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BREEDING AVOCADOS AT C.R.C.

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INTRODUCTION

The Citrus Research Center (formerly known as the Citrus Experiment Station) is the only public institution in California now conducting a large-scale avocado breeding program. In earlier years, a large number of avocado seedlings were produced at the Los Angeles campus of the University *of* California. The remainder of these-trees and the accompanying records have now been turned over to C.R.C. (7). Seedling evaluation and selection of promising ones for general trial is continuing (4, 7).

California produces about two-thirds of the total United States avocado crop. This represents an annual return to the state of a little under ten million dollars.

The development of improved varieties would probably permit a considerable expansion of production. Prices in recent years have been depressed by a failure to reach a sufficiently enlarged market with fruit which has been in abundant supply due to unusually heavy crops. As a result, we have had the paradoxical situation of a glut of fruit in some of the older markets, while much of the United States itself is actually an undeveloped market.

Development of this wider market is hindered by the great fluctuations in California's annual avocado production. It is axiomatic that sound market development must be based on consistent supply. This is true to an unusual degree of the avocado, since it is a fruit with a unique flavor; most adults need to develop a taste for it over a considerable period of time. The avocado industry in California is largely based on the Fuerte variety. Fuerte bearing is quite erratic. Hence markets that can be economically developed in large-crop years cannot be maintained in small-crop years, which tends to restrict the needed market expansion.

Moreover, the very fact that annual production fluctuates greatly tends to reduce average price. Large-crop years have resulted in temporary fruit gluts, with accompanying depressed prices. Such prices, in turn, result in consumer resistance to adequate price increases in small-crop years.

It would seem, therefore, that the California avocado industry would be much benefited by new varieties with heavy and consistent production. This may be oversimplified to: "A Fuerte that bears dependably." Actually, recent experience indicates that the shipping quality of the Fuerte is not always adequate. But a major aim of the avocado breeding program at C.R.C. is the development of three or more varieties, each Fuerte-like in

appearance and quality, each a consistent and heavy fruit producer, with marketing seasons such that among them they will permit fruit harvesting every month of the year.

However, selections of different shape or color are not rejected if their other qualities are favorable. Partly, this may permit alternative market offerings to meet differing consumer preferences with respect to fruit appearance. Partly, such appearance differences may be useful if associated with differences in flavor, or even differences in such matters as protein, vitamin, or calorie content, or effect on blood-cholesterol levels. Moreover, if a potential new variety has sufficient merit otherwise, it would probably be quite unwise to reject it just because of "non-ideal" appearance; the Hass variety is an excellent example, and has itself helped to prepare the consuming public for high quality avocados of differing appearance.

BREEDING METHODS

Our two major approaches are:

1) Hybridizing of different varieties,
2) Selfing within a variety.

Hybridization

Hybridization involves the transfer of pollen from the stamen (male flower part) of one variety to the pistil (female flower pan) of a second variety. Unfortunately for such breeding, an avocado tree may produce a hundred or more times as many flowers as it does mature fruits (1), and we have as yet found no way of predicting which flowers will be the ones to set fruit. So nearly all of the labor of hand pollinating is actually wasted, and the labor rates per set fruit become quite high.

Still, this is the only way that we can combine in one seedling the desirable characters that are distributed among two or more varieties.

We have made hybridizations involving the following 33 varieties: Alpha, Anaheim, Bacon, Blake, Clifton, Dickinson, Duke, Edranol, Elsie, Fuerte, Gehee, Halsted, Hass, Henry's Select, Irving, Kimmel, Leucadia, Lulu, Lyon, Mexicola, Murietta Green, Nabal, Northrup, Nowels, Puebla, Rincón, Routh, Ryan, Tecapan, Topa Topa, Wright, Wurtz, Zutano. We have also used the non-commercial species Persea Flocossa. Some 126 different crosses have been made, each cross involving two of the above varieties. The varieties most Frequently used have been Hass, Fuerte, Bacon, Zutano, Mexicola. Duke, Clifton, and Anaheim.

For example, our major hybridizing efforts in recent years have been expended on the cross of Hass with Bacon. We hope to combine the high flesh quality, small seed size, spreading tree habit, and heavy setting abilities of Hass with the much hardier tree of the Bacon variety; the Bacon may also introduce less crop alternation, slightly-larger fruit size, and green fruit color. Skin thickness and texture about intermediate between the two varieties would be ideal. Because of their dissimilar harvest seasons, hybridizing them may yield selections with a useful intermediate marketing season.

