# Book 1

# Chapter 4

# Avocado Rootstocks

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Commercial producing avocados are not grown to maturity from seedlings, but rather, like most commercial fruit crops, are grafted with good known varieties onto rootstocks. Common seedling avocado rootstocks in California have traditionally been selected from the Mexican or Guatemalan races of *Persea americana*. The third race, the West Indian, has not been used due to concerns that they would not tolerate California's cold winters. Most of the California avocados were grafted onto Topa-Topa seedling rootstocks (a pure Mexican variety) because they germinated fairly uniformly in the nursery and provided thick shoots that were ideal for tip-grafting. Horticultural traits were generally not considered, and in fact Topa-Topa was very susceptible to both root rot (caused by *Phytophthora cinnamomi)* and salinity.

The scions (e.g. 'Hass') grafted onto the rootstocks are essentially clonals because they impart the good fruit qualities from known varieties and since the budwood has come from mature trees, they have overcome the juvenility factor that is common with seedlings. But seedling rootstocks may be quite variable in their characteristics. Now most of the new rootstocks selections are grown as clonals to preserve good qualities selected by scientists and nurserymen.

In most fruit crops, improved rootstocks for commercial production are selected to impart a beneficial horticultural quality to the tree, such as increased fruit yield, vegetative vigor, dwarfing, salt tolerance, lime tolerance, and disease resistance. The devastation caused by Phytophthora root rot in the avocado industry caused researchers to concentrate on finding tolerance or resistance to the disease problem as the first priority (Whiley et al.1990). A program begun by Dr. George Zentmyer at the University of California, Riverside (UCR) in the 1950's resulted in the selection of a number of root rot "tolerant" rootstocks that have become available to growers, and identification of promising genetic material for breeding in the future. Rootstocks that originated from the Zentmyer (and later the Michael Coffey) research programs include Duke 7, G1033, G6, Martin Grande (collectively G755A, G755B, G755C), Barr Duke and Thomas (Coffey and Guillemet 1987). Other rootstocks of interest have emerged from efforts by private nurserymen; most notable is the Toro Canyon which has some degree of salinity and root rot tolerance. (H. Brokaw, personal communication). Starting in the early 1990's, John Menge carried on the rootstock selection program at UCR that resulted in even more promising selections that were field-tested by him and the farm advisors, and later (after Menge's retirement) by Greg Douhan at UCR. The Zentmyer and Coffey programs concentrated on testing rootstock material imported from Central America, and in selecting "escape" trees from local orchards in California. Menge continued to import and test selections from research programs in Israel, Mexico, Central America, Australia, and South Africa, and began to cross selections in special open-pollinated isolation blocks in California. Seedlings from these isolation blocks are being tested for improved resistance to root rot and three new selections (Zentmyer, Uzi and Steddom) are becoming available to growers (in 2015). A selection from South Africa (Dusa) has become very popular in California in recent years and has done quite well in research trials, as long as the soil is not kept saturated.

While the search for root rot tolerance led the way in rootstock development in California, knowledge of other important characteristics of rootstocks has lagged behind. A notable example of a problem that almost developed was a University recommendation in the late 1980's to plant G755 (Martin Grande) rootstocks in Phytophthora-infested soils because of its consistently good ratings for tree growth in replant situations. Researchers were not aware that Hass/G755 was very slow to come into bearing until Arpaia, Bender, and Witney reported yield data from their rootstock trial on "clean" soil in Irvine, CA (Arpaia et al. 1995). While the search for root rot tolerance is still a top priority in the industry, it has also become a priority to study other cultural aspects of rootstocks.

Fortunately, the California avocado industry may benefit in the future from a rootstock selection program in Israel. It was discovered in the 1940's that West Indian selections generally had more salinity tolerance than Mexican selections (Oppenheimer 1947). In 1982 Ben-Ya'acov began a program to select the most salt-tolerant West Indian selections that also showed that least lime-induced chlorosis (Ben-Ya'acov and Michelson 1994). Some of these selections are also believed to have some degree of root rot tolerance. The best of Ben-Ya'acov's selections were brought to California in 1999 and, under a research program headed by Dr. David Crowley at UCR, are now out in field trials with highly saline water for irrigation. These selections will also be tested for root rot tolerance. Although West Indian selections are still believed to be sensitive to cold, most of the California avocado groves are located on slopes above the frost line, thus a good salt-tolerant West Indian rootstock may find an important place in the future in California avocado production.

