

## **Screening and Evaluation of New Rootstocks with Resistance to *Phytophthora cinnamomi* 2004**

### **Continuing Project: Year 13 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 are currently attempting to import two new rootstocks from South Africa which have been selected for extremely high yields as well as *Phytophthora* resistance. They are Super #3 and Super #4. Two other excellent rootstocks from their breeding blocks are Ft 3 and V 100. We are also bringing in *Phytophthora* resistant material from Chile.

We still have genetically engineered avocado rootstocks from Richard Litz, University of Florida. We would like to verify they do contain chitinase or gluconase genes before we produce clones for testing.

#### **Breeding Program**

We have screened approx. 2000 seeds from the breeding blocks for resistance to *Phytophthora cinnamomi* in 2003. We have retained 68, which showed a high degree of resistance. Most of these varieties had maternal parents of G6, Barr Duke, Spencer, UC 2001, Thomas, Pond or Margy. This is the first time we have tested second generation fruit from trees which originally

came from the breeding block. 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 57 seedlings from the breeding blocks, which have shown exceptional resistance to *Phytophthora cinnamomi* after extensive testing. Twenty-two of these are being field-tested. Thirty-five more are ready for field-testing. Three varieties, Zentmyer, Uzi and Steddom are being patented and will be released to the growers as soon as possible.

We are now covering trees with a mesh screen and are using beehives in an attempt to get more crosses between varieties. We now intend to harvest pollen from selected varieties and allow the bees to spread it to the maternal parent. This will allow us to manage and create the crosses we are seeking. We are also picking off bloom of early varieties to force them into a later bloom which will coincide better with the bloom of late 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, Lovatt, VC 207 and VC 218.

In 2003 a new breeding block for salt resistance was established at Agricultural Operations in Riverside. Varieties in this salt block will include Merensky I, Merensky II, Toro Canyon, VC 207, VC 208 and VC 801. Seeds from this block will be harvested and planted on to a strip of land donated by Harlan Beck in Escondido, CA. He will water these trees with extremely salty water and after two years, salt resistant varieties will be harvested and returned to Riverside for cloning further testing. In 2004 a new dwarfing plot consisting of Wilig (South Africa), Erin (PP 21 maternal parent D9), Frolic (PP37 maternal parent D9) and Witney (PP41 maternal parent D9) were set up in Agricultural Operations at UCR.

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

Intensive greenhouse experiments involving the root rot resistance of Elinor (PP28, maternal parent D9), Eddie (PP40, maternal parent Toro Canyon), Anita (PP35, maternal parent UC2001), Dirac (PP36, maternal parent UC 2001) and Thomas were carried out in the greenhouse. Anita had the largest numbers of roots surviving attack by *Phytophthora cinnamomi*. There were no significant differences in the percentage of root length reduced by *P. cinnamomi*. However, root weight reduction by *P. cinnamomi* was 0% for Anita, 18% for Elinor, 44% for Eddie, 57% for Dirac and 58% for Thomas. Shoot weight reduction by *P. cinnamomi* was 8% for Anita, 2% for Elinor, 11% for Eddie, 6% for Dirac and 38% for Thomas. There were no significant differences in the rhizosphere populations of *P. cinnamomi*. All varieties look better than Thomas and Anita seems to be highly resistant to *P. cinnamomi*. Plants being grafted for intensive greenhouse studies in 2005 include Thomas, Medina (PP22, maternal parent Thomas), Witney (PP41

maternal parent Duke 9), Johnson (PP42, maternal parent Duke 9), Fred (PP 44, maternal parent UC 2001).

## Field Evaluation

We now have 29 field trials (6,500+ trees) testing 55 clonal root rot tolerant rootstocks throughout Southern California. The following are brief summaries of the older trials.

