Excerpted from:
Traub, Hamilton P. and T. Ralph Robinson. 1937. Improvement of Subtropical Fruit Other than Citrus. USDA Yearbook Separate No. 1589. 77 pages (Avocado excerpt pp. 10 – 26).

AVOCADO

The avocado is native to Central America and Mexico. Long before the discovery of the Americas it was an important food crop in these regions and also in the northern Andes of South America and the coastal region of the Gulf of Mexico and the Caribbean Isles. The nourishing and appetizing avocado fruits are cheaply produced in tropical America, and they serve in a measure as a meat substitute. Avocado culture has now spread to other regions. The most outstanding developments in commercial culture have taken place in the United States, where thriving industries have been established in California and Florida.

Various names have been applied to this fruit crop, including the inelegant term "alligator pear", but the correct term in English is avocado, a name used as early as 1696, undoubtedly a corruption of the Spanish "ahuacate" or "aguacate", which was adapted from the Aztec "ahuacatl" (*91*).

The cultivated avocado varieties are all included in one species, *Persea americana* Mill. (*P. gratissima* Gaertn.). At one time it was supposed that two species were represented, but this proved not to hold in the light of later investigations (*92*). Within the species three general ecological races are recognized that present distinctions of importance horticulturally. The West Indian or lowland race is most susceptible to injury from cold and matures its fruits in summer and fall. The fruits are low in oil content, and intermediate in the thickness of the leathery skin between the highland Guatemalan and Mexican races. The latter races are relatively more resistant to low temperature, the Mexican race being the hardier of the two. The fruits of the Guatemalan race, maturing in winter and spring, have a thick, woody skin and intermediate oil content. The Mexican race, maturing in the summer, has a very thin skin and high oil content. The coyo, *P. schiedeana* Nees, native to Guatemala and closely related to the avocado, has not proved of value in cultivation.

INTRODUCTION INTO THE UNITED STATES AND HAWAII

In all probability the avocado was brought to Florida by the early settlers, but the first recorded introduction was in 1833, when Henry Perrine sent trees from Mexico to be planted on his government land grant south of Miami (*88*). Only isolated plantings were made in Florida until 1900, when the first avocado nursery was established at Miami by George B. Cellon. The interest in the crop increased after that date, and many plantings have since been made. The late W. J. Krome and other pioneer growers in southern Florida have tested put a great many varieties from California, Central America, and Mexico, including the Department introductions. A number of groves have also been planted in other parts of the State, notably on the east coast in the Fort Myers district and in the south-central ridge section, where Ivey Futch, of Lake Placid, W. F. Ward, of

Avon Park, and others have established successful groves. Smaller plantings are found as far north as Orange County.

Avocado seeds of the West Indian and Guatemalan races reached Hawaii from Central America before 1825. Owing to the lack of an outside market, the Hawaiian industry is being developed on a scale to supply local needs only.

In the lower Rio Grande Valley of Texas seedling introductions of the Mexican race from Mexico have survived in dooryards in a number of instances. Horne (*41*) points out that the Mexican varieties are the most promising for this section, although they should be planted only on an experimental scale. The avocado apparently was introduced successfully into California in 1871, when R. B. Ord secured trees from Mexico, which he planted at Santa Barbara (*39*). J. C. Harvey, Jacob Miller, and Juan Murrieta, of Los Angeles, F. Franceschi, of Santa Barbara, and C. P. Taft, of Orange, were other early avocado growers in California who introduced trees from abroad or produced new varieties from seeds. F. O. Popenoe (fig. 3, *A)* and T. V. Barber, of Altadena, imported budwood of Mexican varieties in 1911—12, and among these the Fuerte and Puebla are outstanding. E. E. Knight, of Yorba Linda, imported and introduced the two Guatemalan varieties, Queen and Linda, while Joseph Sexton, of Goleta, was interested in the varieties of the West Indian race and in Hawaiian varieties. Sexton's experiments were valuable for the industry as a whole; for they demonstrated that the West Indian varieties are not adapted to California conditions.

The avocado collections made by private individuals in the United States were further enriched by the importation of many varieties from Mexico, Central America, and South America by the Department of Agriculture, beginning in 1906. Cook and Collins began the importation of varieties from Guatemala, and the work was completed by the thorough explorations of Wilson Popenoe (fig. 3, *B*), 1916—21, in Guatemala and other Central American habitats as well as the northern Andes of South America (*89*). As a result of the systematic search by Wilson Popenoe, an abundance of worthwhile Guatemalan avocado germplasm was introduced into the United States and made available to plant breeders in other countries as well.

Wilson Popenoe made selections on the basis of desirable characters with special reference to hardiness, early and late fruit maturity, proportion of edible material, and excellent dessert quality. The varieties selected include the whole range of fruit shape, size, and rind color. The following 28 Guatemalan varieties were introduced on this basis for trial in California and Florida: Lamat (P. I. 43476), Kanola (P. I. 43560), Ishkal (P. I. 43602), Coban (P. I. 43932), Kashlan (P. I. 43934), Chisoy (P. I. 43935), Pankay (P. I. 44785), Nabal (P. I. 44439), Nimlioh (P. I. 44440), Panchoy (P. I. 44625), Tumin (P. I. 44627), Benik (P. I. 44626), Kekchi (P. I. 44679), Mayapan (P. I. 44680), Kayab (P. I. 44681), Manik (P. I. 45560), Gabnal (P. I. 44782), Cantel (P. I. 44783), Tertoh (P. I. 44856), Akbal (P. I. 45505), Ishim (P. *I.* 45562), Kanan (P. I. 45563), Chabil (P. I. 45564), Itzamna (P. I. 43486), Batab (P. I. 43487), Chilan (P. I. 43933), Hunapuh (P. I. 44628), and Tamayo (P. I. 53182). Of the Mexican race, Capee (P. I. 54276), Chota (P. I. 53184), Egas (P. I. 53183), and Kaguah (P. I. 45561) were introduced.

One promising source of avocado germplasm, the Mexican highlands, where the Mexican type of avocado has been cultivated since pre-Columbian times, has not been

exhaustively explored.

