is, therefore, necessary to test samples of any variety for cold resistance before using refrigerated storage in commercial quantities. Some varieties are able to withstand temperatures close to freezing.

The ripening process does not proceed at a uniform rate but becomes very rapid just before the fruit softens. This peak rate may be several times the rate before and after the maximum is reached and is apparently the point at which most low-temperature injury occurs. Thus, lower storage temperature can be maintained before and after this point, but storage close to 32° F. will prevent subsequent softening even at room temperature. Fruit which ripened in 3 to 6 days at 80° required 30 to 40 days for ripening at 40° (*43*). Since the price of avocados in Puerto Rico increases rapidly at the end of the season, refrigerated storage would appear to be justified at that time for local consumption as well as for export shipment.

Diseases.—Undoubtedly the most important disease affecting avocados in Puerto Rico is root rot. This disease is physiological, a result of excessive soil moisture conditions; it is also pathological, a result of infections of the fungus *Phytophthora cinnamomi* Rands.

Factors affecting the incidence of this disease have already been discussed under "Soil and Water Relations" (p. 9). Root rot is characterized by a cessation of growth, and by drooping, yellowing, and abscission of the leaves. Partial recovery may follow severe pruning, but no instance of complete recovery from any control method has been reported. Planting of avocados in locations where trees have died from this disease is not recommended. Zentmyer and Klotz (*49*) indicate possible benefits from soil sterilization prior to planting, but trials have not lasted long enough to recommend this practice.

A fungus disease of avocado roots was reported and diagnosed as a *Diplodia* sp. by the Agricultural Experiment Station at Río Piedras, P. R., in 1920–21.

The cercospora spot caused by the fungus *Cercospora purpurea* Cooke, is found in many sections of the island. This disease first appears on the under side of the leaves as purplish, blisterlike swellings which later collapse into small brown angular spots. Gray masses of spores soon appear in rainy periods but may be retarded in

dry weather. The disease appears also on the stems. The first symptoms appearing on fruits are small greenish-white dots which later develop into dark-brown, slightly sunken, irregular surface blotches bearing gray spore masses. The spots increase in size becoming nearly circular, dark-brown dead tissue which is usually cracked or figured. This fungus does not penetrate the flesh but the resulting cracks serve for the entrance of rot organisms (*39*).

Black spot or anthracnose caused by a fungus, *Colletotrichum gloeosporioides* Penz., is another common disease in Puerto Rico. It appears on both the leaves and stems but causes its chief damage to the fruit. The fungus can penetrate the avocado during all stages of development if the skin is broken by cercospora or mechanical lesions, but anthracnose does not develop appreciably until the fruit approaches maturity. The disease can enter readily if the stem is pulled out instead of being cut off when harvested. The spots are more or less circular in outline, bluish-black to dark brown, and slightly sunken with flesh-colored spore masses (*39*). The flesh decays rapidly into a dark, globular mass which is easily separated from the sound flesh.

In Florida (*34*) the recommended control of cercospora spot and anthracnose consists of two to three sprays with bordeaux or other copper sprays at monthly intervals beginning in May. The bordeaux is applied at the rate of 6–6–100 (6 pounds copper sulfate and 6 pounds lime to 100 gallons of water).

Tribasic copper sulfate (copper content 53 percent) at 3 pounds per 100 gallons, basic copper sulfates (copper content 26 percent) at 6 to 100, and basic copper chloride (copper content 45 percent) at 3 pounds to 100 gallons of water were found nearly as effective as the bordeaux, and there is less probability with this spray of increasing scale infection. In groves kept practically free of both cercospora spot and anthracnose by annual application of the copper fungicides, the bordeaux formula may be reduced to 4–4–100. A spray should include an efficient spreader.

Spraying is practically never practiced on Puerto Rican avocado trees, nor is it likely to become much of a factor in avocado culture in the near future because of terrain difficulties, lack of capital, and irregular tree spacings. The logical control under these conditions is to use dusts that eliminate moving of large quantities of water and reduce the cost of the equipment required. No recommendations can be made for their use until experimental work is done in Puerto Rico to determine the choice of materials and the schedules of applications.

Dieback is a disease condition commonly encountered in avocado trees. This condition has never been studied in Puerto Rico, hence little information concerning it is available. The diseases already mentioned may cause some of the damage. A gleosporium fungus causes serious damage in Hawaii but the extent of infection in Puerto Rico is not known. In Puerto Rico a *Diplodia* sp. is frequently found associated with the disease. Other fungi may also cause this condition. It is more severe following a heavy crop of fruit. The dieback is frequently, but not always, preceded by considerable defoliation. The stems die back from the tips or from the old fruit stems until they reach a larger branch. The infection may stop there or may penetrate the larger branch to its point of origin (fig. 13).

FIGURE 13.—A young avocado tree suffering from dieback.

Leaf burn is a physiological condition which results in drying of the leaf tip and, in more severe cases, the margins or even the majority of the leaf area is affected. It is usually related to some unfavorable condition, such as ditches in the root zone or insufficient depth of soil, or perhaps insect injury on the roots.

Avocado scab is a disease caused by a fungus, *Sphaceloma perseae* Jenkins, which is found occasionally in all avocado-growing sections of the island. The expanding leaves are malformed with ⅛-inch purplish-brown to grayish spots on the surface. On the fruit, the lesions start as oval rings, later drying and cracking, a source of infection for rot organisms (*25*). Although the native trees show considerable resistance to scab, some of the better, introduced varieties are sufficiently susceptible to require dusting or spraying for satisfactory production. The spray schedule worked out in Florida requires four to five sprays starting before flowering, using copper compounds such as cuprous oxide, 1½ pounds to 100 gallons (*34*, *35*).

Folliocellosis or frenching is a condition frequently seen. When the condition is present the trees develop a leaf condition suggestive of citrus frenching. In the absence of any controlled experiments, very little information can be offered concerning its true nature and control. Abundant application of barnyard manure and ample drainage in heavy soils seem to alleviate the disease, which is generally believed to be a result of deficiencies or excesses of some minor elements. Zinc deficiency is the cause in California and Florida (*33*).

A leaf-spot caused by a fungus (*Phyllachora gratissima* Rehm.) is widespread. In some locations it has caused the abscission of leaves, but the damage is insufficient to warrant control treatments.

Alga leaf spot (*Cephaleuros virescens* Kze.) occurs frequently but seldom causes serious damage and could be controlled with any materials effective for the more troublesome diseases mentioned above.

A bark canker of avocados growing in Puerto Rico was isolated and identified by J. A. B. Nolla as caused by *Phytophthora parasitica* Dastur from trees near Río Piedras. The disease is not common in Puerto Rico, but has been observed in several localities. Cankers may be cut out and 1 inch of healthy wood removed on all sides. The exposed surface should be coated with a bordeaux paste. Mulches should not be applied close to the trunk as this favors fungal infection in the trunk.

Sunburn is occasionally observed following defoliation. The fruits turn yellow-green or brown on one side or have irregular blotches with indefinite margins. Sunburn is sometimes observed in the absence of defoliation on the variety Itzamna as the fruits are suspended on long stems well below the branches. The flesh is not seriously damaged, particularly when mature fruit is affected, so that no special controls are required. If the leaves are lost, whitewashing the trunk has been recommended to prevent bark injury (*39*).

Powdery mildew (*Oidium* sp.) frequently appears on avocado trees of the island but is seldom sufficiently damaging to require control. When mildew is present the under sides of the leaves are more or less covered with a grayish-white, powdery-looking fungus growth (*39*).

