Root Growth and Water Status of Container-grown Photinia ×fraseri Dress Transplanted into a Landscape

R.C. Beeson, Jr.1
University of Florida, Institute of Food and Agricultural Sciences, Central Florida Research and Education Center, 2700 East Celery Avenue, Sanford, FL 32771-9608

Additional index words: transplant, urban forestry, water potential

Abstract. Photinia plants produced in 11.4-liter polyethylene containers using a pine bark-based medium were transplanted into a well-drained sand and irrigated on alternate days. Polyethylene barriers were placed under half the root balls at transplanting to limit gravitational water loss. Plant water potential was measured diurnally between irrigations, and root growth was determined at 4-month intervals. Plants with barriers averaged higher cumulative daily water stress than control plants over the year, although predawn and minimum water potentials were similar. Growth index and trunk diameter were similar for the plants over barriers and controls, but the former were taller after 1 year. Plants with barriers had twice the horizontal root growth into the landscape site as control plants, resulting in twice the root mass in the landscape after 1 year.

Root balls were typical of container-produced plants, with circling roots and root apices concentrated at the junction of the container bottom and side. Consistent with the practice of most landscape installers, roots were not cut before installation. Native soil was thoroughly washed in backfilling. Plants were irrigated at 0500 hr on alternate days with a micro-irrigation system, using one spray stake (Avocado Spot Spitters; Roberts Irrigation Products, SanMarcos, Calif.) per plant (7.3 liters/irrigation). Irrigation was activated regardless of previous rainfall. On 15 Mar. 1992, each plant received a 50-surface application of Osmocote 18N–2.6P–9.9K (Grace-Serra, Milpitas, Calif.) scattered over the root ball. A 1-m area on either side of the row was kept barren through hand-weeding and with glyphosate.

Plant water potential (Ψf) was measured diurnally at ≥2-h intervals from before dawn until the final interval started 30 min after sunrise. Water potential was measured on a single leaf per plant (from the sunlit side) at each interval using a pressure chamber (model 3000; SoilMoisture Corp., Santa Barbara, Calif.), lined with a moist paper towel, in which pressure was increased to 2.5 kPas–1 (Beeson, 1992). One and one-half hours before sampling, a leaf for the subsequent measurement was covered with aluminum foil lined with a polyethylene sheet to minimize transpiration and permit establishment of Ψf equilibrium between leaf and stem. The foil was sealed around each leaf, with only the petiole exposed. Diurnal Ψf measurements were made on five plant replications of each treatment on days between irrigation. Measurements were taken biweekly for the first 4 months after transplanting, then monthly for an additional 8 months. Cumulative water stress integral (Sf) was calculated as the abscissa value of the integration of each diurnal Ψf curve (Beeson, 1992).

At 17, 34, and 52 weeks after transplanting, root growth into the landscape site of five plants with and without barriers was determined in a sequential manner. One-fourth of the root system of each plant was excavated from each side of the row. The excavated area was within a 90° arc centered perpendicular to the row, with its vertex at the plant’s trunk. Excavation depth was to the end of the deepest root or the bottom of the root ball, whichever was deeper. During excavation, the distance from the center of the trunk to the farthest root tip encountered was measured. All roots within an excavated area were harvested to the point of attachment with the original root ball. Roots were not excavated under the root ball. Harvested roots were washed, and their dry weight determined. Excavated plants were excluded from future measurements.

At transplanting and at each root harvest, stem diameter at 25 mm above the soil, height, maximum canopy width, and width perpendicular to the maximum canopy width were recorded for the five plants in each treatment from which roots would be harvested after 1 year. Canopy dimensions were used to compute a volumetric growth index.

Received for publication 6 Dec. 1993. Accepted for publication 18 June 1994. Florida Expt. Station Journal Series no. R-03266. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

1Associate Professor.
Root length and dry weight were analyzed as repeated measurements using a split-split-plot design, with treatment as the main effect, time as the subplot, and direction (east vs. west) as the sub-subplot (Snedecor and Cochran, 1980). All other variables were analyzed as repeated measurements using a split-plot analysis, with treatments as the main plot and time as the subplot. Root growth rates based on dry weight and height growth were analyzed by regression (Snedecor and Cochran, 1980). In all cases, each plant served as a single replication.

Results and Discussion

Trunk diameter and shoot growth index increased with time after transplanting but remained similar between treatments throughout the first year (data not shown). Planted height also increased linearly with time (Table 1). Plants with barriers grew an average of 0.2 m taller than those without barriers during the first year after transplanting (Table 1).

Maximum root length varied with treatment and time after transplanting but not by direction (Table 1). Treatment x time and time x direction interactions were not significant (Table 1). Roots were longer on plants with barriers (Table 1). The increase in root length was linear with time (Table 1), with length (mm) = 4.8 x week + 26; r² = 0.69.

Differences in root dry weight were found between direction (Fig. 1) and barrier treatments (Fig. 2) as functions of time. Root dry weight (dwt) in the west direction was linear (dry weight = 0.237 x week - 1.0; r² = 0.57) (Fig. 1); in the east direction, it increased with the square of the weeks after transplanting but was not quadratic (dry weight = 0.008 x week² - 1.38; r² = 0.68) (Fig. 1). Reasons for greater growth, as judged by dry weight in the east direction are unknown, but they may have resulted from possible lower soil temperatures than on the west side of the row. If mulched, this difference between row sides might not have occurred. Plants with barriers extended twice as much horizontal root mass into the transplant site after 1 year than control plants (Fig. 2). Barrier plants had similar root dry weight after 34 weeks as control plants after 1 year. Root growth rates for plants with barriers increased geometrically (dry weight = 0.016 x week¹ - 1.78; r² = 0.92) and were significantly greater than the linear increase of control plants (dry weight = 0.41 x week - 2.23; r² = 0.79).

