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# Shoot and Root Growth Phenology of Grafted Avocado

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***Abstract.* The shoot and root growth phenology of grafted avocado *(Persea americana* Mill.) was monitored in above-ground rhizotrons. Scions of a West Indian cultivar, 'Simmonds', and a Guatemalan x West Indian cultivar, 'Lula', were tested on seedling rootstocks of the West Indian cultivar 'Waldin'. Growth rates of individual shoots and roots varied considerably within trees, but shoot and root growth flushes were apparent when mean growth rates were plotted over time. Shoot and root growth flushes alternated on 30 to 60 day cycles. Although shoot growth virtually stopped during the late fall and winter, root growth continued during the entire year. It is suggested that shoot growth flushes could be used to predict periods of maximum root growth activity, and, thus, times during which trees should be protected against *Phytophthora* root rot, caused by *Phytophthora cinnamomi* Rands.**

About 4,500 ha of avocados are under production in Florida (Anonymous, 1986). Most of the fruit grown in south Dade County are cultivars of Guatemalan and/or West Indian descent. Production occurs in unusual soils that are derived from solid limestone; before avocados are grown in the area, the limestone is usually prepared by trenching and scarification (Ruehle, 1963).

*Phytophthora* root rot is widespread in Florida and causes severe damage after flooding that occurs occasionally in low-lying orchards (Ploetz and Schaffer, 1989). During studies on the control of root rot with fungicides, we became interested in root growth cycles in avocado. Whiley and co-workers (Piccone *et al.*, 1987a,b; Whiley, 1987) had developed a nonquantitative growth model for avocado in Australia with which they scheduled fungicide applications for control of root rot. Although different cultivars of avocado are used in Florida than in Australia, we believed that similar information, if generated for Florida cultivars, could be used when controlling root rot in Florida.

The objectives of our study were to: 1) study shoot and root growth cycles of two representative Florida avocado cultivars, 2) estimate seasonal shoot and root growth rates for the cultivars, and 3) investigate the potential for predicting maximum root growth activity by monitoring shoot growth.

## Materials and Methods

The experiments described below were conducted at the Tropical Research and Education Center of the University of Florida in Homestead, Florida. Since the native soil and high water table in the area made the construction of below-ground rhizotrons impractical, above-ground rhizotrons were constructed to study shoot and root growth phenology. Rhizotrons were assembled out of rigid, plastic pots, 80 cm wide and 60 cm deep (Fig. 1A). Each pot was cut and fit with a transparent plexiglass face, 60 cm wide and 30 cm deep, which was fixed parallel to and about 10 cm outside the central, vertical axis of the pot; faces were secured in slots cut in 3 cm-diameter PVC pipes which had been attached to the inside walls of the pot. Rhizotrons had holes in the bottom to allow the free drainage of water and were elevated on concrete blocks.

Rhizotrons were filled with scarified, native soil (Krome very gravely loam: Ruptic-Alfic Lithic Eutrochepts clayey, mixed, hyperthermic; pH «= 7.5; sand: « 65%, silt: « 25%, and clay: 10%), and 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', were wedge-grafted on seedling rootstocks of the West Indian cultivar 'Waldin'. Four 'Lula' and three 'Simmonds' plants were randomized in a complete block design. Plants were watered every other day and were fertilized according to standard practices.

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. Plants were established in the rhizotrons for about two months before measurements of shoot and root growth began. Shortly after shoot and root growth measurement began, rhizotron exteriors were painted white to reduce heat buildup.

Linear extension of shoots and roots in each rhizotron was measured every 7 to 10 days for an entire calendar year; representative shoots (mean number = 14) and all roots that had tips visible behind the plexiglass face (mean number = 6) were measured on each date. Shoot growth was measured from marked reference nodes. Root growth was recorded with indelible marking pens on clear, plastic templates that fit over viewing faces. Unique templates for each rhizotron served as permanent, ongoing records of root growth for plants during the experiment. Only living root tips were monitored (Figs. 1B and 1C); dead or dying root tips were distinguished by their discolored and/or withered appearance. Root growth recorded on templates was digitized and quantified with a Jandel Scientific model 2210 graphic digitizer and Sigma-Scan 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:

$$\text{Mean linear total growth for shoots or roots (mm/day)} = \frac{\text{Total growth}}{\text{(\# days) (\# terminals)}}$$

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.