This germplasm collection contains several varieties, notably Nabal, Benik, Itzamna, and Nimlioh (in California), that give promise of immediate utility in culture, but its main value is for cross breeding to obtain combinations of resistance to low temperature, high quality, long range in marketing season, and other desirable characters represented in the varieties.

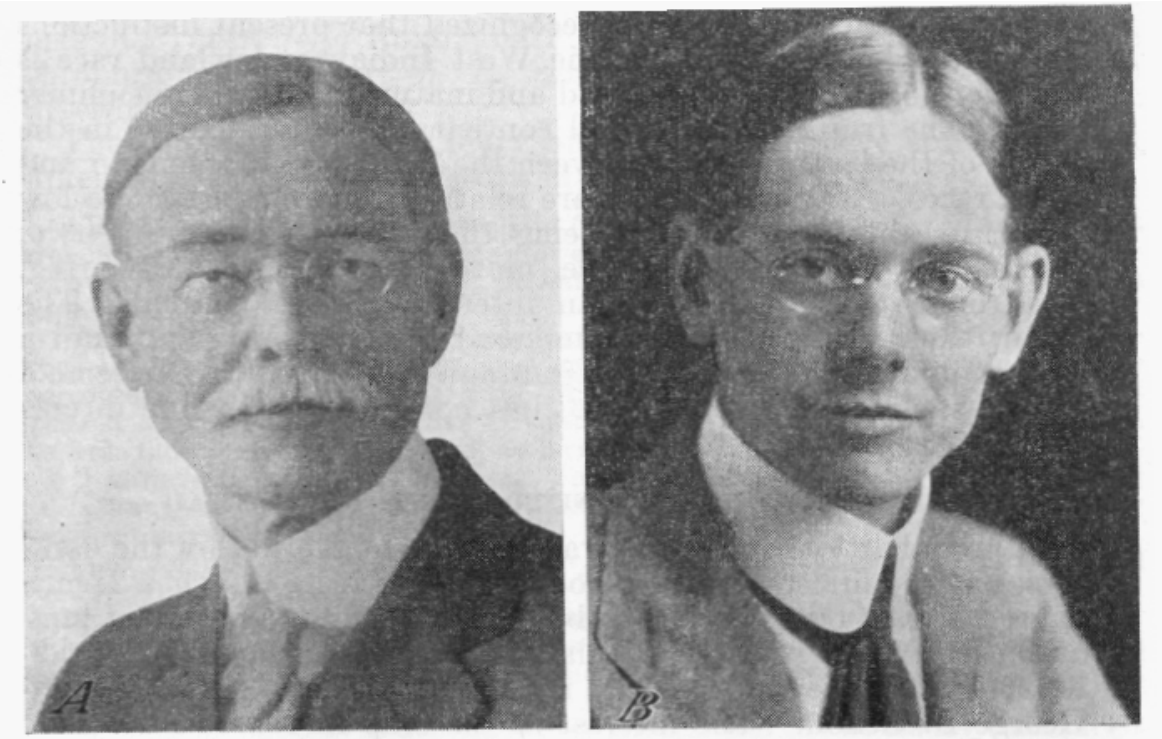

Figure 3.—Popenoe, father and son. *A*, F. O. Popenoe (1863–1934), who introduced and distributed, through the West India Gardens, Altadena, Calif., the Fuerte and Puebla varieties of avocado, which made up 80 to 90 percent of all commercial plantings in California during the last decade. *B*, Wilson Popenoe, agricultural explorer for the United States Department of Agriculture, 1913–25; introduced germ-plasm collection of avocado and its relatives from Mexico, Central America, and South America; also collected annonas, sapotas, and other subtropical and tropical fruits. Since 1925, as director of research [for the] United Fruit Co., he has assembled at Tela, Honduras, extensive germ-plasm collections of tropical and subtropical fruits and other crop plants.

PROGRESS IN AVOCADO IMPROVEMENT

It is highly satisfying to contemplate the future of the avocado industry from the standpoint of the improvement of varieties by plant breeding. The industry has had the benefit of superior varieties from the beginning, and in addition the breeder has for his use a most comprehensive collection of avocado germplasm, which contains types very resistant to low temperature and characterized by other desirable traits to be combined

with the fruit qualities demanded by the market. Fortunately, this germplasm collection has been brought in during the early stages of the industry by the foresight and energy of the early pioneers, and later by Wilson Popenoe, then of the Department. The thorough manner in which the work has been done by Popenoe may be gauged in some measure by noting the total of 287 separate avocados (*Persea americana*) introductions, and 62 separate introductions within species related to it.

