Root Development Patterns in Field Grown Peach Trees

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Abstract. The objective was to determine the interrelationship between root growth and plant available soil water (PAW) for young, nonbearing, and mature fruiting peach trees (Prunus persica L. Batsch) over 7 years. Root growth observed with minirhizotrons indicated that young, nonbearing trees developed new white roots throughout the growing season. The pattern of new white root growth became bimodal when the trees fruited. White root production in mature trees appeared in March, preceding budbreak, ceased in June, resumed following fruitremoval in August, and persisted through January. The appearance of white roots was inversely related to the presence of fruit and was not correlated to PAW levels in the 0 to 90 cm depth. The lack of root growth response to PAW levels was attributed to a root system that penetrated the soil to depths beyond our zone of sampling. Circumstantial evidence suggests that deep roots help maintain the surface root system when the surface soil dries.

In the past, technical problems have limited the ability to study plant root systems for extended periods. Consequently, knowledge of root growth and development in field grown peach trees lags behind the information available on the aerial portion. The development of minirhizotron technology (Bland and Dugas, 1988; Glenn et al., 1987; Meyer and Barrs, 1983; Upchurch and Ritchie, 1983; Vos and Groenwald, 1983) has provided a new tool to examine long-term developments in plant root systems in the field.

Further information is needed to understand the interrelationships between root function and development, other competing plant tissues, and the environment. Cockcroft and Olsson (1972) and Richards and Cockcroft (1975) reported a depression in new root production in peach that was related to low soil water availability. Williamson and Coston (1989), however, demonstrated that while there was a depression in new root production during the growing season, it was not related to water stress, but rather to fruiting. No long-term studies of deciduous tree fruit root growth and development have been published to clarify these sink and soil-plant interactions. Our objective was to determine the interrelationship between root growth, fruiting, and available soil water for juvenile, nonbearing trees and mature fruiting trees.

Materials and Methods

‘Summerglo’ and ‘Redhaven’ peaches on ‘Halford’ rootstock were planted in hand-dug holes in Spring 1983 (P1983) and 1984 (P1984), respectively. These studies were adjacent and were managed the same way following planting. All trees were cut back to a height of 1 m at planting. A randomized complete-block design was used with five replications. Each plot was 3 m wide, 13.5 m long, and contained three trees with a guard tree between plots in the row. Tree rows were spaced 6.0 m apart, with 4.5 m between trees within the row and were oriented parallel to the slope. The trees were pruned each spring in an open center form. The 3 m drive middle was maintained in a ‘Kentucky-31’ (K-31) tall fescue (Festuca arundinacea Schreb.) sod. The treatments were: 1) Trees were planted in K-31 sod, in which a 3-m strip was treated immediately after planting with 2.2 kg a.e. (acid equivalent)/ha N-(phosphonomethyl) glycine (glyphosate) (killed sod). When the sod had died, a residual herbicide treatment of 1.12 kg a.i./ha N’(3,4-dichlorophenyl)-N, N-dimethylurea (diuron) + 1.12 kg a.i./ha 5-chloro-3(1,1-dimethylethyl)-6-methyl-2(1H,3H) pyrimidinedione (terbacil) was applied. 2) Trees were planted in a K-3 1 sod that was plowed the fall before planting, leaving a 3 m wide bare soil surface in the plot area. Trees planted in the plowed bare soil were divided into two groups: a) The first group was maintained weed-free by shallow rototilling and hand-hoeing (cultivated) the 3 m strip, b) The second group received no cultivation, but maintained a 3 m weed-free strip with the same residual herbicide treatment applied to the killed sod (herbicide). The same residual herbicide treatments were applied once each year. No injury symptoms were noted on the trees. The area used in the P1984 study was fertilized the previous fall with 100 kg·ha' of 10N-8.3P-4.4K following plowing. A rain gauge was installed in the plot area 0.30 m above the soil surface. Rainfall data were collected daily. The soil was a Hagerstown silt loam (fine, mixed, mesic Typic Hapludalf) with a 3% slope and a southern exposure. Bedrock was >3.5 m deep. The tree-row treatment strip was slightly crowned and channeled rainfall runoff into the interface of the grass middle and tree row treatment strip 1.5 m from the access tube location. Runoff did not accumulate near any access tube, as indicated by sediment deposition.