## Results

Growth rates varied considerably among shoot and root terminals on a given tree, and non-growing terminals were often observed on trees which had several other shoots or roots that were actively growing. However, trends of shoot and root growth were defined when mean data for the two scion cultivars were plotted over time (Figs. 2A and 2B).

Shoot and root flushes alternated and were cyclical. Most shoot growth occurred when daily minimum temperatures exceeded 20C and day lengths exceeded 12 hours, although conspicuous decreases in shoot growth rates occurred for both cultivars during the summer month of July (Fig. 2). 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 about 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 in the rhizotrons (data not shown).

## Discussion

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. (Reed, 1938; Krishnamurthi *et al.,* 1960; Wutscher, 1973; Bevington and Castle, 1985;), macadamia *(M. integrifolia* Maid. & Btch.) (Stephenson and Cull, 1986) and tea *(Camellia sinensis* L.) (Yamashita, 1985). Obviously, information on shoot and root growth phenology has application to many management practices for perennial crops, including disease control.

Our results corroborate those of Davenport (1982) and Whiley and co-workers (Piccone *et al.,* 1987a,b; Whiley, 1987). Davenport's (1982) reported periods of vegetative and floral activity for 'Lula[1] and 'Simmonds' agree with our observations. Although Piccone *et a/.,* (1987a,b) and Whiley (1987) studied different avocado cultivars and field-grown trees in Australia, their nonquantitative shoot and root growth cycles generally match those in Figs. 2A and 2B. They observed that spring and summer flushes of vegetative growth were followed within 45 to 60 days by flushes of root growth. They indicated, however, that root growth declined to very low levels or completely stopped during much of the year, whereas root growth in our study declined, at most, to 1/3 the maximum rates observed during the year.

Our results indicate that roots may be actively growing in irrigated south Florida avocado orchards during the entire year, but that there are certain, maximum periods of root growth activity. It is during these periods that trees would experience the greatest threat from *Phytophthora* root rot. Since shoot growth flushes precede root growth flushes by 30 to 60 days (Piccone *et al.,* 1987a,b; Whiley, 1987; this study), it should be possible to predict these periods by monitoring shoot growth activity. Although the application method, mode of action, and the distribution and movement of a given fungicide within a tree all affect Phytophthora root rot control, knowledge of avocado root growth phenology could obviously help determine when fungicides should be applied for optimal control of this important disease.

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Table 1. Maximum and mean annual rates of shoot and root growth of grafted avocado plants.[z]

| Scion cultivar | Maximum | | Annual | |
|---|---|---|---|---|
| | Shoot | Root | Shoot | Root |
| Lula | 3.4* | 4.2 | 0.9*** | 2.5 |
| Simmonds | 4.8 | 4.2 | 1.4 | 2.7 |

[z] Scions were grafted to seedling rootstocks of 'Waldin'. Maximum and annual growth are mean linear rates of extension in mm/day. Shoot and root growth rates within columns are separated with the Waller Duncan *k* ratio t-test; * = $P \leq 0.05$, *** = $P \leq 0.001$.

Fig. 1. (A) Typical rhizotron used to monitor growth cycles of avocado; picture was taken shortly before growth measurements began. To insure against heat build-up in the soil, all exterior surfaces of rhizotrons were painted white shortly after this picture was taken. To exclude light from viewing faces, they were covered with aluminum shields which, in turn, were forced tightly against faces by a plywood sheet. (B) Viewing face of one of the rhizotrons showing extent of root growth when root growth measurement 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).

