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

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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.**

Unsightly appearance of container-grown plants transplanted into a landscape generally is due to chronic water stress, which can cause severe dieback or plant death (Costello and Paul, 1975; Matheny et al., 1979). This chronic water stress is the result of water withdrawal from the root ball by the surrounding soil and drastically reduced irrigation frequency compared to nursery production. When transplanting container-produced plants into a landscape, root systems often retain their container dimensions, with little root exploration into surrounding soil (Costello and Paul, 1975; Matheny et al., 1979).

Artificial media have a coarse texture with large macropores for improved aeration to counter perched water tables in containers (Spomer, 1974). For optimum growth, high container moisture levels must be maintained. In locations such as the southeastern United States, maintaining high moisture levels requires daily irrigation much of the year—twice or more per day during the summer is optimum (Beeson, 1992; Keever and Cobb, 1985) because of limited soil volume and low water-holding capacities of container media (Costello and Paul, 1975).

In a landscape, water loss from a newly transplanted root ball can occur due to gravitational forces and differences in texture between the container medium and soil. Ground beds, with their deeper drainage, tend to have lower matrix potentials than those of container media, resulting in gradients that pull water toward the soil. In a container, the container's bottom obstructs water movement from gravitational forces, causing a perched water table (Spomer, 1974), but in the soil, the water column is continuous from the medium to the soil water table (Matheny et al., 1975; Nelms and Spomer, 1983). This continuous water column can be broken in loam soil by insulating the root ball with pea gravel or coarse sand, resulting in greater water retention by the transplanted root ball (Matheny et al., 1979). However, this method is not practiced during landscape installation due to extra material costs and labor requirements. Also, backfilling with other than native soil is generally thought to impede root exploration into the landscape (Hummel and Johnson, 1985; Whitcomb, 1979). My objective was to determine if placing an inexpensive, water-impermeable barrier, which could be installed quickly below a container-grown root ball, would improve transplanted plant water status and speed landscape establishment.

Materials and Methods

Thirty photinia plants produced in 11.4-liter containers consisting of 3 pine bark : 1 Florida peat : 1 sand medium were transplanted 12 Feb. 1992 into an excessively drained Astatula fine sand (typic, uncoated, hyperthermic quartzip samments; Carlisle et al., 1978). Infiltration rate of this soil was 16 $mm\cdot min^{-1}$. At transplanting, a barrier consisting of a square polyethylene sheet (0.15 mm thick; 0.36 × 0.36 m) was installed under half of the plants by tucking the corners inward and placing 10 to 25 mm of native soil on top before plant installation. Barriers were slightly concave (≈30 mm deep) due to the shape of the transplant hole. Transplant holes were hand-dug 10 to 15 cm wider than the root ball. Photinia were transplanted in a single row oriented north–south on 0.9-m centers with the barriers installed under alternating plants. 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 during 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-g 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 glyphosphate.

Plant water potential (ψ_T) was measured diurnally at ≈2-h intervals from before dawn until the final interval started 30 min after sunset. 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 $kPa\cdot s^{-1}$ (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 ψ_T equilibrium between leaf and stem. The foil was sealed around each leaf, with only the petiole exposed. Diurnal ψ_T 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 (S_ψ) was calculated as the absolute value of the integration of each diurnal ψ_T 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.

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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). Plant 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 × time and time × direction interactions were not significant (Table 1). Roots were longer on plants with barriers (Table 1). The increase in root lengths was linear with time (Table 1), with length (mm) = 4.8 × week + 26; $r^2 = 0.69$.

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 × week – 1.0; $r^2 = 0.57$) (Fig. 1); in the east direction, it increased with the square of the weeks after transplanting but was not quadratic (dry weight = $0.008 \times \text{week}^2 - 1.38$; $r^2 = 0.68$) (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 = $0.016 \times \text{week}^2 - 1.78$; $r^2 = 0.92$) and were significantly greater than the linear increase of control plants (dry weight = 0.41 × week – 2.23; $r^2 = 0.79$).

Table 1. Analysis of canopy growth and maximum excavated root lengths of transplanted photinia during the first year after transplanting.

Variable	Mean plant ht (m)	Mean max (m) root length
Treatment (T)[z]		
Control	0.77[y]	0.185[y]
Barrier	0.97	0.213
F value	**	*
Weeks after transplanting (W)		
0	0.73[x]	0.00[x]
17	0.82	0.15
34	0.91	0.18
52	1.01	0.27
Linear	*	**
Quadratic	NS	NS
Direction (D)		NS
Interactions		
T × W	NS	NS
W × D		NS

[z] 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.

