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AVOCADO BREEDING IN CALIFORNIA

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Practically all of the avocado varieties that have been introduced for commercial propagation in California over the past 35 years have originated as selections made within the State. In earlier years also, numerous promising seedlings were selected locally. However, the seeds from which many of these early trees grew were imported, chiefly from Mexico and Guatemala. These two countries also provided the embryonic California avocado industry with a number of commercial varieties by means of grafting wood from selected trees (9—especially the 1934 edition, 14, 19).

While the great majority of the early introductions have proven to be inferior because of one weakness or another, several are still being grown rather extensively. A generally good reflection of comparative total production of the major varieties is provided by the receipt records of the cooperative marketing agency, Calavo Growers. In the 1955-56 season, Calavo received four hundred or more field boxes of each of 25 different varieties (1). Of these varieties, 16 have been developed wholly within California. The other 9 varieties originated from importation of propagating materials from Mexico or Guatemala. Seeds from Mexico have given rise to 2 of the varieties, the importations being in 1899 and 1911. One variety resulted from seed brought in from Guatemala in 1899. Budwood from selections made in Mexico in 1911 to 1912 produced 3 of the varieties. The remaining 3 varieties originated from budwood selections from Guatemala, 1914-1917.

Of the latter 3 varieties from Guatemala, two, Nabal and Itzamna, were selected by Wilson Popenoe, working for the Office of Plant Exploration and Introduction of the United States Department of Agriculture. Considering the time spent and the top caliber of the man heading the exploration, the results in terms of varieties directly adapted to California must be regarded as disappointing. Unfortunately, it was not realized at that time that the California consumer of avocados wants a much smaller fruit than is preferred in most other avocado-consuming regions of the world. Most of Popenoe's introductions were too large-fruited. Others bore poorly under California conditions, or lacked other desirable characters. It is probably as breeding materials that they have made — and are making — their major contribution. However, for about 20 years Nabal was usually second only to Fuerte in total California avocado production. It was removed from the list of varieties recommended for planting by the California Avocado Society only in 1951. Nabal and Itzamna are both still recommended for planting in parts of Florida (20).

The more recent plant exploration projects in Mexico and Central and South America have been headed by Schroeder and Zentmyer of the University of California, and by a private grower, Harlan Griswold (8). The primary concern has become a search for

sources of resistance to avocado root rot, *Phytophthora cinnamomi.* A number of lines with varying degrees of resistance have been brought back, largely amongst other *Persea* species than *Americana* (21, also earlier Yearbooks).

Various types and species of general botanical and horticultural interest have also been collected (17, also earlier Yearbooks).

With regard to improved varieties, Griswold (8) believed that the best chance of finding superior material for California by foreign exploration lies in hybrids of the West Indian and Mexican races especially for early fall fruit maturity. However, these introductions have so far failed to fruit satisfactorily under race of the species is ill-adapted to the comparative rigors of California's climate.

In any discussion of California avocado varietal history, it must be borne in mind that the Fuerte has dominated the industry to a remarkable degree. After its introduction as grafting wood from Atlixco, Mexico, in 1911, Fuerte rapidly became the leading variety in California. For the past twenty years it has averaged well over two-thirds of the total California production. It is a good, hardy tree and has fruits that are nearly ideal with respect to season of maturity, size, appearance and quality. Popenoe (13) stated recently that "In prehistoric times, by the laborious process of selection and propagation by seed, the avocado was developed from small-fruited wild forms, of which many are still found in the forests of Mexico and Central America, to the splendid varieties now being propagated vegetatively, varieties which so admirably meet the needs of man that modern science has not been able to better them materially."

The Fuerte's great drawback is its erratic bearing habits. Because of this, the preferred variety for most of the California avocado growing areas is instead Hass (15), even though the tree of the latter is markedly more susceptible to adverse environmental factors (12). During the past two springs, some 28,000 Fuerte trees were topworked to other varieties, chiefly Hass (2). Yet, because of the length of the Fuerte lead and the actually very slow turnover of even obviously inferior avocado trees, it will doubtless be many years before the Fuerte supremacy is seriously challenged. If an early solution can be found for the problem of low Fuerte yields then this variety may well maintain its position of leadership for decades — there is probably no variety now generally known which would rival it for California.

Except for Fuerte, all of the avocado varieties at present being planted on a commercial scale in California originated within the State. Every variety being propagated commercially, including Fuerte, is the result of endeavor by private growers — Popenoe's introductions are the only important avocado varieties which have resulted from the activities of governmental institutions. Thus varietal improvement is the one major aspect of avocado culture in which the University of California has not made significant direct contributions to date; in the evaluation of promising new varieties, the University branches at Los Angeles and Riverside, and especially the Agricultural Extension Service, have assisted the industry greatly.

