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Clonal Rootstocks: Personal Observations and a Peek into the Future

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With the introduction of avocado root rot into California orchards, and the discovery of certain genetically identical rootstocks which are resistant or tolerant to the disease, clonal avocado rootstocks are becoming increasingly popular. Many growers are using them exclusively as replants; others are planting them in new acreages.

This is only a beginning. I believe that new avocado rootstock clones will be discovered and adopted widely during the coming two decades. Some selections will be root rot resistant; some will have other special characteristics; some will combine root rot resistance and other distinct features.

In this article I will discuss clonal rootstocks from four points of view: first, a brief historical perspective; second, general observations on their performance in the field; third, the latest in root rot resistant clonal stocks; and finally, a look at the potential uses for clonal rootstocks in the future. Keep in mind as you read that this is not a scientific report, but rather a subjective evaluation from the point of view of one nurseryman who raises clonal stocks for planting in commercial groves, including his own.

A BRIEF HISTORY OF THE DEVELOPMENT OF AVOCADO CLONING

The techniques used in avocado cloning were not commercially practiced until recently. Rooting cuttings, an old and commonly used cloning process that requires no etiolation, is notably unsuccessful with most avocado rootstocks. It was not until the early 1950's that workable cloning procedures were developed by Dr. F.F. Halma and E. F. (Ted) Frohlich for Halma's work on rootstocks. These techniques enabled Dr. G.A. Zentmyer to reproduce certain specific avocado seedlings which he found to be tolerant to the presence of *Phytophthora cinnamomi (Pc).* He needed clones of those seedlings in order to prove that his selected clones were indeed effective in tolerating the fungus. Subsequent commercialization of the procedure has permitted avocado nurserymen to produce large quantities of these clonal rootstocks, which now comprise a significant proportion of newly planted trees in California.

WHAT IS THE EXPERIENCE IN USING THESE ROOTSTOCKS

Are they truly root rot resistant? Do they make satisfactory growth? Do the resulting trees bear satisfactory fruit? These are frequently asked questions, and we'll try to answer them on the basis of field observations.

Are they root rot resistant?

Yes, these trees are resistant to avocado root rot. More precisely, the infected trees are reasonably tolerant of normal field concentrations of *Phytophthora cinnamomi* propagules (reproductive fungal parts such as spores) when planted in otherwise suitable avocado soil conditions. In this respect they are far superior to our traditional seedling rootstock varieties. A large number of field observations confirms this. One can divide the illustrative sites into young plantings, with most trees obtained from commercial nurseries after 1975, and older plantings (10-20 years old) of University - grown clonal rootstocks.

First, the **recent clonal plantings**—those planted during the past 7 years, say. Some of these in infested ground are uniformly and notably successful. Some are failures. More usual is the situation where most of the trees are doing well, but the planting has some trouble spots. Usually, one can generalize a bit about where these trouble spots are likely to be found.

Fig. 1. *A troubled area on the infested Engesser grove in Carpinteria. These Hass on clonal Duke 7 are within an area among other satisfactory trees. Photographed February 25, 1983.*

First, there is the case of uneven terrain of heavy claylike soil. Usually, the troubled trees are concentrated in low-lying areas, likely to collect drainage from surrounding higher ground, or, they are placed along natural shallow drainage ways. Apparently, the greater concentration of water, and perhaps the incoming flow of *Pc* propagules from surrounding terrain, has something to do with the problem. At any rate these are areas which require patience and extra care.

Then there are frequent difficulties also, in heavy soils, when the resistant trees are planted adjacent to, or in the near runoff wash areas from, mature and infected trees.

New trees are difficult to establish under these two general sets of circumstances. Fortunately, with patience and special care, some growers are dealing effectively with these problems, using physical diversion of runoff water flows and chemical means. The recent registration of Ridomil® has been a big help. By applying the material around the struggling young trees at a rate of 1 fluid ounce per square yard, three times per year, many have sprung forth with new life. This procedure promises to ease the establishment of the young trees; it is hoped that, once established, the trees will function satisfactorily without further chemical assistance. This hope requires further proof.

