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The Relationship Among Root Growth, Shoot Growth, and Fruit Growth of Peach

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Abstract. **The number, length, and elongation rate of white roots were related to vegetative and reproductive growth of young own-rooted 'Redhaven' peach trees from June 1985 until Oct. 1986. Root growth of fruiting and nonfruiting trees were similar, except for a period of 3 to 4 weeks each year either during the final stage of fruit growth or immediately after harvest. During these periods, cropping reduced white root length per tree in both years, and total root growth per tree and number of growing root tips in 1986. Number of elongating root tips was correlated with total root elongation and was a better indicator of total root elongation than was mean root elongation rate of individual root tips.**

Knowledge of the growth and development of roots and their role in physiological and developmental plant processes lags far behind our understanding of aerial plant organs. The lack of knowledge of plant root systems can be attributed in large part to technical difficulties inherent to root research. Roots are important sources of many chemicals that influence shoot growth, such as cytokinins (13, 18, 19), gibberellins (15, 17), aminocyclopropane-1-carboxylic acid (ACC) (5, 6), and amino compounds (20). However, our understanding of the growth and development of root systems for most plants remains limited. Establishing interrelationships between root growth patterns and various growth and developmental processes occurring in other organs should improve our understanding of root function.

Cockroft and Olsson (8) observed peaks of root growth in the spring and fall with very little root growth occurring during the summer for peaches. Richards and Cockroft (16) reported increased concentrations of roots near the soil surface and continued root growth throughout the growing season if frequent irrigation was provided. A constant supply of water to the roots, as occurs with trickle irrigation, may result in enhanced root growth during the growing season. Relationships among root, shoot, and reproductive growth have been studied for various tree fruits where cultural practices such as trickle irrigation were not used. With development of chemigation and other relatively new cultural practices, the periodicity of root growth and its influence on plant performance should be re-evaluated. The purpose of this study was to determine the relationship among root, shoot, and reproductive growth of young peach trees where soil moisture was not a factor limiting root growth.

Materials and Methods

Twenty root observation boxes were constructed outdoors at the South Carolina Agricultural Experiment Station in Clemson, S.C. The boxes (80 × 55 × 30 cm) contained ≈ 0.1 m^3 of Cecil sandy loam soil that had been passed through hardware cloth to remove debris. Each box was constructed of 1.2-cm-thick plywood and insulated with 5.1-cm-thick sheets of styrofoam on all sides except the top and bottom. Fronts of the boxes were constructed of bi-layer safety glass oriented at a slight angle inward from top to bottom to encourage root development at the soil–glass interface. The glass surfaces were covered with sheets of styrofoam wrapped in aluminum foil and held in place with Velcro (Velcro USA, Manchester, N.H.) adhesive strips. Eight of the boxes contained tensiometers at 15-, 30-, and 40-cm depths. Four of the boxes contained thermisters positioned against the inside surface of the glass at 15-, and 30-cm depths. Two thermisters were also placed at 15- and 30-cm depths in an adjacent high-density peach orchard to monitor actual soil temperatures at the orchard site.

In Spring 1985, one 1-year-old own-rooted 'Redhaven' peach tree was planted in each root observation box. Ten of the trees were allowed to carry light crops in 1985 (averaging eight fruit per tree) and 10 trees were defruited as soon as initial fruit set could be determined. In 1986 the fruiting trees were allowed to carry an average of 27 fruit per tree, while nonfruiting trees were defruited. All trees received daily irrigations sufficient to wet the entire soil profile.

In May 1985, roots became visible against the glass and measurements for roots, shoots, and fruit were initiated. Root growth was traced daily with colored pens on acetate sheets affixed to the glass. Root tracings were made for eight of the 20 boxes (four fruited and four nonfruited trees) during the 1985 and 1986 growing seasons. Tracings were taken from one 972-cm^2 and two 200-cm^2 rectangular sections of the glass surface in 1985 and 1986, respectively. Root tracings were measured with a Zeiss Interactive Digital Analysis System (Carl Zeiss, Thornwood, N.Y.) to determine root elongation, number of growing roots, and mean elongation rate of individual roots for each 24-hr period. Weekly averages for root elongation, number of growing roots, and mean elongation rate were computed from daily values collected during the 1985 and 1986 growing seasons. Root elongation and number of growing roots were reported per square decimeter of glass surface area. White root length was determined on all 20 boxes at weekly intervals during the 1985 and 1986 growing seasons by the line intersection method of Head (10). Less frequent measurements of white root length were taken during Winter 1985–1986.