Insects.—One of the most frequently observed insects on avocado trees in Puerto Rico is the locally common subterranean termite or "comején" (*Nasutitermes costalis* (Holmgren)). The termites first attack dead branches or branch stubs and penetrate from these into the heartwood. Fortunately, infestation can be easily determined by the presence of their characteristically narrow, covered runways on the outside of the bark. This insect is found on many other plants besides the avocado. It can be controlled by introducing powdered

arsenicals, such as lead arsenate or paris green, into the tunnels and nests.

Extreme care should be exercised in handling and storing both fungicides and insecticides to keep them out of reach of children and domestic animals and away from any possible food contamination.

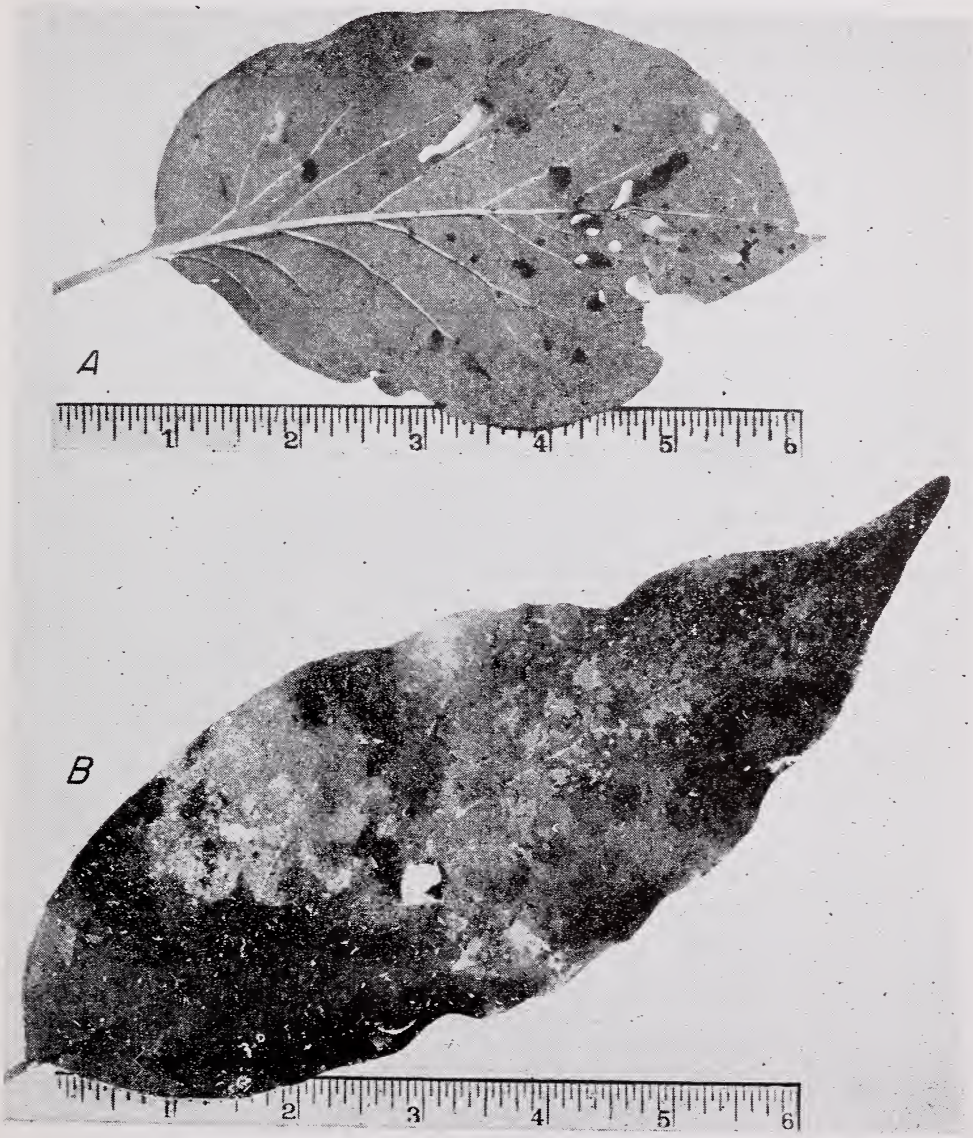

FIGURE 14.—*A*, Leaves chewed by adults of the sugarcane weevil root borer. *B*, Sooty mold developing on upper surface of leaf. Scale or mealybug infestation results in development of sooty mold on lower leaves.

Another serious pest is the sugarcane root weevil or "vaquita" (*Diaprepes abbreviatus* (L.)). The adults chew out sections of the leaf margins or circular holes between the veins ¼ to ⅜ of an inch in diameter (fig. 14, *A*). The chief damage is on the lower leaves. Young trees may be nearly defoliated as a result of this feeding. The extent of damage to the roots by the larvae is unknown. Griffiths

(*15*) recommends hand-picking, a laborious job which must be repeated often, as the adult weevils drop to the ground as soon as the branch is jarred. Lead arsenate spray, 5 pounds to 50 gallons of water, or bordeaux or other copper sprays used against diseases are recommended. Trap crops, such as castor-oil-plant (*Ricinus communis* L.) (*15*) or bay-rum trees (*Pimenta officinalis* Berg.), can be planted around the orchard. The area below the branches may be cultivated or covered with cloth in order to facilitate the collection and killing of the adult weevils which fall to the ground on shaking. Periodic dusting with DDT at regular intervals has proved effective at Isabela.

Most of the other insect enemies of the avocado are seldom sufficiently injurious to justify control measures. The red-banded thrips (*Selenothrips rubrocinctus* (Giard)) sometimes becomes troublesome in the nursery bed and may require spraying with DDT at 2 pounds of the 50-percent wettable powder to 100 gallons of water.

The Federal Experiment Station has been introducing many parasites and predators of harmful insects into Puerto Rico. Some of these are now fairly well distributed and materially reduce the infestations, particularly of scale insects and mealybugs. The most important of these are a black lady beetle with a large red spot on each wing cover (*Chilocorus cacti* (L.)), and a small wasp parasite (*Pseudaphycus utilis* Timb.), which attacks the avocado or palm mealybug (*Pseudococcus nipae* (Mask.)). The Surinam toad (*Bufo marinus* L.) imported by this station from Barbados in 1920, preys on the adults of many soil insects including the sugarcane root weevil.

Scale insects may sometimes increase rapidly (fig. 15). Their excretions may result in the development of a sooty mold fungus on the leaves below (fig. 14, *B*). If the scale insects require additional control, a spray containing 2 percent of highly refined mineral oil emulsion will be effective. Two applications at 3-week intervals should be applied during the cool of the day (*48, p. 86*).

ECONOMICS

Distribution and sales.—The island of Puerto Rico is not large enough to present much of a transportation problem so far as distance is concerned, but the rough terrain and the inaccessibility of many avocado-growing sections complicate distribution of this crop. Of the 30 to 40 million fruits produced annually on the island, less than a quarter are sold in the three main markets of the island; the balance is consumed on or near the farms, or sold in the local town markets. The principal city markets are at Río Piedras, where the fruits from the northern regions are sold for metropolitan San Juan, Mayaguez on the west coast, and Ponce on the south coast.