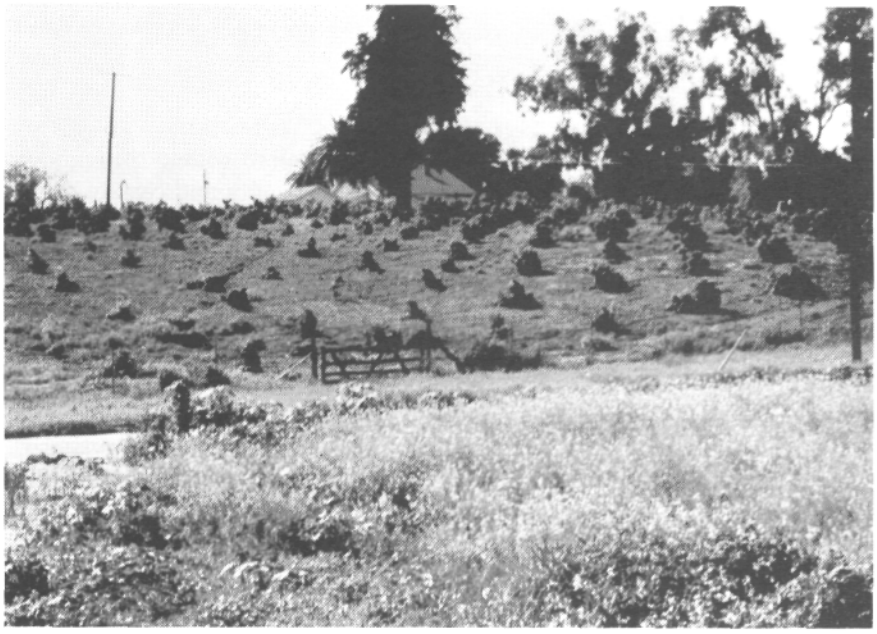

Fig. 2. *This infested area is on the site of a previously infected orchard that was removed. Most of the orchard is doing well. This low-lying portion is having trouble. Soil is heavy and boggy. Trees are Hass on clonal Duke 7. Photographed at Santa Barbara February 25, 1983.*

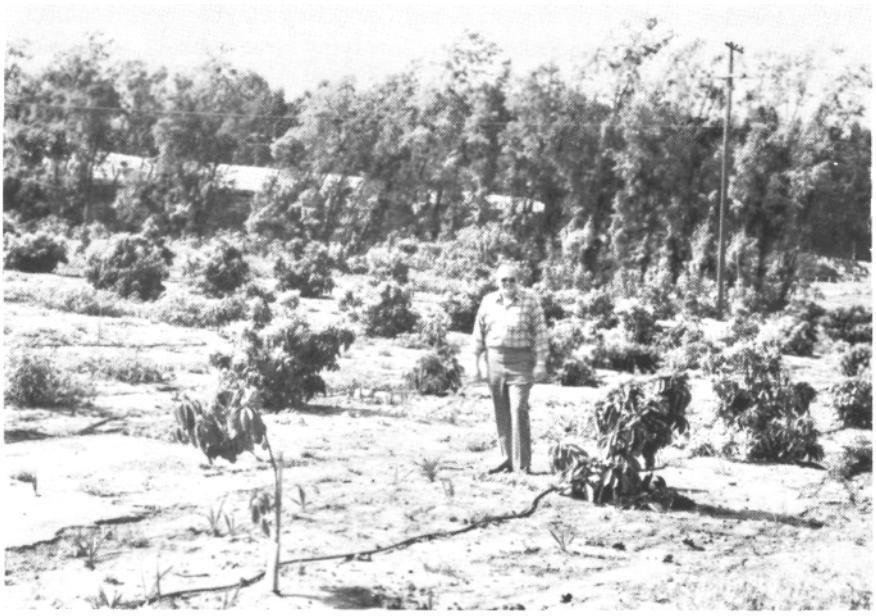

Fig. 3. *This is a low-lying drainage area on an infested Santa Barbara orchard site planted to Hass on clonal Duke 7. The tree by Mr. Kendrick's left side was nearly dead last year; has been rejuvenated with Ridomil. The new replacement tree in the foreground should make strong growth during 1983. This site of heavy soil has received 33 inches of rain so far this year. Photographed February 25, 1983.*