Ever since its introduction to California, growers have indulged in the interesting and very occasionally profitable hobby of growing avocado seedlings in the hope of obtaining a better variety. These have been grown in all numbers, from a couple over-grown rootstocks to a few thousand seedlings. A few bud sports have been selected (7).

In this way the new varieties of about the past 35 years have originated. Some one hundred and seventy-three varieties have been registered to date by the originator, with the California Avocado Society. Unfortunately, the great majority of these actually were inferior to existing varieties for culture in California. One result has been a tendency toward multiplied confusion in the variety picture, but this has been rectified by ceaseless labor on the part of the Variety Committee of the California Avocado Society (15, and earlier Yearbooks). This committee has now reduced the number of varieties recommended for planting in California to just three: Hass, Fuerte, and Rincon. Moreover, of the eight districts into which the avocado-growing area is divided, Fuerte is recommended for only three and Rincon for only two districts, with Hass in seven. There are also two experimental varieties, Bacon and Zutano (15).

Perhaps a more serious result of the abundance of named varieties has been an accentuation of the marketing problem. Inferior fruit brings a lower return, and small lots of different fruit types are more expensive to pack and more difficult to sell (3, 5, 6). A named variety — especially when named by oneself — is probably less likely to be removed or topworked than seedling trees of equal merit — or demerit.

Hence the California Avocado Society has recently initiated an Avocado Improvement Committee, with representatives from all parts of the industry (4). This committee has been assigned the task of encouraging the topworking of all seedlings and varieties which have been "weighed and found wanting." This would include by far the larger part of the varieties at present being grown in California. This campaign has already made appreciable progress (2).

At the same time, the California Avocado Society has altered its registration policy for new varieties. By making a nominal charge for this registration, and by limiting the official publicity on new, untried varieties to names only, it hopes to discourage the indiscriminate introduction and dissemination of types that are not superior to varieties already being grown.

However, it should not be overlooked that the widespread growing of avocado seedlings has been highly beneficial to the industry, for that is the method by which valuable new varieties like Hass and Rincon have originated. Coit (5) stresses the desirability of continuing to grow large numbers of seedlings from which future, ever better selections can be made. As stated by Storey (18), "That there are so many varieties, with more entering the picture each year, is neither surprising nor cause for alarm. It is in fact a healthy sign, for it indicates that an intensive search for better varieties is going on all the time."

The seedlings developed by private growers have added relatively little to our knowledge of avocado genetics. Apparently practically all have arisen from open pollination. In very few cases is even the maternal parent known, or at least reported (14).

Controlled avocado breeding was begun on the Los Angeles campus of the University of California in 1939, by W. E. Lammerts (10). The methods included the use of bees inside screened cages or greenhouses containing trees of two varieties of different flowering type (A versus B), and hand pollination, both selfing and crossing (11). The latter proved to be a laborious and expensive way of producing hybrids. From over

50,000 flowers pollinated in 1941 and 1942, only 35 fruits matured.

This is similar to the experience of others. The avocado produces a tremendous number of flowers, of which only a very small percentage can possibly set fruit under even the best of conditions. "This presents a serious difficulty in controlled pollination work and has seriously retarded progress this makes the bagging technique of very little value" (19). "Controlled crosses by hand are not a promising field of activity in avocados" (20).

To add to Lammerts' difficulties, a number of his seedlings died from root rot. In his final public report when resigning from the avocado breeding project in 1946, he stated (11): "I have never worked with, a plant that was quite as cantankerous and difficult to handle from all points of view."

Larger progenies were obtained at U.C.L.A. by harvesting "close-pollinated" fruit — that is, fruit from trees of a given variety that are far enough removed from trees of any other variety to quite well preclude the danger of cross-pollination. These progenies showed considerable uniformity. One progeny set could usually be distinguished without difficulty from any other progeny set (10, 16).

Another important observation from these progeny sets was a consistent difference in precocity. Seedlings from some varietal parents, especially Mexicola, fruited at a young age, and also set good crops. Seedlings from other parents, especially Fuerte, set their first fruits later in life, and generally set poor or nil crops.

Lammerts (10) observed that a few varieties, especially Lyon, set appreciable fruit even in cages from which bees and other large flying insects had been excluded. Such a set in the absence of pollinating insects has not been obtained with any of the varieties tested at Riverside. If Lammerts' cages actually were insect free, the explanation presumably is that a few avocado varieties can set fruit from pollen transported by gravity or wind.