Fruit for market is placed in large burlap bags and carried to the nearest road by man or horse. Middlemen or "intermediarios" have established a series of depots in the chief avocado-growing sections where truckload lots are assembled. These depots are seldom special structures but a part of a country store, the owner acting as agent for the avocado broker.

The grower can sell his fruit to the broker on the tree or at the depot, or he can retail it himself locally. Unless he has a truck, the

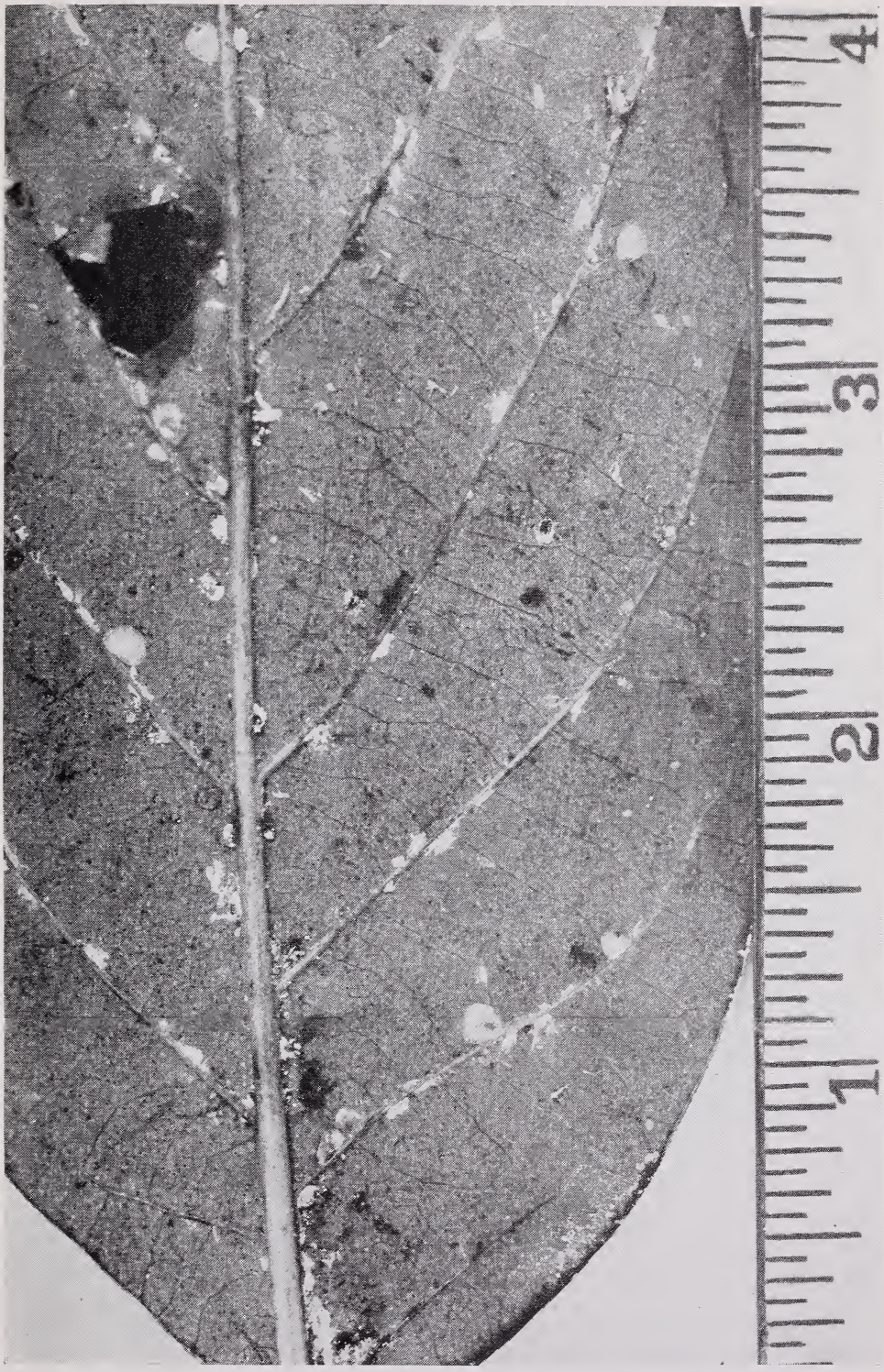

FIGURE 15.—Under side of avocado leaf showing medium to heavy infestation of scales and mealybugs. Such insects may cause formation of black sooty mold on the leaves beneath (fig. 14, *B*) and ultimately retard growth and cause leaves to drop.

distances to the cities are usually too great for horseback trips. He must, therefore, accept the broker's price or sell his crop locally. The brokers haul the fruits to the cities and sell them to the wholesalers, who in turn sell them to retailers or vendors. The owners at each step try to resell as soon as possible to avoid loss from spoilage, for a more rapid turn-over of their money, and because storage facilities are extremely limited.

Fruit is usually not graded until it reaches the retailer, although the prices paid at each stage are adjusted to the size of the fruit in the lot. The retailer may separate his stock into several classes varying in price as much as 50 percent between the extremes.

In Florida most of the fruit is taken to large packing houses by the grower. In California and to a lesser extent in Florida and Hawaii the fruit is packed, shipped, and sold through growers' cooperatives which may handle the fruit as far as the retailer. Most of the fruit produced in Florida is shipped in large refrigerated trucks to northeastern markets. Shorter runs from California are handled similarly, while shipments to the east coast are usually made in refrigerated railroad cars. Airplane shipments are beginning to find a place in avocado transportation particularly where production costs are sufficiently low to justify the cost of air shipment.

Volume air movement of avocados began near the end of World War II when Cuba shipped over a million pounds in a year to the United States. The actual flying distance for those shipments was only from Havana to southern Florida; the remaining distance to northern markets was made by truck or railroad. However, with the gradual reductions in air freight rates the differential between air and surface transportation has been reduced. Shorter transportation time is reflected in better condition of the fruit on arrival and longer storage life.

Prices.—Since the Puerto Rican fruit is almost entirely of the West Indian race, it is available only from May to December. Most fruit is marketed in August and September, with a fair supply during July, October, and November. The supply during June and December is extremely limited, with none at all available in some years. The price of the fruit fluctuates violently depending on the supply (fig. 16). While most of the fruit is sold at a wholesale price of $2 to $4 per 100 fruit, when the supply drops sharply the price rises to as much as $8. The price paid for the fruit rises rapidly at each step in its distribution, the consumer paying two to four times the price received by the farmer.

Efforts to rectify the tremendous price increase along the distribution line are being made by the Government through the Puerto Rico Agricultural Company and by cooperatives. The company plans a system of truck routes through the mountains for collection of farm products which they will sell in a series of modern markets in various island cities. Puerto Rican growers are becoming interested in the cooperative system. However, further development will be necessary before it reaches the effectiveness and efficiency attained by cooperatives in California, Florida, and Hawaii, where substantial savings are made to the participating growers.

One of the largest cooperatives handling avocados in Puerto Rico is the Villalba Vegetable Growers with 400 members, 150 of whom

grow avocados. Although tomatoes and a few other vegetables are graded by this cooperative, no attempt is made to grade the avocados. The growers are paid the prevailing price for the fruit in the country and a share of the profits based on their proportion of the total business of the cooperative at the end of the year. Several other cooperatives of the island handle fruit as items in their program, but the business of avocado growing has not developed sufficiently to create a cooperative for this crop alone.

