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Avocado Breeding in California

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SYNOPSIS

The current Californian programme emphasises self-pollination to test for breeding worth, followed by inbreeding of the selected parents and hybridisation, if indicated. Breeding for enhanced resistance to Phytophthora cinnamomi *is also being done, Cultivar selection is accelerating. No selection has yet proven commercial superiority, but Gwen has produced at a per-hectare-rate more than seven times that of Hass, with fruit of apparently comparable quality.*

EARLY HISTORY

Avocado breeding at the University of California, Riverside, began in the 1 930s and has continued to the present time. Later, an extensive breeding programme was also carried out at the University of California, Los Angeles and then discontinued after some years. No commercially useful cultivar came out of these programmes at either location.
Both programmes primarily involved hybridisation by hand. The tedious chore of collecting pollen, applying it to numerous stigmas and protecting the pollinated flowers from honey bees, was performed by many hired students each spring, at heavy total labour cost. The number of seedlings obtained was relatively small compared to the effort, because of the extremely floriferous nature of the avocado: less than 0,1 per cent of the flowers may be able to grow into mature fruit. Moreover, the Fuerte cv was dominant commercially and was therefore largely used in the breeding programme; it proved to be an inferior breeding parent.

INBREEDING

The author took over the UC Riverside breeding programme in 1956. He believed that there had to be a great increase in the number of seedlings produced, if they were to have a reasonable chance for commercial success. That required much lower production costs per seedling. The solution was to erect large screen cages around trees, put a hive of bees inside, with water, and to let the bees do the breeding work. One could enclose two trees, of the varieties to be hybridised, or graft in branches of the pollinator, obtaining a mixture of hybrids and self -pollinations. These could eventually be differentiated if the two parents were sufficiently distinct, such as Mexican and Guatemalan. An even cheaper method, when suitable plantings were available or could be designed, was to simply harvest fruits from trees of two adjoining cvs in the field.

It seemed that self-pollinating the better cvs might be a worthwhile alternative breeding approach. This could be very cheaply done by harvesting fruit of the desired cv from isolated trees, usually from the center of a large grove; or by screening a tree of cvs lacking such commercial groves, with bees.

When the results of such selfing were compared to those from the earlier (or continuing) hybridisation, three significant observations were made. Firstly, average seedling quality was about as high in the 'selfs' as a whole, as in the hybrids. Secondly, however, the groups from self-fertilisation varied more widely and the best were of higher average worth than any hybrid group produced. Lastly, nearly every cv was so genetically variable (heterozygous), that even if it were sub-commercial in one or more traits (fruit size or shape, flesh colour, tree form, etc), some of its seedlings could be expected to segregate toward the opposite extreme. That is, every cv tested proved to have within itself the genetic potentialities for the ideal fruit, without the necessity of hybridisation.

One important exception is Pinkerton, An overwhelming majority of its selfs have a still more elongated fruit shape. Yet, Pinkerton has exceptionally precocious and otherwise favourable seedlings; it, perhaps uniquely among the cvs that were tried, merits hybridising.

Selfing proved to have significant advantages for cvs in general under Californian conditions. It favours parents that self-fertilise most readily, which should have an advantage for ultimate commercial production. It also reduces excessive vegetative vigour, tilting the balance toward greater fruitfulness. Furthermore, it gets rid of some inferior recessive (or largely recessive) alleles, for future breeding advantage.

Selfing identifies superior breeding parents for further selfing or hybridising. This is important, as breeding value proved to vary widely from cv to cv. Narrow-sense heritability was much higher for some cvs than for others: the average phenotypic worth of any set of seedlings from self -fertilisation cannot be accurately predicted from the parental phenotype. Avocado flower dichogamy has produced immense genetic variability, but epistatic and other interactions preclude high predictability.

When the author began his breeding programme, the major Californian cv was Fuerte, with Hass following close by. Much of the breeding effort of his predecessors had gone into hybridising these two cvs. Unfortunately, all this work failed to produce a single serious commercial candidate. Hand-hybridising failed to produce enough seedlings to give much likelihood of success. The author's selfing of Fuerte showed that its seedlings are remarkably inferior - perhaps the poorest average of any cv tested. Of several hundred, not one was even worth keeping for further breeding. Other cvs that were progeny-tested by selfing and then discarded because of progeny inferiority, included Bacon, Zutano (these two were next in commercial importance), Hacienda, Hashimoto, Linda, Nowels, Teague and others. On the other hand, Hass proved to be probably the best of all progeny-tested parents. Other cvs with high average seedling quality from selfing, were Irving, Stewart, Nabal, Murrieta Green and Pinkerton.