[y] Annual mean of four measurement periods of five single-plant replications.

[x] Mean of 10 single-plant replications of plants with barriers and control plants combined.

NS, *, ** Nonsignificant or significant at $\alpha = 0.05$ or 0.01, respectively.

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 ψ_T 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 ψ_T, although differences among weeks were significant (data not included). Predawn ψ_T ranged from –0.03 to –0.22 MPa, with measurements consistently more than –0.06 MPa by week 37. Minimum ψ_T 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 ψ_T depended on the time after transplanting. Plants with barriers had more negative dusk ψ_T than control plants at 8 and 12 weeks after transplanting (Fig. 3). Dusk ψ_T were consistently more than –0.25 MPa after week 37 (Fig. 3). Control plants ($9.02 \pm 3.75\ \text{MPa}\cdot\text{h}^{-1}$) averaged significantly ($\alpha = 0.05$) lower S_ψ values than plants with barriers ($9.44 \pm 4.3\ \text{MPa}\cdot\text{h}^{-1}$) for the year following transplanting. Differences in S_ψ 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 ≈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 (Beeson 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 ψ_T curves were similar between control plants and those over a barrier. Differences in dusk ψ_T and S_ψ values between control plants and those with barriers may be linked to differences in timing of shoot flushes 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

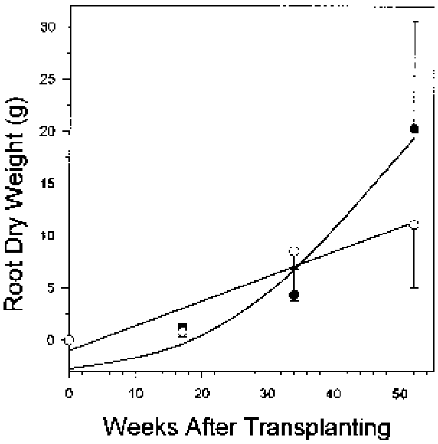

Fig. 1. Increases in horizontal-root dry weight extending from the original root ball for the (●) east and (○) west sides as a function of weeks after transplanting. Each point is a mean of 10 plants per side and based on excavation of 50% of an area surrounding a root ball. Vertical bars indicate the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

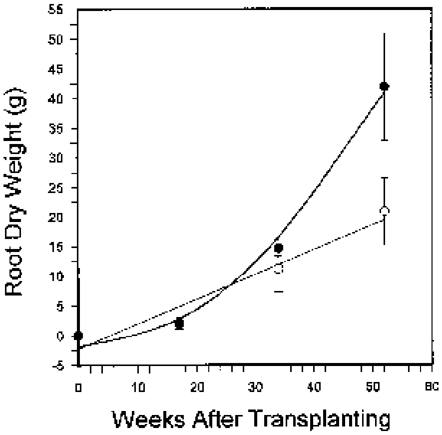

Fig. 2. Increases in horizontal-root dry weight extending from the original root ball at each root excavation for (○) control plants and (●) plants with barriers. The latter had a polyethylene sheet installed below the root ball. Each point is the mean of five plants per treatment and based on 50% excavation of an area surrounding a root ball. Vertical bars indicate the SE of the mean.