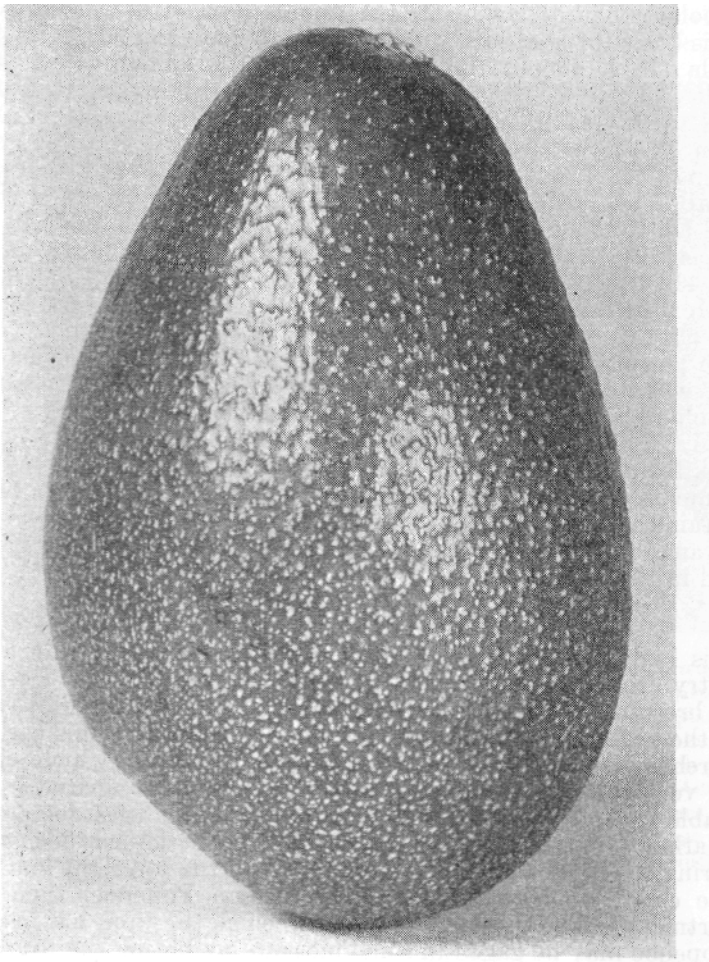

Figure 4.—Typical fruit of the Fuerte avocado—reputed to be a natural hybrid of Guatemalan × Mexican origin; almost ideally adapted to market requirements as to size, color, long season of maturity, and hardiness, under California conditions; not adapted to Florida.

California

The commercial avocado industry in California is concentrated largely in southern California, and the most important producing districts are in the coastal region extending from San Diego to Santa Barbara, including portions of San Diego, Los Angeles, Ventura, and Santa Barbara Counties, and all of Orange County. Commercial avocado groves have also been planted farther inland in protected locations on the foothill slopes of the Santa Paula, San Fernando, San Gabriel, and Santa Ana Valleys. On the whole, therefore, the avocado plantings are mostly located in the milder sections of the citrus

area. The industry in California is at present founded almost entirely on one variety, the Fuerte, which fulfills the market preference for a medium-sized fruit weighing from 8 to 14 ounces, maturing mainly during winter and spring, December to June, but with some ripe fruits available practically every month of the year (fig. 4). The Fuerte variety was introduced into California in 1911 from Atlixco, State of Puebla, Mexico, where the original tree is still in a thriving condition (fig. 5). Under California conditions the trees have proved to be highly resistant to low temperature, vigorous in growth, and fairly productive. The Fuerte is assumed to be a natural hybrid between the Guatemalan and Mexican races. A series of seedlings of the Fuerte grown about 1920 at the plant introduction garden of the Department at Buena Vista, Fla., showed segregation for anise odor of leaves, individuals occurring both with and without this odor. This lends confirmation to the hypothesis of hybrid origin, although cross-pollination from different sources may have affected the resulting progeny.

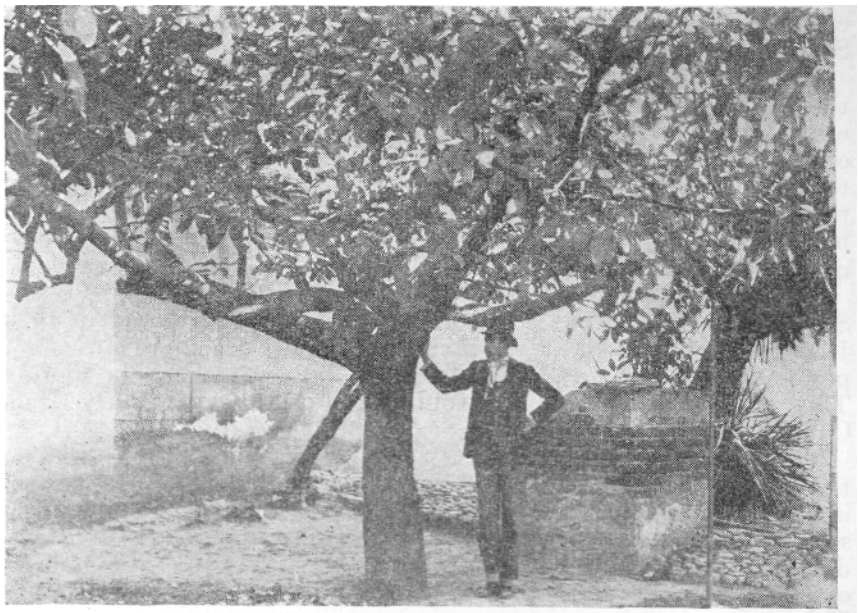

Figure 5.—The original Fuerte avocado tree, a seedling tree growing near Atlixco, Mexico; considered a hybrid between Guatemalan and Mexican races. Approximately 90 percent of the trees in commercial avocado groves in California are of this variety.

Another variety, Puebla, also introduced from Atlixco in 1911, is second in importance. It is of the Mexican race, highly frost-resistant, a vigorous grower, maturing in California from December to February, which is later than most varieties of the Mexican race. Other varieties such as the Nabal, Queen, Taft, Anaheim, Dickinson, and Mayapan are also recommended by the California Avocado Growers Association for planting.

The selection of new varieties from the numerous introductions and from local seedlings was begun under the direction of Hodgson and his coworkers at the southern branch of the University of California at Los Angeles in 1931, but artificial hybridization has not yet been undertaken.

Florida

In the early history of the avocado industry in Florida the early maturing varieties were grown, mostly of the West Indian race, but Cuban competition in the summer and fall seasons has forced growers to extend their marketing season by the use of fall and winter varieties of the Guatemalan race and hybrids. The leading varieties for planting at present are Waldin, Trapp, Fuchsia (West Indian race); Taylor, Wagner, and Itzamna (Guatemalan race); and Collinson and Lula (hybrids). Many of the varieties planted earlier have been discarded, and there is a tendency toward the planting of fewer varieties. Even the best varieties have obvious defects, and the final work has not yet been done in varietal selection. The varieties cultivated in Florida have been described in detail by Toy (*121*) Stahl (*109*), and Wolfe, Toy, and Stahl (*137*).

In the chief center of avocado production in Florida—Dade County— the early to midseason varieties are of the West Indian race. In central Florida the early maturing varieties are of the Mexican race or its hybrids. The varieties of the West Indian race are characterized by relatively low oil content of the fruit and maturity seasons ranging from summer to late fall. The varieties of the Mexican race have relatively high oil content and under Florida conditions are usually early in maturity.

The earliest maturing variety, Fuchsia, originated by C. T. Fuchs, Sr., Homestead, Fla., as a chance seedling, was introduced in 1920. It is apparently of the West Indian race. The tree is vigorous and productive, and the fruit matures from June to August in Florida. This variety is suitable for southern Florida, particularly Dade County.