With hybridising, breeding worth is confounded between the two parents; with selfing, one obtains immediate clarification. Although there may be complementary combining abilities, such that selfing results are not the whole story, the author's experience with hybrids has generally paralleled the expectations from the respective selfings.

PRESENT APPROACHES

Selfing fixes alleles at a rate too rapid for most effective selection guidances. After selfing has identified a preferred parent, the author's procedure has been to grow out several hundred of its progeny, discard and remove about 90 - 95 per cent and then to permit the remaining superior siblings to self or inter-hybridise. Hence it is basically inbreeding. With open pollination, there is also the risk of out-crossing to other avocados some distance away. Since the author's concern is commercial improvement, rather than genetic studies, this limited out-crossing is quite acceptable.

The author is hybridising deliberately, using the inexpensive method of harvesting from isolated trees of the two chosen cvs. At times he grafts in branches of two or more pollinators that are expected to equally provide genes for traits in which the mother tree is lacking; for example, round-fruited pollinators in a Pinkerton tree. The author has also harvested extensively from adjoining grafts of several better selections, when all have demonstrated a superior breeding value.

While ultimate commercial success remains to be proven, the author's top selections appear to be so superior for breeding purposes, that he would ordinarily never return to even the better original cvs. This has two exceptions. Firstly, an impressive selection may lack a specific trait or two, which a raw cv appears to provide best. Secondly, the author took advantage of the recently marked enlargement of his breeding programme to go back to Hass for several thousand seedlings, feeling that he had never adequately explored the genetic possibilities of that remarkable cv.

At this stage (1987), the author has more seedlings than ever before, about 60000. This spring will be his final planting of major size. University space is quite inadequate; nine-tenths of his seedlings are on private properties. Private land is necessary for the large number of seedlings needed to enhance the prospects of early commercial success. However, such properties carry heavy risks - most seedlings are occasionally found dead, usually from drought or animals. During the 1987 winter, frost killed several thousand.

ROOTSTOCK BREEDING

This involves selfing and hybridising the lines identified by George Zentmyer, Fred Guillemet and Mike Coffey, as having some tolerance of root rot, in order to try to increase that tolerance to a level that would provide a commercial solution to the problem. Tolerance of salinity and chlorosis is receiving much less attention, as is dwarfing.

BREEDING RESULTS

Selfing followed by line inbreeding, has resulted in markedly superior progeny groups. Twenty five years ago, the desirable generation time was 10 years - now it is five. Desirable spacing distance per seedling varies with type; then it averaged about 12 m^2, now it is about six. This reflects a four-fold increase in efficiency. Also significant, but

more difficult to quantify, mean raw seedling quality has clearly increased. This is also true of the hybrids at present produced by crossing selected parents.

A distinction can be made between the soundness and the success of a breeding programme. Its soundness is shown by the average performance of the progeny populations and this can be rated rather early in the programme. Its success is shown only by proven superior cv(s), which requires a certain amount of segregation luck and which necessarily takes more time. The Californian avocado breeding programme would appear to have definitely demonstrated its soundness, but it has not yet confirmed its success.

Table 1 gives yield data from the only good field comparison of Hass with the author's four selections that were considered the most promising commercially. Except for the third line, the data reflect spring 1984 graftings that set fruit one and two years later, with fruit harvest another year later in both cases. Number of trees per cv varied from 18 to 41, split among replication groups. One is hesitant to extrapolate from such relatively small numbers to a per-hectare basis, but even 18 trees were found to be sufficient for considerable confidence and limited results elsewhere are also supportive of differences of more or less this magnitude.

The data are based on fruit size approximations; for 1986, only Gwen and Esther had enough fruits to merit precise comparisons and the 1987 figures are on-tree estimates. Therefore, all estimates are averages to the nearest ounce, which converts to the metric counterparts shown in Table 2.

TABLE 1 Yields at SCFS from spring 1984 topworks.