Leaf emergence was quantified daily by the method of Haun and Coston (9) for five shoots on each tree in 1985 and on four fruiting and four nonfruiting trees in 1986. Weekly shoot elongation was measured on all trees during the 1985 and 1986 growing seasons. Fruit diameters (four fruit per tree) were measured daily from 17 May to 20 June on 10 trees in 1985 and from 29 Apr. to 23 June on four trees in 1986. Fruit diameter (four fruit per tree) were measured weekly on all 10 fruiting

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trees in 1986. The widest portion of the fruit perpendicular to the suture was measured.

The experiment was conducted as a completely random design with four or 10 replications per treatment, depending on the characteristic measured.

Results

The insulated boxes provided root zone temperatures similar to the soil in an orchard. The mean weekly temperatures in the boxes seldom varied by more than 2°C from temperatures taken at 15- and 30-cm depths in an adjacent high-density peach orchard (data not shown). In 1986, tensiometer readings indicated soil water potentials approaching −70.0 kPa on days with high transpirational demand. However, these conditions did not occur for more than 1 to 2 hr since boxes were irrigated each afternoon with enough water to saturate the entire soil profile.

White root length for fruited and nonfruited trees followed a similar pattern from June 1985 until Oct. 1986 (Fig. 1). Each year, maximum white root length occurred during the late summer, after the cessation of shoot growth but before leaf abscission. White root length was less for fruiting trees than for nonfruiting trees during a 3-week period corresponding with the late part of Stage III of fruit growth and for 4 weeks beginning 2 weeks after harvest in 1985 and 1986, respectively ($\alpha = 0.10$) (Fig. 2). Cropping reduced length of white roots > 0.5 mm in diameter for 4 weeks beginning at the second harvest date in 1986 (data not shown).

In 1986, fruiting trees had slower root elongation rates (Fig. 3), with fewer actively growing roots than nonfruiting trees (Fig. 4). Lower root elongation rates and fewer elongating roots were first observed 1 week before the first harvest and lasted for 5 weeks ($\alpha = 0.10$).

Periods of reduced white root length of nonfruited trees occurred during peak periods of shoot growth in 1985 (June–August) and followed the period of maximum shoot growth in 1986 (June–July) (Fig. 5). A similar pattern was noted for fruited trees (data not shown).

In 1985, shoot growth for fruited (data not shown) and nonfruited (Fig. 6) trees occurred in two distinct flushes during periods of low root elongation rate. Peak periods of root elon-

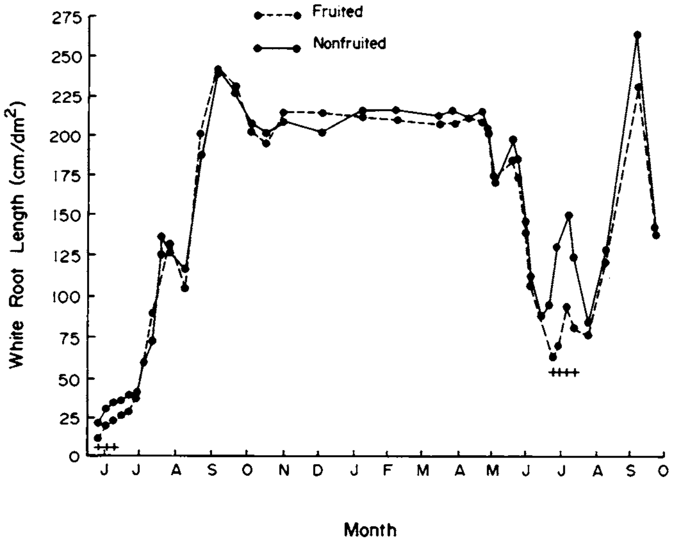

Fig. 1. White root length of fruited and nonfruited 'Redhaven' peach trees from June 1985 until Sept. 1986. + Denotes significant difference at the 10% level, *t* test.

