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Avocado Clonal Rootstock Production Trial

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***Abstract.* A project designed to evaluate the performance of 'Hass' on ten avocado rootstocks in the absence of *Phytophthora cinnamomi* has been established at the University of California South Coast Research and Extension Center in southern California. In March, 1991, the fourth year of yield data were collected from the trial. Total yield from years 2 through 5 show the highest cumulative yields from 'Hass' planted on Duke 7 (103.5 kg/tree), and the lowest on G755B (19.5 kg/tree). There were no statistical differences in average fruit size in years 2 to 4. Average fruit weight per tree for these years was 260 g. In the fifth year, average fruit size was smaller (151 g) than in previous years with G755A producing the largest fruit (171 g) and Toro Canyon the smallest (121 g).**

Using canopy volume data, the yield efficiencies of 'Hass' on the various rootstocks were calculated. In 1990, Duke 7 and Thomas produced significantly more fruit per cubic meter of canopy than all other rootstocks (P<0.01). This was followed by Topa Topa, Borchard, Toro Canyon, and G1033 with intermediate yield efficiencies. The poorest group of performers were D9 and the three G755 root-stocks. In 1991, the rootstocks differentiated into two statistical groupings (P<0.01); the three G755 rootstocks were again the poorest performers based on a yield per canopy volume basis whereas the remaining rootstocks were statistically similar.

The cost to produce avocados in California has increased substantially in the last decade due largely to rising costs in irrigation water and the widespread incidence of *Phytophthora cinnamomi* (Takele *et al.,* 1992, Coffey, 1987b). The 20-year (1969-70 through 1989-90) average production in California has been 6286 kg/ha, with a high of 9807 kg/ha in 1974-75 and a low of 3042 kg/ha in 1971-72 (Anon., 1991). In order to remain competitive both in the national and international market, it is imperative that tree productivity be increased so that the economic viability of the California industry can be maintained. Wolstenholme (1990) in a review of the factors involved in controlling tree productivity identified vegetative-reproductive competition as a major contributor to relatively low yields in subtropical and tropical trees. Whiley *et al.* (1988, 1991), in fact, has demonstrated the importance of carbohydrate manipulation in managing tree productivity and has identified cultural practices which may be helpful in increasing productivity in established trees.

A long-term approach towards increased tree productivity could be accomplished through a plant breeding program designed to identify both improved rootstock and scion selections. Indeed, this may be the most satisfactory solution given that *Phytophthora cinnamomi* resistance or any other desirable attribute (i.e., salinity or cold tolerance) may also be selected in the same breeding program. Bergh and Martin (1988) have reported the potential for increased fruit production in the Gwen cultivar relative to the Hass cultivar. Whiley *et al.* (1990) reviewed the prospects of other varieties and rootstocks relative to tree productivity.

In the past, the rootstock selection program of the University of California has largely focused on the identification of rootstocks which exhibit varying degrees of tolerance to *Phytophthora cinnamomi* (Coffey, 1987a; Coffey and Guillemet, 1987; Gabor *et al.,* 1990; Zentmyer, 1991). Menge *et al.* (1992) has reviewed the current status of these rootstocks under infested conditions, but little evaluation of the horticultural attributes such as tree productivity, vegetative vigor and fruit quality of these selections have been made under either infested or noninfested settings. A trial was established in 1986 to evaluate the horticultural characteristics of promising clonal rootstocks under non-infested conditions. This paper reports the first 4 years of production data from the trial and illustrates the potential for increasing productivity through root-stock selection.

Materials and Methods

The following clonally propagated rootstocks were selected for testing under *non-Phytophthora cinnamomi* infested conditions at the University of California South Coast Research and Extension Center in Irvine, CA: G755A, G755B, G755C, Duke 7, Borchard, D9, Toro Canyon, Topa Topa, Thomas and G1033. The Topa Topa trees, included to serve as an industry standard under non-infested conditions, are typically propagated as seedling trees but were clonally propagated for this trial. All trees with the exception of Thomas and G1033 were planted in April, 1986. The Thomas and G1033 trees were planted in April, 1987, in preselected sites that were included in the original experimental design.