**Root Rot Tolerance and Replanting**

There is no true "resistance" to *Phytophthora cinnamomi* in the avocado rootstocks that are graft-compatible to scions of *Persea americana*. There is (to date) only a degree of "tolerance" to the disease based on the capacity of the rootstock to regenerate roots rapidly (Duke 7), or a physiological response which retards lesion development (as found in Martin Grande) (Coffey 1987a). Therefore, successfully re-establishing avocados into a soil where previous avocados had died from root rot is not as simple as merely replanting with a tolerant rootstock.

Rootstocks that have a degree of root rot tolerance and are currently available for the commercial industry include Duke 7, G-6, Barr Duke, Toro Canyon, Borchard, Day and Fairchild. Many of our groves have varieties that were popular in previous years but are no longer available. An example would be 'Thomas' from the UCR program that was popular in the 1990's because it consistently gave the highest ratings for tree survival and growth when replanted into root rot soils. It was later discovered that Thomas was susceptible to a trunk canker caused by *P. citricola*. Thomas may also have increased susceptibility to trunk cankers caused by *Dothierella* fungi (Menge, personal communication) and is quite sensitive to salinity. Martin Grande also performed well in some root rot replant trials, but is not recommended due to poor performance in yield trials (Arpaia et al. 1995). New selections that performed better than Thomas in Menge's root rot trials were the PP4, PP14 and PP24 (re-named 'Zentmyer', 'Uzi' and 'Steddom'). Budwood from these rootstocks were released to the industry in 2013 and trees should become available in 2015. A summary of rootstock characteristics based on research and observation in California in 2003 is presented in Table 1.

Also available to California growers are two selections from South Africa known as Merensky 1 (a Duke 7 seedling formerly known as Latas) and Merensky 2 (South African selection formerly known as

Dusa). In limited trials in California, they have been performing slightly better than Thomas in root rot tolerance, and about equal to Zentmyer. Their yields under root rot conditions are comparable to Zentmyer and somewhat better than Uzi or Steddom. Both of the South African selections performed well in salinity field trials, but Zentmyer and Thomas do poorly with saline irrigation water. Dusa is now the top-selling clonal avocado rootstock in California.

**Table 1. Characteristics of Avocado Rootstocks**

**Commercially Available to Growers in California in 2003**

| | Topa Topa | Lula | G-6 | Duke 7 | Thomas | G755A,B,C (Martin Grande) | Barr Duke | Toro Canyon | D9 | Borchard |
|---|---|---|---|---|---|---|---|---|---|---|
| **Normal Propagation Method** | seed | seed | seed | clonal | clonal | clonal | clonal | clonal | clonal | clonal |
| **Horticultural race** | Mexican | Guat. X West Indian | Mexican | Mexican | Mexican | Hybrid-*P. americana x P. shiedeana* | Mexican | Mexican | Mexican | Mexican |
| **Parentage** | | | seedling | Duke | escape seedling | market collection | Selfed Duke 6 seedling | | Irradiated Duke seedling | |
| **Geographic origin** | California | Florida | Antigua, Guatemala | UC Riverside | Escondido, CA | Guatemala | Fallbrook, CA | Saticoy, CA | UC Riverside | Camarillo, CA |
| **Productivity "clean" soil (a)** | 3 | ? | 3 | 4 | 2 | 1 | 3 | 3 | 2.5 | 4 |
| **Productivity "root rot" soil (b)** | 1 | ? | 3.5 | 3 | 3 | 2 | 3 | 3.5 | 3 | 2 |
| **Tree size "clean" soil (a)** | 5 | ? | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| **Tree size "root rot" soil (b)** | 0.5 | 0.5 | 1 | 2 | 4 | 1.5 | 1.5 | 3 | 2.5 | 0.5 |
| **Tolerance to P. cinnamomi (c)** | 0 | ? | 2 | 3 | 4.5 | 5 | 3.5 | 2.5 | 3.5 | 0.5 |
| **Tolerance to P. citricola (d)** | 3 | ? | 3 | 4 | 2 | 3 | 3 | 5 | 4 | 3 |
| **Salt tolerance (e)** | 2 | ? | 2 | 3 | 1 | 2 | 2 | 3 | 3 | 3 |
| **Frost tolerance (f)** | 4.5 | 1 | 4.5 | 4 | 4.5 | 1 | 4.5 | 4.5 | 4.5 | 4.5 |
| **Tolerance to Dothierella (g)** | 5 | ? | 2 | 5 | 2 | ? | 5 | 5 | 5 | 5 |

