

Results of Recent Tests for Root Rot Tolerance in Avocado Rootstocks in California

J. A. Menge, B. S. McKee F.B. Guillemet and E. C. Pond

Dept. Plant Pathology, University of California, Riverside

SUMMARY

Rootstocks from different sources have been tested for tolerance to avocado root rot caused by *Phytophthora cinnamomi* in infested soil in the greenhouse and in replicated field plots. Under greenhouse conditions, clonal rootstocks were rated for the percent of healthy roots after three months in *P. cinnamomi*-infested soil. The following rootstocks are in order of greatest to least percent healthy roots: UC2011 (Duke-Statom seedling), D9 (irradiated Duke seedling), UC2003 (survivor tree, Escondido, CA), Velvick (Australia), Spencer (survivor tree, Pauma Valley, CA), Thomas (survivor tree, Escondido, CA), Evstro (South Africa), Aguacate de Mico (Guatemala), Krupp (survivor tree, Escondido, CA), UC2002 (Barr-Duke seedling), Rollie (survivor tree, Santa Barbara, CA), Borchard (susceptible control), CRI-80 (Costa Rica), Hibbard (survivor tree, Pauma Valley, CA) and Peru #1 (Peru). When rated for the percent reduction in root weight caused by *P. cinnamomi*, the rootstocks were reorganized into the following order from least to greatest: Velvick, Spencer, Krupp, UC2011, Evstro, Rollie, Thomas, D9, Aguacate de Mico, CRI-80, Borchard, UC2002, Peru #1, UC2003 and Hibbard. In one field trial avocado trees rated from healthiest to most diseased were: Thomas, UC2011, Duke 9, Queretaro (survivor tree, Mexico), Duke 7, Hibbard. and CRI-80. In a second field trial, avocado trees rated from healthiest to most diseased were: Thomas, Evstro, Duke 7, Topa Topa (susceptible control), Golden (Duke 6 seedling), Velvick and Aguacate de Mico. In a third field trial avocado trees were rated from healthiest to most diseased were: Thomas, UC2001 (Duke 7 seedling), Toro Canyon (Brokaw selection) and G755B (*P. shiedeana* x *P. americana* seedling, Guatemala).

KEYWORDS

Phytophthora cinnamomi

INTRODUCTION

Phytophthora root rot of avocado (*Persea americana* Mill.) caused by *Phytophthora cinnamomi* Rands is the limiting factor for avocado production in many areas of the world (Zentmyer, 1980; Pegg et al., 1982; Kotze and Darvas, 1983; Coffey, 1987). In California, it affects 60% to 75% of the groves and loss in 1987 was estimated to be approximately \$30 million (Coffey, 1987).

The best long-term solution for controlling avocado root rot is the use of *Phytophthora*-tolerant rootstocks. Zentmyer began the search for *Phytophthora*-resistant rootstocks in the 1940's and this led to the selection of Duke 6 and Duke 7 varieties (Zentmyer, 1963). In 1975, Duke 7 became the first *Phytophthora*-tolerant rootstock to be commercially successful. More recently the Thomas variety has emerged as the rootstock of choice for replanting *Phytophthora cinnamomi*-infested sites (Menge et al., 1992). Since then, the UC Riverside project funded by the California Avocado Commission has continued to select and breed for *Phytophthora* tolerant varieties. This study is an update on progress in the search for *Phytophthora*-tolerant avocado varieties.