Similarly, the Fuerte has been hybridized with varieties that are more consistent bearers, or more precocious bearers, or more cold hardy, or better shippers, or smaller seeded, or that could be expected to extend the Fuerte season in either direction.

The extensive use of such discredited varieties as Anaheim and Mexicola may be surprising. But if these two are crossed, one of the resulting hybrids may well combine the better qualities of both into a desirable whole. Thus, the Anaheim fruit is too large for most markets, while the fruit of Mexicola is too small; Mexicola fruits are too thin-skinned for good shipping, while Anaheim fruits have a thicker skin than is needed; Anaheim fruits are low in oil, while Mexicolas have a very high oil content; Mexicola fruits have the somewhat undesirable purple color, while Anaheim are a good glossy green; Anaheim fruit flavor is only fair, while that of Mexicola is excellent; the Mexicola seed is too large for a commercial fruit, while Anaheim fruits have relatively small .seeds; the Anaheim tree is very tender to frost, while Mexicola trees are much more cold hardy than any present commercial variety; Mexicola fruits mature about 6 months from time of bloom, while Anaheim requires about 15 months—for their hybrids, the marketing season possibilities are almost limitless; both varieties are prolific bearers.

The Clifton variety has been used as a source of fall maturity combined with good size and quality. The Duke is even earlier and is very cold resistant; its often loose seed is a major drawback that unfortunately reappears in most of its hybrids. While .somewhat less early and also less hardy, the Zutano is a more consistent and heavy producer than either Clifton or Duke, It is apparently of wide adaptation. However, its fruit is too low in quality, and is subject in many regions to severe end spotting; both of these objectional features are present in a large proportion of the Zutano offspring.

Hybridization can be carried out between trees in cans in the greenhouse, or between field plants, of which the female parent has been protected from large flying insects by sleeves or screening.

Selfing

Instead of hybridizing different varieties, our avocado breeding is now largely confined to selfing within certain varieties. This is being done for two reasons. First, the avocado does not breed true, unlike many plants such as the tomato. Just by selfing any one variety, plants so variable are obtained that ordinarily no two are' alike. Hence it is not necessary to hybridize different varieties in order to obtain a great range of seedling types from which to select. The chances of obtaining a superior new variety are probably at least as good in a selfed population as in a hybrid population of the same size.

Secondly, self-pollinated fruits can be obtained much more cheaply than hybrids— the large per-seedling cost for hybrids pointed out earlier can be cut to one-tenth or so by a selfing program. This is especially true of seedlings obtained from fruits set ¡n isolated orchards. Our results have indicated that bees usually transfer avocado pollen a distance no greater than about two orchard rows; so in large orchards of one variety it is not difficult to obtain seeds that can safely be regarded as self-pollinated.

Varieties from which such isolated seed is not available, or single seedling trees of

special interest, can be self-fertilized by bees inside a screen cage surrounding the tree. Such cages can be erected in differing sizes as needed. Figure 1 shows a cage that is a cube of 16 feet. The sides are rigid, while the top is covered with a loose sheet of the screening, tacked onto the wooden frames at the edges.

Figure 1. Lumite screen cage, containing avocado tree and beehive. Note door in left-hand corner of far side.

Self-fertilized seed has been obtained by either of the above two methods from the following 18 varieties: Anaheim, Bacon, Edranol, Fuerte, Canter, Gehee, Hass, Indio. Irving, Lyon, Mexicola, Mayo, Mac-Arthur, Nabal, Nowels, Rincón, Taft, and Zutano. A few of these are so different from our commercial ideal that it is unlikely that seedling variation will be great enough to result in many seedlings in the commercially acceptable range. Instead, our major aim with such progeny sets is to obtain more uniform breeding material for subsequent hybridizing.

To give some indication of our objectives, among Edranol progenies, for example, we are hoping to find seedlings that add greater cold resistance, good setting ability, and more attractive fruit appearance to the small seed and excellent flavor of the parent. In the case of the Gehee. we already have cold resistance, heavy setting ability, attractive fruits—and also fine flavor; here, if smaller seed size segregated out and the parental virtues were not lost, we would have something good.