From the purple-fruited Mexicola variety selfed, Lammerts (11) obtained a minority of fruits with the more desirable green color. He concluded that skin color in avocados is determined by a single gene, with the factor for green recessive to that for purple, and Mexicola therefore heterozygous. However, hybrid trees at Riverside which set fruit for the first time this fall are proving to have fruits with purple skins even though both parents, (Fuerte and Jalna), have green fruits. If both sets of results are correct as to assigned parentage, then Lammerts' monogenic color-determination hypothesis will have to be rejected.

Present avocado breeding work at U.C.L.A. (C. A. Schroeder, private communication) "is concerned primarily with establishing the several progenies at the South Coast Field Station (near Tustin, California) and with the production of inter-specific hybrids, especially from the point of view of their use as root-stock materials." Several selections from earlier U.C.L.A. seedlings are being tested by different growers, who report that a few "show promise."

Avocado breeding at the Citrus Experiment Station of the University of California, Riverside, was first started as a project in 1937 by J. W. Lesley, now Geneticist Emeritus. During the Second World War, a shortage of personnel brought the project to a halt. From 1953 to 1955, Peter A. Peterson headed the work. In late 1956 the writer

was placed in charge of the project, assisted by a laboratory technician, Philip Villa.

The methods of producing progenies have been approximately the same at C.E.S. as at U.C.L.A. At the present time, two general procedures are being used; hybridization of different varieties and selfing within a variety. By the former procedure it is hoped to combine within one new seedling the complementary virtues of each parent. By the selfing procedure it is hoped to learn what degree of genetic heterozygosity the different varieties possess, to determine which varieties are likely to yield the most promising offspring — a type of progeny test, to establish homozygous lines for further hybridization, and possibly to discover one or more superior new varieties in the process.

For each general procedure we have two methods of obtaining the desired progenies.

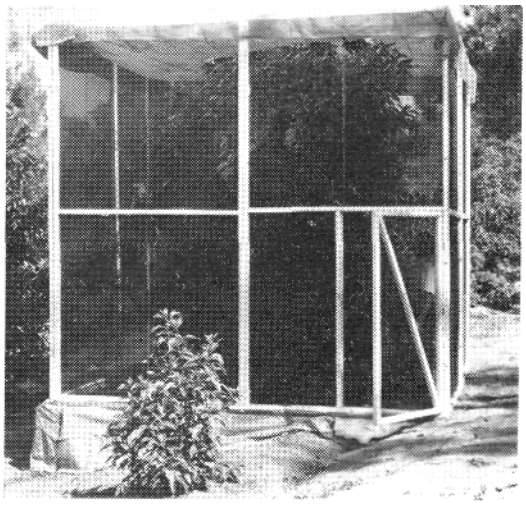

Fig. 1. Field bee cage. This particular cage is 12 feet in all three dimensions — they can be assembled in various shapes and sizes to fit the form of the tree.

Selfing is carried out by a hive of bees enclosed with a tree of the desired variety inside a "Lumite" plastic screen cage (Figure 1). Clean water must be supplied to the bees regularly. Even a small colony in a one-story hive appears to find the flying range much too restricted — the bees act quite demoralized and spend most of their time crawling around on the cage ceiling rather than working the avocado flowers. This method apparently would be expected to work not nearly so well in most avocado regions as it does here in California, where, because of an overlap of flower stages I and II due to the cooler climate at flowering time, or for some other reason, self-pollination is usually abundant when bees are present (9). Even so, caged trees at C.E.S. usually set considerably less fruit than comparable trees which are not caged. It is most important to cage a tree in its "on" yield year. Abundant flowering is no guarantee of good fruit set.