MATERIALS AND METHODS

Selected rootstocks described in Table 1 were rated for resistance to *P. cinnamomi* under greenhouse conditions. Clonal rootstocks were produced as described by El-Hamalawi *et al.* (1995) using the methods of Frolich and Platt (1971). However, scion varieties were not grafted on top of the rootstocks. The clonal rootstocks were planted into 12-L-pots, containing an avocado soil which was a Placenta sandy loam with the following soil characteristics; pH, 5.4; organic matter 3.16%; EC, 2.50 millimhos/cm; NH₄-N, 5.1 ppm; NO₃-N, 84 ppm; P, 75 ppm; K, 85 ppm; Ca, 13.6 meq/l; Mg, 6.9 meq/l; Na, 6.5 meq/l; Zn, 95 ppm; Mn, 21.8 ppm; Cu, 0.86 ppm and Fe, 60 ppm. The soil was steamed for 24 hr at 80C to destroy the natural inoculum of *P. cinnamomi* in the soil. Part of the soil was reinfested with inoculum of *P. cinnamomi* at a rate of 0.1% w/v by mixing soil and inoculum for 15 min in a cement mixer. The inoculum was prepared by twice autoclaving millet seed (121C; 15psi) in 2-L flasks for one hour and then adding inoculum of *P. cinnamomi* from agar plates and allowing the fungus to grow for three weeks. Ten to 20 replicate clonal rootstocks of each selection were transplanted to *P. cinnamomi* infested soil and a similar number were transplanted to non-infested soil. The rootstocks were grown for three months in the greenhouse at 23-36C. Rootstocks were fertilized once per week with a 14% Hoagland's solution (Hoagland and Arnon, 1939). After three months, roots were washed from the pots, separated from the tops, weighed and the percent of healthy roots was visually estimated. Root weights from *Phytophthora*-infested soil were compared with root weights from non-infested soil to compute the percent reduction in root weight caused by *P. cinnamomi*. Experiments were conducted over a period of four years. Thomas rootstocks were present in each experiment and were used to normalize the results for the comparison between experiments.

Clonal rootstocks with Hass scions, produced as described above, were produced commercially by Brokaow Nursery, Saticoy, California and C&M Nursery, Nipomo, California. Rootstock varieties described in Table 1 were planted in commercial sites near Irvine, Somis and Carpinteria California (Tables 3, 4 and 5), which were naturally heavily infested with *P. cinnamomi*. All trials were randomized block designs with 20 replicate trees per rootstock variety. After three years of growth, trees were rated for appearance and canopy volume and stem diameters were measured using methods described in Menge *et al.* (1992).

RESULTS AND DISCUSSION

Table 1 lists all of the rootstocks used in this study and their pertinent characteristics. After exposure to *P. cinnamomi* in the greenhouse, the following rootstocks were placed in order of greatest to least percent of healthy roots: UC2011, D9, UC2003, Velvick, Spencer, Thomas, Evstro, Aguacate de Mico, Krupp, UC2002, Rollie, Borchard, CRI-80, Hibbard and Peru #1 (Table 2). Rootstocks exhibiting more healthy roots than Thomas (UC2011, D9, UC2003, Velvick and Spencer) are considered to be quite tolerant of *P. cinnamomi* since it is considered to be the best rootstock for planting in *P. cinnamomi*-infested soil in California (Menge, *et al.* 1992). Borchard is considered a susceptible rootstock and, therefore, rootstocks ranked below Borchard (CRI-80, Hibbard and Peru #1) are not suitable for planting in *P. cinnamomi*-infested sites. When rated for the percent

reduction in root weight caused by *P. cinnamomi*, the rootstocks were reorganized into the following order from least to greatest: Velvick, Spencer, Krupp, UC2011, Evstro, Rollie, Thomas, D9, Aguacate de Mico, CRI-80, Borchard, UC2002, Peru #1, UC2003 and Hibbard (Table 2). Krupp and Rollie grew very poorly in the soil provided so that, even without *P. cinnamomi*, roots were very small. This accounted for the small additional reduction caused by *P. cinnamomi*. UC2003 apparently has the ability to produce abundant roots but is damaged severely by *P. cinnamomi*.

In the field trial at Irvine (Table 3), trees rated from healthiest to most diseased were: Thomas, UC2011, Duke 9, Queretaro, Duke 7, Hibbard. and CRI-80. Thomas appeared to be the superior tree since it also had the largest stem diameter and canopy volume. Queretaro, Duke 7, Hibbard and CRI-80 were significantly poorer trees as judged by appearance and trunk diameters.