Covering the leaf with the plastic sheet-lined aluminum foil permitted a measure of shoot water potential rather than the more dynamic leaf water potential. Previous studies showed that the ψₜ of leaves, which were enclosed so that transpiration was arrested, came into equilibrium with that of the shoot (Begg and Turner, 1970; Garnier and Berger, 1985). There were no differences between treatments for predawn or minimum ψₜ, although differences among weeks were significant (data not included). Predawn ψₜ ranged from -0.03 to -0.22 MPa, with measurements consistently more than -0.06 MPa by week 37. Minimum ψₜ occurred from midmorning to late afternoon, depending on climatic conditions; it ranged from -0.35 to -1.9 MPa and was consistently less than -1.2 MPa, from weeks 10 to 30 (24 Apr. to 6 Sept.). Differences between treatments for dusk ψₜ depended on the time after transplanting. Plants with barriers had more negative dusk ψₜ than control plants at 8 and 12 weeks after transplanting (Fig. 3). Dusk ψₜ were consistently more than -0.25 MPa after week 37 (Fig. 3). Control plants (9.02 ± 3.75 MPa h⁻¹) averaged significantly (α = 0.05) lower Sₑ values than plants with barriers (9.44 ± 4.3 MPa h⁻¹) for the year following transplanting. Differences in Sₑ values also were significant among weeks (data not shown).

Horizontal root growth into the landscape site was superior for plants with barriers. Almost all excavated root growth extending from a root ball was horizontal and remained so to the root tip. An abrupt change in soil texture was observed at 200 mm below the soil surface. Deepest roots paralleled, but rarely penetrated this division. No differences were observed between treatments in the spatial position of horizontal roots, and maximum root depth rarely exceeded the bottom of the root ball. Roots extending directly underneath the root ball were not harvested but likely constituted a minimal percentage of the total. Most woody plant roots are within the upper 0.3 m of soil and tend to grow horizontally rather than vertically (Gilman, 1990). In this study, maximum root lengths measured after 1 year were much less than maximum horizontal root lengths of several tree species measured 1 year after transplanting into similar soil types (Besson and Gilman, 1992; Gilman, 1990). This result hints at the important differences in root growth between trees and shrubs in a landscape, which may be due to differences in plant size at transplanting or perhaps more basic differences in physiology or root morphology. Most harvested roots extended only half the distance of the longest roots at each harvest. Thus, even after 1 year, most roots were within a 0.6-m radius of the stem.

Except at 8 and 12 weeks after transplanting, key points of the diurnal ψₜ curves were similar between control plants and those over a barrier. Differences in dusk ψₜ and Sₑ values between control plants and those with barriers may be linked to differences in timing of shoot fluxes between treatments. Plants with barriers achieved budburst earlier after transplanting, causing treatments to remain out of synchrony for shoot growth during the rest of the experiment. For example, at week 12, three of

<table>
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*Control plants were removed from the container and transplanted directly into the landscape. Plants with barriers were treated similarly, but an impermeable polyethylene barrier was installed directly beneath the root ball.

*Annual mean of four measurement periods of five single-plant replications.

*Mean of 10 single-plant replications of plants with barriers and control plants combined.

NS, * ‡ Nonsignificant or significant at α = 0.05 or 0.01, respectively.

Fig. 1. Increases in horizontal-root dry weight extending from the original root ball for the (●) east and (O) west sides as a function of weeks after transplanting. Each point is a mean of 10 plants per side and based on excavation of 50% of an area surrounding a root ball. Vertical bars indicate the ±SE of the mean.

Fig. 2. Increases in horizontal-root dry weight extending from the original root ball at each root excavation for (●) control plants and (O) plants with barriers. The latter had a polyethylene sheet installed below the root ball. Each point is the mean of five plants per treatment and based on 50% excavation of an area surrounding a root ball. Vertical bars indicate the ±SE of the mean.
Fig. 3. Water potential measured after sunset (dusk) during the first year after transplanting into a landscape. (●) Plants with barriers were installed with a polyethylene sheet below the root ball. (○) Control plants were not. Each point is the mean of five plant replicates. Vertical bar represents the LSD between treatments.

The five plants with barriers measured had ample new shoot growth; whereas, only one of the control plants had expanding shoots. Expanding shoots may transpire more water than mature leaves (Andersen and Brodbeck, 1988). Though differences in weeks were significant for $\psi_m$ values, the interaction with treatments was not; thus, the difference due to the passage of time has little merit because these values respond to daylength and, hence, are seasonally dependent.

Root growth is inversely proportional to water stress (Becker and Fuller, 1987; Nambiar et al., 1979). Thus, greater growth of plants with barriers suggests higher overall water status than for control plants. Yet on days between irrigations, plants with barriers had similar $\psi_m$ values and, therefore, similar water status. Measurements of $\psi_t$ were made on days between irrigation, on the premise that $\psi_t$ differences between treatments would be larger than on the day of irrigation, but this was not the case. Similar water status between treatments on nonirrigated days, but greater root growth of plants with barriers, may be reconciled, considering the relatively small amount of available water within a 11.4-liter root system. For marketable plants, available water stored within such containers is not sufficient to prevent growth-inhibiting water stress from developing within 8 to 10 h after irrigation (Beeson, 1992). Thus, on days between irrigations, transpiration demands likely exceeded the remaining available water within the original root ball even if drainage to the soil did not occur.

The overall higher water status of plants with barriers implied by the data for roots developing within 8 to 10 h after irrigation (Beeson, 1992). Thus, on days between irrigations, transpiration demands likely exceeded the remaining available water within the original root ball even if drainage to the soil did not occur.