The outstanding example of cooperative avocado marketing is the Calavo Growers of California. This association is a nonstock, nonprofit, cooperative marketing agency which has several packing houses

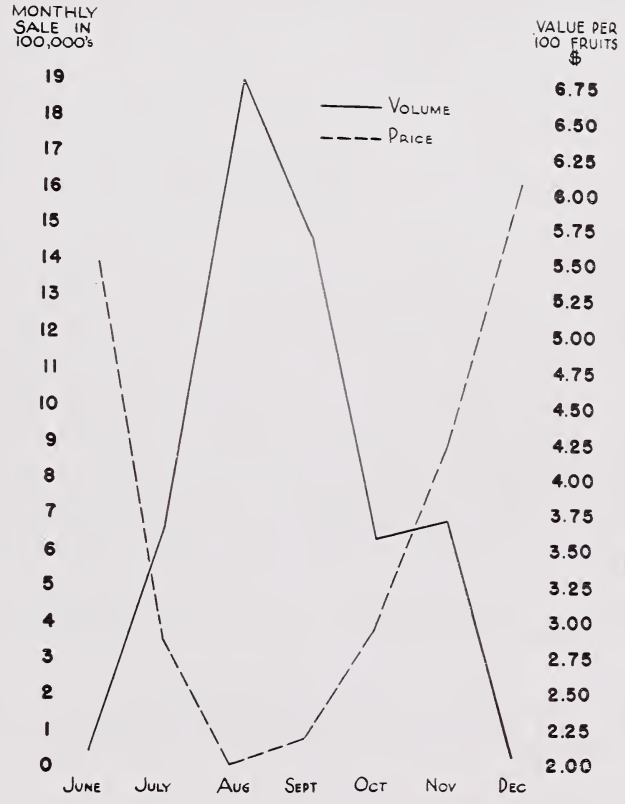

FIGURE 16.—Volume and wholesale price, by months, of avocado fruits in the principal city markets of Puerto Rico averaged for the years 1943, 1945, and 1946.

in the various avocado-growing districts of southern California. This organization started with little capital in 1924 and has grown rapidly to dominate the entire avocado industry in the United States. Through publicity the demand for avocados has kept pace with the increasing volume of production.

The avocado association advertises in many ways. Demonstrations and educational talks describe the fruit and ways of using it. Slides, store window displays, recipe booklets, radio, and printed advertisements are also utilized. A brand name "Calavo" is used to distinguish the best grade and varieties of fruit. Since the fruit so labeled has become associated with top quality by the consumer, it is sold at a

premium. This trade name is stamped only on fruit of those varieties with the best eating quality and only after the fruit is sufficiently matured on the tree to insure top quality on softening. Even then, fruit with skin blemishes or other defects are packed in a lower grade.

To guard against overproduction or underproduction at any time during the harvest season, each grower submits an estimate of his production by varieties to the association. To be sure that the fruit is sufficiently mature before picking, every grower submits samples of fruit from all his varieties as they approach maturity to the packing house for test of their oil content. The cooperative then assigns each grower a picking schedule which he must follow. By this method the organization controls the supply in such a way as to obtain the best price for the most fruit throughout the year and consequently

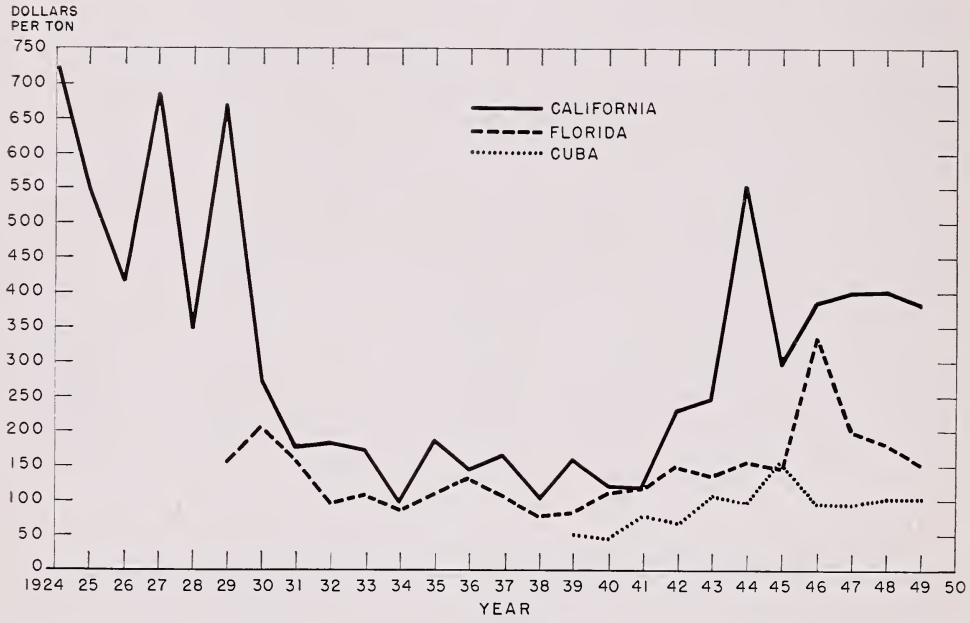

FIGURE 17.—Equivalent return for avocados per ton to growers in California and Florida at the packing house compared to the declared value of imported Cuban fruit. (From U. S. Department of Agriculture Bureau of Agricultural Economics.)

higher profits for all the members of the cooperative. By controlling the distribution and sales of members' products throughout the United States as far as the retailer, the cooperative plays a major role in regulating the price of avocados. Figure 17 shows the variability of prices for avocados grown in the United States from year to year and the consistently higher price for the fruit grown in California as compared with fruit grown elsewhere.

Cuban avocados have figured substantially in the supply of avocados for the eastern United States for many years, reaching a maximum of 12 million pounds in 1940. Only during the war years and the severe drought of 1945 have the volumes been too low to affect the price. Cuban fruit is valued normally below that produced and shipped in the United States (fig. 17). Since at least a part of the Florida production is within the 5-month period when the duty-free

Cuban avocados can enter the United States, June to September, it is not surprising that the value of the Florida crop is depressed.

Avocados bring a greater return per pound than almost any other fruit grown in the United States. The chief exception is dates which require a far greater amount of attention and more specialized climatic conditions. Table 4 gives the relative prices per pound obtained by the growers for some more common fruits based on a weighted average of the country as a whole during 1941 and 1942. The price for avocados during 1941 was low while that for 1942 was somewhat better but still below that of recent years.

Production costs.—The only data available to the writer concerning the actual cost of producing avocados that can be considered representative of an avocado-growing section of the world are those from southern California (*2*, *41*). These figures have been published annually for a number of years. During the 10-year period preceding 1947 the cost of avocado production practically doubled. However, the cost per pound of fruit produced has been reduced by the increased yields. The increasing efficiency of California marketing cooperatives has also increased the grower's income (table 4).

TABLE 4.—*Relative income from selected fruits received by growers in the United States* [1]

Fruit	Price per pound	
	1941	1942
	Dollars	*Dollars*
Apples	0. 022	0. 030
Avocados	. 050	. 106
Dates	. 075	. 112
Oranges (on the tree)	. 016	. 027
Grapefruit	. 034	. 047

[1] Based on "Prices received for fruit and nut crops by types of sale and utilization groups." Unnumbered publication. Bureau of Agricultural Economics, U. S. Department of Agriculture. [Processed.]