The other early variety, Gottfried, is apparently a hybrid between the Mexican and West Indian races, since seedlings from trees in isolated locations show segregation for anise-scented and non-anise scented individuals. It originated at the United States Plant Introduction Garden; Miami, in 1906 from a seed collected on the premises of Edward Gottfried, Key Largo, Fla., and was introduced in 1918. This variety is very resistant to low temperature and is exceedingly vigorous and productive in Orange County, where it is grown for local market, but it is not adapted to southern Florida. The maturity season ranges from June to September.

The Trapp variety (fig. 6, A) was the first named variety to be introduced in Florida, and it is still being planted in spite of the fact that it is a rather weak grower, owing in part to its tendency to overbear, and is susceptible to insect and disease injury. The fruit matures from September to November. It originated as a chance seedling grown by H. A. Trapp, of Coconut Grove, and was introduced in 1901 (fig. 7). It is outstanding in historical interest, as it was the first-named variety of the avocado to be propagated vegetatively in Florida. This was done by George B. Cellon, of Miami.

The Peterson variety was introduced in 1928 by Peter Peterson, of Modello. The fruit resembles that of the Trapp but averages smaller in size and is more attractive in color. It matures from the middle of September to the middle of November.

The Waldin variety, originated by B. A. Waldin at Homestead, was introduced in 1917. The fruit matures from October to December in Florida. This is one of the outstanding varieties for planting in Dade County.

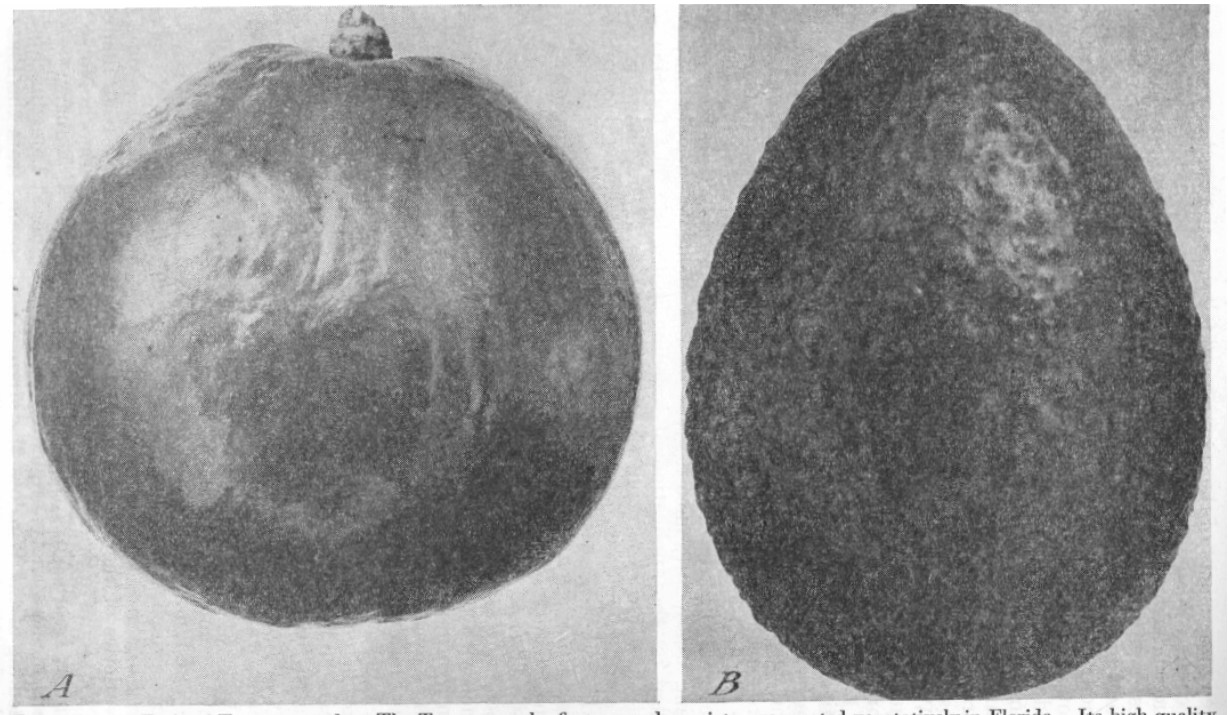

Figure 6.—A, Fruit of Trapp avocado. The Trapp was the first avocado variety propagated vegetatively in Florida. Its high quality and medium size have contributed to its continued popularity. *B*, The Taylor avocado. Its hardiness, small size, regular bearing habit, and winter season of maturity in Florida have contributed to the commercial importance of this variety.

The improvement of the summer and fall varieties has been arrested on account of Cuban competition, and this has stimulated efforts to produce later-maturing varieties. In general these fall into two classes from the genetic standpoint—varieties of the Guatemalan race and hybrids.

Among the varieties of the Guatemalan race, Taylor and Wagner are outstanding. Taylor originated at the United States Plant introduction Garden at Coconut Grove as a seedling of Royal and was introduced in 1914 (figs. 6, *B,* and 8). The fruit matures from the middle of December to the middle of February. It was one of the first Guatemalan varieties to be planted commercially, and it has not lost its popularity. Its tall, slender growth habit is objectionable the Wagner variety, also a seedling of Royal, originated by C. F. Wagner, of Hollywood, Calif., and introduced in 1914, is similar to Taylor, but the season of maturity is somewhat later (Jan. 15 to Mar. 1), and the fruits are rounder in form. The Taylor and Wagner varieties are adapted to southern and central Florida.

The Itzamna variety is a direct introduction from Guatemala, made by the Department in 1916 and distributed in 1923. The fruits mature from February 15 to April 15. On the basis of its performance so far it is being planted in southern Florida.

The group of interracial hybrids is the most interesting from the breeding standpoint, since it gives some evidence as to what may be expected by the application of breeding methods. The hybrids so far introduced are the result of open pollination. They show hybrid vigor and as a rule are better adapted to local conditions than representatives of the races introduced directly from abroad the most promising natural hybrids so far introduced show Guatemalan-West Indian or Guatemalan-Mexican characteristics in combination.

