

# Screening and Evaluation of New Rootstocks with Resistance to *Phytophthora cinnamomi*

## Continuing Project; Year 10 of 20

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### Benefits to the Industry

Ultimately, the control of Avocado root rot will be accomplished with a resistant rootstock. This project has already provided the industry with several new tolerant rootstocks, which are greatly improving the yields of avocado on land infested with *Phytophthora cinnamomi*. The goal is to find a rootstock that will eliminate *Phytophthora cinnamomi* as a serious pathogen on avocado. Our ability to find such a rootstock has been enhanced as a result of our breeding blocks where we focus on crossing already resistant rootstocks.

### Objectives

To collect, select, breed and develop avocado germplasm which exhibits resistance to *Phytophthora* root rot of avocado.

### Summary

#### Collection and Selection of Germplasm

We have obtained 5 trees from the Farwell Ranch in Fallbrook, Farwell 1-5. These tree appeared to have survived a field epidemic of avocado root rot.

#### Breeding Program

We have screened 1566 seeds from the breeding blocks for resistance to *Phytophthora cinnamomi* in 2001. We have retained 58, which showed a high degree of resistance. Most of these varieties had maternal parents G6, Barr Duke or UC2001. While we can handle up to 12,000 seeds per year, we have begun to revamp one of the 9 breeding blocks every year. Resistant trees will be planted in the blocks instead of grafting resistant buds into existing trees. This will allow more uniform plantings, the establishment of replicated trees and prevent shading and suppression of slower growing germ plasm. We now have 52 seedlings from the breeding blocks, which have shown exceptional resistance to *Phytophthora cinnamomi* after extensive testing. Sixteen of these are being field-tested, two more are being grafted for field tests in 2003. Thirty more are ready for field-testing and four have been grafted to increase budwood in 2002.

Two of seedlings from the breeding block, the Guillement and the Mckee have been judged not commercial and will not be tested further. One variety the Zentmyer will be released to the growers as soon as possible.

We are attempting to synchronize the flowering in the avocado breeding blocks so that varieties flowering at different times have a higher probability of crossing. We have experimented with a program of girdling late varieties (*Persea steyermarkii*, CRI-71, G810, G755) and spraying early varieties (Thomas, Toro Canyon, Barr Duke, Duke 7, and UC2011) with Uniconazole-P. Three year's results indicate no significant alterations in the flowering times or fruit set due to these treatments. We have decided to discontinue these treatments. Instead we are hand pruning the early flowers from some of the early flowering trees. This results in a later production of axillary flowers, which may coincide with the bloom of later varieties. We are now covering trees with a mesh screen and are using beehives in an attempt to get more crosses between varieties. Results from Dr. Clegg's lab indicates that 79% of our

seeds from covered trees containing beehives are outcrossed. However, 68% of our seeds are outcrossed from uncovered trees without beehives. These values are not significantly different. We now intend to harvest pollen from selected varieties and allow the bees to spread it to the maternal parent. This will allow us manage and create the crosses we are seeking.

In 2002 a new breeding block was initiated which contains many of the new *Phytophthora* resistant varieties. The breeding blocks are now made up of Merensky I, Merensky II, VC 256, G755A, Thomas, G810, Toro Canyon, Spencer, Barr Duke, UC2001, CRI-71, Duke 7, G6, D9, UC2011, Zentmyer, *Persea steyermarkii* *Persea nubigena*, Agucate de Anis, Agucate de mico, Berg, Uzi, Guillemet, Rio Frio, Afeck, Mckee, Erin, Medina, Steddom, Martin, Elinor, Pond, Dirac, Eddie, Witney, Johnson, Faber, Bender, Mauk, Downer, Turney, Janice, Gabor, Mary Lou, and Lovatt.

### **Screening and Greenhouse Evaluation of Rootstocks**

Extensive greenhouse trials with Pond (PP29, maternal parent G6), Crowley (PP34, maternal parent UC2001), VC 207 (Day) (Israel, West Indian), Gray (PP 25, maternal parent G6, and Thomas were carried out in 2002. None of the rootstocks was significantly worse than Thomas in any of the root rot categories that were examined. VC 207 and Pond had significantly greater root length than Thomas when grown in *Phytophthora* infested soil. Root weights of Pond were larger than any of the other varieties in *Phytophthora* infested soil. A ranking of these rootstocks from least severely inhibited by *P. cinnamomi* to most severely inhibited, would be: VC 207, Thomas, Gray, Pond and Crowley. Based on these studies all of the rootstocks studied are recommended for field study. Plants being grafted for intensive studies in 2003 include Elinor (PP28, maternal parent D9), Eddie (PP40, maternal parent Toro Canyon), Anita (PP35, maternal parent UC2001), Dirac (PP36, maternal parent UC 2001), Thomas and Borchard.