The plot was designed as a randomized complete block design with 20 single tree replications per rootstock. The trees were planted on 0.5 m high ridge which extended the length of the tree row. The soil type at the experimental site is a mixture of Sorrento loam and San Emigdio sandy loam with an average depth greater than 18m. Trees were spaced 6.1 m x 6.1 m (269 trees/ha). At the time of planting 1 drip emitter (15.1 L/h) was placed at the base of each tree. Two years after planting the drip emitter was replaced with a single low volume minisprinkler (45.4 L/h) placed at the base of each tree. Trees were irrigated as needed using the reference evapotranspiration from the CIMIS system as a guideline (Snyder *et al.,* 1985). Standard fertilization practices for California have been maintained. Samples for leaf analysis have been collected annually since 2 years after planting and have shown that the trees have stayed within the recommended guidelines for nitrogen (Goodall *et al..* 1981).

Trees were harvested each spring in a single harvest (15/2/88; 27/4/89; 19/4/90; and 26/3/91). Total weight and fruit number was recorded for individual trees. Average fruit size was calculated by dividing yield by the number of fruit harvested on an individual tree basis.

Canopy volume was measured approximately 4.5 years after planting. Tree height and canopy width were recorded for individual trees. Two measurements for canopy width were taken; down row canopy width (approximately 1.75 meters from the ground) and across row width. The average of these two values were used. The canopy volume was estimated by assuming the tree approximated the shape of one half of a prolate spheroid. The formula for the volume of a prolate sphere is $V = 4/3\pi ab^2$ where “V” is canopy volume, “a” is the radius of the major semiaxis (tree height) and “b” is the radius of the minor semiaxis (tree width) (Turrell, 1946). Yield efficiency (kg/m^3) was calculated by dividing the yield for an individual tree by its respective canopy volume.

The statistical software package, M-StatC (Freed *et al.,* 1988) was used for data analysis. Mean separation is reported at $P<0.01$ using Duncan's Multiple Range Test.

Results and Discussion

We have now collected 3 years of yield data for all ten rootstocks and 4 years of yield data for all rootstocks except Thomas and G1033 which were planted one year after the remainder of the trial. Table 1 presents the data for both the annual average yield and the average cumulative yield of the various rootstocks. The relative ranking of each rootstock has varied each year in terms of overall productivity, however, a general trend has been observed; the Duke 7, Borchard, and Topa Topa rootstocks lead production in most years. Overall yield has increased approximately eight-fold each year. Although planted one year later and therefore not directly comparable, the Thomas and G1033 root-stocks also show promise as potential high-yielding rootstocks.

When the cumulative data for the first four years after planting is examined, the rootstocks clearly fall into three statistically different categories: those with the highest cumulative yields (Duke 7, Thomas), those with intermediate yields (Borchard, Toro Canyon, Topa Topa and G1033) and those with the lowest cumulative yields (D9, G755A, G755B, G755C) (Data not presented). For the eight rootstocks which were planted in 1986, the rootstocks can again be divided into three statistically different groupings for the 5-year cumulative yield. 'Hass' on either Duke 7 or Borchard resulted in the highest 5-year cumulative yields. The Topa Topa, Toro Canyon, and D9 rootstocks are intermediate followed by the three G755 rootstocks. Although trees in this trial have not yet attained full production, these data indicate that yield, at least in the early stages of tree productivity, can be strongly influenced by the selection of rootstock. The data collected thus far, however, does not reveal any rootstock with superior yield to Duke 7, which is currently considered the industry standard under *Phytophthora cinnamomi* infested conditions (Zentmeyer, 1991; Menge *et al.,* 1992).

It should be noted that the equivalent production per hectare from these trees (Duke 7, 17875 kg/ha or Borchard, 18310 kg/ha) in the 1990-91 commercial season is considerably above either the state average (5125 kg/ha) or the average production of the 'Hass' cultivar in Orange County (10437 kg/ha), the production district in which the trial is being conducted (A. Crane, California Avocado Commission, personal communication). The increase in yield in this trial could be a reflection of several factors, including the fact that the trees are not infected by *Phytophthora cinnamomi,* the trees are located near seedling avocado trees which may be a source of pollen, and the trees are planted into mounded soil. Other than these factors, no obvious difference in cultural care can explain this apparent discrepancy between yields in the trial and average yields for the growing region or the state.