10-20 year old plantings: These trees are distributed widely throughout California avocado areas in former University test plots and certain other orchards. It is difficult to find truly healthy trees in most of these, because they are often in groves that are past their prime, often replete with weeds and suffering from other difficulties that reflect growers' general ennui after suffering root rot infection in those earlier days. A few of these plantings have been kept up, though, and results are very encouraging.

To fully appreciate the conditions in these plots, one has to put oneself in the position of the grower, 15 years ago, remembering the hopelessness of dealing with root rot, and the technological stage of dealing with the disease. These were the days when Frohlich was producing his first clonal rootstocks. They were greenhouse-grown, tender, and immature at planting time. They were unaided by modern chemical compounds, and many times planted in plots regarded as "lost acreages" by discouraged owners. Their future was difficult. In this period, the opinion developed that the trees would not grow if grafted prior to orchard establishment, and were at best slow and erratic performers.

When revisited today, though, these plots deliver a different message. They exist, and they demonstrate almost without exception, that resistant rootstock strains survive and traditional ones don't. Further, these infected trees last a long time.

In the few cases where the trees have received excellent care, they are productive. Often they are smaller than had they been planted in non-infested locations, but they appear healthy and produce normal crops for their size.

Fig. 4. *Hass on clonal Duke 7, planted in 1977. This replant is doing well on deep, heavy, infested soil. Surrounding trees are in various stages of slow decline due to* **Phytophthora cinnamomi**. *Photographed at Saticoy, March 3, 1983.*

Planted before the introduction of the G-6 series, the best trees in the plots are usually on Duke #6 and Duke #7 clonal stocks. Trees on Duke #7 are normally somewhat larger; it is probably for this reason, and because they are easier to propagate, that this has become the more popular of the two clones.

So, the rootstocks, while not perfect, are root rot resistant, they can survive and produce for a long period of time, and suitable, though infested, avocado producing ground can be used for further avocado production.

Do the trees make satisfactory growth?

Yes, under normally favorable conditions.

The striking feature of these trees when well cared for at uniform, high quality sites is their evenness. Because they are clones, they are quite uniform; and they do grow vigorously. Growth of trees on clonal Duke #7, or clonal G-6, is comparable to, if a tad slower than, trees on Topa Topa. Trees on the semi-dwarfing Duke #7 grow equally uniformly but at a slower pace.

Fig. 5. *A University-grown Hass on clonal Duke 6. The tree on this specific rootstock is small for its age. Its healthy appearance contrasts with surrounding trees in various stages of decay. Photographed at Saticoy, March 3, 1983.*

Clonals planted under difficult conditions have sometimes given problems. Most of these troubles have arisen among trees planted in infested locations, trees used as replants among established trees and without extended special care, and trees planted in virgin areas that were previously barren.

In such areas where clonals and traditional seedling-stocked trees are planted side-by-side, if the clonal trees are in trouble, so are the traditional trees. However, under certain circumstances the clonally-stocked trees have suffered significantly higher first year losses than the seedling-stocked trees. The question arises: if clonal trees are so great, why can't they perform at least as well as traditionally-grown trees?

The answer lies, I believe, in the qualitative differences in the character of vulnerability in these two types of trees when they are very young.

Ted Frohlich found, during his early work in the growing of clonal stocks, that they were difficult to graft to fruiting varieties such as Fuerte, Hass, etc. He found, especially, that it was totally unpractical if the rootstock portion did not have leaves. Once the leaves

were removed, in preparation for grafting, the rootstock usually died. In answer to this problem, he grew the rootstocks for longer periods of time and then grafted them. Regardless of how well developed the young tree became, though, as long as it was in the nursery, leaves (from rootstock or scion) were necessary to its survival.