In the field trial at Somis (Table 4), avocado trees rated from healthiest to most diseased were: Thomas, Evstro, Duke 7, Topa Topa, Golden, Velvick and Aguacate de Mico. Thomas was clearly the superior tree since it also had the largest trunk diameter and canopy volume. Evstro also performed well and was not significantly different from Thomas with regard to appearance and canopy volume. Topa Topa is considered susceptible to *P. cinnamomi*, so those trees performing worse than Topa Topa (Golden, Velvick and Aguacate de Mico) are not considered suitable for planting in *P. cinnamomi*-infested soil. Velvick, which had performed well in the greenhouse, did not grow well under field conditions.

The field trial in Carpinteria survived a freeze during its second year, which severely damaged the trial. Avocado trees rated from healthiest to most diseased were: Thomas, UC2001, Toro Canyon and G755B, however, there was no statistical difference in appearance between any of the varieties. Only G755B had significantly smaller canopy volume than the other varieties. The freeze may have damaged this Guatemalan variety more than the others.

CONCLUSIONS

Thomas remains the best variety for replanting *P. cinnamomi*-infested sites in California. Evstro and UC2011 performed well at one field site.

ACKNOWLEDGEMENTS

This work was supported by grants from the California Avocado Commission.

LITERATURE CITED

- Coffey, M. D. 1987. *Phytophthora* root rot of avocado: an integrated approach to control in California. Plant Dis. 71: 1046-1052.
- El-Hamalawi, Z.A., J.A. Menge, and F. B. Guillemet. 1995. Infection court and factors affecting the expansion of stem canker of avocado caused by *Phytophthora citricola*. Plant Dis. 79: 384-388.
- Frolich, E. F.; and R. G. Platt. 1971. Use of the etiolation technique in rooting avocado cuttings. Calif. Avocado Soc. Yrbk. 55: 97-109.
- Hoagland, D. R., and D. I. Arnon. 1939. The water culture method of growing plants without soil. Calif. Agri. Exp. Sta. Circ. 347.
- Kotze, J. M., and E. M. Darvas. 1983. Integrated control of avocado root rot. California Avocado Soc. Yrbk. 67: 83-86.
- Menge, J. A., F. B. Guillemet, S. Campbell, E. Johnson, and E. Pond. 1992. The performance of rootstocks tolerant to root rot caused by *Phytophthora cinnamomi* under field conditions in Southern California. Proc. Second World Avocado Cong. P. 53-59.
- Pegg, K. G., L. I. Forsberg, and A. W. Whiley. 1982. Avocado root rot. Queensland Agric. J. 108: 162-168. Zentmyer, G. A. 1963. The Duke avocado. Calif. Avocado Soc. Yrbk. 47: 28-36.
- Zentmyer, G. A. 1980. *Phytophthora cinnamomi* and the diseases it causes. Amer. Phytopath. Soc. Monograph 10, 96p.

Table 1.
Description of rootstocks used in this study.

| Rootstock | Horticultural race | Geographic origin | Comments |
|------------------|---|--------------------------|--|
| Aguacate de Mico | Guatemalan | Guatemala | |
| Borchard | Mexican | Camarillo | Standard clonal root stock with low <i>Phytophthora</i> resistance |
| CR1-80 | West Indian | Costa Rica | |
| D9 | Mexican | UC Riverside | Irradiated Duke seedling |
| Duke 7 | Mexican | UC Riverside | Duke seedling |
| Evstro | Mexican | South Africa | |
| G755B | Hybrid- <i>P. americana</i> x <i>P. shiedeana</i> | Coban, Guatemala | Market Collection |
| Golden | Mexican | Fallbrook | Duke 6 seedling |
| Hibbard | Mexican | Pauma, Valley | Survivor tree |
| Krupp | Mexican | Escondido | Survivor tree |
| Peru #1 | West Indian | Peru | |
| Queretaro | Mexican | Queretaro, Mexico | Survivor tree |
| Rollie | Mexican | Santa Barbara | Survivor tree |
| Spencer | Mexican | Pauma Valley | Survivor tree |
| Thomas | Mexican | Escondido | Survivor tree |
| Toro Canyon | Mexican | Saticoy | Survivor tree, Brokaw Nursery |
| Topa Topa | Mexican | California | Standard seedling root stock with low <i>Phytophthora</i> resistance |
| UC 2001 | Mexican | Riverside | Duke 7 seedling |
| UC 2002 | Mexican | Fallbrook | Barr Duke seedling |
| UC 2003 | Mexican | Escondido | Survivor tree |
| UC2011 | Mexican | Alta Loma | Duke Statom seedling |
| Velvick | Mexican | Australia | |

Table 2.