Since field observations seemed to indicate that there may be some differences in overall tree size, canopy volume was measured in order to rank the trees based on relative yield efficiency. Analyzing the data in this manner allowed for correction for any differences in yield data which may have occurred due to tree size. Four and one-half years after planting there were no significant differences in overall canopy volume (Table 2). It is interesting to note, however, that there is considerable variability among the G755 rootstocks which represented both the largest canopy volume (G755C) and one of the smallest (G755A). Evaluating the data in this manner did little to change the overall ranking of the rootstocks based on annual production. Four years after planting, Thomas and Duke 7 had the highest overall yield efficiency followed by G1033, Topa Topa, Borchard, and Toro Canyon. The D9 was intermediate and the G755 rootstocks collectively were the lowest. For the fifth year, the rootstocks fall into three categories: the highest yield efficiency (Topa Topa, Duke 7, Borchard, D9, and Toro Canyon); intermediate yield efficiency (G755A); and lowest yield efficiency (G755C and G755B).

There were no significant differences in average fruit size detected among rootstocks 2 to 4 years after planting (Table 3). For the rootstocks planted in 1986, average fruit size for these three years ranged from 254 g (Year 4) to 264 g (Year 3). The Thomas and G1033 rootstocks also produced similarly sized fruit during years 2-3. Fruit harvested in 1991, regardless of planting date, were substantially smaller than in previous years (average 155 g). There were significant differences detected in average fruit size between rootstocks planted in 1986. These differences were not necessarily related to yield, since average fruit size from the Borchard and Duke 7 rootstocks (the two rootstocks with the highest yields in year 5), was not significantly different than fruit size from the two lowest yielding rootstocks (G755B, G755C).

In conclusion, this project will provide horticultural information pertaining to the vegetative vigor and productivity of selected clonal rootstocks in the absence of

Phytophthora cinnamomi. We have demonstrated from the data collected over the last 5 years that there may be differences due to rootstock on early tree productivity. The information generated from this project will be useful in the short term as an aid to growers in rootstock selection and hopefully in the long term to plant breeding programs.

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Literature Cited

Anon. 1991. Annual report: 1989-90. Calif. Avocado Commission. Santa Ana. CA, USA. p. 52-53.

Bergh, B.O., and G. Martin. 1988. The Gwen avocado. Calif. Avocado Soc. Yrbk. 72:195-207.

Coffey, M.D. 1987a. A look at current avocado rootstocks. Calif. Grower. 11:15-17.

Coffey, M.D. 1987b. Root rot of avocado - an integrated approach to control in California. Calif. Avocado Soc. Yrbk. 71:121-138.

Coffey, M.D. and F. Guillemet. 1987. Avocado rootstocks. Calif. Avocado Soc. Yrbk. 71:173-179.

Freed, R., S.P. Eisensmith, S. Goetz, D. Reicosky, V.W. Smail, and P. Wolberg. 1988. User's Guide to MSTAT-C: A software program for the design, management, and analysis of agronomic research experiments. Michigan State Univ., East Lansing, Ml, USA.

Gabor, B.K., F.B. Guillemet, and M.D. Coffey. 1990. Comparison of field resistance to *Phytophthora cinnamomi* in twelve avocado rootstocks. HortScience 25:1655-1656.

Goodall, G.E., T.W. Embleton, and R.G. Platt. 1981. Avocado fertilization. Univ. of California. Div. of Agricultural Sci., Oakland, CA, USA. Lflt. 2024. 8p.

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. Proceedings of the Second World Avocado Congress, pp. 53-59.

Snyder, R., D.W. Henderson, W.O. Pruitt, and A. Dong. 1985. California irrigation management information system. Final Report. Land, Air, and Water Resources Papers. No. 10013 A, B, C. Dept. of Land, Air, and Water Resources. Univ. of California, Davis, CA, USA.

Takele, E., J.L. Meyer, D.E. Stottlemyer, M.V. Yates, M.L. Arpaia, G.S. Bender, and G.W. Witney. 1992. Economic evaluation of integrated irrigation and fertilization practices of avocados. Proceedings of the Second World Avocado Congress, pp. 577-582.