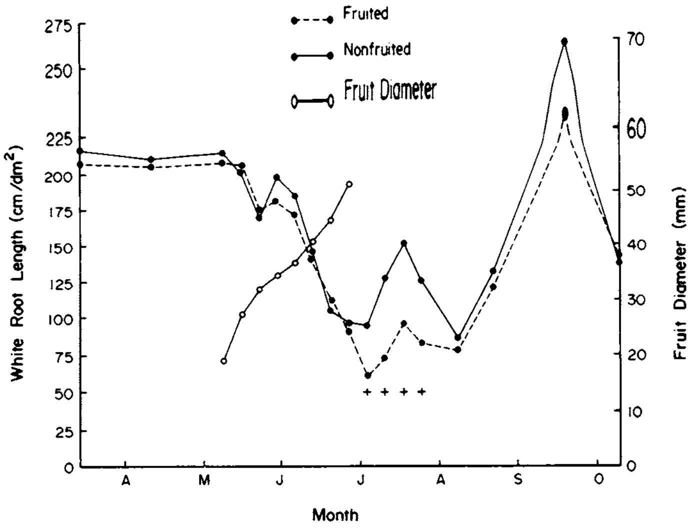

Fig. 2. The relationship between fruit diameter and white root length of 'Redhaven' peach in 1986. + Denotes significant difference at the 10% level, *t* test.

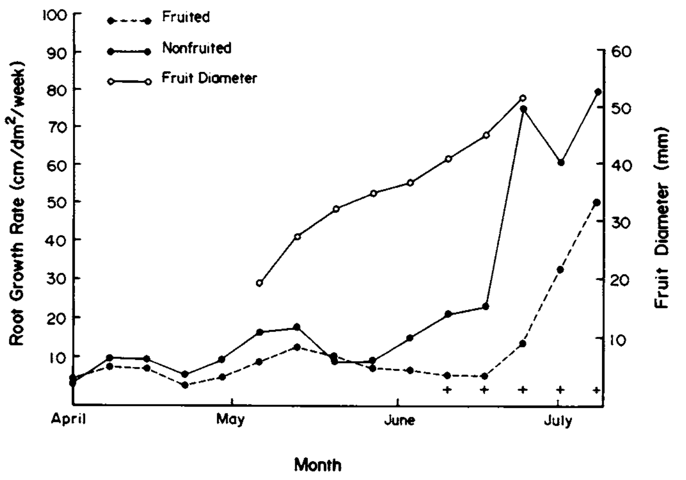

Fig. 3. The relationship between fruit diameter and root growth rate of 'Redhaven' peach in 1986. + Denotes significant difference at the 10% level, *t* test.

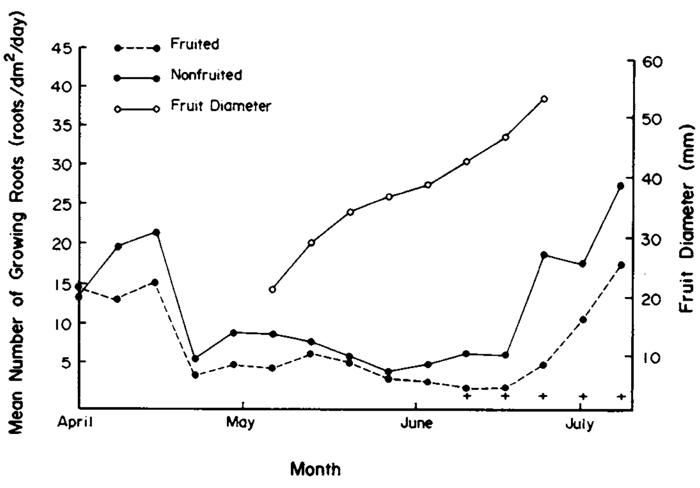

Fig. 4. The relationship between fruit diameter and the number of elongating root tips for 'Redhaven' peach in 1986. + Denotes significant difference at the 10% level, *t* test.