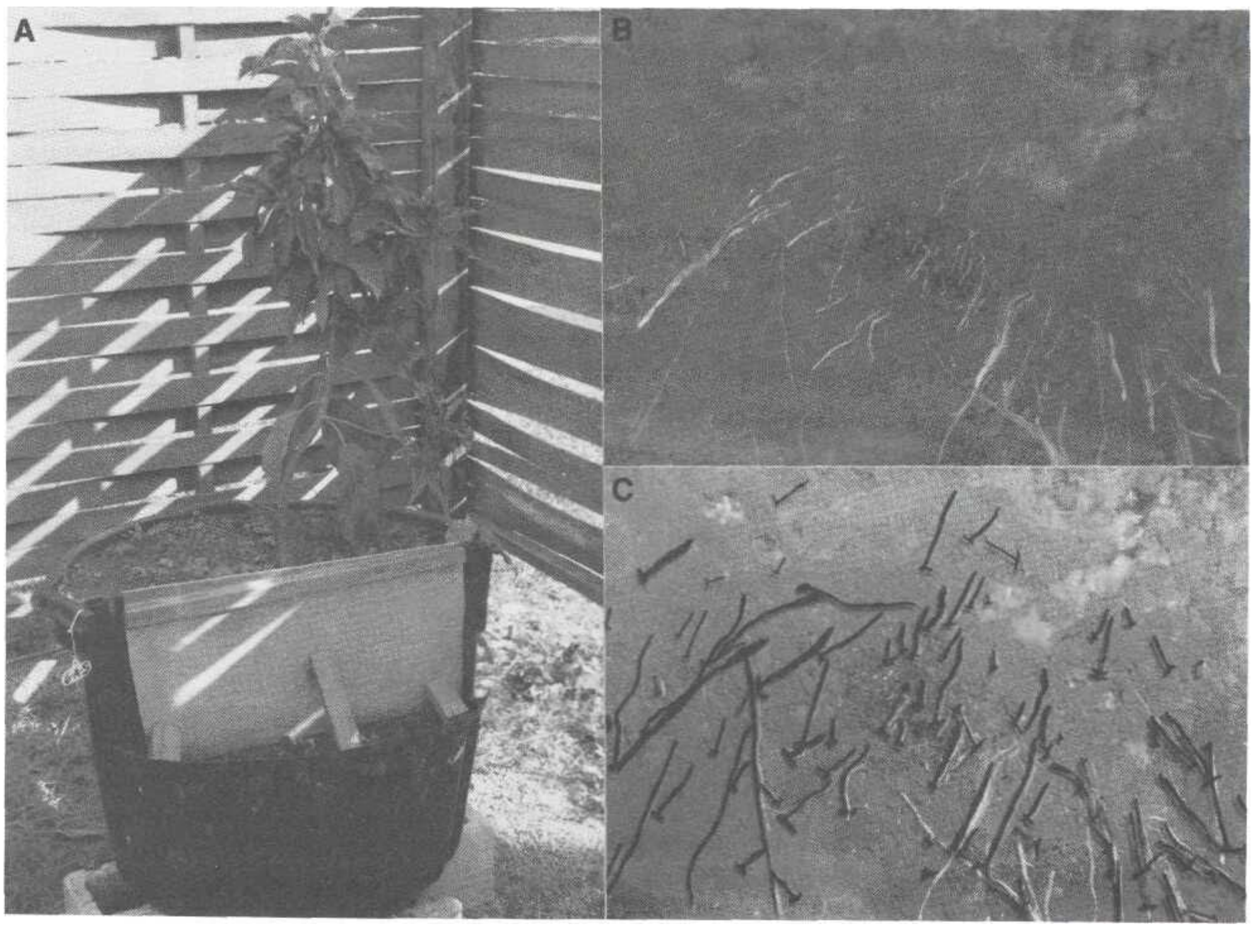

Fig. 2. (A) and (B) Mean shoot and root growth of grafted avocado in rhizotrons. Scions of 'Lula' and 'Simmonds' were each grafted to seedling rootstocks of 'Waldin'. Data are combined means for series of three sample dates for replicate plants of each scion cultivar. Each datum represents - 100 measurements 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) day length in Homestead, FL during a calendar year.