Turrell, F.M. 1946. Tables of surfaces and volumes of spheres and of prolate and oblate spheroids and spheroidal coefficients. Univ. of California Press, Oakland, CA, USA. 153p.

Whiley, A.W., J.S. Kohne, M.L. Arpaia, and G.S. Bender. 1990. Future prospects with new avocado cultivars and elite rootstocks. S. A. Avocado Growers' Assn. Yrbk. 13:16-20.
Whiley, A.W., J.B. Saranah, B.W. Cull, and K.G. Pegg. 1988. Manage avocado tree growth cycles for productivity gains. Old. Agric. J. 114:29-36.
Whiley, A.W., and B.N. Wolstenholme. 1991. Carbohydrate management in avocado trees for increased production. S. A. Avocado Growers' Assn. Yrbk. 13:25-27.
Wolstenholme, B.N. 1990. Resource allocation and vegetative-reproductive competition: opportunities for manipulation in evergreen fruit trees. Acta Hort. 275:451-459.
Zentmeyer, G.A. 1991. Bringing the beast to bay. Calif. Grower. 15:28,30.

Table 1. Yield (kg/tree) for 'Hass' avocado on selected clonal rootstocks.

Rootstock	Years from Planting				Cumulative
	2	3	4	5	
Planted 1986					
G755A	0.3 b[z]	1.5 c	2.8 d	30.6 b	35.2 c
G755B	0.0 b	1.7 c	1.1 d	16.7 b	19.5 c
G755C	0.0 b	0.8 c	0.9 d	24.6 b	26.3 c
Duke 7	0.6 b	6.7 ab	29.7 a	66.5 a	103.5 a
Borchard	0.4 b	3.8 bc	20.8 b	68.4 a	93.1 a
D9	1.1 b	1.3 c	9.3 cd	57.9 a	69.6 b
Toro Canyon	3.8 a	2.9 c	17.0 bc	61.1 a	84.8 ab
Topa Topa	0.2 b	7.5 a	17.7 bc	64.0 a	89.4 ab
Significance	0.01	0.01	0.01	0.01	0.01
Planted 1987					
Thomas	0.8	3.0	35.2 a	—	39.0 a
G1033	0.2	4.1	19.3 b	—	23.6 b
Significance	NS	NS	0.01		0.01

[z] Mean separation within a column by Duncan's Multiple Range Test; NS = not significant.

Table 2. Canopy volume and yield efficiency for 'Hass' avocado on selected clonal rootstocks.

Rootstock	Canopy Volume (m^3)[z]	Yield Efficiency (kg/m^3) Years from Planting	
		4	5
Planted 1986			
G755A	25.9	0.11 d	1.57 ab
G755B	28.0	0.05 d	0.64 b
G755C	32.3	0.03 d	0.79 b
Duke 7	28.6	1.10 a	2.55 a
Borchard	30.9	0.67 bc	2.47 a
D9	26.2	0.35 cd	2.38 a
Toro Canyon	29.4	0.60 bc	2.19 a
Topa Topa	29.1	0.72 b	2.88 a
Planted 1987			
Thomas	28.5	1.26 a	—
G1033	24.1	0.75 b	—
Significance[y]	NS	0.01	0.01

[z] Canopy volume measured 4.5 years after planting. Calculated volume is a half prolate spheroid ($V = 0.5[4/3\pi ab^2]$) where a is the radius of the tree height and b is the radius of the canopy diameter (Turrell, 1946).

[y] Mean separation within a column by Duncan's Multiple Range Test; NS = not significant.

Table 3. Average fruit size (g) for 'Hass' avocado on selected clonal rootstocks.

Rootstock	Years from Planting			
	2	3	4	5
Planted 1986				
G755A	254[z]	253	218	171 a
G755B	—	232	214	144 abc
G755C		249	240	159 ab
Duke 7	276	275	263	151 ab
Borchard	250	271	288	156 ab
D9	267	288	281	171 a
Toro Canyon	293	276	265	121 c
Topa Topa	263	262	263	138 be
Significance	NS	NS	NS	0.01
Planted 1987				
Thomas	250	252	166	---
G1033	250	290	170	---
Significance	NS	NS	NS	

[z] Mean separation within a column by Duncan's Multiple Range Test; NS = not significant.