The Indio or Desert variety originated with a seedling tree just west of the town of Indio in the Coachella Valley. While the fruit shows some characteristics of Guatemalan ancestry, this seedling has demonstrated a remarkable degree of adaptation to the climatic rigors of this low-elevation desert. By selfing we hope to maintain overall tree hardiness while selecting for better fruit quality.

The Taft, Lyon, and Nabal are all older varieties that produce a green summer fruit of

high quality; in each case the fruit is larger than optimum, and each has problems associated with tree productiveness. But each has such outstanding virtues that if selfing does not eliminate the major flaws, it should at least fix the virtues so that suitable hybridizing will be likely to have favorable results.

Taft was the major variety in California some 40 years ago. It produces a fine fruit with good market acceptance. But the trees are so slow to come into bearing and bear so poorly most years that the Taft soon disappeared from commercial contention. The Lyon suffers from what seems to be the reverse fault: it bears so precociously and so heavily that the tree is severely stunted and sometimes killed outright. While this can be partly alleviated by judicious fruit removal, a basic propagation and tree-development difficulty remains. So, in spite of some rather vociferous early publicity, the Lyon also soon had to be taken off the list of varieties recommended for planting in California.

The Nabal variety frequently bears very little for one or two or three years at the time, then sets so large a crop that the trees may be injured. Us fruit quality is considered by some to be unsurpassed by any other known variety. This introduction by Wilson Popenoe came on the scene later than the Taft or the Lyon, and lasted considerably longer. From the 1934-35 .season to the 1953-54 season. Nabal production in California, while quite variable, was usually second only to that of Fuerte. In 1951, it was removed from the list of varieties recommended for commercial planting by the Variety Committee of the California Avocado Society. Since then its annual production has remained relatively uniform, while the production of certain other summer-maturing varieties, notably MacArthur and Hass, has increased markedly.

In 1957, the MacArthur was also removed from the recommended list. It has a somewhat smaller fruit than the above three varieties, is more resistant to cold than most Guatemalan types, and usually has a regular, heavy production. Fruit flavor is mediocre. The fruit is often objectionably crook-necked, and this is combined with a not very attractive pale, pebbled appearance to produce limited market appeal. It seems reasonable to hope that among its descendants we will find a superior green summer fruit.

The Rincón produces a more attractive and higher quality fruit. It ¡s harvested during the Fuerte season, but while selling at a slight discount it has proven profitable in the districts where ¡t is best adapted—chiefly coastal Ventura and Santa Barbara Counties. By selfing it we hope to find its good bearing ability in seedling trees that grow better and perhaps have greater cold hardiness as part of their adaptation to more inland areas; segregates that extend the harvest season in both directions are also anticipated.

Of the three major commercial varieties at the present time (6), the Fuerte is limited in its geographical adaptation by its failure to bear near the coast, and in many inland areas also; the Hass is limited especially by its tenderness to frost; the less important Rincón is limited both by frost tenderness and shy Fruit-bearing inland. Neither of these two common limitations applies to the Bacon variety; it bears consistently in all avocado areas where it has been tried, and it is considerably more cold hardy than even the Fuerte. While still listed as an "experimental" variety (6), it will-perhaps soon be rated as fully commercial; another real freeze would probably expedite this. The Hass and the

Bacon varieties are receiving major emphasis in our selfing program. Among Bacon progeny we are looking especially for improvements in yielding ability, in fruit flavor, in flesh color, in seed size, in mature appearance—all of which are characters in which the present variety is fairly good. Also, its harvesting season is rather limited; a Bacon type maturing two months earlier would do much to fill the autumn supply-hollow of California avocados.

While the Bacon is the most cold-hardy of all recognized commercial varieties, two fall thinskins—Ganter and especially Yama have proven themselves to be considerably hardier (2, 3). We are now growing a selfed progeny of the former, and we hope to obtain Yama seeds this fall. Both varieties have good-flavored fruits of high oil content. But in both cases the fruits are small, and are too thin-skinned to ship for any appreciable distance. Ganter was condemned for commercial fruit-consumption purposes by the Variety Committee of the California Avocado Association (as it was then named) as long ago as 1927; Yama is a more recent variety that has not merited large-scale commercial consideration.