No data are available on production costs in Puerto Rico. They are a very minor fraction of those in California, Florida, or Hawaii, as no irrigation is normally required, little fertilizer or sprays are applied, and cultivation is very seldom practiced. While the cost of land in Puerto Rico is relatively high it is still less than that of southern California where irrigation systems must be constructed. An investment of several thousand dollars per acre in that area is quite common before fruit are produced; yet even under these conditions the profit from avocados has resulted in a rapid and relatively large increase in the acreage of avocados planted.

Growers' returns.—California's average production ranges from 4,000 to 8,000 fruits per acre because of the variations from year to year. The yield varies from 1 to 2 tons per acre per year, but some orchards yield 3 to 4 tons or even more. The price received in California ranges from $100 to $400 per ton. The gross income per acre

varies from $200 to $1,600. In some instances $1,000 per acre was paid in southern Florida for the fruit on the trees in World War II years. Even with increased cost of production, there are good possibilities for excellent profits at these prices.

At a wholesale price of $3 per 100 fruits—a rough average in recent years in Puerto Rico—the average tree on the island is returning $3 to the grower who brings his fruit to market, since the average yield per tree per year is approximately 100 fruits. The spacings commonly noted in avocado groves are made to obtain between 80 and 100 trees per acre. At this rate $240 to $300 per acre per year is grossed with very little production cost.

Prospects for avocado growing in Puerto Rico.—Avocados have been growing in Puerto Rico for several hundred years. They have become accepted as a gift of nature requiring little or no attention beyond harvesting the fruit. The spread of root rot and other diseases has materially affected both the production and quality of the fruit. Through improved cultural conditions and the use of superior varieties, the quality and yield can be increased and the fruit marketed over a longer period of time.

The fruits are popular and could help eliminate some of the nutritional deficiencies common among the island residents. Moreover, avocados would be available most of the year.

Avocados have been increasing in price for a number of years. It is quite unlikely that with the increasing incidence of disease in avocado trees and the increasing population that the fruit will drop in price to anything like the very low prices of former years when they could be bought several for a cent. However, prices of avocados are bound to follow changes in the economic conditions in the island. Improved cultural practices and careful harvesting and handling of superior market varieties would increase the yield per acre, improve the qualities of the fruit, and permit the development of an export trade.

Puerto Rico has a climate well suited for avocado growing. No instance of frost has ever been recorded. The trees can be grown up to several thousand feet elevation, thus permitting the production of winter fruiting types which hold most promise for export. The rainfall in most areas is usually sufficient. The humidity is never too low or the temperature too high to cause injury. Most soils do not require nearly so much nor so frequent fertilization as those in Florida. The passage of hurricanes on an average of once in 11 years represents a serious threat to the avocado grower just as it does in Florida. However, their severe damage is usually confined to portions of the island rather than the island as a whole.

The West Indian type of avocado, although grown almost exclusively in Puerto Rico, is poorly suited for export trade as the skin is thin and the seed is often loose in the cavity causing it to damage the flesh when shaken. Since the season of West Indian fruit production is severely restricted, the fruits are available during only one-third of the year. The use of superior Guatemalan and Guatemalan-West Indian hybrids should result in a type of fruit better suited for export and would extend the season of availability several months.

Avocado production should be centered on well-drained soils to reduce root rot damage. The use of grafted plants should become more general, particularly for growers who have large plantings and for those interested in export.

Since avocados are a high income crop when properly grown, there is likely to be an increase in the number of trees on suitable land. There is sufficient of this type of land in Puerto Rico to permit a considerable increase in production. In fact, the size of the area where avocados can be profitably grown may exceed the combined avocado-growing areas of California and Florida.

LITERATURE CITED

(1) ANONYMOUS.
1935. AVOCADO OIL. Pharm. and Cosmetics 1: 73.
(2) ———
1948. AVOCADO STUDY SHOWS ALTERNATE FRUIT BEARING. Calif. Citrog. 33: 305.
(3) APPLEMAN, D.
1944. PRELIMINARY REPORT ON TOXICITY OF AVOCADO LEAVES. Calif. Avocado Soc. Yearbook 1944: 37.
(4) ASENJO, C. F., and GOYCO, J. A.
1942. PUERTO RICAN FATTY OILS: 1. THE COMPOSITION OF THE LIQUID FRACTION OF EXPRESSED AVOCADO PULP OIL. Oil and Soap 19: 129–130.
(5) BAILEY, L. H.
1937. THE STANDARD CYCLOPEDIA OF HORTICULTURE. Ed. 2, vol. 3, pp. 2555–2556, illus. New York.
(6) BEMBOWER, W.
1946. PICKING AND HANDLING AVOCADO FRUITS TO BE MARKETED. Hawaii Univ. Agr. Ext. Cir. 201.
(7) BRUSH, W. D., MURPHY, L. S., and MELL, C. D.
1916. TREES OF PORTO RICO. U. S. Dept. Agr. Bul. 354, Appendix I, pp. 56–97.
(8) BURGIS, D. S., and WOLFE, H. S.
1946. DO AVOCADO ROOTS DEVELOP ROOT-HAIRS? Fla. State Hort. Soc. Proc. 58 (1945): 197–198.
(9) CHENOWETH, A. R.
1942. PAYING TRICKS IN PICKING AVOCADOS. Calif. Avocado Soc. Yearbook 1942: 108–109.
(10) COLLINS, G. N.
1905. THE AVOCADO, A SALAD FRUIT FROM THE TROPICS. U. S. Bur. Plant Indus. Bul. 77, 52 pp., illus.
(11) CRUESS, W. V., and HARROLD, E.
1927. INVESTIGATIONS ON THE UTILIZATION OF CULL AVOCADOS. Calif. Avocado Assoc. Yearbook 1927: 34–38.
(12) DAVENPORT. P. M.
1946. CUBA'S AVOCADO OUTPUT—AIR SHIPMENTS LOOM LARGE. Foreign Com. Weekly, November 2, 1946, pp. 5–6. 32, illus.
(13) FRANCE, J. G.
1947. PRACTICAL POINTS IN AVOCADO PRUNING. Calif. Avocado Soc. Yearbook 1947: 89–91.
(14) GRIFFITH, J. P.
1923. NOTES ON PUERTO RICO'S LARGEST PLANTATION OF IMPORTED AVOCADOS (AGUCATES), VILLALBA, PUERTO RICO. Puerto Rico Prog., November 3, 1923. [Processed].
(15) ———
1923. THE AVOCADO IN PUERTO RICO. Puerto Rico Insular Sta. Cir. 72, 41 pp., illus.
(16) GRISWOLD, H. B.
1941. ANNUAL TREE PRODUCTION RECORD PLAN. Calif. Avocado Soc. Yearbook 1941: 103–104.
(17) ———
1944. CELLOPHANE WRAPPED AVOCADOS. Calif. Avocado Soc. Yearbook 1944: 53–55, illus.