		Hass	Gwen	Whitsell	Esther	Hx48
Fruit #, harvested	1986:	4	93	8	87	26
	1987:	133	248	182	301	252
	[1987, first crop[z]:	2	140	19	88	163]
Calculated kg/ha, thousands[y]	1986:	0	16	2	17	5
	1987:	9	35	33	55	39
	Total:	9	51	35	72	44
Calculated total kg/ha, thousands, at recommended spacing*:		9	70	48	64	61
	Tree volume m^2:	29.0	10.1	4.6		

[Z]Topworked one year later, spring 1985.
[Y]At the grafted spacings: 6 m^2 for Hass, 6x3 m for the other four cvs; for the respective fruit size averages, see text,
[X] Hass, 6 m^2; Gwen, Whitsell and Hx48, 3.6 m^2; Esther 4.6 m^2.

TABLE 2 Comparative yields of new cultivars.

Harvest	Hass	Gwen	Whitsell	Esther	Hx48
1986	252 g	336	392	392	364
1987	252 g	280	364	364	308

The abovementioned are the 1984 grafts; 1985 grafts (harvested 1987) averaged about the same as the 1986 fruits above, except for Hass 280g and Hx48 336g.

Table 1 seems to indicate two things, firstly that Hass is doomed as a major cv, at least under Californian conditions. Even if all the new selections in Table 2 eventually prove to have fatal flaws, they demonstrate that Hass production is far below what is at present genetically possible. Secondly, it indicates that subtropical avocado industries will be gaining a significantly stronger economic base in the competition for the consumer's food spending. This is because of fixed costs, when production/hectare increases, production cost/kg decreases. Thus the fruit can be sold profitably at a more competitive price. The advantage is greatest for growers nearest to the market: declining production cost per unit means increasing relative importance of shipping costs.

Caution should be taken, however. The data in Table 1 is only from the first two years. Only a handful of older trees of the new selections are in existence. The data suggest that heavy production will continue indefinitely, but surely not at anything like the two-year huge advantage over Hass. The author's surmise to Californian growers is that Gwen can be expected to bear twice as much fruit per acre as Hass; even this greatly reduced deficit would, of course, doom Hass economically.

Although every Gwen tree in the differing climates of Riverside and South Coast Field Station and in different soils and irrigation methods at both locations, has set heavily, this has not been consistently true of the young trees on private properties. At least one private grower has had set even greater than University of California experience, but several have had little set on healthy, vigorous trees the first ten years. The reason for the discrepancy, or whether it will correct itself is not known.

None of these selections has had adequate fruit quality testing, including storage and shipping. Apparently as a result of climatic abnormalities, all UC avocado cvs (including Hass) have tended to have subnormal fruit in recent years; under these conditions, Esther and Hx48 have had unacceptably poor quality.

Gwen: The most promising of the four. Table 1 shows that it has thus far outborne Hass by more than seven times. Early in the season, it may ripen with shrivel-creasing. It has a nuttier' flavour than Hass and rates superior, at least later in the season. It is expanding rapidly in California.

Whitsell: The flavour is less Hass-like, more spicy and the fruit larger. One major planting of 13 000 trees should give it a good test. It has a 'B' flower.

Esther: At its best, the flavour is mild. The fruit is larger and trees are good, with consistent, heavy production.

Hx48: At its best, the flavour is on a par with Hass, but it seems more prone to environmental harm. The fruit is Hasslike, but a bit slimmer, glossier (black) and attractive. Trees may be more prone to heat injury.

FUTURE PROSPECTS

At present, the authors have the largest number of seedlings ever, about 60 000. About nine-tenths of these are planted on private properties. The more recent seedlings are predominantly derived from Gwen, Whitsell, Hass and Pinkerton hybrids. Certain early Mexican lines have been used in search of earlier maturity, as well as greater hardiness. For the main Hass season, even if Gwen passes all commercial tests, still better selections are possible. The authors have several times the total number of seedlings from which Gwen and Whitsell were selected.

TAXONOMY

Concurrent with the breeding programme, a number of research studies have been conducted. For example, electrophoretic analyses of 30 codominant alleles involved in different enzyme systems indicated that the three horticultural races are separate taxa, with the West Indian one most and the Guatemalan one least distinct genetically, a conclusion compatible with other chemical analyses, physiology and morphology, field distribution and ecotype-climate adaptation. (Manuscript submitted to *Systematic Botany).*

Reasonably classified as botanical varieties of *Persea americana,* the races become: *P. americana* var am*ericana* (West Indian), var *guatemalensis* (Guatemalan) and var *drymifolia* (Mexican). This classification is contrary to certain other taxonomic systems that have been suggested.

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