A series of greenhouse evaluations were made on the susceptibility of some of the promising new rootstocks to canker diseases caused by *Phytophthora citricola* and *Fusicoccum sp.* (*Dothiorella*). For both diseases Thomas was by far the most susceptible (Table 1). Merensky I (Latas) was moderately susceptible to *Phytophthora citricola* canker, while Uzi (PP14), Merensky II (Dusa), Steddom (PP24), and Zentmyer (PP4) were moderately resistant (Table 1.). Zentmyer (PP4) and Merensky I (Latas) were resistant to *Dothiorella* canker, while Uzi (PP14), Steddom (PP24) and Merensky II were moderately susceptible (Table 1).

### **Field Evaluation**

We now have 33 field trials (6,000+ trees) testing 49 clonal root rot tolerant rootstocks throughout Southern California. The following are brief summaries of the older trials.

In a 6-year-old trial in Camarillo, CA under heavy root rot pressure, trees yielded as follows from the greatest to least: Merensky IV (W-14 South Africa), VC 256 (Israel), Halma Duke, Spencer (Pauma Valley), Merensky III (Evstro -South Africa), Thomas, Gordon (South Africa), Borchard,) and UC 2023 (G755 C seedling). All of the varieties seem to be doing well except for Borchard. This was the first year of sizeable yields with maximum yields at about 140 lbs/tree.

A 5-year old trial in Camarillo, CA under heavy root rot pressure was rated as follows from the healthiest to the poorest: Merensky III (Evstro-South Africa), Spencer (Pauma Valley), G755A (*P. schiedeana* x *P. americana* seedling) and Velvick. Tree sizes from the largest to the smallest were: G755A, Merensky III, Spencer and Velvick. Only Velvick is doing poorly in this trial. Analysis of leaf nutrients indicated that Merensky III and Spencer leaves contained the most nitrogen with G755A and Velvick containing the least. Velvic had the least leaf phosphorus. G755A had the greatest leaf calcium and magnesium levels. Merensky III had the most leaf potassium with Velvic having the least. Spencer had the highest leaf sodium levels. Spencer and G755A had higher levels of leaf manganese compared to the other two varieties. Merensky III and Spencer had higher levels of copper in the leaves than the other two varieties. Merensky III and G755A had higher levels of iron in the leaves than the other rootstocks. Leaf zinc was similar for all rootstocks. Levels of nitrogen and copper were below optimal levels in trees with G755A and Velvick rootstocks. Phosphorus levels were below optimal levels with all rootstocks. Zinc levels

were above optimal levels only with the G755A rootstock. It appears the Merensky III rootstock is the best of this group for providing a well-rounded nutrient level for scion leaves.

A 4-year old trial in Somis, CA under heavy root rot pressure was rated as follows from healthiest to the poorest: Merensky III (Evstro -South Africa), Berg (PP5 -maternal parent D9), Zentmyer (PP4- maternal parent Barr Duke), Thomas, G755A (*P. schiedeana* x *P. americana* seedling) and Duke 7. Tree sizes from largest to smallest were: Zentmyer (PP4- maternal parent Barr Duke), Berg (PP5-maternal parent D9), Merensky III (Evstro-South Africa), G755A (*P. schiedeana* x *P. americana* seedling), Thomas, and Duke 7. Fruit set from greatest to least was as follows: Merensky III (Evstro- South Africa), G755A (*P. schiedeana* x *P. americana* seedling), Thomas, Duke 7, Zentmyer (PP4- maternal parent Barr Duke) and Berg (PP5 -maternal parent D9). Only Duke 7 is doing poorly in this plot. Leaf analysis from this plot indicated that there were substantial differences in leaf analysis due to rootstock. However rootstock did not significantly affect leaf concentrations of nitrogen, sodium, zinc, and copper. Merensky III, Berg and Zentmyer had greater leaf concentrations of phosphorus than did G755A, Thomas and Duke 7. G755A had higher levels of leaf calcium than did Zentmyer and Berg. G755A had higher leaf concentrations of magnesium than the other rootstocks. Thomas and Berg had higher concentrations of potassium in the leaves than did Merensky III and Duke 7. G755A had the highest concentrations of leaf manganese and Zentmyer and Duke 7 had the lowest. Thomas and Duke 7 had the highest levels of iron in the leaves while Zentmyer, Berg and G755A had the lowest. In this trial all trees had less than optimum levels of phosphorus. Trees on G755A and Duke 7 had less than optimal levels of nitrogen in their leaves. Only Duke 7, G755A and Merensky III had optimum levels of calcium. All rootstocks except Duke 7 had less than optimal levels of zinc in the leaves.