(18) Haas, A. R. C.
1937. chemical composition of avocado fruits. Jour. Agr. Res. 54: 669–687, illus.
(19) ———
1939. ph as it affects growth of citrus, avocados, and walnuts. Pacific Rural Press and Calif. Farmer 137 (26): 574–575, illus.
(20) Higgins, J. E., Hunn, C. J., and Holt, V. S.
1911. the avocado in hawaii. Hawaii Agr. Expt. Sta. Bul. 25, 48 pp., illus.
(21) Hodgson, R. W.
1947. avocado tree decline. Calif. Citrog. 32: 517.
(22) ———
1947. the california avocado industry. Calif. Ext. Cir. 43, 93 pp., illus. (Revised).
(23) ———, and Eggers, E. R.
1939. correlations between size of seed, seedling and nursery tree in the avocado. Calif. Avocado Assoc. Yearbook 1938: 92–96.
(24) Jamieson, G. S., Baughman, W. F., and Hann, R. M.
1928. avocado oil: the composition and constants of a little-known pericarp oil. Oil and Fat Indus. 5: 202–206.
(25) Jenkins, A. E.
1934. sphaceloma perseae the cause of avocado scab. Jour. Agr. Res. 49: 859–869, illus.
(26) Kellogg, J. H.
1935. the priceless dietetic value of the citrus, the avocado, and the papaya. Calif. Avocado Assoc. Yearbook 1935: 91–95.
(27) Love, H. T.
1943. avocado oil studies. Puerto Rico (Mayaguez) Agr. Expt. Sta. Rpt. 1942: 18–19.
(28) Mattill, H. A.
1917. the digestibility of the fat of the avocado. Calif. Avocado Assoc. Ann. Rpt. 1916: 93–95.
(29) Pope, W. T.
1924. the guatemalan avocado in hawaii. Hawaii Agr. Expt. Sta. Bul. 51, 24 pp., illus.
(30) Popenoe, W.
1919. the avocado in guatemala. U. S. Dept. Agr. Bul. 743, 69 pp., illus.
(31) ———
1930. manual of tropical and subtropical fruits. 474 pp., illus. New York.
(32) ———
1941. the avocado—a horticultural problem. Trop. Agr. [Trinidad] 18: 3–7.
(33) Ruehle, G. D.
1940. zinc deficiency of the avocado. Fla. State. Hort. Soc. Proc. 53 (1940): 150–152, illus.
(34) ———
1943. the cause and control of avocado scab. Fla. Agr. Expt. Sta. Press Bul. 580. 4 pp., illus. (Revised 1945.)
(35) ———
1943. cause and control of cercospora spot and of anthracnose of the avocado. Fla. Agr. Expt. Sta. Press Bul. 583, 4 pp., illus.
(36) Ryerson, K.
1923. Avocado culture in california, part 1: history, culture, varieties, and marketing. Calif. Agr. Expt. Sta. Bul. 365: 573–629, illus.
(37) Stahl, A. L.
1933. changes in composition of florida avocados in relation to maturity. Fla. Agr. Expt. Sta. Bul. 259, 61 pp., illus.
(38) ———, and Vaughn, P. J.
1942. pliofilm in the preservation of florida fruits and vegetables. Fla. Agr. Expt. Sta. Bul. 369, 91 pp., illus.
(39) Stevens, H. E., and Piper, R. B.
1941. avocado diseases in florida. U. S. Dept. Agr. Cir. 582, 47 pp., illus.
(40) Stout, A. B.
1933. the pollination of avocados. Fla. Agr. Expt. Sta. Bul. 257, 44 pp., illus.

(41) WAHLBERG, H. E.
1935. FIVE-YEAR STUDY ON AVOCADO COSTS COMPLETED. Calif. Avocado Assoc. Yearbook 1935: 106–107.
(42) WARDLAW, C. W.
1937. NOTES ON THE PHYSIOLOGY AND BIOCHEMISTRY OF TROPICAL FRUITS: I. AVOCADOS. Trop. Agr. [Trinidad] 14: 34–41.
(43) ———, and LEONARD, E. R.
1935. THE STORAGE OF AVOCADO PEARS. [Trinidad] Imp. Col. Trop. Agr. Low Temp. Res. Sta. Mem. No. 1, 20 pp., illus.
(44) WEATHERBY, L. S.
1934. COMPOSITION OF AVOCADO SEED. Calif. Avocado Assoc. Yearbook 1934: 132–144, illus.
(45) ———
1935. THE DIETETIC VALUE OF CALAVOS IN THE PREVENTION OR CURE OF ANEMIA. Calif. Avocado Assoc. Yearbook 1935: 53–55.
(46) WESTER, P. J.
1916. PLANT PROPAGATION IN THE TROPICS. Philippine Bur. Agr. Bul. 32, 87 pp., illus.
(47) WILLIAMS, R. O.
1919. THE AVOCADO. Trinidad and Tobago Dept. Agr. Bul. 18: 125–128.
(48) WOLFE, H. S., TOY, L. H., and STAHL, A. L.
1946. AVOCADO PRODUCTION IN FLORIDA. Fla. Ext. Serv. Bul. 120, 107 pp., illus. (Revised).
(49) ZENTMYER, G. A., and KLOTZ, L. J.
1946. MICROORGANISMS IN AVOCADO TREE DECLINE. Calif. Citrog. 31: 436–437.

ADDITIONAL REFERENCES

ANONYMOUS.
1941. VARIETY LIST FOR THE 1941 YEARBOOK. Calif. Avocado Soc. Yearbook 1941: 13–19.

———
1944. ESTABLISHING AN AVOCADO ORCHARD. Calif. Citrog. 29: 190–191.

APPLEMAN, D., and LAFAYETTE, N.
1941. BIOCHEMICAL STUDIES OF THE FUERTE AVOCADO FRUIT—A PRELIMINARY REPORT. Calif. Avocado Soc. Yearbook 1941: 60–63, illus.

BARRETT, C.
1935. TRAINING AND PRUNING AVOCADO TREES. Calif. Avocado Assoc. Yearbook 1935: 98–103.

BIALE, J. B.
1941. THE CLIMACTERIC RISE IN RESPIRATION RATE OF THE FUERTE AVOCADO FRUIT. Amer. Soc. Hort. Sci. Proc. 39: 137–142, illus.

———
1941. THE RELATIONSHIP BETWEEN RIPENING AND RESPIRATION OF THE FUERTE AVOCADO. Calif. Avocado Soc. Yearbook 1941: 64–65, illus.

———
1946. EFFECT OF OXYGEN CONCENTRATION ON RESPIRATION OF THE FUERTE AVOCADO FRUIT. Amer. Jour. Bot. 33: 363–373, illus.

———
1947. CONTROL OF VAPORS IN STORAGE ESSENTIAL FOR PROLONGING LIFE OF AVOCADOS AND CITRUS FRUITS. Calif. Agr. [Calif. Agr. Expt. Sta.] 1 (9): 1, 3, illus.

BISCHOFF, W. H.
1945. AVOCADO INDUSTRY EXPANDING. Amer. Eagle [Fla. ed.] 5(17): 1, 4.

BLANCHARD, V. F.
1940. MORE REGULARITY OF PRODUCTION NECESSARY IN AVOCADO INDUSTRY. Calif. Avocado Assoc. Yearbook 1940: 31–32.

BURKHILL, I. H.
1935. A DICTIONARY OF THE ECONOMIC PRODUCTS OF THE MALAY PENINSULA. Vol. 2, pp. 1697–1699. Govt. of the Straits Settlements and Federated Malay States.

BYRD, N. P., BLAIR, R. E., and PHILLIPS, H. C.
1946. ACREAGE ESTIMATES: CALIFORNIA FRUIT AND NUT CROPS, AS OF 1945. Calif. Crop and Livestock Reporting Serv., 29 pp.

CINTRÓN, C. L., and COOK, D. H.
1932. NUTRITIONAL STUDIES OF THE FOODSTUFFS USED IN THE PORTO RICAN DIETARY [II]. Porto Rico Jour. Pub. Health and Trop. Med. 7: 435–441.