A 6-year old trial established in Carpinteria CA in salty soil under heavy root rot pressure was rated as follows for greatest to least yield. Merensky II (Dusa-South Africa), Thomas, VC 256 (West Indian-Israel), Zentmyer ( PP4-maternal parent Barr Duke). Merensky II also had the largest fruit. Trees were rated from healthiest to the poorest: VC 256 (West Indian-Israel), Merensky II (Dusa- South Africa), Thomas and Zentmyer (PP4- maternal parent Barr Duke). Tree sizes from largest to smallest were: Merensky II (Dusa- South Africa), Zentmyer (PP4-maternal parent Barr Duke), Thomas and VC 256 (West Indian-Israel). Fruit set ratings from heaviest to lightest are: Merensky II (Dusa- South Africa), Thomas, Zentmyer (PP4- maternal parent Barr Duke) and VC 256 (West Indian-Israel). A few VC 207 (Day –West Indian -Israel) were planted at this site and they have virtually no salt damage. Salt damage for the rest of the varieties, from least to worst were VC 256 (West Indian- Israel), Merensky II, ( Dusa- South Africa), Thomas and Zentmyer (PP4- maternal parent Barr Duke). Thomas and Zentmyer are far more susceptible to salt damage than the other varieties. Nutrient uptake of N, P, K, Na, Zn, Mn, Cu, and Fe, did not vary among the rootstocks. However, VC 256 and Merensky II took up more Ca than Thomas and Zentmyer. Thomas took up less Mg than Zentmyer, Merensky II and VC 256. Thomas and Zentmyer took up more Cl than VC 256 and Merensky II. VC 256 took up more boron than Merensky II which took up more than Thomas and Zentmyer. Only Merensky II and VC 256 are performing adequately in this difficult plot.

A 5-year old trial established in Temecula CA on root rot infested soil. It was rated for greatest to least yield as follows: Merensky III (Evstro- South Africa), Thomas, Zentmyer (PP4-maternal parent Barr Duke), Toro Canyon and Duke 7. It rated as follows from healthiest to poorest: Thomas, Zentmyer (PP4- maternal parent Barr Duke), Toro Canyon, Merensky III (Evstro-South Africa) and Duke 7. 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: Thomas, Zentmyer (PP4- maternal parent Barr Duke), Merensky III (Evstro-South Africa), Duke 7 and Toro Canyon. Duke 7 is failing in this plot.

A 5-year old trial established in Escondido, CA on root rot infested soil. Yields are rated from greatest to least as follows (Table 1): Rio Frio (Guatemala), Zentmyer (PP4- maternal parent Thomas), Merensky II (Dusa-South Africa), Uzi (PP14-maternal parent G6), Merensky I (Latas-South Africa), Spencer seedling (Pauma Valley), Steddom (PP24-maternal parent Toro Canyon), Thomas, VC 241 (Israel), Leo (Brokaw selection), Spencer (Pauma Valley), G755A (*P. schiedeana* x *P. americana* seedling), Guillemet (PP15-maternal parent Thomas), Duke 7 and Poly N (polyploid UCLA). Zentmyer produced the largest fruit. Tree health rated as follows

from healthiest to poorest : Merensky I (Latas-South Africa), VC 241 (Israel), Rio Frio (Guatemala), Zentmyer (PP4- maternal parent Thomas), Merensky II (Dusa-South Africa), Spencer seedling (Pauma Valley), Uzi (PP14-maternal parent G6), Steddom (PP24-maternal parent Toro Canyon), Thomas, Leo (Brokaw selection), Guillemet (PP15-maternal parent Thomas), Duke 7, Spencer (Pauma Valley), G755A (*P. schiedeana* x *P. americana* seedling), and Poly N (polyploid, UCLA). Tree sizes from largest to smallest were: Uzi (PP14-maternal parent G6), Merensky I (Latas-South Africa), Merensky II (Dusa- South Africa), Steddom (PP24-maternal parent Toro Canyon), Zentmyer (PP4-maternal parent Barr Duke), Thomas, Rio Frio (Guatemala), G755A (*P. schiedeana* x *P. americana* seedling), VC 241 (Israel), Leo (Brokaw selection), Spencer seedling (Pauma Valley), Spencer (Pauma Valley), Guillemet (PP15-maternal parent Thomas), Duke 7 and Poly N (polyploid UCLA). Interesting results from the leaf analysis indicate Zentmyer, Merensky I and Guillemet take up the most nitrogen with Rio Frio, VC 241 and G755A taking up the least. VC 241 takes up very little phosphorous. Uzi and Rio Frio take up the most calcium with Leo, Poly N and Guillemet taking up the least. Duke 7 takes up the most potassium with Steddom and Uzi taking up the least. Zentmyer, Spencer and the Spencer seedling take up the most boron with Poly N, Uzi and Guillemet taking up the least. Chloride uptake from least to most (Table 2) is: Rio Frio, Merensky II (Dusa), Poly N, Merensky I (Latas), Duke 7, Spencer seedling, VC 241, Guillemet, Zentmyer, Spencer clonal, Thomas, Leo, Steddom, G755A, and Uzi. Only Poly N and G755A are performing poorly in this trial. VC 241 may be a dwarfing rootstock. Rio Frio is a surprise and is performing very well. Merensky I and II, Uzi, Zentmyer and Steddom are all excellent rootstocks at this site.