***Legend: 0 = poor, 5 = best***

Ratings by J. Menge, G. Bender, and M.L. Arpaia, 2002

**Footnotes:**

a. Yield and canopy volume expressed as percentage in comparison to Topa Topa, based on 7 years of data (6 years for Thomas) at South Coast Field Station (Arpaia et al. 1993)

b. Yield and canopy volume expressed as percentage in comparison to Thomas (consolidated data from J.A. Menge, 2002)

c. Consolidation of performance of young replant trials, ratings by John Menge

d. Results from greenhouse trials by A. Alizadah and J. Menge (unpublished)

e. Rootstock trial in sand tanks treated with three levels of saline water (Oster and Arpaia, 1991)

f. Observations by G. Bender and J. Menge after freezes in 1988-1991.

g. Results from greenhouse trials by A. Alizadah and J. Menge (unpublished).

To increase the chances for survival and growth of the young replant tree, the root-ball should be drenched with a solution of fosetyl-Al (Aliette) or a solution of buffered phosphorous acid at the time of planting, followed by two to three foliar sprays with the same chemical that year. Mounding to improve drainage (to keep the root ball above the level of native soil), mulching with a wood-based mulch (3-4 inches deep, keeping the much away from the trunk to avoid excess moisture) and applications of gypsum (5-10 pounds per young tree applied on the surface) to the soil should all be done at the time of planting to help the young tree withstand *Phytophtora* infection. Great care must be taken to water the young trees correctly. Avocado trees that have been watered daily at the nursery cannot be placed on a once-a-week irrigation schedule, the schedule often seen in a mature grove. At the same time, they cannot withstand standing water and poor drainage. The young trees should be placed in their own irrigation block, with a tensiometer placed at the edge of the root ball of a representative tree guiding the irrigation frequency.

**The Clonal Rootstock.** Since the early 1950's, researchers at the University of California, Riverside have scouted for avocado trees apparently surviving *Phytophthora* root rot in areas of southern Mexico, Guatemala, and other countries in Central America. Unusual-looking avocado fruit have also been purchased from local markets (in the hopes of finding wild hybrids) and the seed from these selections were shipped to the University of California under USDA permit. These selections, along with local selections found in California, are subjected to rigorous screening either in water-bath tanks infested with *P. cinnamomi* zoospores, or in soil infested with high populations of *P. cinnamomi* propagules. Surviving trees are usually subjected to a second screening; the survivors are grown up and eventually placed in field trials in infested groves.

Promising selections are also grown as un-grafted trees for later use by the University and by private nurseries. Most of these trees produce seed for propagation, but some do not, and some are very slow to come into production. In addition, seedlings grown from these seeds are variable in quality and usually do not have the same degree of root rot tolerance as the parent tree. To overcome this problem, a "cloning" technique was developed by Edward Frolich at U.C.L.A. in order to preserve the desired characteristics of the parent tree (Frolich and Platt 1972). To produce the clonal rootstock, budwood from the Duke 7 tree (for instance) is grafted onto a vigorous seedling in the greenhouse. After six to eight weeks, the young plant is placed into a completely darkened chamber for about 10 days. The lack of light causes "etiolation", a blanching of the green bark. Etiolation is necessary because avocados have difficulty rooting from cuttings with green bark, but less so with bark that is blanched by lack of light. Rooting hormone is then applied to the lower part of the Duke 7 scion, soil is either brought up around the lower part of the Duke 7 scion, or the whole plant is re-potted so that the lower part of the Duke 7 scion is buried, and rooting takes place from the etiolated Duke 7 bark. Eventually a Hass or other suitable avocado variety is grafted onto the Duke 7. Some nurseries place a constriction ring around the base of the clonal rootstock (below the clonal roots) so that the seedling roots are constricted and eventually die, leaving only the clonal roots. Other nurseries will clip off the seedling roots, and still other nurseries will leave the seedling roots attached with the belief that the extra roots will help the tree establish better at planting time.