Comparison of *Phytophthora cinnamomi*-resistant rootstocks of avocado under greenhouse conditions.

| Rootstock | % healthy roots after 3 months | % reduction in root weight by <i>P. cinnamomi</i> |
|------------------|---------------------------------------|--|
| UC2011 | 86 | 18 |
| D9 | 68 | 43 |
| UC 2003 | 40 | 63 |
| Velvick | 38 | 0 |
| Spencer | 36 | 0 |
| Thomas | 33 | 35 |
| Spencer | 36 | 0 |
| Thomas | 33 | 35 |
| Evstro | 20 | 19 |
| Aguacate | 15 | 43 |
| Krupp | 15 | 0 |
| UC 2002 | 11 | 56 |
| Rollie | 11 | 25 |
| B orchard | 11 | 50 |
| CR1-80 | 10 | 47 |
| Hibbard | 8 | 77 |
| Peru #1 | 1 | 56 |

Table 3.

Growth and appearance of Hass avocados on seven clonal rootstocks grown-for three years in *Phytophthora cinnamomi*-infested soil in Irvine CA under field conditions.

| Rootstocks | Appearance rating^y | Trunk diameter cm | Canopy volume cuM |
|-------------------|--------------------------------------|--------------------------|--------------------------|
| Thomas | 0.35A ^z | 6.49A | 4.28A |
| UC2011 | 0.78AB | 5.29B | 4.19A |
| D9 | 1.38BC | 4.40BCD | 2.17B |
| Queretaro | 1.50BC | 4.50BC | 2.73AB |
| Duke 7 | 1.70CD | 4.09CD | 1.84B |
| Hibbard | 2.42DE | 4.50BC | 2.97 AB |
| CR1-80 | 2.63E | 3.33D | 1.93B |

^y0=completely healthy; 5=dead

^zMeans in each column not followed by identical letters are significantly different (P=0.05) according to ANOVA and mean separation by Waller's k-ratio t test.

Table 4.

Growth and appearance of Hass avocados on seven clonal rootstocks grown for three years in *Phytophthora cinnamomi*-infested soil in Somis CA under field conditions.

| Rootstocks | Appearance rating ^y | Trunk diameter cm | Canopy volume cu M |
|------------------|--------------------------------|-------------------|--------------------|
| Thomas | 0.07A ^Z | 4.19A | 1.56A |
| Evstro | 0.28A | 3.46B | 1.43AB |
| Duke? | 0.45A | 3.43B | 1.25BC |
| Topa Topa | 1.55B | 3.72AB | 1.06C |
| Golden | 2.05BC | 2.42C | 0.74D |
| Velvick | 2.76CD | 1.76D | 0.54D |
| Aguacate de Mico | 3.20D | 2.32C. | 0.59D |

^y0=completely healthy; 5=dead

^zMeans in each column not followed by identical letters are significantly different (P=0.05) according to ANOVA and mean separation by Waller's k-ratio t test.

Table 5.

Growth and appearance of Hass avocados on four clonal rootstocks grown for three years in *Phytophthora cinnamomi*-infested soil in Carpinteria, California under field conditions.

| Rootstocks | Appearance rating ^y | Canopy volume M ³ |
|-------------|--------------------------------|------------------------------|
| Thomas | 1.8A ^Z | 7.15A |
| UC 2001 | 2.1A | 6.74A |
| Toro Canyon | 2.5A | 6.11A |
| G755B | 3.4A | 3.00B |

^y0=completely healthy; 5=dead ^zMeans in each column not followed by identical letters are significantly different (P=0.05) according to ANOVA and mean separation by Waller's k-ratio t test.