In the cases of these two varieties, also the Mexicola and perhaps the Gehee, there seems little likelihood of obtaining a new commercial variety by selfing alone. But selfing will make them more uniform genetically, and so they will become more useful for hybridization. The logical type to hybridize with their descendants are large-fruited, small-seeded, usually cold-tender Guatemalans. So this is partly why we are also selfing varieties like Anaheim, Lyon, Nabal, and Taft.

Two others of our selfed varieties may need explanation. The Nowels is listed as an experimental variety for the Corona area (6) and is also doing well in Ventura County (2). It is a thicker-skinned and smaller-seeded fall fruit with good appearance and also good quality. Its chief drawback is its tendency to alternate huge crops one year with practically no fruit the next, the heavy crops resulting in undersized fruits and often sunburned branches. We hope that one or more of its seedlings will have more regular fruit setting ability.

The Mayo is another fruit that comes off during the fall season of low avocado supply in California; it is also of good size, with a smaller proportionate seed than most of the Mexican fall fruits; it also has a good flavor. It is inferior to the Nowels in skin thickness for shipping purposes, in appearance, and in mature oil content— that of Mayo is dangerously close to the 8% legal minimum. Its chief advantages are hardiness to cold and consistent production. If neither of these varieties gives us, from among its offspring, a good fall avocado, then it may be desirable to hybridize the best of the descendants on either side—each variety has virtues that compensate for the major drawbacks of the other.

GROWING THE SEEDLINGS

Seeds obtained by these methods are then prepared for planting. Different treatments to hasten germination have been tried by us and by others. (5). We have obtained most rapid and uniform germination if small sections of seed top, bottom, and three or four sides are sliced off with a sharp knife, and the peeling is removed from the remainder of

the seed. But simply slicing off both ends of the seed requires so much less hand labor when thousands of seeds are being treated that the small delay in germinating time is of minor importance. If the seeds are planted without any treatment, however, germination is much delayed and very irregular.

Such treatment is especially important in the case of seeds stored for any appreciable length of time (5). We have stored seeds in peat moss, in a cold room at about 40°F., for several months. Germination percentage gradually declines, more rapidly with somewhat immature seed. Stored seed should be treated with a fungicide such as Semesan or Arasan.

We usually plant the seeds directly in individual cans. A soil mix of two parts soil to one part peat moss to one part sand, has worked well. The mixture is sterilized, either by steam or with a chemical fungicide. This destroys any Phytophthora organisms that may be present; also any other harmful organisms and weed seeds.

The avocado seeds are planted so that the top end is about even with the soil surface. Then a layer of peat moss is sprinkled on to protect the seed from sunburn and also to keep the surface from drying out too rapidly.

We have not found it practical at C.R.C. to germinate seeds in containers out of doors, except for a short period in spring. During summer and fall, the seedlings are usually killed by heat as they emerge. By the time that day maximum temperatures are more moderate, night temperatures are so low that germination is delayed and many seeds rot without sprouting. Hence our seedlings are best grown in the greenhouse. However, since greenhouse space is inadequate for our needs, we have had to try other methods. One of the most successful substitutes has been the summer outdoor growing of seedlings under elevated roofs of lumite or double cheesecloth. With very careful watering, this has worked out fairly well

Figure 2. Avocado seedling progeny sets in greenhouse. Note in foreground that set at right has germinated much better and more uniformly than set at left. All seedlings are about 3 months from seed planting.

Figure 2 shows a number of self-pollinated progeny sets growing in the greenhouse. Some varieties produce a uniform lot of good seedlings, for example, Ganter, Zutano, MacArthur, and Edranol. Other varieties consistently produce a large proportion of poor seedlings or seeds that never germinate. Examples of this latter, less favorable situation are found in the offspring of the Bacon, Hass, and Irving varieties.

Although the avocado seed is large and contains much nutrition, in our soils we find nitrogen deficiency symptoms when the plants are about the height of those in Figure 2. Calcium nitrate corrects the symptoms in about 10 days; by a month after treatment, the fertilized trees will be showing considerably more new growth than those not fertilized. By about two months after treatment, the fertilized seedlings will again be showing nitrogen deficiency symptoms.