Unfortunately, because of the extra care required to produce a tree on a clonal rootstock, the trees are more expensive, usually about twice the cost of a tree on a seedling rootstock. Given the problems that can occur in the grove with an eventual invasion by *P. cinnamomi*, the initial investment in clonal rootstocks is prudent.

**Yield in "Clean" Soil.** Yield is obviously an important factor in choosing a rootstock. The only long term trial comparing yield and other horticultural attributes of Hass grafted onto various rootstocks in "clean" soil (without the presence of *P. cinnamomi*) is at the UC Research and Extension Center in Irvine, CA. That project was started in 1986; results were reported in 1995 (Figure 1) (Arpaia et al. 1995) and in 1996 (Arpaia et al. 1996). The rootstocks that were evaluated were clonal-propagated G755A, G775B, G755C, Toro Canyon, Borchard, Duke 7, D9, Thomas, and G1033. Clonal propagated Topa Topa was also in the trial to
serve as a control. (At the time of the trial most of the avocado trees in California were grown on seedling Topa Topa). Thomas and G1033 were planted a year after the initial planting because the trees weren't available at the time of planting in 1986.

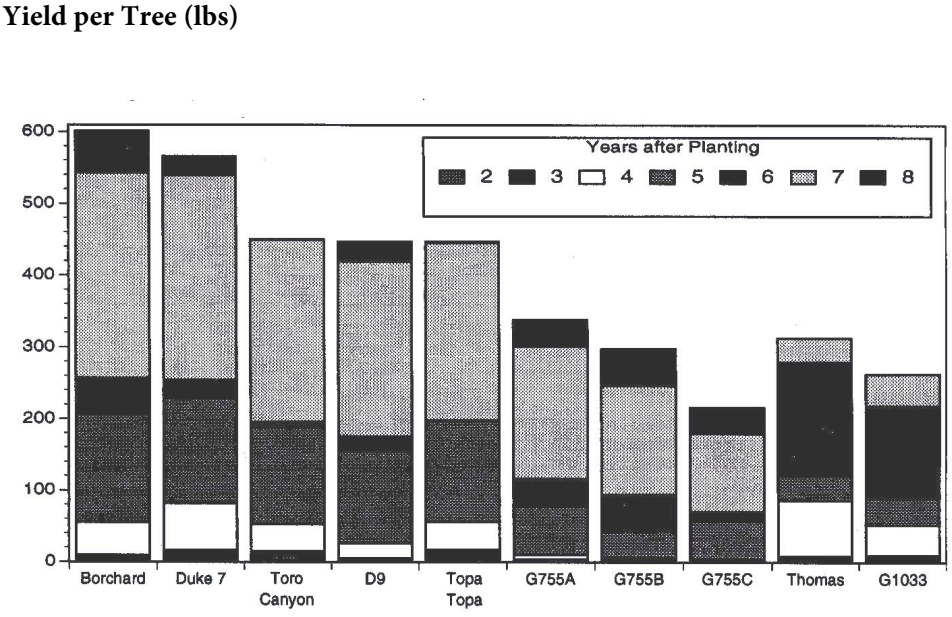


Figure 1. Cumulative yields (lbs/tree) of Hass avocado on clonal rootstocks after 8 years field production under *Phytophthora* – free conditions (Arpaia et al. 1995).

After nine years, Borchard and Duke 7 were the highest producing rootstocks. It should be noted, however, that Borchard is susceptible to *P. cinnamomi* and would probably not be recommended if there were a possibility of root rot contamination in the grove. The Toro Canyon, D9 and Topa Topa rootstocks have comparable and moderate yields, and the three G755 rootstocks were less productive. Although they can't be compared directly, Thomas and G1033 were bearing at a rate slightly ahead of G755A.

Yield efficiency was also calculated with the thought that trees with more fruit per canopy volume could be the better choice of rootstock, especially if the trees were planted on a closer spacing than the 20' x 20' spacing in this trial. After 6.5 years, Borchard produced the largest trees and Toro Canyon and G755C produced the smallest trees; the others were comparable in size. After 7.5 years, the Borchard still produced the largest trees, G755C produced the smallest trees, and Toro Canyon was

comparable to the others. When the yield in the seventh year (an "on" year) was divided by the 6.5 year canopy volume, Toro Canyon emerged as the most efficient in yield per canopy volume, followed closely by Duke 7, D9, Topa Topa and Borchard. In this comparison, Thomas in the seventh year ranked sixth in yield efficiency, followed in order by G1033, G755A, G755B and G755C.