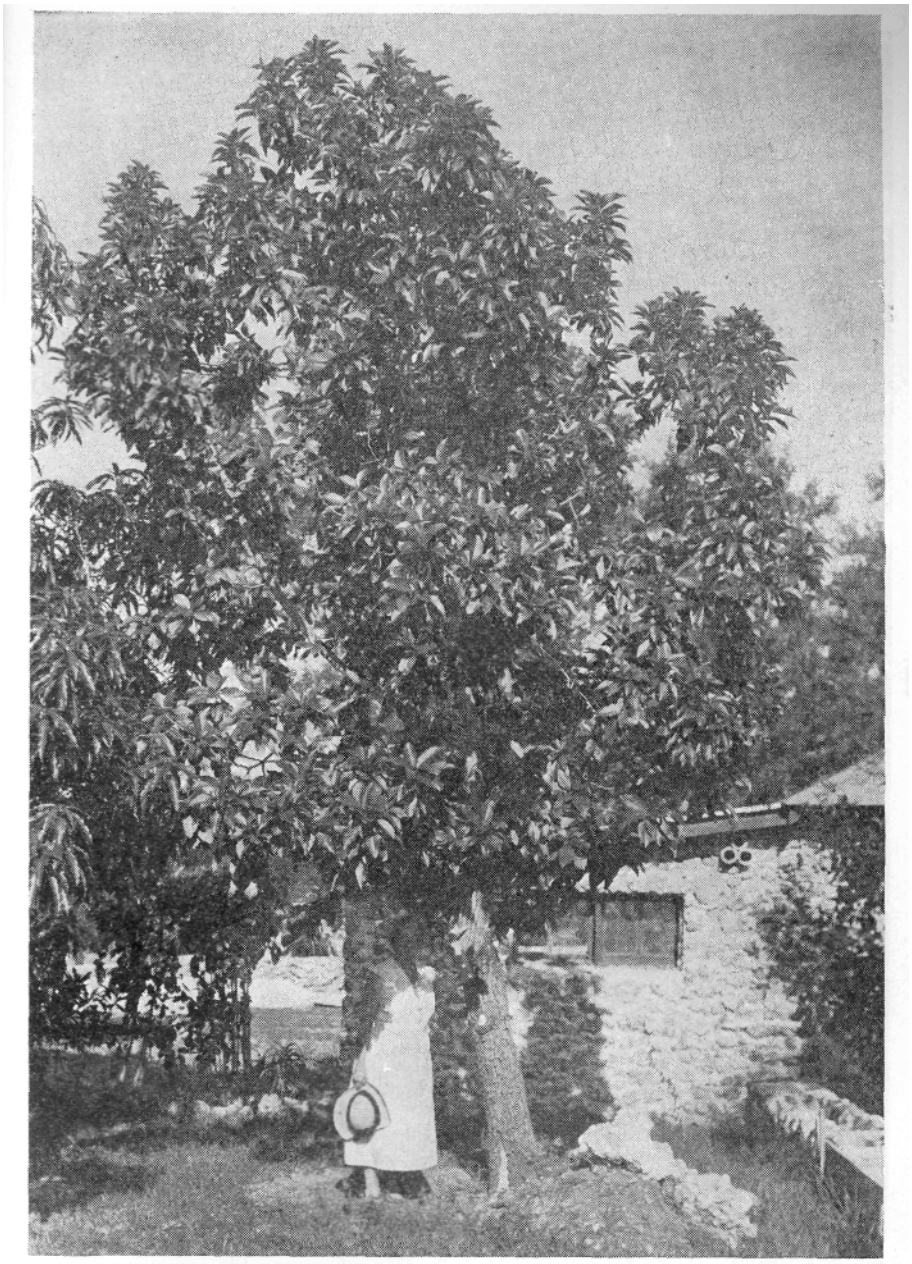

Figure 7.—Parent tree of the Trapp avocado. Originated as a seedling of the West Indian race; parent tree grown by H. A. Trapp, of Coconut Grove, Fla.; first fruiting about 1898. Propagated by George B. Cellon and introduced in 1901 for commercial planting; the first named variety of avocado. The original trunk is shown, but the top of the tree was broken off near where Mrs. Trapp has her hand, and the present top is a relatively recent (10 years old) outgrowth from the stump.

23818—37——7

The Collinson variety, originated at the Plant Introduction Garden at Coconut Grove, from a Collins seed, was introduced in 1920 and has met with popular favor. It appears to be a Guatemalan-West Indian hybrid and is highly resistant to scab. The season of maturity is from November 15 to February. It is adapted to southern and central Florida.

Figure 8.—Taylor avocado tree, growing in Dade County, Fla., showing typical upright habit. This variety originated as a seedling of the Royal, planted in 1907 at the United States Plant Introduction Garden at Miami, Fla.; first fruited in 1913; propagated for commercial planting in 1914. The leading variety of the Guatemalan race for Florida planting.

The Fuerte, the chief variety grown in California, is not adapted to Florida conditions. Apparently it is a natural Guatemalan x Mexican hybrid, introduced from Mexico. However, the Lula originated by George B. Cellon at Miami from a seed of the Taft variety and introduced in 1921, shows evidence of Guatemalan-Mexican parentage and is an outstanding variety in Florida, in spite of its high degree of susceptibility to scab. The season of maturity is from December to February.

The outstanding varieties of recent introduction are the Booth seedlings, which originated in Dade County from Guatemalan seeds, gathered in a grove interplanted with trees of the Trapp and Waldin varieties of the West Indian race. Selections have been made so as to secure a wide range in maturity periods—Booth No. 8 November; Booth No. 7, December; and Booth No. 3, January.

The Dunedin variety, originated by L. B. Skinner at Dunedin Fla. is a seedling of the Winslow, the original seed coming from the Plant Introduction Garden at Miami. The tree is evidently a Guatemalan-West Indian hybrid like the Winslowson, but is more hardy than the latter and holds its fruit later into winter. The fruit is of excellent quality and medium size, and the tree is a vigorous grower.