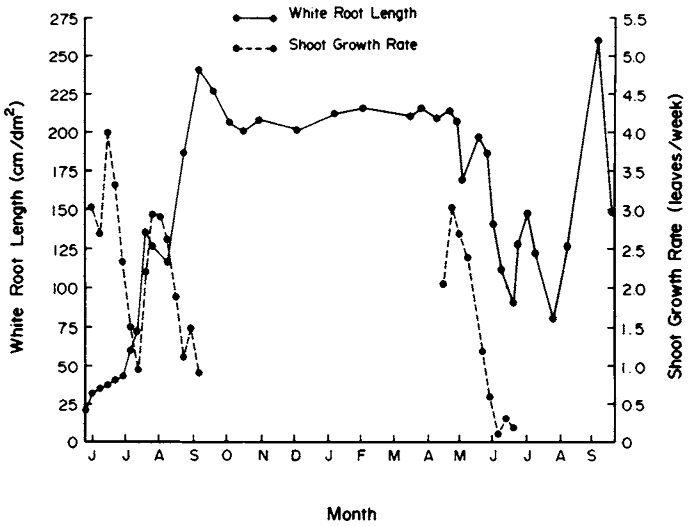

Fig. 5. The relationship between shoot growth rate and white root length of 'Redhaven' peach in 1985 and 1986.

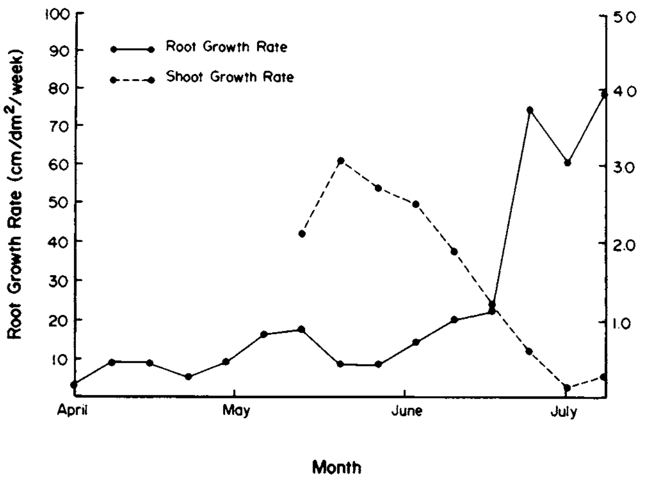

Fig. 7. The relationship between shoot and root growth rates of nonfruited 'Redhaven' peach in 1986.

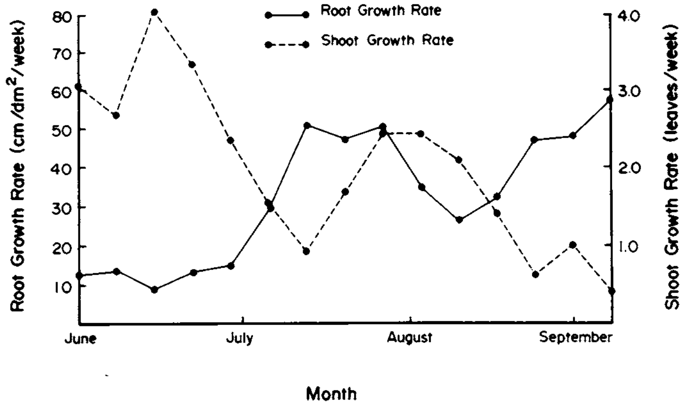

Fig. 6. The relationship between shoot and root growth rates of nonfruited 'Redhaven' peach in 1985.

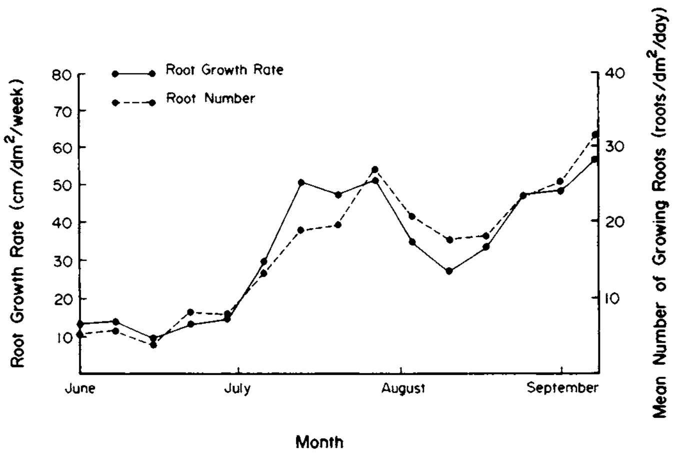

Fig. 8. The relationship between root growth rate and number of elongating root tips for nonfruited 'Redhaven' peach in 1985.

gation followed each flush of shoot elongation. Shoot and root elongation rates were significantly correlated for nonfruiting trees ($r = -0.63$), but not for fruiting trees. In 1986, maximum shoot elongation rate occurred during a period of low root elongation, with root elongation rate increasing as shoot elongation rate decreased for nonfruiting trees (Fig. 7) and fruiting (data not shown) trees.