CLARK, O. I.
1923. AVOCADO POLLINATION AND BEES. Calif. Avocado Assoc. Ann. Rpt. 1922–23: 57–62, illus.

COIT, J. E.
1935. MARKETABILITY OF AVOCADO VARIETIES. Calif. Avocado Assoc. Yearbook 1935: 59–64, illus.

———
1943. AVOCADO LEAVES DANGEROUS FOOD FOR LIVESTOCK. Calif. Avocado Soc. Yearbook 1943: 37.

COOK, M. T.
1938. PLANT DISEASE SURVEY. Puerto Rico Insular Sta. Rpt. 1936–37: 108–111.

COOK, O. F., and COLLINS, G. N.
1903. ECONOMIC PLANTS OF PORTO RICO. U. S. Natl. Mus. Contrib. U. S. Natl. Herbarium 8 (2): 57–280, illus. Washington, D. C.

DAVIS, S. J.
1939. AVOCADO GROWING IN THE REDLAND DISTRICT. Fla. State Hort. Soc. Proc. 52 (1939): 71–73.

DEBARD, A. S.
1941. PERMANENT COVER VERSUS CULTIVATION. Calif. Avocado Soc. Yearbook 1941: 75–76.

DONNELLY, M.
1944. RAIN AND DROUGHT IN AVOCADO DECLINE. Calif. Avocado Soc. Yearbook 1944: 27–31.

———
1941. ROOT DISTRIBUTION OF YOUNG AVOCADO TREES ON BENCH TERRACES. Amer. Soc. Hort. Sci. Proc. 39: 101–109, illus.

DOZIER, H. L.
1926. SOME NEW AND INTERESTING PORTO RICAN LEAFHOPPERS. Porto Rico Dept. Agr. Jour. 10: 259–265, illus.

EGGERS, E. R.
1942. EFFECT OF THE REMOVAL OF THE SEED COATS ON AVOCADO SEED GERMINATION. Calif. Avocado Soc. Yearbook 1942: 41–43, illus.

ELLIOTT, J. M.
1923. PRACTICAL POINTERS ON BUDDING AND GRAFTING AVOCADOS. Calif. Avocado Assoc. Ann. Rpt. 1922–23: 23–24.

FLANDERS, S. E.
1944. CONTROL OF THE LONG TAILED MEALYBUG ON AVOCADOS BY HYMENOPTEROUS PARASITES. Jour. Econ. Ent. 37: 308–309.

FRANCE, J. G.
1944. AVOCADO TREE DECLINE—SO WHAT? Calavo News 18 (2): 8–11.

———
1946. SO, YOU ARE GOING TO BE AN AVOCADO GROWER. Calif. Citrog. 31: 90–93.

FURR, J. R., REECE, P. C., and GARDNER, F. E.
1947. SYMPTOMS EXHIBITED BY AVOCADO TREES GROWN IN OUTDOOR SAND CULTURES DEPRIVED OF VARIOUS MINERAL NUTRIENTS. Fla. State Hort. Soc. Proc. 59 (1946): 138–145, illus.

GONZÁLEZ RÍOS, P., and MAYORAL REINAT, A.
1931. EL CULTIVO DEL AGUACATE EN PUERTO RICO. Puerto Rico Insular Sta. Cir. 93, 34 pp., illus.

GROSZMANN, H. M.
1947. AVOCADO VARIETIES. Queensland Agr. Jour. 1947, 64: 8–12.

HAAS, A. R. C.
1941. SOIL MOISTURE RANGE AND THE GROWTH OF YOUNG LEMON AND AVOCADO PLANTS. Calif. Avocado Soc. Yearbook 1941: 87–91.

———
1943. BORON CONTENT OF AVOCADO TREES AND SOILS. Calif. Avocado Soc. Yearbook 1943: 41–52, illus.

———
1947. RAINFALL DISTRIBUTION UNDER FUERTE AVOCADO TREES. Calif. Avocado Soc. Yearbook 1947: 47–50, illus.

HANSEN, F. J.
1943. NITROGEN FERTILIZATION OF AVOCADOS. Calif. Avocado Soc. Yearbook 1943: 62–64.
HARRIS, J. A., and POPENOE, W.
1916. FREEZING-POINT LOWERING OF THE LEAF SAP OF THE HORTICULTURAL TYPES OF PERSEA AMERICANA. Jour. Agr. Res. 7: 261–268.
HARROLD, E. V.
1931. AVOCADO PRESERVATION AND UTILIZATION. Hawaii Agr. Expt. Sta. Rpt. 1930: 19–22.
HODGKIN, G. B.
1944. THE AVOCADO SITUATION AND AGRICULTURAL COOPERATION. Calif. Avocado Soc. Yearbook 1944: 62–65.
HODGSON, R. W.
1942. THE NITROGEN REQUIREMENT OF THE AVOCADO TREE IN CALIFORNIA. Calif. Avocado Soc. Yearbook 1942: 33–35.
———
1945. AVOCADO DECLINE INVESTIGATIONS: A PROGRESS REPORT, OCTOBER 27, 1944. Calif. Avocado Soc. Yearbook 1944: 24–27.
HORNE, W. T.
1934. AVOCADO DISEASES IN CALIFORNIA. Calif. Agr. Expt. Sta. Bul. 585, 72 pp., illus.
———, KLOTZ, L. J., and ROUNDS, M. B.
1941. AVOCADO TRUNK CANKERS. Calif. Avocado Assoc. Yearbook 1941: 46–47.
———, and PALMER, D. F.
1935. THE CONTROL OF DOTHIORELLA ROT ON AVOCADO FRUITS. Calif. Agr. Expt. Sta. Bul. 594, 16 pp., illus.
HUBERTY, M. R.
1943. THE DRAINAGE AND PERMEABILITY CHARACTERISTICS OF THE SOILS ON WHICH AVOCADO TREE DECLINE AND COLLAPSE ARE PREVALENT. Calif. Avocado Soc. Yearbook 1943: 38–39.
———, and PILLSBURY, A. F.
1943. SOLID, LIQUID, GASEOUS PHASE RELATIONSHIPS OF SOILS ON WHICH AVOCADO TREES HAVE DECLINED. Amer. Soc. Hort. Sci. Proc. 42: 39–45, illus.
IBARRA, D. S.
1929. EL AGUACATE. [Tacubaya, D. F., Mexico.] Sec. de Agr. y Fomento, Dir. Gen. de Agr. y Ganad., 48 pp., illus.
JAFFA, M. E., and GOSS, H.
1923. AVOCADO CULTURE IN CALIFORNIA, PART 2: COMPOSITION AND FOOD VALUE. Calif. Agr. Expt. Sta. Bul. 365: 630–638.
JONES, T. H.
1917. A LIST OF THE COCCIDAE OF PORTO RICO. Puerto Rico Dept. Agr. Jour. 1: 1–16.
LYNCH, S. J.
1941. NEW AVOCADO VARIETIES. Fla. State Hort. Soc. Proc. 54(1941): 142–144, illus.
———, and STAHL, A. H.
1939. STUDIES IN THE COLD STORAGE OF AVOCADOS. Fla. State Hort. Soc. Proc. 52(1939): 79–81.
MACMILLAN, H. F.
1943. TROPICAL PLANTING AND GARDENING. Ed. 5, 560 pp., illus. London. (Reprinted 1946.)
MARSHBURN, A. R.
1941. PERMANENT COVER FOR AVOCADO ORCHARDS. Calif. Avocado Soc. Yearbook 1941: 77–78.
MCCLELLAND, T. B.
1926. REPORT OF THE HORTICULTURIST. Porto Rico (Mayaguez) Agr. Expt. Sta. Rpt. 1924: 15, 17, illus.
MILES, L. E.
1917. SOME DISEASES OF ECONOMIC PLANTS IN PORTO RICO. Phytopathology 7: 345–351, illus.
MILLER, J. C.
1944. TREE REPLACEMENT AND TOPWORKING. Calif. Avocado Soc. Yearbook 1944: 57–59, illus.