Toro Canyon continued to be the most efficient tree in the ninth year, followed by Topa Topa, Borchard, and Duke 7.

Yields from the new generation of root rot-tolerant rootstocks from the UCR research program will continue to be evaluated in "clean" soil (and in root rot soil) in the coming years from new plantings at the South Coast Research and Extension Center.

**Yield in Root Rot Soil.** Improvements in *P. cinnamomi* resistance in the rootstocks have resulted in three good selections from the UC Riverside breeding program ('Zentmyer', 'Uzi' and 'Steddom') and several from South Africa, one of which is currently the most popular clonal rootstock in California ('Dusa') (Menge et. al 2012). Average yield and canopy volumes from all of the rootstock trials combined in the northern and southern avocado-growing regions in California are in Table 2. It can be seen that all of these rootstocks performed better than 'Thomas', a rootstock from the UCR program in the early 1990's. The three new rootstocks from the UCR program were released to nurseries at the end of 2012 and it remains to be seen how popular they become with growers.

**Table 2.** Yield and canopy volume from three new UC Riverside rootstocks compared to an older rootstock ('Thomas') and a popular rootstock derived from a South African breeding program ('Dusa'). This data was derived from all of the northern and southern avocado rootstock trials in California. The scion cultivar was 'Hass".

| | Yield (lbs/tree) | | | Canopy volume (cu ft$^2$) | | |
|---|---|---|---|---|---|---|
| Cultivar | 3 yrs | 4 yrs | 5 yrs | 3 yrs | 4 yrs | 5 yrs |
| Thomas | 28.3 | 18.7 | 3.6 | 333.20 | 401.50 | 753.00 |
| Dusa | 38.7 | 85.1 | 117.4 | 409.00 | 532.00 | 1584.00 |
| Zentmyer | 38.4 | 19.4 | 114.1 | 445.00 | 410.00 | 1573.00 |
| Uzi | 41.1 | 70.0 | 96.3 | 461.00 | 669.00 | 1338.00 |
| Steddom | 45.8 | 63.6 | 90.4 | 380.50 | 478.00 | 1257.00 |

**Salinity Tolerance.** Tolerance to saline irrigation water is emerging as a very important quality for avocado rootstocks in California. Not only are more growers drilling wells (which often produce water of higher salinity than district water), but also reclaimed water (with a higher salinity content) is becoming more available in the avocado-growing districts. The familiar "tip-burn" on the leaves in the fall is a sign that the tree is absorbing too much chloride during the season, and these leaves will have to drop off of the tree during the winter. Leaves that grow to replace these leaves often grow at the expense of flowering and fruit-set, resulting in chronically low yields in some groves.

Rootstocks vary in their ability to absorb and transport chloride and sodium. Of the avocado races, Mexican rootstocks are most susceptible to salinity and West Indian rootstocks are the most tolerant of salinity. Guatemalan rootstocks are generally intermediate in their tolerance of salinity, although Embleton found that the Guatemalan cultivar 'Anaheim', when used as a rootstock, induced more

chloride accumulation in the scion than did neighboring Mexican rootstocks (Embelton et al.1962). As mentioned, Mexican rootstocks are the most common type in Southern California due to their tolerance of cold weather, colder soils, and heavier soils. Unfortunately, only limited research has been conducted in California on comparative salinity tolerance of the different types of Mexican rootstocks

One study reported in the literature compared the effects of salinity on young Hass grafted onto Thomas, Toro Canyon, Parida, Duke 7, G755B, or Barr Duke (Oster and Arpaia, 1991). These plants were grown in sand tanks, irrigated once a day with one of three different saline water solutions (2.2, 3.2 or 4.2 dS/m). The trees were grown for nine months under these saline conditions, then harvested and analyzed.

