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## SHOOT AND ROOT GROWTH CYCLES OF AVOCADO IN SOUTH FLORIDA

Randy C. Ploetz, José L. Ramos, Jorge L. Parrado and Emily S. Shepard

University of Florida, IF AS, Tropical Research and Education Center, 18905 SW 280th Street, Homestead, FL 33031

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### ABSTRACT

Shoot and root growth of grafted avocado (*Persea americana* Mill.) was monitored in rhizotrons constructed of large pots and plexiglass windows. A West Indian cultivar, 'Simmonds', and a Guatemalan X West Indian cultivar, 'Lula', were tested as scions on seedling rootstocks of the West Indian cultivar 'Waldin'. Growth was calculated as linear extension rates (mm day<sup>-1</sup>). Although growth rates of individual shoots and roots varied considerably within trees, conspicuous flushes of shoot and root growth were evident when mean rates of shoot and root growth were plotted over time. Flushes of shoot and root growth were synchronized and alternated on 30 60 day cycles. Shoot growth virtually stopped during the late fall and winter, but root growth, although it slowed to about 1/3 the maximum rates during these seasons, continued throughout the year. This information is relevant to the control of phytophthora root rot of avocado (caused by *Phytophthora cinnamomi* Rands) with fungicides. Since flushes of root growth in avocado precede flushes of shoot growth by 30 60 days, shoot growth flushes could be used to predict the peak occurrence of susceptible host tissue (i.e., actively growing root tips) and, thus, the optimum time for fungicide treatment.

### INTRODUCTION AND REVIEW OF LITERATURE

The Guatemalan and West Indian races of avocado (*Persea Americana* Mill.) and their hybrids dominate commercial production in Florida. A diverse collection of cultivars is currently grown in the state; 25 major and 29 minor cultivars were listed recently by the Florida Avocado Administrative Committee (Anonymous, 1986).

The periodicity of shoot and root growth has been studied for several perennial crops including avocado (Piccone *et al.*, 1987a, b; Whiley, 1987), *Citrus* spp. (Bevington and Castle, 1985; Krishnamurthi *et al.*, 1960; Reed, 1938; Wutscher, 1973), macadamia (*M. integrifolia* Maid. & Btch.) (Stephenson and Cull, 1986) and tea (*Camellia sinensis* L.) (Yamashita, 1985). Information on cycles and the interrelationships between shoot and root growth has direct application to the management of perennial crops.

Our interest in growth cycles of avocado arose during studies on phytophthora root rot,

caused by *Phytophthora cinnamomi* Rands. The disease is important in Florida and other avocado-growing regions (Ploetz and Schaffer, 1989; Zentmyer, 1980). Although phytophthora root rot can be controlled with fungicides (Coffey *et al.*, 1984; Darvas *et al.*, 1984), its optimal management depends on knowing when actively growing root tips, which are the primary susceptible tissue of the host, will be present in an orchard (Whiley *et al.*, 1986; Zentmyer, 1980). Thus, the scheduling of fungicide applications for control of the disease would benefit from reliable information on root growth cycles.

Whiley and co-workers (Piccone *et al.*, 1987a, b; Whiley, 1987) reported a general growth cycle for shoots and roots of avocados grown in Australia (primarily cultivars of Mexican and Guatemalan descent). We are aware of only two studies on the growth and development of cultivars of avocado that are grown in Florida and neither of these papers provided information on root growth or gave quantitative estimates of shoot and root growth (Davenport, 1982; Yenning and Lincoln, 1958). Our objectives in this study were to: 1) describe shoot and root growth cycles for two representative Florida avocado cultivars under cultural and environmental conditions that mimic those found in South Florida avocado orchards, and 2) obtain a quantitative estimate of seasonal shoot and root growth for the cultivars. Portions of this information have been reported previously (Ploetz *et al.*, 1991).

## **MATERIALS AND METHODS**

*Rhizotron construction and use.* Most avocados in South Florida are produced in an unusual soil which, in its native state, is solid limestone (Ruehle, 1963). In order to grow avocados, trenches are carved in the limestone and the limestone surface is scarified.