This semi-requisite relationship of leaves to clonally-rooted tree survival remains a factor in tree survival for at least a year after the plant leaves the nursery. Very often defoliation in the first year spells tree loss.

Ordinary seedling-rooted trees do not thrive when defoliated, of course, but they often struggle back and recover. Clonally-rooted trees are less apt to do so.

The lesson is clear, then. During the first year after planting, these trees are particularly vulnerable to neglective irrigation schedules, overwatering, and severe defoliating winds. Also, they are best planted in the spring of the year, so that new young leaves can develop before the onset of their first winter in the orchard.

Another vulnerability of these trees has been a sudden unexplained collapse of a small percentage of them one or two years after planting. A perfectly fast-growing healthy-appearing tree may enter into a wilt overnight. It seems more common among clonally-rooted trees than seedling-rooted trees.

The record of successes in growing these trees on the whole, is good under generally favorable conditions. I can say, too, that success rates have improved rapidly during the past two years as growers have become accustomed to clonally-rooted trees and learned of their special characteristics and vulnerabilities.

Do clonally-stocked trees fruit well?

The fruiting of trees grafted to these rootstocks has not been extensively studied. However, records of Bacon avocado crops have been kept at UCR's South Coast Field Station. Also, in 1984, Dr. Coffey of UCR will establish a Hass avocado plot, which will give us the chance to compare crops on a range of rootstocks, including all currently-used root rot resistant rootstocks and a sizable group of candidates for the future.

The Bacon records at SCFS are interesting. At first, it was reported that the Bacons on clonal Duke #7 were more fruitful than Bacons on Ganter (Mexican-type) seedling rootstocks. A year later, results were reversed. After a few more years, and at the latest report, it was found that average production was comparable, but that cyclical fluctuations were more pronounced on clonal rootstocks.

In our normal uncontrolled field observations, we have detected no differences in fruiting of the clonal trees, as compared to traditionally-grown trees.

EXPANDING THE LIST OF CLONAL ROOT ROT-RESISTANT ROOTSTOCKS

The initial cultivars discovered by Dr. Zentmyer seem to be just the first in a long list of rootstocks which will eventually prove valuable for planting in *Pc*-infested locations.

Already there are some ten or more clones being tested for *Pc* resistance. These

include additional Zentmyer introductions from foreign lands, and the duplication of the rootstocks of surviving trees in infested California locations. It may be of interest to review a few of these selections.

Zentmyer selections:

G-6 Series—Guatemalan finds of Mexican type. Significant resistance through a mechanism apparently different from the Duke series.

G-755 Series (A, B, and C)—*Persea schiedeana* - a *P. americana* relative - very vigorous.

G-1008—Guatemalan importation. Less vigorous. Survivals from infested locations:

Thomas—a promising survivor from San Diego County.

Barr Duke—a Duke #6 seedling, very vigorous, survived well as a seedling in a UCR infested plot.

Toro Canyon—surviving tree from Carpinteria. Initially showing well in test plots.

P Series (Parent, PI, P3, P6)—less vigorous stocks of unknown parentage, doing well in an infected plot in Carpinteria, and bearing large crops at a young age.

Other:

D9—one of Bob Bergh's irradiated Duke seedlings.

This list is dated, and will be expanding almost monthly as new selections are tried.

One might ask: Why experiment with all these selections when we have resistant varieties already? The answer is multifold. Root rot resistance between varieties may not be equal. Also, resistance in a specific variety may not necessarily be traced to the same biological mechanism as in another resistant variety. Further, some clones may be better than others for salt-tolerance, say, or fruitfulness, or tree shape, etc.

Currently, the most popular root rot-resistant clonal stocks in California are Duke 7 and G-6, both introductions of Dr. Zentmyer's. In many cases, these trees are giving satisfactory results hi *Pc*-infested locations, a most hopeful sign. They are the best cultivars now available, with which we have experience. The problem is they're not perfect. As discussed above, they can stand what one might call normal levels of infestation, and yet be overwhelmed by adverse conditions. Dr. Michael Coffey is currently field-testing for superior strains which will stand such conditions. Many of the varieties listed above are candidates for just this purpose. I expect that in the future more resistant varieties will indeed be found.

