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Comparison of Field Resistance to *Phytophthora cinnamomi* in Twelve Avocado Rootstock

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***Abstract. Twelve* avocado *(Persea americana* Mill.) rootstock selections were tip-grafted with a commercial scion, cv. Hass, and evaluated for their field resistance to *Phytophthora cinnamomi* Rands. Percentage difference in trunk cross-sectional area of the inoculated compared to uninoculated rootstock, the overall growth in trunk cross-sectional area, and visual rating of disease severity of the commercial scion were used to evaluate rootstock over 79 weeks. Avocado trees on the rootstock selections Thomas, Martin Grande (G75Sa, b, and c), Barr Duke, and D9 demonstrated the highest level of resistance to *P. cinnamomi,* whereas those on Topa Topa, Borchard, and G6 had the lowest levels. Trees on Duke 7, G1033, and Toro Canyon rootstock were intermediate in their levels of resistance. Among uninoculated rootstock, trees on Thomas and G6 exhibited the greatest growth in trunk cross-sectional area. whereas those on D9 showed the least.**

Phytophthora root rot (PRR), caused by *Phytophthora cinnamomi,* is the principal disease problem of avocados in many areas of the world (Coffey, 1987; Kotzé and Darvas, 1983; Pegg et al., 1982). *P. cinnamomi* was first identified as the causal agent of PRR on avocados in California in 1942 (Wager, 1942). It now affects ≈ 60% to 75% of the groves in the state. In 1987, annual losses from PRR in California were estimated to be about $30 million (Coffey, 1987).

An important feature of the integrated approach for control of PRR is the use of vegetatively propagated clonal rootstock that express moderate resistance to *P. cinnamomi* (Coffey, 1987; Zentmyer, 1980). The identification of moderate resistance in seedlings of the Duke cultivar in the 1950s (Zentmyer, 1963) gave rise to an extensive collecting and screening program of the avocado and other closely related *Persea* sp. from Central America, Mexico, and California (Zentmyer, 1978). Selections that have shown moderate resistance to PRR include Duke 7 and G6 (Zentmyer, 1978).

Recently, the three Martin Grande selections (G755 a, b, c) from Guatemala have exhibited resistance (Coffey, 1987; Coffey and Guillemet, 1987). Other new selections, such as Thomas, also have given good indications of useful resistance in preliminary tests (Coffey, 1987).

The ultimate test of resistance in a rootstock is to evaluate it in the field, grafted with a commercial scion, in the presence of the pathogen. This paper reports on the field performance of avocado trees on 12 rootstock either uninoculated or inoculated with *P. cinnamomi.*

Twenty each of 12 rootstock (Table 1) were propagated as cuttings (Dolan and Coffey, 1986; Frolich and Platt, 1971). The rootstock were rooted in a mix of 1 peat : 1 peflite (v/v), transferred into 10-liter pots, and allowed to develop an extensive root system. Rootstock were tip-grafted with the commercial scion, cv. Hass, 12 months before being planted in the field. The experiment was conducted at the South Coast Field Station near Tustin, Calif., on a San Emigdio sandy loam soil (coarse-loamy, mixed calcareous, thermic Typic Xerofluvents) (Wachtell, 1978) (67% sand, 18% silt, 15% clay, pH 7). Each tree was planted in a 30-cm-diameter hole, 45 cm deep, spaced 4.6 m within a row and 6 m between rows in a completely randomized design. Trees were irrigated with minisprinklers twice a week.

Ten randomly selected trees on each rootstock were inoculated with *P. cinnamomi 4* weeks after planting. The inoculum consisted of *P. cinnamomi* grown on sterilized millet seed for 1 week and then mixed with UC mix C (Baker, 1972) to a final concentration of 30 propagules/g soil dry weight (ppg). The inoculum was placed in two 4 × 15-cm (diameter/depth) holes, positioned opposite each other immediately adjacent to the root ball, which was then covered with a 2.5-cm casing of field soil.

The remaining 10 trees of each selection were used as uninoculated controls. To prevent infection of these trees, each tree was treated with a solution containing the fungicide fosetyl-Al at 3 $mg \cdot ml^{-1}$, initially applied as a 1-liter preplant drench, then as foliar sprays to runoff at monthly intervals for the first 6 months and every 3 months thereafter. A reference point on the trunk of each rootstock was marked with paint and used for diameter measurements. The trunk cross-sectional area (TCSA) was calculated from these diameter measurements. Resistance to PRR was determined by measuring the TCSA at the beginning of the experiment and 79 weeks after inoculation, and then comparing the growth differences between the inoculated vs. uninoculated trees within a rootstock. As well, the overall growth of the trees was compared. These growth differences were expressed as a percentage. The rootstock were also evaluated by rating the tree foliage on a visual scale of 0 to 5, where 0 = healthy and 5 = completely defoliated, 14 and 55 weeks after inoculation.

Seventy-nine weeks after inoculation, trees on Martin Grande, Thomas, D9, and Barr Duke showed the least difference in TCSA

Table 1. Avocado rootstock selections screened for resistance to *Phytophthora cinnmnomi* in a field experiment at the South Coast Field Station near Tustin, Calif.