A 5-year old trial established in Carpinteria, CA on root rot infested soil experienced some water stress in the past year. Yield was rated from greatest to least: Uzi (PP14-maternal parent G6), Thomas, Merensky II (Dusa-South Africa), Zentmyer (PP4-maternal parent Barr Duke), Merensky I (Latas-South Africa), Mckee (PP19-maternal parent UC 2001), Merensky III (Evstro-South Africa), Merensky IV (South Africa), Aguacate de Mico (Mexico), Poly N (polyploid –UCLA). Tree health 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, Mckee (PP19-maternal parent UC 2001), Merensky IV (South Africa), 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 III (Evstro-South Africa), Merensky I (Latas-South Africa), Mckee (PP19-maternal parent UC 2001), Merensky IV (South Africa), Aguacate de Mico (Mexico), and Poly N (polyploid –UCLA). Fruit set rating from heaviest to lightest is as follows: Zentmyer (PP4-maternal parent Barr Duke), Uzi (PP 14, maternal parent G6), Merensky I (Latas-South Africa), Merensky II (Dusa- South Africa), Thomas, Mckee (PP19-maternal parent UC 2001), Merensky III (Evstro-South Africa), Merensky IV (South Africa), Aguacate de Mico (Mexico), and Poly N (polyploid –UCLA). Only Uzi, Thomas, Zentmyer, and Merensky II are now performing well in this trial. It appears that Uzi, and Zentmyer are able to thrive even when stressed for water.

A 5-year old trial in Escondido, CA on root rot infested soil was rated as follows for yield from highest to lowest: Zentmyer (PP4-maternal parent Barr Duke), Thomas, Aguacate de Mico (Guatemala). Tree health 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). None of the trees in this plot are performing adequately. Salt stress is impacting both the Zentmyer and Thomas.

A 4-year old trial in Escondido, CA on root rot infested soil was rated as follows from healthiest to poorest: Thomas, Mckee (PP19, maternal parent UC2001), VC 256 (Israel). Tree size ranked from largest to smallest was: Mckee (PP19, maternal parent UC2001), Thomas, VC 256 (Israel). Yield from greatest to least was: VC 256 (Israel), Mckee (PP19, maternal parent UC2001), Thomas. None of the varieties in this plot are performing adequately.

A 4-year old trial established in Carpinteria CA in salty soil under heavy root rot pressure was rated for yield from heaviest to lightest: Toro Canyon (Brokaw selection), Merensky II (Dusa, South Africa), Mckee (PP19, maternal parent UC2001), Zentmyer (PP4-maternal parent Barr Duke). Trees were rated as follows from healthiest to the poorest: Merensky II (Dusa, South Africa), Toro Canyon (Brokaw selection), Mckee (PP19, maternal parent UC2001), Zentmyer (PP4-maternal parent Barr Duke). Tree size was rated from largest to smallest was: Zentmyer (PP4-maternal parent Barr Duke), Toro Canyon (Brokaw selection), Merensky II (Dusa, South Africa), Mckee (PP19, maternal parent UC2001). Fruit set rating from largest to smallest was: Toro Canyon (Brokaw selection), Merensky II (Dusa, South Africa), Mckee (PP19, maternal parent UC2001), Zentmyer (PP4-maternal parent Barr Duke). Zentmyer was severely damaged by the salt.

A 4-yr old trial in Ventura, CA on root rot infested soil was rated as follow from healthiest to poorest: Zentmyer (PP4, maternal parent Barr Duke), Thomas, Pond (PP29, maternal parent G6), Mckee (PP19, maternal parent UC2001), D9. Tree size was rated from largest to smallest was: Thomas, Pond (PP29, maternal parent G6), Zentmyer (PP4, maternal parent Barr Duke), Mckee (PP19, maternal parent UC2001), D9. This is a severe site and only the Zentmyer is performing adequately.