Trees were visually rated on a scale of 1 to 5, where 1 represented vigorous growth and 5 represented a dead plant. Toro Canyon and Duke 7 had the best appearance with ratings of 1.56 and 1.83 respectively. Barr Duke had the worst appearance with a rating of 2.56. Thomas, G755B, and Parida were intermediate in appearance with ratings of 2.00, 2.28, and 2.33. Toro Canyon, Parida, and Duke 7 had the lowest amounts of chloride in their leaves in that order; Thomas, G755B and Barr Duke had the highest chlolride content in their leaves. Parida had the highest sodium levels in the new growth of any of the rootstocks whereas Toro Canyon and Duke 7 had the lowest levels of sodium in their new growth.

Field experience has indicated that Thomas would not be a good selection for replanting into areas with highly saline irrigation water. Of the rootstocks available to growers, Toro Canyon or Dusa (Merensky II) would probably be the best choices for this situation, but long-term trials under saline conditions are only now underway.

Among the new rootstocks from UCR, Steddom showed more salt tolerance than Thomas or Dusa, with Zentmyer and Uzi showing the least amount of salt tolerance. In their evaluation Dusa was not significantly different from Zentmyer or Uzi in salt tolerance (Menge et. al 2012).

There has been considerable interest in the West Indian rootstocks since they usually have better salt tolerance. The Israeli rootstock program developed by A. Ben-Ya'cov identified approximately 50 clones of high yielding West Indian selections when grown under saline conditions. Ben-Ya'cov and colleagues noted that under conditions where chloride in the irrigation water is 100 ppm, avocado production on West Indian vs. Mexican rootstock is approximately equal. However, when chloride levels equal 300 ppm, Hass avocado production from the VC 51 rootstock (West Indian) was approximately double that of VV57 (Mexican) (Ben-Ya'acov et al, 1991). Ben-Ya'cov noted that these trees must be grown under well-drained conditions in order to be successful.

Drs. David Crowley and Mary Lu Arpaia imported these rootstocks from Israel and set out several trials in California in the early 2000's, but were hampered by freezes in 2007. However, prior to the freeze, one of the field trials compared the California rootstocks to the West Indian selections from Israel and two selections from South Africa gave surprising preliminary results: the Merensky I (Latas) rootstock from South Africa did better than any of the other rootstocks as far as growth and appearance of the Hass scions, followed closely by Merensky II (Dusa) (Crowley, Arpaia and Bender, unpublished).

Another trial set out in 2004 was ready for the first harvest in 2007 when it was virtually destroyed by a freeze. This trial had the Israeli rootstocks VC 44, VC 207, VC 218, VC 801 and the new UCR rootstocks Uzi, Steddom, Spencer and Rio Frio, and Duke 7 and Parida as controls. The trial also had Dusa set in around the trial trees as fillers. The irrigation water was quite saline with an EC of 2.5 and 300 ppm chloride. The UCR rootstocks looked very poorly with severe tip-burn, but the VC (West Indian) rootstocks showed little effect due to the salinity. After the freeze in January, 2007 the severely damaged trees were pruned back and most of the VC series re-grew. More than half of the other rootstocks died. The first harvest then occurred in 2010 and VC 801 averaged 92.2 lbs per tree (Dusa surprised everybody by yielding 139 lb/tree). At the grower request, the trial was discontinued after the 2010 harvest (Bender et. al, 2010). However, the trial did demonstrate that the West Indian rootstocks could have a future in avocado production in California.

Starting in 2009 Crowley and Arpaia began evaluating data related to rootstocks from ten groves in southern California. This research is aimed at the development of a production function that can predict avocado yields related to chloride and salinity in the irrigation water. The model uses an artificial neural network program that enables the researcher to separate out very complex interactions that cannot be detected using traditional statistical procedures. This is important work since we know that chloride toxicity and soil salinity throughout avocado groves reduce yield, "but the there is little information on the extent to which different rootstocks can be used to improve tree performance under saline conditions" (Crowley, D and M.L Arpaia 2010).

If we can find a salt-tolerant rootstock that shows some degree of cold tolerance and root rot tolerance, we might be able to greatly improve the rootstock choices for California growers.

**Frost Tolerance**

There are no reported data on the effect of frost on Hass according to rootstock variety. There is, however, a rating by Menge of the foliage of un-grafted rootstocks. This rating was performed two weeks after a freeze event in Riverside, California in January, 1991. The rating value was the average rating of two rootstocks of the same variety. Due to the low number of trees per rootstock, this cannot be construed to be a scientific rating, but the information may be of interest. In this rating, 0=healthy, 5=dead.