A 4-year old trial established in Carpinteria CA in salty soil under heavy root rot pressure was rated as follows from healthiest to the poorest: Merensky II (Dusa- South Africa), VC 256 (West Indian-Israel), Thomas, and Zentmyer (PP4- maternal parent Barr Duke). Tree sizes from largest to smallest were: Merensky II (Dusa- South Africa), Thomas, Zentmyer (PP4- maternal parent Barr Duke), and VC 256 (West Indian-Israel). Fruit set ratings from heaviest to lightest are: Merensky II (Dusa- South Africa), VC 256 (West Indian-Israel), Thomas, and Zentmyer (PP4- maternal parent Barr Duke). Leaf analysis indicates that rootstock did not affect leaf concentrations of phosphorus, sodium, and manganese on this site. However, VC 256 had higher concentrations of leaf nitrogen in its leaves than did Merensky II. Leaf calcium levels were influenced a great deal by rootstock. VC 256 had the highest levels of calcium in the leaves followed by Merensky II, Thomas and Zentmyer. VC 256 and Merensky II had higher levels of magnesium in the leaves than did Thomas and Zentmyer. There was less chloride in leaves on Merensky II (Dusa- South Africa) and VC 256 than in Thomas and Zentmyer (PP4-maternal parent Barr Duke). Merensky II had lower levels of potassium in the leaves than the other rootstocks. VC 256 had higher levels of zinc in the leaves than did the other rootstocks. VC 256 and Zentmyer had higher levels of copper and iron in the leaves than did Thomas and Merensky II. Only trees on VC 256 had adequate nitrogen in their leaves. Leaves from all rootstocks had inadequate phosphorus in the leaves. Only VC 256 and Merensky II had adequate calcium concentrations in the leaves. Only trees on VC 256 had adequate levels of zinc in the leaves. It appears that VC 256 is excellent at providing a balanced nutrition to Hass avocado leaves. A few VC 207 (Day -West Indian -Israel) were planted at this site and they have virtually no salt damage. Merensky II ( Dusa- South Africa) also seems quite resistant to salt damage while Zentmyer (PP4- maternal parent Barr Duke), Thomas, and VC 256 (West Indian-Israel) exhibited heavy salt damage. VC 256 (West Indian- Israel) was supposed to be quite resistant to salt damage but it was not evident in this plot. Zentmyer and Thomas are performing poorly on this plot.

A 3-year old trial established in Temecula CA on root rot infested soil. It rated as follows from healthiest to poorest: Zentmyer (PP4- maternal parent Barr Duke), Thomas, Toro Canyon, Duke 7 and Merensky III (Evstro-South Africa). Tree sizes from largest to smallest were: Thomas, Zentmyer (PP4- maternal parent Barr Duke), Toro Canyon, Merensky III (Evstro-South Africa) and Duke 7. Fruit set ratings from heaviest to lightest are: Toro Canyon, Merensky III (Evstro-South Africa), Thomas, Duke 7 and Zentmyer (PP4- maternal parent Barr Duke). All rootstocks are performing well in this plot.

A 3-year old trial established in Escondido, CA on root rot infested soil. It rated as follows from healthiest to poorest (Table 2): Merensky I (Latas-South Africa), Zentmyer (PP4- maternal parent Thomas), Rio Frio (Guatemala), Merensky II (Dusa-South Africa), VC 241 (Israel), Uzi (PP14-maternal parent G6), Steddom (PP24-maternal parent Toro Canyon), Thomas, Guillemet (PP15-maternal parent Thomas), Spencer seedling (Pauma Valley), Leo (Brokaw selection), Spencer (Pauma Valley), Duke 7, G755A (*P. schiedeana* x *P. americana* seedling), and Poly N (polyploid, UCLA). Tree sizes from largest to smallest were: Merensky I (Latas-South Africa), Uzi (PP14-maternal parent G6), Merensky II (Dusa- South Africa), Zentmyer (PP4-maternal parent Barr Duke), Thomas, Steddom