A 4-yr old trial from Santa Barbara, CA on root rot infested soil was rated as follows from healthiest to poorest: Zentmyer (PP4, maternal parent Barr Duke), Merensky II (Dusa, South Africa), Steddom (PP24-maternal parent Toro Canyon), Parida (Brokaw selection), Merensky III (Evstro-South Africa), Merensky I (Latas-South Africa), Guillemet (PP15-maternal parent Thomas), Thomas, UC 2023 (*G755C-P. schiedeana x P. americana* seedling), VC 207 (Day-Israel). Tree size from largest to smallest was: Merensky II (Dusa), Parida, Merensky III (Evstro), Merensky I (Latas), Zentmyer, Steddom, Thomas, Guillemet, VC 207 (Day), UC2023. The Guillemet, Thomas, UC 2023 and the VC 207 (Day) are not performing well at this site.

A 3-yr old trial in Santa Paula, CA on root rot infested soil was rated as follows from healthiest to poorest: Merensky I (Latas, South Africa), Merensky II (Dusa, South Africa), Zentmyer (PP 4, maternal parent Barr Duke), Merensky III (Evstro, South Africa), Crowley ( PP 34-maternal parent UC2001), VC 256 (West Indian, Israel), Toro Canyon, VC 207 (Day-Israel), Duke 9 (Irradiated Duke seedling), Thomas, Leo (Brokaw selection), Erin (PP 21 maternal parent Duke 9), Parida (Brokaw selection), Baillard (Brokaw selection), UC 2001 (Duke 7 seedling), UC 2011 (Guatemala), Barr Duke (Duke seedling) and G755A (*P. schiedeana x P. americana* seedling). Tree size from largest to smallest was: Merensky I (Latas), VC 256,

Merensky II (Dusa), Toro Canyon, Zentmyer, Merensky III (Evstro), VC 297 (Day), Thomas, Crowley, Parida, Duke 9, Leo, Baillard, UC 2001, UC2011, Erin and G755A . Baillard, UC 2001, UC 2011, Barr Duke and G755A are not performing well at this site. G755 appears to be damaged by the cold. Erin appears to be a dwarfing rootstock.

A 3-yr old trial in Santa Paula, CA on soil only partially infested with *Phytophthora cinnamomi* was rated as follows from healthiest to poorest: Merensky II (Dusa- South Africa), Pond (PP 29 maternal parent G6), Guillemet (PP 15 maternal parent Thomas), Mckee (PP 19 maternal parent UC 2001), Zentmyer (PP4, maternal parent Barr Duke), Duke 9 (Irradiated Duke seedling), Steddom (PP 24 maternal parent Toro Canyon), Crowley ( PP 34-maternal parent UC2001) and Thomas. Tree size from largest to smallest was: Merensky II (Dusa), Pond, Mckee, Zentmyer, Thomas, Duke 9, Crowley, Guillemet and Steddom. All trees are growing very well at this location. There is little evidence of root rot at this time.

A 3-yr old trial near Temecula on *Phytophthora* infested soil was rated as follows from healthiest to poorest: Zentmyer (PP4, maternal parent Barr Duke), Pond (PP 29 maternal parent G6), Elinor (PP 28, maternal parent D9), Guillemet (PP 15 maternal parent Thomas), Uzi (PP14 maternal parent G6), Crowley ( PP 34-maternal parent UC2001), Steddom (PP 24 maternal parent Toro Canyon), Thomas, G755A (*P. schiedeana* x *P. americana* seedling) and Spencer seedling (survivor tree Pauma Valley). Tree size from largest to smallest was: Pond, Steddom, Thomas, Zentmyer, Uzi, Guillemet, G755A, Elinor, Crowley and Spencer seedling. Only G755A and the Spencer seedling were performing inadequately at this site. *Armillaria* root rot was found in this plot which may be impacting the data. As a result this plot will be dropped from the program.

Six new field trials were established in 2004, three in Santa Barbara Co., one in San Diego Co., and two in Riverside Co. These trials included: Erin (PP21,maternal parent Duke 9), Martin (PP26, maternal parent Duke 9), Elinor (PP28, maternal parent Duke 9), Pond (PP29, maternal parent G6), Margy (PP33, maternal parent Duke 9), Crowley (PP34, maternal parent UC 2001), Anita (PP35, maternal parent UC 2001), Dirac (PP36, maternal parent UC 2001), Frolic (PP37, maternal parent Duke 9), Eddie (PP40, maternal parent Toro Canyon), Witney (PP41, maternal parent Duke 9), Rio Frio (Guatemala), Uzi (PP 14 maternal parent G6), Medina (PP 22 maternal parent Thomas), VC207 (Day, Israel), VC 218 (West Indian, Israel), VC 225 (West Indian, Israel), CI #1 (West Indian, Canary Islands), VC 801 (West Indian-Israel), VC 256 (West Indian-Israel), Fred (PP 44-maternal parent UC 2001), Campbell (PP43 maternal parent UC 2001), Steddom (PP 24 maternal parent Toro Canyon), Afeck (PP 18 maternal parent Thomas), Thomas, G2035 (Guatemala) and Downer (PP52, Spencer seedling).