**Table 3**. Frost damage on various un-grafted rootstocks at UC Riverside – January 1991

| **Rootstock** | **Visual Rating 0=healthy, 5=dead** | **Rootstock** | **Visual Rating 0=healthy, 5=dead** |
|---|---|---|---|
| Thomas | 0 | 1033 | 2.5 |
| D9 | 0 | Nabal | 3 |
| G6 | 0 | Hass parent | 3 |
| Barr Duke | 1 | Bacon | 3 |
| Topa Topa | 1 | G755 A | 3 |
| Duke parent | 1 | Reed | 3.5 |
| Fuerte | 1.7 | Anaheim | 3.5 |
| Duke 7 | 2 | G755B | 3.5 |

| | | | |
|---|---|---|---|
| Rincon | 2 | Lula | 4 |
| Wurtz | 2 | G22 | 4 |
| Susan | 2 | McArhur | 4 |
| Duke 6 | 2 | Hass Prince | 4 |
| Zutano | 2 | G755C | 4 |

**Flower Timing**

Certain rootstocks may have an effect on the timing of flowering. The first author has noted that, in side-by-side plantings, Hass on G6 are often two to three weeks later in flowering than Hass on Topa Topa. This effect has either not been noticed in other rootstock trials, or has not been recorded in the literature.

This effect could be important if bees work the flowers better late in the bloom due to warming temperatures, or the trees are able to take up more nutrients later in the spring because of warming soil temperatures. Hopefully this can be an area of more intensive research in the future.

**Rootstocks for the Future**

The rootstock selection and breeding program in California is very active. Researchers in the program evaluates selections from foreign countries, escape trees in California, and seedlings from isolated breeding blocks. The primary focus is to select rootstocks with improved tolerance to root rot. Mary Lu Arpaia is evaluating the better selections for improved horticultural characteristics. As mentioned in the salinity section, David Crowley is evaluating rootstock characteristics that could lead to improved salinity tolerance.

When the root rot program was directed by John Menge there were approximately 40 different selections (all grafted to Hass) in 30 field trials throughout Southern California, all planted in *Phytophthora*-infested soil. Some of the better selections that developed were Zentmyer (Barr Duke maternal parent), Spencer (Pauma Valley escape tree), Uzi, Steddom and Rio Frio. From South Africa came Merensky 1 (Latas) and Merensky 2 (Dusa). Forty-seven new selections from breeding blocks have been screened and are ready to be planted in the field. All of these are grown as clonals, however Spencer initially showed some resistance as seedlings; Spencer is being tested further for tolerance to *Phytophthora* as seedlings vs. clonals.

Newly imported selections from Israel currently being tested for root rot and salinity tolerance include VC 31, VC 40, VC 51, VC 65, VC 66, VC 75, VC 204, VC 802, VC 803, VC 804, and VC 817. The 800 series are thought to have good tolerance to root rot. A previous import from Israel, the VC 256, was reported in Israel to have tolerance to both root rot and salinity. There is great interest in this particular rootstock, but initial results in California do not show this rootstock to have a high tolerance to root rot, and perhaps not as much tolerance to salinity as had been reported from Israel.

In addition to having good tolerance to root rot and salinity, a successful rootstock, when grafted to Hass, must demonstrate that it will impart good fruit production in the scion. The Menge program collected at least three years of yield data before the rootstock could be considered for release to the industry.

A new line of genetic research was launched in the late 1990's by researchers Witjaksono and Litz, at the University of Florida. They attempted to utilize protoplast fusion to create somatic hybrids between root rot-immune *Persea borbonia*, *P. caerulea,* and *Machilus* spp., and root rot-susceptible *Persea americana* in order to impart root rot resistance into a rootstock that would be graft compatible with commercial cultivars of *Persea* (Witjaksono and Litz, 1998). Apparently somatic hybrids were created, but they had difficulty regenerating the somatic hybrid embryos into plants. Later they have attempted to graft the somatic hybrid embryos into seedling rootstocks in order to eventually create clonal rootstocks.

Transfer of genes and somatic hybridization offers an exciting prospect for speeding up the development of new rootstocks, but this program still has inherent difficulties; and it may take some time before the California grower can reap the benefits.

Gary Bender examining an avocado tree grafted onto a Phytophthora-tolerant rootstock

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