(PP24-maternal parent Toro Canyon), Rio Frio (Guatemala), G755A (*P. schiedeana* x *P. americana* seedling), Leo (Brokaw selection), VC 241 (Israel), Spencer seedling (Pauma Valley), Guillemet (PP15-maternal parent Thomas), Spencer (Pauma Valley), Duke 7 and Poly N (polyploid UCLA). Fruit set from heaviest to lightest is as follows: Merensky I (Latas-South Africa), Merensky II (Dusa- South Africa), Uzi (PP14-maternal parent G6), Steddom (PP24-maternal parent Toro Canyon), Rio Frio (Guatemala), Leo (Brokaw selection), Spencer seedling (Pauma Valley), G755A(*P. schiedeana* x *P. americana* seedling), Spencer (Pauma Valley), Zentmyer (PP4- maternal parent Thomas), Duke 7, VC 241 (Israel), Thomas, Guillemet (PP15-maternal parent Thomas) and Poly N (polyploid, UCLA). Only Poly N is performing poorly in this trial.

A 3-year old trial established in Carpinteria, CA on root rot infested soil experienced some water stress in the past year. It rated as follows from healthiest to poorest: Uzi (PP 14, maternal parent G6), Zentmyer (PP4-maternal parent Barr Duke), Merensky II (Dusa- South Africa), Merensky III (Evstro-South Africa), Merensky I (Latas-South Africa), Thomas, Merensky IV (South Africa), Mckee (PP19-maternal parent UC 2001), Aguacate de Mico (Mexico) and Poly N (polyploid UCLA). Tree sizes from largest to smallest were: Uzi (PP14-maternal parent G6), Zentmyer (PP4-maternal parent Barr Duke), Merensky II (Dusa-South Africa), Thomas, Merensky I (Latas-South Africa), Merensky III (Evstro-South Africa), Merensky IV (South Africa), Mckee (PP19-maternal parent UC 2001), Aguacate de Mico (Mexico), and Poly N (polyploid –UCLA). Fruit set rating from heaviest to lightest is as follows: Merensky II (Dusa- South Africa), Merensky III (Evstro-South Africa), Merensky IV (South Africa), Mckee (PP19-maternal parent UC 2001), Thomas, Zentmyer (PP4-maternal parent Barr Duke), Merensky II (Dusa-South Africa), Uzi (PP 14, maternal parent G6), Aguacate de Mico (Mexico), and Poly N (polyploid –UCLA). Only Uzi, Zentmyer, Merensky II, Merensky III and Merensky I are performing well in this trial.

A 3-year old trial in Escondido, CA on root rot infested soil was rated as follows from healthiest to poorest: Zentmyer (PP4-maternal parent Barr Duke), Thomas, Aguacate de Mico (Guatemala). Tree size ranked from largest to smallest was: Zentmyer (PP4-maternal parent Barr Duke), Thomas, Aguacate de Mico (Guatemala). Fruit set ranked from heaviest to lightest was: Zentmyer (PP4-maternal parent Barr Duke), Thomas, Aguacate de Mico (Guatemala). Both Thomas and Aguacate de Mico are performing poorly in this trial.

Nine new field trials were established in 2002. These trials included VC 256 (Israel, West Indian), Zentmyer (PP4, breeding block, maternal parent Barr Duke), Berg (PP 5, breeding block, maternal parent D9), Medina (PP22, breeding block, maternal parent G 6), Steddom (PP24, breeding block, maternal parent Toro Canyon), Guillemet (PP15, breeding block, maternal parent Thomas), Elinor (PP28, breeding block, maternal parent D9), Pond (PP29, breeding block, maternal parent G6), Mckee (PP 19, breeding block, maternal parent 2001), Afek (PP18, breeding block, maternal parent Thomas), Erin (PP21, breeding block material, maternal parent D9), Crowley (PP34, breeding block material, maternal parent UC2001), Margy (PP33, breeding block material, maternal parent Duke 9), Anita (PP35, breeding block material, maternal parent UC 2001), Frolic (PP 37, breeding block material, maternal parent Duke 9), Parida (Brokaw selection), Witney (PP41, breeding block material, maternal parent D9), Fred (PP44, breeding block material, maternal parent UC 2001), D9 (irradiated duke seedling), VC 801 (West Indian, Israel), Merensky III (Evstro, South Africa), Merensky I (Latas, South Africa), Bailard (Brokaw selection), VC 218 (West Indian, Israel), VC 225 (West Indian, Israel) and Thomas. Avocado rootstock varieties being propagated for planting in 2003 include: Merensky I (Latas, South Africa), D9, Medina (PP22, breeding block, maternal parent Thomas), Steddom (PP 24, breeding block, maternal parent Toro Canyon), VC 256 (West Indian from Israel), Afek (PP18, breeding block, maternal parent Thomas), Erin (PP 21, breeding block, maternal parent D9), Uzi (PP14, breeding block, maternal parent G6), VC 218 (West Indian, Israel), VC 44 (West Indian, Israel), VC 801 (West Indian, Israel), VC 225 (West Indian, Israel), VC 241 (West Indian, Israel), VC 207 (Day, Israel), Gray (PP25, breeding block material, maternal parent UC 2001), Martin (PP26, breeding block material, maternal parent D9), Rio Frio (PP16, Guatemalan) and Thomas.