Trees being prepared for planting in 2006 include: Afeck (PP 18 maternal parent Thomas), Gray (PP 25 maternal parent G6), Martin (PP26, maternal parent Duke 9), Eddie (PP40, maternal parent Toro Canyon), Johnson (PP42 maternal parent Duke 9), Campbell (PP43 maternal parent UC 2001), Fred (PP 44-maternal parent UC 2001), CI #2 (Canary Island), SA-1 (Lansfield South Africa), Thomas, VC 218 (West Indian-Israel), VC 801 (West Indian-Israel)), VC 241 (West Indian-Israel), VC 207 (Day-Israel)), VC 225 (West Indian- Israel), Berg (PP5 maternal parent Duke 9), Rio Frio (Guatemala), Uzi (PP 14 maternal parent G6), Dirac (PP 36 maternal parent UC 2001), Witney (PP41, maternal parent Duke 9) and Downer (PP52, Spencer seedling).

## 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), and Steddom (PP24-maternal parent Toro Canyon). Zentmyer (PP4- maternal parent Barr Duke) is also growing well but is sensitive to salt. We are preparing to release these 4 rootstocks to growers. New rootstocks which appear to be showing promise are Rio Frio (Guatemala), Medina (PP22, maternal parent Thomas), Anita (PP35 maternal parent UC 2001) and Afeck (PP18, maternal parent Thomas). Erin (PP21 maternal parent D9) appears to dwarf Hass avocado. It might be useful for dense plantings, backyard trees, or for pollinator varieties. Witney (PP 41 maternal parent D9) and Frolic (PP 37 maternal parent D9) are slow growing varieties that set fruit quickly and stay relatively small. They could be used for dense plantings at close spacing.

Table 1. Fruit yield of Hass avocados growing on various rootstocks in Escondido, CA, 2002 <sup>1</sup>

| Rootstock    | Total fruit weight (kg) | Individual fruit weight (kg) | Rootstock      | Total fruit weight (kg) | Individual fruit weight (kg) |
|--------------|-------------------------|------------------------------|----------------|-------------------------|------------------------------|
| Rio Frio     | 24.7 a                  | 0.19 abc                     | Thomas         | 15.0 abc                | 0.17 abc                     |
| Zentmyer     | 21.0 ab                 | 0.23 a                       | VC241          | 12.2 abcd               | 0.20 abc                     |
| Merensky II  | 18.6 ab                 | 0.21 ab                      | Leo            | 11.3 bcd                | 0.15 abc                     |
| Uzi          | 18.3 ab                 | 0.18 abc                     | Spencer clonal | 11.3 bcd                | 0.14 bcd                     |
| Merensky I   | 18.0 ab                 | 0.16 abc                     | G755A          | 9.6 bcd                 | 0.12 cd                      |
| Spencer sdlg | 17.0 ab                 | 0.17 abc                     | Guillemet      | 8.4 bcd                 | 0.20 abc                     |
| Steddom      | 16.6 abc                | 0.17 abc                     | Duke 7         | 3.9 cd                  | 0.13 bcd                     |

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

Table 2. Leaf analysis of chlorine on Hass avocado growing on various rootstocks in Escondido, CA, 2002

| Rootstocks     | Chlorine (ueq/g <sup>12</sup> ) | Rootstocks       | Chlorine (ueq/g <sup>12</sup> ) |
|----------------|---------------------------------|------------------|---------------------------------|
| Uzi            | 16.79 a                         | VC241            | 8.92 de                         |
| G755A          | 13.21 b                         | Spencer seedling | 8.26 e                          |
| Steddom        | 12.96                           | Duke 7           | 8.06 e                          |
| Leo            | 12.77 b                         | Merensky I       | 5.10 f                          |
| Thomas         | 11.83 bc                        | Poly N           | 4.51 fg                         |
| Spencer clonal | 10.79 bcd                       | Merensky II      | 4.35 fg                         |
| Zentmyer       | 10.78 bcd                       | Rio Frio         | 2.39 g                          |
| Guillemet      | 9.74 cde                        |                  |                                 |