MOZNETTE, G. F.
1922. THE AVOCADO: ITS INSECT ENEMIES AND HOW TO COMBAT THEM. U. S. Dept. Agr. Farmers' Bul. 1261, 31 pp., illus.
NOLLA, J. A. B.
1926. THE ANTHRACNOSES OF CITRUS FRUITS, MANGO AND AVOCADO. Puerto Rico Dept. Agr. Jour. 10(2): 25–63, illus.
NORIEGA, C.
1944. CULTIVO DEL AGUACATE. Rev. Agr. [Guatemala] 21: 183–203.
PALMER, D.
1935. PRACTICAL METHODS OF DISEASE CONTROL IN AVOCADOS. Calif. Avocado Assoc. Yearbook 1935: 72–80.
PARKER, E. R., and ROUNDS, M. B.
1944. AVOCADO TREE DECLINE IN RELATION TO SOIL MOISTURE AND DRAINAGE IN CERTAIN CALIFORNIA SOILS. Amer. Soc. Hort. Sci. Proc. 44: 71–79, illus.
PILLSBURY, A. F., and HUBERTY, M. R.
1944. DRAINAGE OF AVOCADO ORCHARDS. Calavo News 18(3): 5, 8–11, illus.
PIPER, R. B., and GARDNER, F. E.
1944. COMPARATIVE SEASONAL DEVELOPMENT OF AVOCADO FRUITS AND SEEDS. Fla. State Hort. Soc. Proc. 56(1943): 122–124, illus.
POPENOE, W.
1942. AGUACATES DE CHINA. Calif. Avocado Soc. Yearbook 1942: 27–32, illus.
———, and BUTLER, A. F.
1928. PROPAGATION DE L'AVOCATIER. Lab. d'Agron. Colon. Rev. de Bot. Appl. et d'Agr. Colon. 8(83): 478–482, illus. Paris.
PRATT, H. K., and BIALE, J. B.
1944. RELATION OF THE PRODUCTION OF AN ACTIVE EMANATION TO RESPIRATION IN THE AVOCADO FRUIT. Plant Physiol. 19: 519–528, illus.
PREST, R. L.
1943. THE AVOCADO. Queensland Agr. Jour 57: 270–281, illus.
REECE, P. C.
1939. THE FLORAL ANATOMY OF THE AVOCADO. Amer. Jour. Bot. 26: 429–433, illus.
ROBINSON, T. R., and SAVAGE, E. M.
1926. POLLINATION OF THE AVOCADO. U. S. Dept. Agr. Cir. 387, 16 pp., illus.
ROLFS, P. H.
1904. THE AVOCADO IN FLORIDA, ITS PROPAGATION, CULTIVATION AND MARKETING. U. S. Dept. Agr. Plant Indus. Bul. 61: 36 pp., illus.
ROQUE, A.
1935. ANNUAL REPORT OF THE ASSISTANT PHYTOPATHOLOGIST, 1934–1935. Puerto Rico Insular Sta. Rpt. 1934–35: 30–40.
ROSE, D. H., ET AL.
1943. MARKET DISEASES OF FRUITS AND VEGETABLES, CITRUS AND OTHER SUBTROPICAL FRUITS. U. S. Dept. Agr. Misc. Pub. 498, 57 pp. illus.
ROUNDS, M. B.
1942. HANDLING AVOCADO ORCHARD SOILS. Calif. Avocado Soc. Yearbook 1942: 69–70.
RUEHLE, G. D. and LYNCH, S. J.
1940. COPPER SULFATE AS A CORRECTIVE FOR DIEBACK, A NEW DISEASE OF THE AVOCADO. Fla. State Hort. Soc. Proc. 53: 152–154, illus.
SCHROEDER, C. A.
1944. MULTIPLE EMBRYOS IN THE AVOCADO. Jour. Hered. 35: 209–210, illus.
SIERRA, H. M.
1944. PERSPECTIVA FUTURA DEL AGUACATE. Rev. Agr. [Guatemala] 1 (2): 56–57, illus.
SMAKEL, H. J.
1928. THE MULCHED BASIN SYSTEM. Calif. Avocado Assoc. Yearbook 1928: 25.
SOTO, T.
1946. PUERTO RICO NECESITA PRODUCIR MAS AGUACATES. Puerto Rico Univ. Agr. Ext. Serv. Monthly Newsletter 3 (6): [2].

STELL, F.
1935. REPORT OF MYCOLOGIST, 1934. Trinidad and Tobago, Admin. Rpt., Dir. Agr. 1934: 47–50.
STEVENSON, J. A.
1917. ROOT ROT OF AVOCADO. Puerto Rico Bd. of Commrs. of Agr. 5th Rpt. 1915–16: 73.
STOKDYK, E. A.
1932. SALES METHODS AND POLICIES OF THE CALAVO GROWERS OF CALIFORNIA. Univ. Calif. Agr. Expt. Sta. Bul. 539, 52 pp., illus.
STROMBERG, E. O.
1944. CARE OF AVOCADO GRAFTS. Calavo News 18 (2): 4–5.
TRAUB, H. P., POMEROY, C. S. ROBINSON, T. R., and ALDRICH, W. W.
1941. AVOCADO PRODUCTION IN THE UNITED STATES. U. S. Dept. Agr. Cir. 620, 28 pp., illus.
———, and ROBINSON, T. R.
1939. EFFECT OF VARIOUS DEGREES OF HEADING BACK ON SUBSEQUENT GROWTH OF AVOCADO TREES. Fla. State Hort. Soc. Proc. 52 (1939): 43–48, illus.
TURNBOW, G. D., and CRUESE, W. V.
1927. INVESTIGATIONS ON THE USE OF FRUITS IN ICE CREAM AND ICES. Calif. Agr. Expt. Sta. Bul. 434, 38 pp., illus.
VALENCIA, G. R.
1912. CULTIVO Y EXPLOTACIÓN DEL AGUACATE. [Mexico] Estac. Agr. Cent. Bol. 71, 70 pp., illus.
WAGER, V. A.
1942. PHYTOPHTHORA CINNAMOMI AND WET SOIL IN RELATION TO THE DYING BACK OF AVOCADO TREES. Hilgardia 14: 517–532, illus.
WARDLAW, C. W.
1938. THE AVOCADO (PERSEA AMERICANA MILL.) IN THE WEST INDIES. Trop. Agr. [Trinidad] 15 (10): 225–226.
WOLCOTT, G. N.
1933. AN ECONOMIC ENTOMOLOGY OF THE WEST INDIES. 688 pp., illus. San Juan.
ZENTMYER, G. A., and KLOTZ, L. J.
1947. THE CINNAMON FUNGUS AND AVOCADO DECLINE. Calif. Avocado Soc. Yearbook 1947: 40–42.

U. S. GOVERNMENT PRINTING OFFICE: 1951