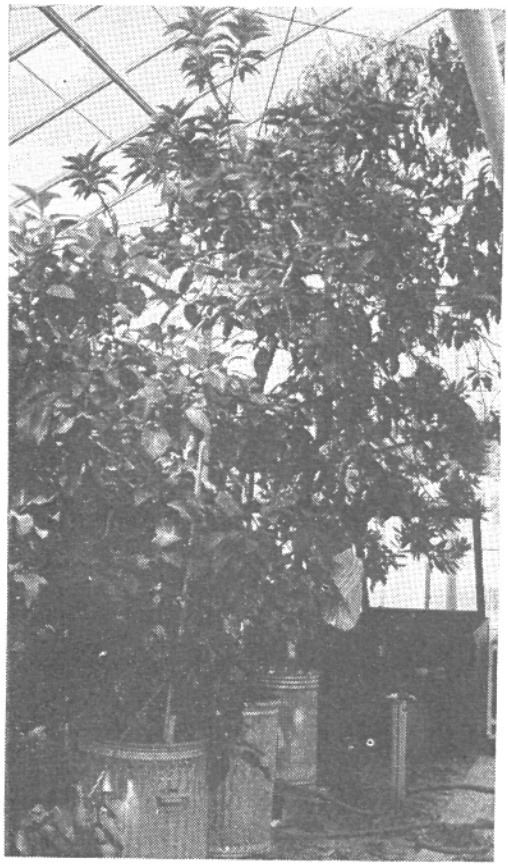

Fig. 2. Greenhouse trees. The four visible in the front row are Zutano, Bacon, P. skutchii and P. borbonia. Zutano and Bacon are newer experimental varieties with very hardy trees and also consistent production — unfortunately the fruit quality of both leaves much to be desired. They are probably of Mexican-Guatemalan hybrid origin.

A much less expensive method of producing self-fertilized seed is through the use of isolated trees as described in the discussion of the U.C.L.A. breeding program. In the absence of definite information concerning bee and other insect behavior in avocado groves, we have established a rather arbitrary necessary separation of about 150 yards. Limited evidence indicates that, at least in some areas, this is several times what the distance would need to be to reasonably rule out the cross pollination danger. Suitable orchards of the various desired varieties are scarce, so we are arranging with certain growers of other crops to set out three or four trees of each variety in good isolation.

Hybridization is carried out both in the greenhouse and in the field. The former method is very simple. Trees of the desired variety are established in cans (Figure 2) and then placed in an insect-free greenhouse. These trees will blossom earlier than field trees, so hybrids are possible between varieties whose blossoming period ordinarily does not overlap. By moving trees in and out of the greenhouse, and by controlling the temperature within the greenhouse, further control of blossoming time is possible.

In the field, hybridization requires the use of some flying-insect excluder such as cheesecloth sleeves. These are tied at each end. Emasculation is not practiced, since bagged, non-pollinated flowers have failed to produce fruit with the varieties that we

have tested even as greenhouse flowers that are not pollinated have never matured a fruit. After the tree is through blooming the cheesecloth bags are replaced with open mesh bags. (figure 3)

Fig. 3. Mesh bags around hybridized fruits produced by hand pollinations. The tree is a Nowels (Mexican-Guatemalan hybrid). Zutano was the pollen parent used. Approximately 160 fruits matured, the largest number of hybrids yet obtained from hand pollination of a single tree.

This permits the entrance of much more light, while protecting the fruits and catching any that fall. Even quite immature seeds will commonly germinate satisfactorily. Mesh bags are also placed over fruits that set on trees caged for selfing. The cage is removed as soon as blooming is over, not only to let in more sunlight, but also to permit predators to control any harmful pest that may have built up in number, such as *Amorbia* caterpillar. We plan to use screen cages around entire trees as an alternate method to cheesecloth or similar bagging.

Year	Location	Flowers Pollinated	Fruits Matured
1954	Greenhouse	1,032	39 (3.8%)
1955	Greenhouse	10,267	133 (1.3%)
1956	Greenhouse	12,205	79 (0.7%)

At C.E.S., proportionate fruit set has been about as good on field trees as in the greenhouse. This is perhaps due to the fact that a much larger number of field trees make possible a better choice of trees in their "on" year for yield. Greenhouse trees are placed in cans of varying size — most are 30-gallon cans but some trees, especially

species other than *P. Americana,* are in smaller cans. It has been found that trees in the largest cans will mature a maximum of only about 30 fruits under our conditions. If more set, they will drop when still quite small. Comparative proportions of mature fruit are shown in Table above.

Location	Flowers Pollinated	Fruits Matured
Field	1,917	69 (3.6%)
Field	8,978	185 (2.1%)

To date, some 1,200 seedlings of known parentage have been produced at C.E.S. It is felt that this number is quite inadequate, so an accelerated breeding program is planned for the next few years. A shortage of land on which to plant out these hybrids has apparently been largely solved by arrangements that are being made to set out the trees as a screen, or landscape planting, or windbreak, on various suitable private and public properties in Southern California.

Fig. 4. Avocado hybrids growing at the Citrus Experiment Station. These trees vary from three to five years of age. The particular hybrid being examined in this photograph is the only tree on the Station producing fruit with a red-colored skin — both parents were green-fruited.

In a variety, we are looking for something that "Bears well, looks well, a ship well and eats well" (5). The various components of these major requirements have been listed in detail (9, 19).

We are also concerned with rootstock improvement. The prime needs here include resistance to root rot, resistance to salinity injury, dwarfing or semi-dwarfing effect, and uniformity.

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