The variety named Fairchild in honor of David Fairchild was introduced in 1933. It is a first-generation progeny of Collinred, a Collinson sister seedling, originated at the Plant Introduction Garden at Coconut Grove. The fruit is characterized by a red blush. The variety has not been extensively tested.

Philippine Islands

Avocado improvement was begun in the Philippine Islands by the late P. J. Wester, who introduced many varieties from the United States early in the twentieth century. The work is now being continued by J. P. Torres, F. G. Galang, and E. K. Morada and is concerned chiefly with intensive study of the introduced varieties and locally produced seedlings. The breeding method used is that of mass selection. The existing varieties are being classified as to their flowering and fruiting habit and other important tree and fruit characters.

Although imported varieties such as Cardinal and Pollock and local varieties such as Suarez, Lopena, and Batangas No. 2 have been distributed for commercial planting, the greater part of the trees planted are miscellaneous seedlings (*22*).

Foreign Countries

In the foreign countries where avocados are grown commercially the industry as a rule is based on varieties introduced from the United States.

In the West Indies, Cuba, and the British possessions avocado industries are based primarily on miscellaneous seedling trees. In Cuba one variety of the West Indian race, Somerford (Catalina) has been introduced. In Trinidad, Pollock is grown, but most of the trees planted are seedlings.

G. Gandara, of the Mexican Department of Agriculture, reports that in Mexico the

avocado is an important product, the annual commercial production being estimated at 63 million pounds. The main season of the crop is in the summer and autumn months. The types grown are largely seedlings ranging from rough fruits with thick rind of many shapes and sizes to smooth fruits with thin skin. Colors vary from green to dark purple. The type predominating in Chiapas is large, green or yellow like the Nimlioh of Guatemala. In Querétaro the Mexican type with smooth rind and anise-scented leaves predominates. The experiment stations where selection work is in progress are at Querétaro, Querétaro; Acapulco, Guerrero; Leon, Guanajuato; Hocelchacan, Campeche; and Oaxaca, Oaxaca. Selection is being made of types better suited to commercial propagation and if possible resistant to attack by the weevil *Heilipus lauri* Boh.

In Brazil, Jaoa Dierberger, Jr., of Sâo Paulo, has introduced the outstanding American varieties, and these have now been tested out for some years. On the basis of these tests different groups of varieties are recommended for the highlands in the section of Sâo Paulo and the lowlands around Santos.

In Queensland, Australia, the American varieties have been introduced and are under test by the Queensland Acclimatization Society at Brisbane.

J. A. Campbell, director of the division of horticulture, New Zealand Department of Agriculture, Wellington, reports that some progress has been made in the introduction of avocado varieties.

For the Union of South Africa and Rhodesia, Blatt (5) recommends that 50 percent of any commercial planting should be Fuerte and that the remainder should include wholly or in part Nabal, Puebla, Taft, Queen, Mayapan, Dickinson, and Anaheim.

OBJECTIVES AND METHODS IN AVOCADO BREEDING

The application of scientific breeding methods to the improvement of the avocado has only begun, and the major achievement up to the present time is the introduction of an extensive germplasm collection, which contains most of the valuable material nature has provided. The varieties available are being intensively studied in both California and Florida. A comprehensive collection has been assembled by Hodgson and his coworkers at the southern branch of the University of California at Los Angeles; in Florida variety collections are maintained at the Florida State Subtropical Experiment Station at Homestead by Wolfe and his coworkers, and at the Plant Introduction Garden at Coconut Grove, under the leadership of T. B. McClelland. The ideals to be sought in avocado breeding vary somewhat with the various production regions, as would be expected. In 1920 Krome (*57*) outlined the requirements for an ideal commercial avocado variety for Florida—

(1) compact tree growth;

(2) a regular fruiting habit;

(3) season of maturity best suited to market demand, fall or winter;

(4) color of fruit, green when mature;

(5) size medium, averaging from 1 to 1½ pounds;

(6) shape round, oblate, or slightly oblong, without pronounced neck;

(7) freedom from fiber;

(8) good flavor and oil content;

(9) seed small to medium-sized.

To these-requirements the following additions or amendments might now be made:

(1) resistance to diseases affecting foliage, fruit, and stem, chiefly scab and Cercospora spot;

(2) resistance to cold injury;

(3) size of fruit from 10 to 16 ounces;

(4) smooth or only slightly corrugated skin, thin to medium in thickness;

(5) smooth, creamy pulp, free from soapy or insipid flavor, with oil content at least 6 percent, preferably higher;

(6) seed tight in cavity with seed coat adhering to seed.

An objective particularly important from the standpoint of marketing and grove cultural requirements should be emphasized. On account of the necessity for interplanting varieties of the A and B flowering groups, to be discussed later, it would be highly desirable to produce varieties with quite similar fruiting characters in each of these groups. Ivey Futch, at Lake Placid, Fla., has grown a seedling (B group) from Lula (A group) which is fairly similar to the parent variety and in addition is less subject to scab.

In California regular bearing habit and season of maturity are the characters that need most attention in improvement breeding, since at least three varieties, Fuerte, Nabal, and Taft, are now ranked as excellent in quality and satisfactory with regard to attractiveness and marketability of the fruit. Varieties similar to Fuerte, with regular bearing habit and maturing fruits at different seasons, are needed. The ideal avocado fruit from the standpoint of marketing, according to the variety committee of the California Avocado Growers Association, is described as follows:

(1) Size, 6 to 12 ounces;

(2) shape, typically pyriform (pear-shaped);

(3) color, dark green;

(4) seed, less than 12 percent of fruit, tight, with seed coats adhering to seed;

(5) skin, medium thin, tough, with smooth surface, yielding when softening;

(6) flesh, oil content 16 to 22 percent, free from fiber, deep yellowish green;

(7) flavor, rich and nutty, free from sweetness, bitterness, and soapiness;

(8) must have the quality of remaining good on the inside until after senescent decomposition is quite apparent on the outside;

(9) evenness of maturing and softening over all parts of the fruit;

10) long keeping quality in both common and cold storage;

(11) cut surface should remain bright and attractive for several hours.