Acrylic access tubes (57 mm in diameter with a 3 mm wall thickness, 1 m in length) were installed at a 20° to 25° angle from the vertical, 0.5 and 1.0 m from the trunk of one tree, in each plot. Three tubes, 20 cm apart, were installed at each distance so that their tops were inclined toward the tree row (total of six tubes per single tree plot) in four replications of the experiment in P1983 and five replications in P1984. One of the outer tubes of the three tubes at each distance from the tree was used as an access tube for the neutron moisture probe. Soil water content was determined using a calibrated neutron moisture probe (Campbell Pacific Nuclear, model 503). Soil water content measured from 4.2 cm diameter cores (volume water per volume soil) was calibrated to count ratios from the neutron moisture probe. The neutron moisture probe was
inserted into the hole, and readings were taken with the center of diameter soil cores at depths of 0 to 0.15, 0.15 to 0.30, 0.30 to 0.60, and 0.60 to 0.90. After the cores were collected, an acrylic tube was inserted into the hole, and readings were taken with the center of measurement at the midpoint of each depth increment. Soil water content was determined by weight loss at 105°C and converted to volumetric water content by multiplying the gravimetric water content by the soil bulk density. The 0 to 0.15-m depth had a calibration curve separate from the other depths. All calibration curves had a coefficient of determination ($R^2$) of 0.95. The instrument has a field measurement error of ±0.5%, or 1.5 mm of water in a 0.30-m increment of soil. During the first growing season of each study, soil water content was measured 0.50 m from the tree. During the subsequent years, soil water content was measured 1 m from the tree. Soil water content was determined one to three times per week. For each sampling date, the soil moisture content value was converted to a percentage of plant available water using Eq. 1:

$$\text{PAW} = \frac{[\text{SWC} - \text{LL}]/(\text{DUL} - \text{LL})]}{\times 100}$$

where PAW = plant available water content (%); SWC = measured soil water content at a sampling date; LL = lower limit of plant available water and assumes water is unavailable below this level; and DUL = drained upper limit of available water and represented the in situ water holding capacity of the soil. DUL was determined for each neutron probe access tube in the two field studies each spring. The DUL values were reproduced over all years within +6% (v/v). LL was calculated from textural characteristics of the soil, according to equations developed by Cassel et al. (1983). LL was =60% of the DUL and (DUL-LL) was =14% (v/v).

The six acrylic tubes per plot were used as minirhizotrons to view the peach root system. The system used is described in Glenn et al. (1987). Briefly, a boroscope was used to observe and count the number of white and brown roots present on a 2-cm strip of the tube facing the tree. Counts were made for the 0 to 30, 30 to 60, and 60 to 90 cm depths during the growing season and dormant season beginning in 1983 and ending in 1987 in the P1983 study. The root counts in the P1984 study were started in 1984 and continued until 1988, with more frequent sampling in the P1984 study area. Root length was calculated from root counts using the following assumptions: 1) the depth of view into the soil was 0.1 cm; 2) the width of the viewing field was 2 cm; 3) the length of the viewing field was 30 cm, resulting in a viewed soil volume of 6 cm$^3$; and 4) the average length of a counted root in the viewing field was 1 cm. We recognize that there is a considerable controversy over the best technique to convert minirhizotron root count data to root length density (Bland and Dugas, 1988; Keng, 1988; Meyer and Barrs, 1983; Vos and Groenwald, 1983). Validation of any mathematical conversion has low confidence due, in part, to the high degree of spacial variability in root systems and the modification of the soil environment by, the observation tube (Upchurch and Ritchie, 1983). We have converted the root count data to units of root length density (cm/cm$^3$), which are most familiar in root studies and can be compared to published data.

Root count data were transformed using an exponential transformation, according to Glenn et al. (1987) before analysis of variance (ANOVA). The design was a split plot with soil management as the mainplot and sampling date as the sub-subplot. ANOVA demonstrated a significant depth × sampling date interaction for both study areas. Data were analyzed for each study area by depth in a split-plot design with each soil management treatment as the mainplot and each sampling date the subplot. A least significant difference (LSD) for each depth and study area was determined. The length of brown woody roots >0.5 cm in diameter was analyzed using a split-plot design in which each soil management treatment was the mainplot and depth was the subplot. Means were separated using a protected Duncan’s multiple range test.

Correlations and regression analysis of root length with PAW levels over time were performed across soil management treatments. Correlation coefficients were tested for significance using attest at $P = 0.05$.