The seedlings require an average of about six months from seed planting to a height of three feet or so, when they are ready for permanent planting. This length of time varies with the variety. Selfed Zutanos, for example, are exceptionally vigorous and may be ready for hardening off in four months. On the other hand, most selfed Dukes grow extremely slowly for the first few months, then more and more rapidly; they have needed up to a year in the greenhouse before they were large enough to go out.

Avocado seedlings from the greenhouse need careful hardening off before going into the field. During seasons when the weather is not too hot, here at Riverside this is best done in full sun (Figure 3). If foliage is sparse, ¡t may be desirable to protect the stems from sunburning by applying a white latex paint. During the summer months, seedlings out of doors should have the protection of a lathhouse, or lumite or similar sunshade.

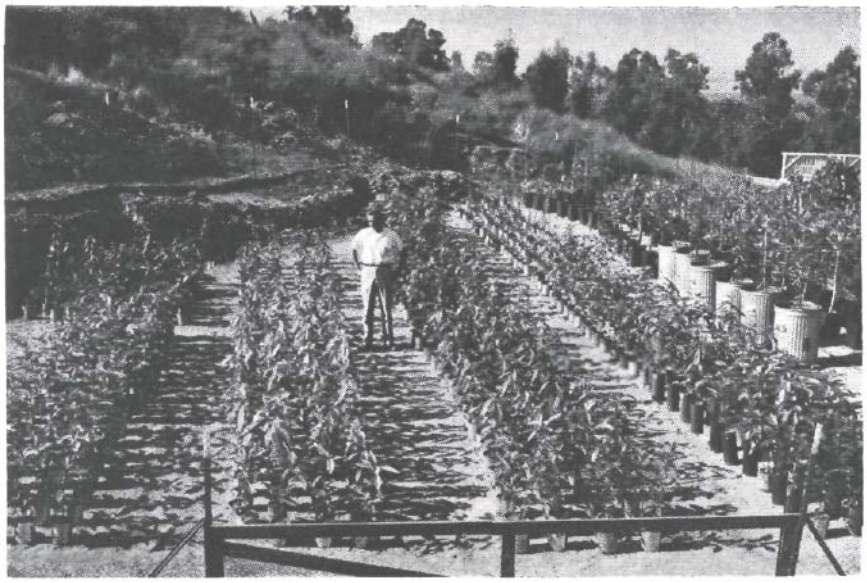

Figure 3. Avocado progeny sets, about 6 months from seed planting, being hardened-off outside before planting in permanent field locations. Most are in gallon cans; a few at right are in tar-paper bands.

The most practical container for growing our avocado seedlings has been gallon-size

cans. Tar-paper bands have also been tried (Figure 3) but these are more expensive, are less durable, and probably provide a less favorable shape for the root ball.

So far we have planted out about 12,000 seedlings. Over half of these have been placed with private cooperators in San Diego, Orange, Los Angeles, Ventura, Santa Barbara, Riverside, San Bernardino, Tulare, and Glenn counties. However, tree mortality on private properties has proven disappointingly high.

We have made about 40 seedling selections to date; these are being propagated and tried out in several counties. No selection as yet approaches the point where we could recommend it for commercial planting.

LITERATURE CITED

1. Bergh, B. O. 1957. Avocado breeding in California. Proceedings of the Florida State Horticultural Society 70:284-290.
2. Delphey, C. C. 1959. Progress report on avocado varieties. University of California Agricultural Extension Service, Ventura County Project No. 68. 14 pp.
3. Delphey, C. C. 1960a. Surveys reveal severe frost damage. In Fruit facts for avocado growers. University of California Agricultural Extension Service Sheet for March 16, 1960.
4. Delphey, C. C. 1960b. Hybrid avocado trees being tested in Ventura County, pp. 55-57. In California Avocado Society Yearbook, 1960.
5. Halma, F. F. and E. Frolich. 1949. Storing avocado seeds and hastening germination, p. 136-138. In California Avocado Society Yearbook, 1949.
6. Rounds, M. B. 1960. Report of the Avocado Variety Committee, 1960, p. 23-26. In California Avocado Society Yearbook, 1960.
7. Schroeder, C. A. I960. Progress report on the avocado breeding program at U.C.L.A., p. 121-124. In California Avocado Society Yearbook, 1960.