Another reason to discover a variety of resistant clones is that once a clone, and one clone only, is used as protection against a specific disease, the grower stands the risk that the target disease will become well adapted to living on a specific clone, and overcome the clone's resistant mechanisms. If, for instance, all the avocado trees in Southern California were grafted on clonal G-6, and if *Pc* were to adapt in such a way that it could freely attack these trees, it might wipe out the entire industry.* It therefore seems wise for us to seek various clones in order to reduce the risk. Dr. Coffey already suspects that different resistance mechanisms are at work hi Duke 7 and G-6, and is

looking for yet varying mechanisms in other stocks. The future of the clonal experimental work seems bright on the basis of root rot resistance alone.

** Such an occurrence would be analogous to that in which **Tristeza** eventually eliminated all Sweet Orange Trees that had been grafted to Sour Orange rootstock in the 30's and 40's. Apparently, a genetic change in the disease organism or its vector resulted in a disaster*

OTHER POSSIBILITIES FOR CLONAL ROOTSTOCKS

As far as rootstocks are concerned, the attention of the California avocado industry has been consumed almost exclusively by the problem of avocado root rot. Other areas of opportunity are, however, on the horizon. Included are: salt-tolerance of avocado rootstocks, the effect of rootstocks on the fruiting characteristics of various varieties, tree size, and tolerance to soil conditions which cause what we call lime-induced chlorosis. I'll say a word about each of these areas.

Salt-tolerant stocks

As everyone knows, and recognizes as important, water in Southern California is becoming scarcer, more expensive, and saltier. Already a serious problem in some areas, salt burn promises to become a widespread hazard.

The initial work in salt-tolerant rootstocks was done in Israel. Faced with a much more serious problem than ours, in the 1950's they isolated candidate stocks which seemed to be especially tolerant of the high-salt, high chloride condition of their scarce water. Since that time, they have planted several experimental orchards on these clonal rootstocks and on subsequently discovered candidate varieties. This work is conducted under the direction of Dr. Ben-Ya'acov.

The Israelis generously shared four of their early selections with us, which are currently being tested in California. In fact, your Society is sponsoring such a test in sand-beds. The test includes Israeli varieties and the commonly known California root rot-resistant candidates. Preliminary results of this experiment may be available during the summer and fall of 1983. We eagerly await the outcome.

Influence of rootstocks on fruiting characteristics

The influence of rootstocks on fruiting characteristics has so far been completely ignored in California. In Israel a considerable effort is being made, and has resulted in "copy trees": exact rootstock and scion duplicates of certain outstanding trees already growing in various conditions. Among those being copied, are specific trees which produce large quantities of high-quality fruit in orchards whose average production is otherwise disappointing.

Our own efforts are just beginning. It's my understanding that Dr. Coffey expects to plant, in 1984, a plot of Hass, our most popular fruiting variety, on trees of various root rot-resistant clonal stocks. He plans to measure the growth and fruit output of these trees. We expect that the results will change the complexion of California plantings in

the 1990's.

Tree size

One of the problems in growing avocado trees is that they get too large. Unlike oranges, lemons, peaches, etc., they don't stop growing once they've reached the limits for sensible picking. If we could control tree size by using clonal stocks, it would make thinning easier, and certainly help solve the problem of harvesting unreachable fruit in areas that are already difficult to harvest.

Some work on this has already begun. We do have an instance in which Hass has been propagated to one of Dr. Bergh's selected small varieties. The tree is distinctly smaller than neighboring trees on the clonal Duke 7 rootstock. Also, trees grafted to clonal Duke 6 are smaller, when mature, than those on Clonal Duke 7. Two experimental plots have been planted on an every-other-tree basis to candidate dwarfing rootstocks. Results are a few years away.