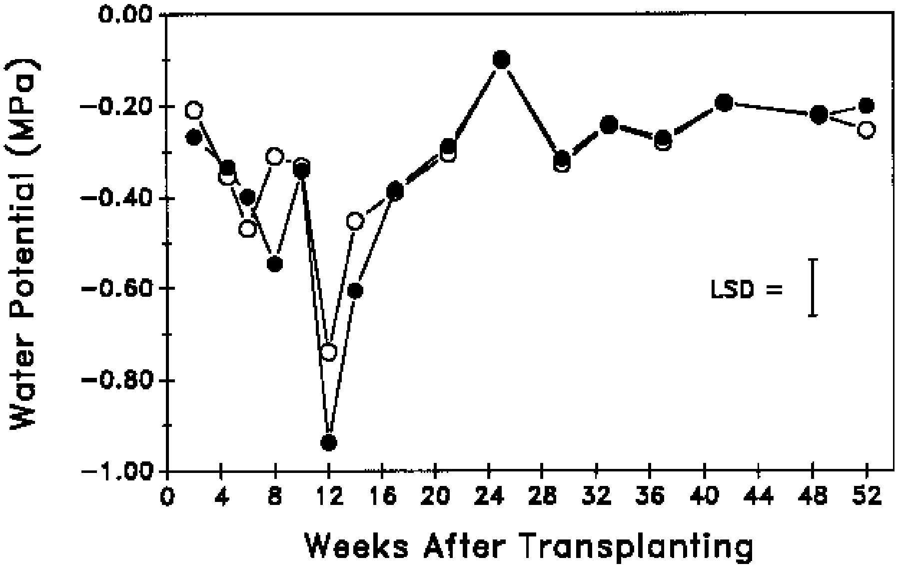

Fig. 3. Water potential measured after sunset (dusk) during the first year after transplanting into a landscape. (●) Plants with barriers were installed with a polyethylene sheet below the root ball. (○) Control plants were not. Each point is the mean of five plant replicates. Vertical bar represents 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 S_ψ 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 S_ψ values and, therefore, similar water status. Measurements of ψ_T were made on days between irrigation, on the premise that ψ_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 likely occurred during days with irrigation or following rainfall. In sand soils, rapid water loss from a transplanted root ball occurs due to textural differences and gravitational forces, unless the soil is saturated (Nelms and Spomer, 1983). The macropore structure of the Astatula sand, exemplified by high-infiltration rates, suggests that most water withdrawn would be through the bottom of a root ball by gravitational forces. Water-holding capacities of Astatula sands are low (8 to 13 mm/30.5 mm of soil). The same macropore structure presumably would limit lateral water movement in much the same way as the buffer zones reported by Matheny et al. (1979). Therefore, it seems a barrier under a root ball reduces gravitational water loss, resulting in a larger amount of available water on days of irrigation or substantial rainfall. Turgor-dependent growth by cell expansion may have occurred more rapidly in plants with barriers than in control plants at this time. This hypothesis could be tested by diurnal ψ_T measurements on adjoining days with and without irrigation.

Literature Cited

Andersen, P.C. and B.V. Brodbeck. 1988. Water relations and net CO_2 assimilation of peach leaves of different ages. J. Amer. Soc. Hort. Sci. 113:242–248.

Becker, C.A., G.D. Mroz, and L.G. Fuller. 1987. The effects of plant moisture stress on red pine (*Pinus resinosa*) seedling growth and establishment. Can. J. For. Res. 17:813–820.

Beeson, R.C., Jr. 1992. Restricting overhead irrigation to dawn limits growth in container-grown woody ornamentals. HortScience 27:996–999.

Beeson, R.C., Jr., and E.F. Gilman. 1992. Diurnal water stress during landscape establishment of slash pine differs among three production methods. J. Arboriculture 18:281–287.

Begg, J.E. and N.C. Turner. 1970. Water potential gradients in field tobacco. Plant Physiol. 46:343–346.

Carlisle, M.A., R.E. Caldwell, F. Sodek, III, L.C. Hammonds, F.G. Calhoun, M.A. Granger, and H.L. Breland. 1978. Characterization data for selected Florida soils. Univ. of Florida, Gainesville.

Costello, L. and J.L. Paul. 1975. Moisture relations in transplanted container plants. HortScience 10:371–372.

Garnier, E. and A. Berger. 1985. Testing water potential in peach trees as an indicator of water stress. J. Hort. Sci. 60:47–56.

Gilman, E.F. 1990. Tree root growth and development. II. Response to culture, management, and planting. J. Environ. Hort. 8:220–227.

Hummel, R.L. and C.R. Johnson. 1985. Amended backfills: Their cost and effect on transplant growth and survival. J. Environ. Hort. 3:76–79.

Keever, G.J. and G.S. Cobb. 1985. Irrigation scheduling effects on container media and canopy temperatures and growth of ‘Hershey’s Red’ azalea. HortScience 20:921–923.

Matheny, N.P., R.W. Harris, and J.L. Paul. 1979. Irrigation requirements of transplanted container-grown plants. Proc. Intl. Plant Prop. Soc. 29:82–90.

Nambiar, E.K.S., G.D. Bowen, and R. Sands. 1979. Root regeneration and plant water status of *Pinus radiata* D. Don seedlings transplanted to different soil temperatures. J. Expt. Bot. 30:1119–1131.

Nelms, L.R. and L.A. Spomer. 1983. Water retention of container soils transplanted into ground beds. HortScience 18:863–866.

Snedecor and Cochran. 1980. Statistical methods. 7th ed. The Iowa State Univ. Press, Ames.

Spomer, L.A. 1974. Two classroom exercises demonstrating the pattern of container soil water distribution. HortScience 9:152–153.

Whitcomb, C.E. 1979. Factors affecting the establishment of urban trees. J. Arboriculture 5:217–219.