BREEDING TECHNIQUE

The flowering habit of the avocado presents two features of importance in developing a suitable breeding technique. Normally the pistils mature before the stamens begin to discharge pollen, which should aid in securing abundant cross-pollination, Only a very small percentage of fruits are set, which presents a serious difficulty in controlled pollination work and has greatly retarded progress.

Flowering Habit

The avocado normally blooms from January to May in the United States, the exact time depending on the locality and the variety. The flowers are perfect, having both pistils and stamens, and pollination is normally accomplished by the agency of insects. The investigation of Nirody (*74*), Stout (*111, 113*), and Robinson and Savage (*96*) have shown that in the avocado flower the pistil normally matures before the stamens. Nirody's work also established the fact that this alternate development of the sex organs is decidedly synchronous for the tree as a whole, which led him to conclude that cross-pollination is necessary for fruit setting.

The work of Stout in California and Florida, however, shows that the maturing of stamens and pistils at different times (dichogamy) is much more pronounced than was indicated by Nirody. Stout has shown that the flowers of a particular tree normally have two distinct periods of opening instead of one. During the first opening the stigmas of the pistils are receptive but the anthers are not yet mature; and during the second opening of these same flowers the pollen is shed, but the stigmas are no longer receptive. His work led him to group all of the varieties studied into two classes from the standpoint of periods of flower opening, as explained in the next paragraph. He observed, however, that weather conditions markedly affect the periods of flower opening and the degree of overlapping of these periods. Stout's important work was later confirmed by Robinson and Savage (*96*). Skutch (*103*) has reported on avocado trees in Panama that exhibit an erratic behavior with regard to flowering habit.

The normal behavior may be briefly summarized as follows: Under favorable weather conditions the flowers of varieties in group A have a first opening during early forenoon when the pistils are receptive but no pollen is shed. By midday they begin to close tightly. At about this time, with some overlapping in certain varieties, the flowers that opened and closed in the forenoon of the previous day now have a second or afternoon opening and shed pollen. In group B, the first opening when the pistil is receptive normally takes place in the afternoon while pollen is being shed by the group A varieties on their second opening. The second opening of group B flowers normally takes place the following morning, when they shed pollen, which is ready for transfer to the receptive pistils of group A flowers opening for the first time. Thus the complete flowering cycle of group A varieties includes the forenoon of one day and the afternoon of the next, extending over approximately 30 to 36 hours; while the group B varieties

complete their cycle during one afternoon and the next forenoon, in 20 to 24 hours. To insure pollination in the greatest degree, mixed orchard plantings of the two flowering groups should generally be made.

As to the need for varieties of the reciprocal group as Pollenizers, an important exception is the Fuerte variety (group B) as grown in the most favorable districts in California. Here the synchronization of the two openings of flowers is not complete because of cooling breezes, and this result in several hours' overlap with consequent opportunity for self-pollination. No interplanting of group A and B varieties is required in such a case (*95*).

All attempts to germinate avocado pollen in culture media have so far been unsuccessful.

Control of Pollination

The avocado produces an enormous number of flowers, of which only a very small percentage even under the most favorable conditions set fruit that is held to maturity. This makes the bagging technique of very little value. This handicap, however, is counterbalanced by the dichogamous nature of the avocado, already explained, which normally leads to a high percentage of cross-fertilization. If the expensive tree-tenting technique is employed (covering trees of two varieties under one tent) with the use of bees to transfer the pollen, abundant results should be achieved. To facilitate this it would be desirable to propagate the two parental varieties on the same stock or to graft one into the other. One variety, Collinson, does not produce pollen, and by using it for the seed parent even the possible error from the overlapping of the first and second flower-opening periods would be obviated. Neither is emasculation necessary with such a flower.

Most of the achievements in avocado breeding so far have resulted from the use of open-pollinated seeds from mixed plantings. Such superior varieties as Fuerte, Taylor, Wagner, Lula, and Collinson give an indication of what may be accomplished. Department workers have recently succeeded in making some artificial cross-pollinations by the use of the bagging technique (Collinson x Fuerte, Taylor x Fuerte), but the seedlings have not yet reached the fruiting stage.

BREEDING FOR DISEASE RESISTANCE AND OTHER CHARACTERISTICS

The Department project on avocado breeding, begun in 1932 under the leadership of Traub, Stevens, and Robinson, is concerned primarily with breeding for disease resistance. Avocado varieties show wide variation in resistance to avocado scab (*Sphaceloma perseae* Jenkins), the major disease of avocado in a humid climate, as well as to other diseases. The work has now been carried on for three seasons. The testing technique consists in exposing the plants to natural infection and to artificial inoculation with pure cultures. Some seedlings produced as a result of cross-pollinations are used in these experiments, but up to the present the larger number have been from open-pollinated seed from mixed plantings of the desired parents. The percentage of seedlings that show resistance to avocado scab varies widely among

different varieties, as is shown in table 2.

TABLE 2.—*Percentage of seedling plants showing resistance or susceptibility to avocado scab, Sphaceloma perseae*

Season and seed parent variety	Seedlings tested	Highly resistant	Slightly resistant	Highly susceptible
Seeds of 1934 season:	*Number*	*Percent*	*Percent*	*Percent*
Collins	100	3.0	67.0	30.0
Perfecto	190	2.6	26.8	70.6
Fuerte	128	2.3	21.8	75.9
McDonald	87	0	0	100.0
Wagner	99	1.0	39.3	59.7
Taylor	92	0	57.6	42.4
Lula	84	0	14.2	85.8
Waldin	86	2.3	3.4	94.3
Seeds of 1935 season:				
Taylor	47	14.8	27.2	58.0
Collinson	131	97.1	2.2	.7
Winslowson	30	10.0	0	90.0
Lula	122	40.9	25.4	33.7
Kellerman	29	96.6	3.4	0

With such tests as a basis, appropriate parents are being selected for use in crossing. Collinson and Kelierman seedlings, with a relatively high percentage resistant to scab, deserve special attention from breeders. Duplicate tests of seedlings can be made in two localities at once by using the method of splitting the avocado seed into two or more fractions before planting and thus growing two or more plants from it, as suggested by Traub and Auchter (*125*).