Rootstock[z] selection	Horticultural race	Geographic origin
Martin Grande (G755a, G755b, G755c)	Hybrid[y]	Coban, Guatemala Market collection
Thomas	Mexican	Escondido, Calif. Field collection, root rot area
D9	Mexican	Riverside, Calif. Irradiated Duke budwood
Barr Duke	Mexican	Fallbrook, Calif. Duke 6 seedling
Duke 7	Mexican	Riverside, Calif. Duke seedling
G1033	Guatemalan	Hawaii Hayes seedling
Toro Canyon	Mexican	Toro Canyon, Calif. Field collection, root rot area
G6	Mexican	Acatenango volcano, Guatemala Field collection
Borchard	Mexican	Camarillo, Calif. Field collection
Topa Topa	Mexican	Ojai, Calif. Seedlings of cultivar Topa Topa

[z]Tops Topa is a seedling rootstock; the remainder are vegetatively propagated cuttings
[y]*Persea americana* × *Persea schiedeana* hybrid (Ellstrand et al. 1986).

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Table 2. Comparison of percentage growth difference in trunk cross-sectional area (TCSA) relative to uninoculated controls and percentage overall growth in TCSA from the planting date of trees on 12 avocado rootstock, 79 weeks after inoculation with *Phytphthora cinnamomi.*

Rootstock	Growth difference' (%)	Overall growth[y] (%)	
		Inoculated	Uninoculated
Topa Topa	86.2 ax	50 c	984 cd
G6	85.4 a	122 bc	1520 ab
Borchard	84.5 a	41 c	1100 bc
Toro Canyon	67.0 ab	254 bc	878 cd
G1033	66.7 ab	254 bc	1130 bc
Duke 7	66.7 ab	188 bc	871 cd
Barr Duke	58.9 bc	178 bc	591 cd
D9	53.3 bcd	169 bc	484 d
Thomas .	50.1 bcd	873 a	1710 a
G755a[w]	47.3 bcd	231 bc	585 cd
G755b[w]	41.9 cd	297 b	586 cd
G755c[w]	38.0 d	315 b	645 cd

'Growth difference in TCSA was calculated as: ((uninoculated – inoculated) /uninoculated) x *100.*
[y]Overall growth TCSA was calculated as: ((TCSA at 79 weeks - initial TCSA)/initial TCSA) ×

'Means within a column followed by a different letter are significantly different according to Duncan's new multiple range test (P= 0.05).
[w]G755a, G755b, and G755c are collectively referred to as Martin Grande.

Table 3. Comparison of visual ratings of 'Hass' avocado trees on 12 rootstock 14 and 55 weeks after inoculation with *Phytophthora cinna - momi.*

Rootstock	Visual rating[z]	
	14 wk	55 wk
Borchard	3.7 a[y]	4.4 a
Topa Topa	.3.1 ab	4.4 a
G6	0.7 de	3.7 ab
G1033	2.2 bc	2.9 bc
D9	1.4 cd	2.8 bc
Toro Canyon	1.2 cde	2.6 bcd
Duke 7	1.1 cde	2.2 cd
G755c[x]	0.7 de	2.2 cd
Barr Duke	0.1 de	1.8 cdc
G755a[x]	0.2 de	1.7 cdc
G755b[x]	1.2 cde	1.4 de
Thomas	0.0 e	0.7 e

'Visual ratings are on, a scale of 0 to 5, where 0 = healthy and 5 = completely defoliated.
[y]Means within a column followed by a different letter are significantly different according to Duncan's new multiple range test (P = 0.05).
[x]G755a, [x]G755b, and G755c are collectively referred to as Martin Grande.

(Table 2). There was no growth difference among trees on the three G755 selections (Table 2). "

Thomas-rooted trees showed by far the greatest overall growth in TCSA of the inoculated trees (Table 2). It was followed by trees on Martin Grande (G755 a, b, and c), G1033, Toro Canyon, Duke 7, Barr Duke, and D9. Trees on G6, Topa Topa, and Borchard showed the least growth in TCSA. Among uninoculated trees, those on Thomas and G6 showed the greatest growth in TCSA, those on D9 the least (Table 2).

At 14 weeks after inoculation, trees on Thomas, Martin Grande, Barr Duke, Duke 7, Toro Canyon, and G6 appeared healthiest based on visual ratings, whereas trees on Borchard and Topa Topa rootstock appeared most diseased (Table 3). These same rankings were maintained 55 weeks after inoculation, except for trees on G6, which by then were no longer significantly different from the susceptible Topa Tops-rooted trees. Generally, trees on uninoculated rootstock appeared healthy and there was no difference in visual ratings, ranging from O to 0.6 at 14 weeks and O to 1.1 at 55 weeks (P = 0.05).

Thomas expressed a level of resistance to PRR equivalent to or greater than the three Martin Grande selections. These selections were more resistant than Duke 7 and G6, as previously reported (Coffey et al., 1988).

In this field experiment, rootstock were artificially inoculated with *P. cinnamomi*, which created a higher level of inoculum density (30 ppg) than the range of 1 to 3 ppg typically found in naturally infested soils (Kellam and Coffey, 1985). Under these conditions, Duke 7 was more resistant to PRR than G6, which is contrary to earlier reports suggesting that Duke 7 and G6 were equally resistant (Coffey, 1987; Zentmyer, 1978; Zentmyer et al., 1988). In fact, Kellam and Coffey (1985) also found that G6 supported a lower population of *P. cinnamomi* and had fewer roots infected than both Topa Topa and Duke 7. However, in our field experiment the level of resistance of G6 was the same as that of the susceptible Borchard and Topa Topa rootstock (Gabor and Coffey, 1988; Kellam and Coffey, 1985). Consistent with our results, Dolan and Coffey (1986) found that etiolated shoots and roots of G6, grown in vermiculite, were more susceptible to *P. cinnamomi* than those of Martin Grande or G1033.

In conclusion, trees on Thomas, Martin Grande, Barr Duke, and D9 were the most resistant to PRR. Trees on Topa Topa, Borchard, and G6 were highly susceptible and those on Duke 7, G1033, and Toro Canyon were intermediate in their susceptibility to PRR.

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