Additionally, the first indications are that a recent Israeli salt-tolerant candidate is dwarfing in nature. Efforts are currently being made to import the rootstock so that we may try it in California.

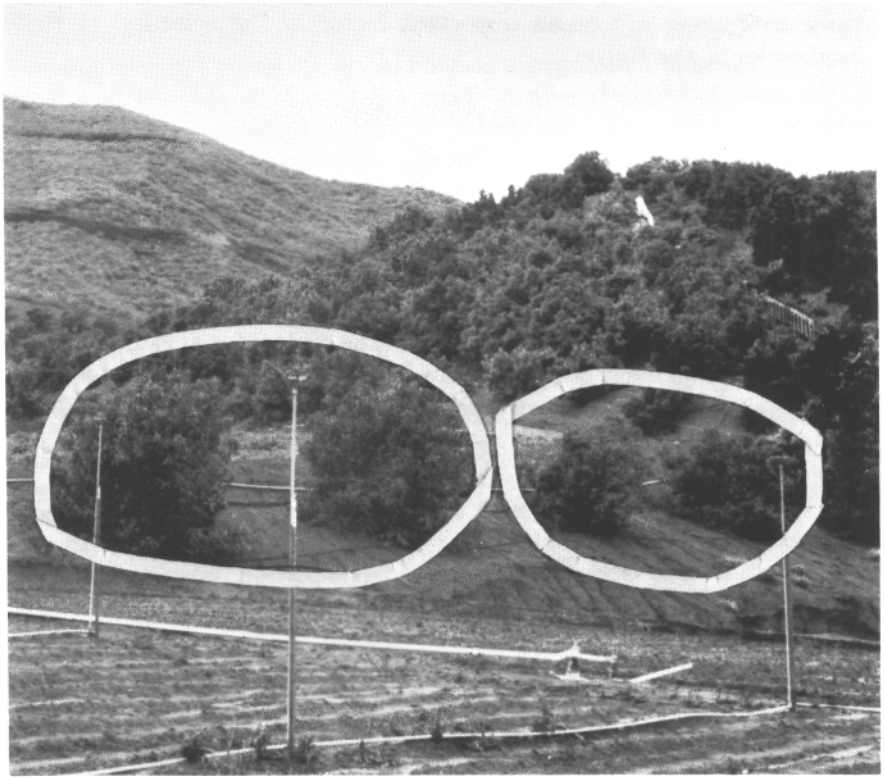

Fig. 6. *Dwarfing tendency of some rootstocks. The two encircled Hass trees to the right in the photograph are on clonal rootstocks chosen at the suggestion of Dr. Bergh. Those encircled on the left are on clonal Duke 7 planted one year* **later**. *Photographed at Ventura March 3, 1983.*

"Lime-induced Chlorosis"

One of the old-time problems in numerous California orchards is the yellowing of avocado trees when planted in certain soils. This has traditionally been attributed to high calcium or calcareous soils. Actually, we don't know very much about its specific causes. It can't very well be due to calcium alone, because Florida soils are full of it, and some of our more calcareous soils don't produce the symptoms. Whatever the real causes, we do know that some soils are more prone to this condition than others. Also, generally speaking, Mexican seeds adapt to the condition more readily than Guatemalans, a fact which probably explains the original selection of Mexican seeds in traditional use as avocado rootstocks.

At least one California rootstock has been clonally propagated especially to withstand these conditions. We don't know how effective this cultivar will be, as it has only recently been distributed experimentally into areas prone to the malady. While the success of this particular rootstock remains uncertain, there's no question that the ability to produce green trees under these conditions will be an important factor in the selection of clonal rootstocks in the future.

CONCLUSION

The California avocado industry has come a long way in the last thirty years. One of our most recent and far-reaching innovations is clonal rootstocks. It seems likely that clonals will be crucial to our success in growing special trees in response to special problems, root rot being one of several.

Given today's economic conditions and the difficulties ahead for those of us dependent on avocados for our livelihood, it behooves us to use every technique we can to maximize production in the face of current and future obstacles.