The ecological races of the avocado vary considerably in resistance to low temperature. The lowland or West Indian types are the most frost-tender, Guatemalan more hardy, and Mexican most hardy. Harris and Popenoe (*30*) have shown, by the freezing-point lowering technique that the tissue fluids of the West Indian type freeze at somewhat higher temperature than those of the other two races. They conclude that since the difference in freezing points of tissue fluids is slight, this character is only one of the causes responsible for the considerable variation in resistance to low temperature.

The varieties secured as a result of open pollination indicate that suitable combinations with respect to resistance to low temperature may be secured even when varieties of the West Indian race are used as one of the parents. Collinson, apparently a West Indian-Guatemalan cross, is almost as hardy in this respect as some of the Guatemalan types. The Booth seedlings, apparently crosses of the same class, also seem to be quite resistant to low temperature. Gottfried, apparently a Mexican-West Indian cross, is very hardy. Crosses between the Guatemalan and Mexican races are quite frost-resistant, as would be expected. Good examples of this are found in Fuerte and Lula.

Differences in reaction to storage conditions may determine to a considerable degree the value of avocado varieties as breeding material or for fruit utilization. With the Winslowson variety in Florida, losses have resulted from marked discoloration of the pulp, especially under low-temperature conditions of shipment or storage. A storage temperature of 50°F. completely inhibits ripening in the Winslowson avocado but is not detrimental to the Collinson and some other varieties.

Breeding for certain other desirable characters, such as tree habit, stem length and strength, skin thickness and color, seed size, quality and color of flesh, and oil content,

should also be seriously considered.

A recent study by Traub and Robinson[5] of 18 open-pollinated seedlings of Lula in the grove of Ivey Futch at Lake Placid, Fla., has shown a very wide variation in oil content (5 to 22.25 percent) as well as in fruit size, percentage of flesh, and skin thickness. Small-sized fruits largely predominate, for only 5 out of 33 produce fruit approximately as large as that of the parent variety (over 10 ounces). The percentage of flesh also varies widely in the series, although the greater number tested gave about 50 percent of flesh compared to the whole weight of the fruit. The skin was generally thin in all specimens. Only one seedling somewhat resistant to scab was found in the whole series. Tree habit varies from low and spreading in a few instances to the upright columnar growth characteristic of the Lula, the latter habit predominating.

CYTOLOGY OF THE AVOCADO

The cytology of the avocado has received very little attention. Van Elden at the California Agricultural Experiment Station (*10*) has determined the diploid chromosome number in several of the species of *Persea* to be in all probability 24. In 1932 Longley (see appendix) determined 12 as the haploid chromosome number in the varieties Lyon, Linda, Taft, Queen, Panchoy, Taylor, Wagner, Puebla, Fuerte, Winslowson, and a West Indian seedling.

Literature Cited

5. Blatt, R. J. 1931. Avocado growing in South Africa. Rhodesia Agr. Jour. 28:270-277, illus.

10. California Agricultural Experiment Station. 1929. [Diploid chromosome number in species of the genus *Persea*.] Calif. Agr. Expt. Sta. Ann. Rept. 1927-28: 106.

22. Condit, I. J. 1935. The avocado in the Orient. Calif. Avocado Assoc. Yearbook 1935: 109-110.

30. Harris, J. A., and Popenoe, W. 1916. Freezing-point lowering of the leaf sap of the horticultural types of *Persea americana*. Jour. Agr. Research 7: 261-268.

39. Hodgson, R. W. 1930. The California Avocado Industry. Calif. Agr. Ext. Cir. 43, 86 pp., illus.

41. Horne, W. T. 1933. Some California results with avocados which may be of interest in the Rio Grande Valley. Ann. Citrus Inst. Edinburg Col. (Tex.), Proc. 2: 73-81.

57. Krome, W. J. 1920. What constitutes a good commercial variety of avocado. Fla. State Hort. Soc. Proc. 33: 66-71. 270-277, illus.

74. Nirody, B. S. 1922. Investigations in avocado breeding. Calif. Avocado Assoc. Ann. Rept. 1921-22: 65-78, illus.

83. Perrine, H. E. 1885. The true story of some eventful years in Grandpa's life. Buffalo, N. Y.

[5] Unpublished work

89. Popenoe, W. 1919. The avocado in Guatemala. U.S. Dept. Agr. Bull. 743, 69 pp. illus.

91. Popenoe, W. 1927. Manual of tropical and subtropical fruits, excluding the banana, coconut, pineapple, citrus fruits, olive, and fig. 474 pp., illus. New York.

92. Popenoe, W. 1927. Wild avocados. Calif. Avocado Assoc. Yearbook 1927: 51-54.

95. Robinson, T. R. 1931. Some aberrant forms of flower mechanism in the avocado. Calif. Avocado Assoc. Yearbook 1931: 107-111.

96. Robinson, T. R. and Savage, E. M. 1926. Pollination of the avocado. U.S. Dept. Agr. Cir. 387, 16 pp., illus.

103. Skutch, A. F. 1932. Observations on the flower behavior of the avocado in Panama. Torreya 32: 85-94, illus.

109. Stahl, A. L. 1933. Changes in composition of Florida avocados in relation to maturity. Fla. Agr. Expt. Sta. Bull. 259, 61 pp., illus.

111. Stout, A. B. 1923. A study in cross-pollination of avocados in southern California. Calif. Avocado Assoc. Ann. Rept. 1922-23: 29-45, illus.

113. Stout, A. B. 1933. The pollination of avocados. Fla. Agr. Expt. Sta. Bull. 257, 44 pp., illus.

124. Toy, L. R. 1929. Avocados in Florida. Fla. State Dept. Agr. Bul. 24 (n. s.), 39 pp., illus.

125. Traub, H. P., and Auchter, E. C. 1934. Propagation experiments with avocado, mango, and papaya. Amer. Soc. Hort. Sci. Proc. (1933) 39: 382-386.

137. Wolfe, H. S., Toy, L. R., and Stahl, A. L. 1934. Avocado production in Florida. Fla. Agr. Expt. Sta. Bull. 272, 96 pp., illus.