In other, more typical soils, rhizotrons could be constructed beneath the soil surface in order to examine root behavior. Since the limestone soils in South Florida did not lend themselves to the use of below-ground rhizotrons, we constructed above-ground rhizotrons. The rhizotrons were assembled with rigid plastic pots, 80 cm wide and 60 cm deep, that were cut and fit with transparent plexiglass faces 60 cm wide and 30 cm deep (Fig. 1 A). Each face was parallel to and about 10 cm outside the vertical center axis of the pot and was secured in slots cut in 3 cm-diameter PVC pipes which had been attached to the inside walls of the pot. Each pot had holes in the bottom to allow the free drainage of water and was filled with scarified, native limestone soil from the area (Krome very gravely loam: RupticAlfic Lithic Eutrochets clayey, mixed, hyperthermic; pH ca. 7.5; sand: ca. 65%, silt: ca. 25%, and 25 clay: 10%).

Rhizotrons were elevated on concrete blocks and their exteriors were painted white to prevent heat buildup in the soil (Ploetz *et al.*, 1991). Aluminum shields were made to cover the plexiglass faces and exposed edges and portions of the faces outside the viewing surface were painted with flat black spray paint to exclude light. The shields were removed only when root growth readings were taken.

Each rhizotron was planted with a single, grafted avocado plant that had grown for the previous year in an 8 L pot. Scions of either the West Indian cultivar, 'Simmonds', or the Guatemalan x West Indian cultivar, 'Lula', that were wedge-grafted on seedling rootstocks of the West Indian cultivar 'Waldin' were utilized; the scion and rootstock

cultivars are used commonly in Florida. Four 'Lula' and three 'Simmonds' plants were randomized in a complete block design in full sunlight, and plants were fertilized with 12 g of a 20-20-20 soluble fertilizer in 1 L of water every 2 3 weeks and were irrigated by hand every other day. Plants were established in the rhizotrons for about two months before measurements of shoot and root growth began.

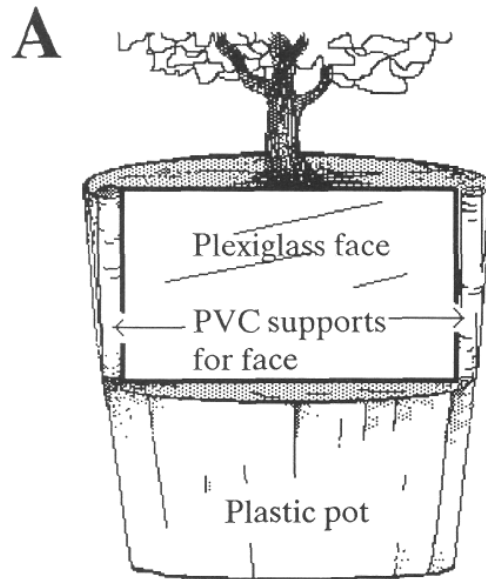




Fig. 1. A) Diagram of rhizotron used to monitor growth cycle of avocado shoots and roots. The transparent plexiglass face in each rhizotron was in direct contact with soil and roots and was exposed to light only when root growth was recorded. B) Viewing face of one of the rhizotrons showing the extent of root growth when root growth measurements began. C) Viewing face in B) showing manner in which individual roots and the position of root tips were noted on templates during each root measurement (nonmarked roots did not have tips that were visible on the face).

*Shoot and root growth measurement.* Linear extension of shoots and roots in each rhizotron was measured every 710 days for an entire calendar year. The number of shoots and roots that were measured on a given plant varied during the experiment due to changes in plant size, shading of shoot terminals, root mortality, growth of roots out of the field of view on the rhizotron face and other noncontrollable factors. On a given sample date, extremes of 2 and 39 shoots (mean =14) and 0 and 51 roots (mean = 6) were measured per plant.