## Conclusions

It appears that we have several rootstocks that are consistently performing better than our standard resistant variety, Thomas under root rot conditions. These are Uzi (PP14-maternal parent G6), Merensky I (Latas –South Africa), Merensky II (Dusa- South Africa) and Steddom (PP24-maternal parent Toro Canyon). Zentmyer (PP4- maternal parent Barr Duke) is also growing well but shows some saltburn and has consistently low yields. We have obtained some of our first yield results for many of the new rootstocks. Merensky II appears to provide excellent yields and has been released to growers. Merensky III also seems to yield well. Preliminary data indicates Merensky I may

also yield well. It appears that Steddom and Uzi may be susceptible to *Fusicoccum* (*Dothiorella*) Canker, while Merensky I may be susceptible to *Phytophthora citricola* canker. More yield data must be gathered on the new varieties before they can be released. It appears that rootstocks strongly influence the concentration of nutrients in the leaves of Hass. Different rootstocks may require different fertilizer regimes. Because of the success of our first UCR breeding plot material we are increasing our efforts with these varieties.

Table 1. Susceptibility of promising rootstock varieties to *Phytophthora citricola* and *Fusicoccum* (*Dothiorella*) cankers <sup>1</sup>

Rootstock	Canker size	
	<i>P. citricola</i> <sup>2</sup> (sq. cm)	<i>Fusicoccum</i> <sup>3</sup> (sq cm)
Uzi (PP14)	4.7 b	6.2 b
Merensky II	4.8 b	5.2 b
Steddom (PP24)	4.9 b	6.1 b
Zentmyer (PP4)	5.0 b	3.4 c
Merensky I (Latas)	5.1 ab	3.4 c
Thomas	5.7 a	7.4 a

<sup>1</sup> Mean values in each column followed by identical letters are not statistically different according to Waller's k-ratio t test. <sup>2</sup>Data is combined from 3 inoculation sites and 3 isolates of the pathogen. <sup>3</sup>Data is combined from both scion and rootstock inoculation from two replicate experiments.

Table 2. Growth and fruit set by 3-year-old Haas avocados on experimental rootstocks in a *Phytophthora*-infested grove near Escondido CA, 2002 <sup>1</sup>

Rootstocks	Tree rating	Canopy volume	Trunk diameter	Fruit set rating	Tip Burn	Cankers	Dead
	0-5;5=dead	cu ft	cm	0-5;5=heavy		Number trees affected	
Zentmyer	0.00c	397.4abc	7.12bcd	1.53cd	0	0	0/15
Rio Frio	0.00c	313.5cdef	6.33cdef	2.13bcd	0	0	0/16
Merensky I	0.00c	543.6a	8.74a	3.50a	0	0	0/14
Merensky II	0.02c	409.0abc	7.81abc	2.84ab	0	1	0/17
VC 241	0.06c	238.4defg	6.19defg	1.41cd	0	0	0/16
Uzi	0.29bc	504.3ab	8.57ab	2.76ab	2	0	1/17
Steddom	0.36bc	376.1bcde	7.07bcd	2.43bc	0	0	1/14
Thomas	0.44bc	388.5bcd	6.75cde	1.12de	0	0	1/17
Guillemet	0.59bc	192.0fgh	4.90fgh	1.12de	3	1	2/17
Spencer sdlg	0.63bc	225.8efg	5.24efgh	1.56cd	0	0	2/16
Leo	0.67bc	288.2cdef	5.89defgh	1.60cd	0	0	2/15
Spencer clonal	0.69bc	163.8fgh	4.65gh	1.54cd	0	0	5/16
Duke 7	1.00b	129.3gh	4.38h	1.47cd	0	0	3/15
G755A	0.16b	294.1cdef	5.86defgh	1.56cd	2	1	3/16
PolyN	4.12a	65.6h	1.26i	0.24e	0	0	14/17

<sup>1</sup> Mean values in each column followed by identical letters are not statistically different according to Waller's k-ratio t test.