**Results and Discussion**

The soil management treatments had no measurable effect on white or brown root growth at either the 50 or 100 cm distances; therefore, the data were pooled across treatments at each sampling date to characterize general root development patterns. At the end of the first growing season in P1983 and P1984, white roots were still present in October (Figs. 1 and 2). During the second growing season, white root growth peaked in July in both studies. White roots persisted through October in P1983, but were absent in P1984. During the third growing season, white root growth was virtually absent on the July and October sampling in P1983. During the third growing season in the P1984 study, white root growth occurred March through May only in the 0 to 30 cm depth.

![Fig. 1. Root length density of white roots for three growing seasons for peach trees planted in 1983 (P1983).](Image)
(October through November at all depths), and some white roots were still present in January. During the fourth growing season in P1984, white root development peaked in May at the 0 to 30 cm depth, decreased during July and August, and increased at all depths in September through December. White roots were absent in February, preceding the fifth growing season, and again rose in April of the fifth growing season.

In both study areas, when the peach trees were juvenile (nonfruiting), white root growth in the 0 to 30 cm depth occurred throughout the growing season. Once the trees were fruiting, white root development became bimodal, with an absence of white roots coinciding with fruit growth. Similarly, Williams and Coston (1989) found a rise in the number of white roots during April and following fruit harvest in container-grown trees. These periods of root growth varied by depth in our study. Roots in the 0 to 30 cm depth exhibited both spring and fall flushes of growth. Roots at the 30 to 60 cm depth exhibited a spring flush; however, fall root growth was dominant. Roots in the 60 to 90 cm zone had only a fall root growth period, with no evidence of new root growth in the spring. The soil temperature in April and May was probably too low in the 60 to 90 cm depth for root initiation. We have found April and May soil temperatures of 12°C at the 60 to 90 cm depth and of 19°C in September (Glenn and Welker, 1987). According to Cooper (1973), peach root elongation and branching are minimal at temperatures <15°C. Richards and Cockcroft (1975) and Cockcroft and Olsson (1972) have shown that peach root growth is periodic. Richards and Cockcroft (1975) attribute the lack of summer root production to soil drying and induced new summer root growth through irrigation. Williamson and Coston (1989) attribute the reduction in white root growth to the partitioning of assimilates between roots and shoots rather than soil moisture. In our studies, soil moisture conditions in September and October were as dry or drier than in July and August (Fig. 3), and yet root growth was initiated during this period. It is our interpretation that sink competition explains more clearly the periodicity of root growth than does soil moisture conditions for rain-fed trees. We found that white root growth preceded and followed periods of shoot and fruit growth, and the change in white root counts showed no significant correlation with plant available water levels in the 0 to 90 cm depths.

Root growth is limited by plant available water; but within the conditions of our study, we found no instances in which the change in root counts could be correlated with plant available water over a range of 2% to 98% PAW. This result indicates that the root system within 1 m of the tree was using soil moisture from depths >90 cm and/or from soil beyond the 1 m sampling area. Fabiao et al. (1985) found that eucalyptus (Eucalyptus globulus Libil.) root growth, in the 0 to 40 cm depth, continued throughout periods of prolonged drought. Caldwell and Richards (1989) have shown that
water absorbed by deep roots in moist soil can move through the roots to drier soil layers at night. This hydraulic lift is an important ecological mechanism for plant survival.

In the spring of the fifth growing season in P1984, woody roots >0.5 cm in diameter were limited to the 0 to 60 cm depth, none were found below 60 cm (Table 1). The lack of woody roots >0.5 cm in diameter below 60 cm suggests that large roots using deeper soil moisture are infrequent and/or developed at distances >1 m from the tree.

In conclusion, the pattern of root development in field grown peach trees indicates that young nonfruiting trees develop new white roots throughout the growing season. However, the pattern of new white root production becomes bimodal with the onset of fruiting. White roots appear in March preceding budbreak and persist through January. The midseason reduction of white root counts was due, in part, to the increasing photosynthetic demand of the fruit crop and was not related to PAW levels. Circumstantial evidence indicates that deep roots do develop in peach, and these roots are important in the development and maintenance of the root system when the surface soil layer is dry.

| Soil depth (cm) | RLD (cm/cm³) |
|----------------|-------------|
| 0-30           | 0.10        |
| 30-60          | 0.09        |
| 60-90          | 0.00        |
| SE             | 0.03        |

Table 1. The distribution and root length density (RLD) in Apr. 1988 of woody peach roots >0.5 cm diameter. Trees were planted in 1984.

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