In 1985, root elongation rate and number of elongating roots (root no./dm^2 per day) were significantly correlated for both nonfruiting ($r = 0.94$) (Fig. 8) and fruiting ($r = 0.92$, data not shown) trees during the period from June until September. A strong relationship between root elongation rate and number of elongating roots was also evident in 1986; especially from May until July (data not shown).

Discussion

Changing growth rates of white roots observed in this study (Figs. 1 and 2) are similar to reports for apple (2, 11) and peach (8). With apple ('Cox'/M.9), maximum white root length usually occurred after the period of maximum shoot elongation (2). Similarly, with 'Worchester'/MM.104, a small peak in white root length occurred during the spring, followed by a reduction in white root length during shoot elongation, with the major peak of white root length occurring after shoot growth but before leaf fall (11). In our study, white root length of peach followed a pattern similar to that reported for apple where the greatest white root growth occurred after shoot growth had ceased and before leaf abscission in mid-October (Fig. 5). In Australia, distinct spring and fall peaks of white root length of peach with larger peaks in the spring were observed (8). Since these trees were not irrigated during the fall and our trees were irrigated daily until leaf drop, this may account for the discrepancy in relative size of the fall peaks in white root length between the two studies.

The double-peak phenomenon reported here (Fig. 6) is due to a decrease in production of new roots during the summer months and this reduction usually coincides with the major flush of shoot growth. Head (11) suggested that the degree of reduction in white root length and its duration is related to increases in shoot growth. He also suggested that the length of white roots produced after shoot growth ceased was positively related to the amount of prior shoot growth. Alternating flushes of root and shoot growth, similar to those observed herein, have been noted for citrus (4) and two cultivars of Japanese holly (14). No doubt, various environmental, cultural and internal plant factors play a role in controlling seasonal trends in white root length. However, in our study, summer reduction in white root length and root growth rate cannot be attributed to soil moisture or temperature. More likely, reduction is due to internal plant factors that influence the distribution of assimilates between roots and shoots. Competition exists between roots and shoots for assimilates. Shoots seem to provide a more competitive sink for photosynthates than do roots during periods of rapid shoot growth (1, 21). However, the amount of shoot growth that can occur without subsequent root growth is limited by the root system's ability to supply the shoot with essential growth components (e.g., water, mineral, nutrients, and hormones).

The inhibitory effects of cropping on white root length have been reported for apple (3, 12). In 1985 and 1986, our crop loads were 0.25 and 0.44 $kg \cdot cm^{-2}$ of trunk cross-sectional area, respectively. These are relatively light crop loads, but they are similar to those that Head (12) reported for apple (0.20 to 0.59 $kg \cdot cm^{-2}$) loads that were associated with less root growth than for noncropping trees. Chalmers and van den Ende (7) reported a reduction in the annual increment of dry weight partitioned to the root system as peach trees aged. Increased fruiting of older trees is thought to be at least partially responsible for this reduction in the annual increment of dry weight partitioned to the root system. However, with young, irrigated trees, this reduction in root growth appears to be only temporary, lasting ≈4 weeks, with no noticeable effect at the end of the growing season.

The strong relationship between root number and total root growth rate for peach is in agreement with work by others (4) with citrus and suggests that the number of growing roots rather than average growth per root is highly related to total root growth. Considerable root growth of young, irrigated peach trees occurred during the summer months of 1985 and 1986, except during and immediately after periods of rapid shoot extension and reproductive growth. Cropping resulted in a temporary decline in root growth lasting ≈4 weeks. The period of maximum root growth in both years for fruiting and nonfruiting trees was after the cessation of shoot growth and before leaf abscission (August–September). This period appears to be critical for root development of young peach trees, suggesting great importance for appropriate management decisions to be made late in the growing season.

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