Only certain, randomly chosen shoots in exterior portions of the canopy were monitored. In general, an equal number of shoots was measured in each of four canopy quadrants of a given tree. Tagged nodes on each of the monitored shoots were used as reference points and shoot extension was determined on each sample date by measuring from the reference nodes to the ends of terminals.

Only living root tips that were visible behind the plexiglass face were monitored; dead or dying root tips were darkened and/or withered, and were easily distinguished from living root tips. Root growth was recorded by tracing roots with an indelible marking pen on clear plastic templates that were placed over the viewing face (Fig. 1 B & C). Root tips that had died or grown out of the plane of view were removed from growth analyses. Root growth recorded on the templates was digitized and quantified with a Jandel Scientific model 2210 graphic digitizer and SigmaScan software (Jandel Scientific, Sausalito, CA, USA).

Growth rates for shoots and roots of a given plant were computed with Basic and SAS (SAS Institute, Inc., Gary, NC, USA) programs with the following formula:

$$\text{Mean linear growth for shoots or roots (mm day}^{-1}\text{)} = \frac{\text{total growth}}{(\text{no. days}) (\text{no. terminals})},$$

where total growth = the total growth of all measured shoots or roots in mm since the last measurement, no. days = the number of days since the last measurements were taken, and no. terminals = the total number of shoot or root terminals that were measured during the span of time considered.

Maximum growth rates for cultivars were the highest mean rates noted for any sample date during the experiment, and mean annual growth rates for cultivars were a combined average of mean rates for all sample dates; maximum and annual mean rates were separated statistically with the GLM procedure and the Waller Duncan *k* ratio *t*-test of SAS for personal computers (Table 1).

Table 1. Maximum and mean annual rates of shoot and root growth of grafted avocado plants.<sup>2</sup>

| Scion cultivar | Maximum  |           | Annual     |           |
|----------------|----------|-----------|------------|-----------|
|                | Shoot    | Root      | Shoot      | Root      |
| 'Lula'         | 3.4<br>* | 4.2<br>ns | 0.9<br>*** | 2.5<br>ns |
| 'Simmonds'     | 4.8      | 4.2       | 1.4        | 2.7       |

<sup>2</sup>Scions were grafted to seedling rootstocks of 'Waldin'. Maximum and annual growth are mean linear rates of extension in mm day<sup>-1</sup>. Shoot and root growth rates within columns are separated by the Waller Duncan *k* ratio *t*-test; \* = *P* < 0.05, \*\*\* = *P* < 0.001, ns = nonsignificant, *P* ≥ 0.05.

## RESULTS AND DISCUSSION

Robust growth of trees occurred in rhizotrons during the course of the experiment, and rhizotrons were large enough to allow nonrestricted growth of plants during the entire study. Growth rates varied considerably over time among shoot and root terminals on a given tree, and nongrowing terminals were observed commonly on trees which had several other shoots or roots that were actively growing. However, conspicuous trends of root and shoot growth were defined when mean data were plotted over time (Fig. 2 A & B).

Flushes of shoot growth were cyclical with the highest growth rates occurring when daily minimum temperatures generally exceeded 20°C and daylengths exceeded 12 hours (Fig. 2 C & D). Mean maximum rates and mean annual rates of shoot extension were greater for 'Simmonds' than for 'Lula' (Table 1). Shoot growth virtually stopped during the late fall and winter, but root growth, although it declined to 1/3 the maximum rates during these seasons, continued throughout the year. Flushes of root growth occurred about 30-60 days after flushes of shoot growth. Root growth cycled in accordance with shoot growth, but was also correlated with estimated soil temperatures (coefficients of

determination  $\geq 0.48$  and  $P < 0.0001$ ; data not shown).

To our knowledge, this is the first report to quantify shoot and root growth in avocado. Our results corroborate those of Davenport (1982) and Whiley and co-workers (Piccone *et al.*, 1987a, b; Whiley, 1987). Davenport (1982) did not quantify shoot or root growth, but his reported periods of vegetative and floral activity for shoots of cultivars studied in our work agree with the present observations. In general, he reported that floral activity of 'Simmonds' and 'Lula' occurred during the winter and early spring, that flowering was followed by flushes of vegetative growth in the spring and late summer, and that the bulk of vegetative growth occurred between March and September.

Although Whiley *et al.* (Piccone *et al.*, 1987a, b; Whiley, 1987) studied different avocado cultivars and field grown trees in Australia, their shoot and root growth cycles generally match those in Fig. 2 A & B (see "The Rhythm of Avocado Growth" figure on pg. 7 in Piccone *et al.*, 1987a). They observed that spring and summer flushes of vegetative growth were followed within 45 to 60 days by flushes of root growth. However, they also reported that root growth declined to very low levels or completely stopped during much of the year during their work. During our work, root growth declined, at most, to one-third the maximum rates observed during the year.

Our results suggest that root tissue which is susceptible to *Phytophthora* root rot (i.e., root tips) may be present in irrigated avocado orchards in South Florida throughout the year. Based on these results, it should be possible to predict the peak occurrence of susceptible root tissue in the field by monitoring flushes of shoot growth.

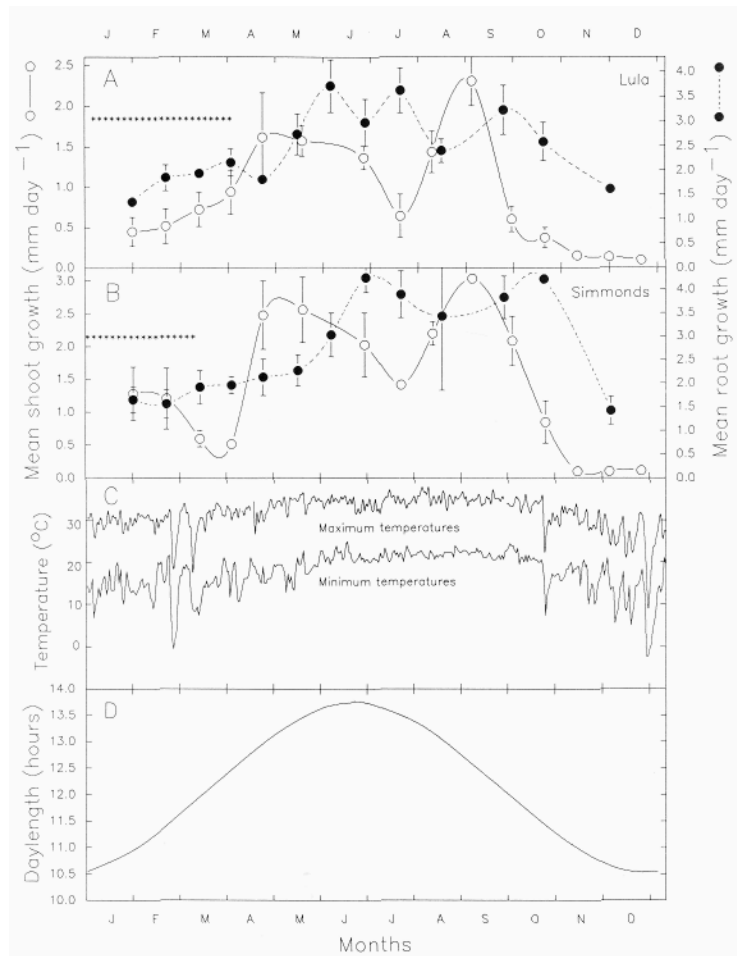


Fig. 2. A) and B) Mean shoot and root growth of grafted avocado in rhizotrons. Scions of 'Lula' and 'Simmonds' were each grafted to seedling rootstocks of 'Waldin'. Data are combined means for series of three sample dates for replicate plants of each scion cultivar. Each datum represents ca. 100 measurements and bars are standard errors. The period during which each cultivar flowered is noted with asterisks (\*\*\*\*\*). C) Maximum and minimum daily temperatures during the year of the experiment and D) daylength in Homestead, Florida during a calendar year.

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