Irrigation and Fertilizer Placement Affect Root and Canopy Growth of Trees Produced in In-ground Fabric Containers[1]

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Abstract

Live oak (*Quercus virginiana* Mill.) and Chinese elm (*Ulmus parvifolia* Jacq. 'Drake') were transplanted from 3.8 liter (#1) containers into 35-cm (14 in) fabric containers in sandy soils. Irrigation or fertilizer was applied all inside, half-in half-out (50/50), or all outside the fabric container during a 2-year production cycle. For live oak, neither irrigation nor fertilizer placement increased fine root mass within the fabric container. Maximum trunk diameter was achieved by applying both irrigation and fertilizer inside the container. For Chinese elm, applying either fertilizer or irrigation inside or half-in half-outside the container increased fine root mass within the harvested root ball. Elm shoot growth was greatest with 50/50 placement of both irrigation and fertilizer. Field site influenced the effect of irrigation on shoot growth, but not root mass. Greater fine root mass occurred in the heavier soil type.

Index words: *Quercus virginiana*, live oak, *Ulmus parvifolia*, Chinese elm, field production, transplanting.

Significance to the Nursery Industry

Although in-ground fabric containers have been used in nursery production for 10 years, optimum placement of fertilizer and irrigation to enhance both trunk growth and fine root development within the root ball have not been thoroughly investigated. For live oak, applying either irrigation or controlled-release fertilizer only inside the container did not increase the mass of fine roots less than 10 mm (0.4 in) within the root ball. However, trunk caliper and height were greatest when both irrigation and fertilizer were applied only inside the fabric container during the first two years. For the rapid-growing Chinese elm, applying at least half the irrigation or fertilizer inside the container enhanced the amount of fine roots within the root ball. Placing both irrigation and fertilizer half inside and half outside of the container produced the most rapid increase in trunk caliper and height and generous fine root development within the harvested root ball. It appears that for less rapid growing species, i.e., live oak, both fertilizer and irrigation should be applied only inside the container the first 2 years. For more rapid growing species, i.e., Chinese elm, half-inside half-outside placement of both irrigation and fertilizer appears to produced the most desirable results. Greater fine root mass was harvested with both species from the soil with a higher clay content.

Introduction

In-ground tree production employing fabric containers is a production system increasingly used in many parts of the United States and other countries (K. Reiger, Root Control, Inc., personnel communication). While these containers ease harvest, post-digging losses can be excessive if trees are not properly handled. Earlier studies indicated the majority of these losses were due to improper water management after digging, and that increases in harvested fine root mass decreased postharvest water stress and improved tree quality (1).

Concentrating irrigation during field production with microirrigation techniques has been shown to enhance fine root development in the irrigated zone without reducing tree growth compared to widespread irrigation (2, 4, 7, 8). The majority of these studies occurred in areas of low rainfall. In central Florida, mean rainfall is 1270 mm (50 in) with most occurring during the months of June through October. In Florida, concentrating irrigation augmented with liquid fertilizer to within the confines of the fabric container tremendously increased harvested fine root mass for *Quercus laurifolia* (laurel oak), but not *Lagerstromeria indica* (crape myrtle) (6). The question arose as to which component was more influential in the stimulation of harvestable fine root mass, fertilizer placement, or irrigation placement.

The current study was designed to differentiate fertilizer placement effects from irrigation placement effects on tree growth and harvested root mass, for two widely grown tree species representative of relatively fast and average growth rates. The objective of this experiment was to determine optimum placement of both fertilizer and irrigation that produced the fastest growing trees with the largest quantity of fine root mass within the harvested root ball. Further, we investigated the effect of field site on tree growth and root mass inside the root ball for irrigation placement only.

Materials and Methods

Site 1. In mid-November 1990, six rows 2 m (6.5 ft) wide and 46 m (150 ft) long within a sodded field of Bahia grass (*Paspalum* sp.) were sprayed with glyphosate. Rows were separated by 3 m (10 ft) wide medians of Bahia grass. A month later, twenty-four 35-cm (14 in) fabric containers (Root Control Bag, Root Control, Inc., Stillwater, OK) were installed on 1.8 m (6 ft) centers within each row and filled with native soil, Apopka fine sand. Apopka fine sand is an excessively-drained sand to a depth of more than 5 m (16 ft) with a water table deeper than 20 m (65 ft). It is classified as a loamy siliceous, hyperthermic Grossarenic Paleudults with bulk densities of 1.45 to 1.65 g/cm^3, available water capacity of 0.03 to 0.05 in/in and < 2% clay (9). Either *Quercus virginana* Mill. (live oak) or *Ulmus parvifolia* Jacq. 'Drake'

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[1] Received for publication February 27, 1995, in revised form May 26, 1995. University of Florida Agricultural Experiment Station Journal Series No. R-04412.

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('Drake' Chinese elm) 2-year-old seedlings, grown in 3.8-liter (#1) plastic containers, were planted into each fabric container. Each row was designated as either a fertilizer or irrigation treatment. Trees were planted as a complete block design, with four trees per block and 3 blocks per species per treatment. The species at the beginning of each treatment was randomly chosen; thereafter, blocks alternated species. After planting, irrigation was applied only inside the fabric container until treatments were initiated in mid-April 1991.

Treatments consisted of three placements of two factors (irrigation or fertilizer). Placements were all inside the fabric container (inside), half inside and half outside (50/50), or all outside the fabric container (outside). The factor not under study within a row was held constant at half inside and half outside. Thus, when irrigation placement was varied, fertilizer placement was 50/50; when fertilizer placement varied, irrigation placement was 50/50. Water was supplied to each tree through low volume irrigation using micro heads on 31 cm (12 in) stakes that produced an inverted cone pattern (Model SP-12; RainBird, Inc., Glendora, CA) for the irrigation treatments, and individual spray stakes (Black Spot Spitters, Roberts Irrigation Products, San Marcos, CA) for the fertilizer treatments. Trees in the inside and 50/50 irrigation treatments had one stake per tree, while trees in the outside irrigation treatment had two stakes per tree on opposite sides of the fabric container. All trees received the same volume of water per irrigation. Initially, trees were irrigated at ca. 4 liters/tree (1.2 gal/tree) on alternating days. Irrigation volume and frequency increased proportional to tree growth. At harvest, irrigation volumes were about 31 liters/tree (8 gal/tree) daily. A controlled-release fertilizer (Osmocote 14N–11.6K–6.0K, Grace-Sierra, Malpitas, CA) was applied by hand on April 14 and July 9, 1991, and February 12, May 15 and July 15, 1992, at a rate of 336 kg N/ha (7 lb N/1000 ft^2) based on estimated root area (5). Fertilizer application area outside a container varied with tree size; from adjacent to the container initially to within an 3.4 m^2 (36 ft^2) area centered on a container. Initial fertilizer application was 80 g (2.7 oz) per tree with a final application of 240 g (8.4 oz) per tree. Tree shoots were pruned or staked as required to produce commercially acceptable trees. Weed growth was periodically controlled within rows with glyphosate.

Table 1. **Effects of fertilizer and irrigation placement on final tree height and trunk caliper of Chinese elm 'Drake' at field site 1.**

	Height (m)	Trunk caliper (mm)
Main effect		
Fertilizer	3.21	49.3
Irrigation	2.96	47.6
	**[z]	ns
Subplot effect[y]		
Inside	3.00b[x]	48.4b
50/50	3.28a	51.0a
Outside	2.98b	46.0c
	**	**

[z] **, ns signify significant differences of 0.01 or not significant; respectively.

[y] Placement location of either fertilizer or irrigation in relation to perimeter of the in-ground fabric container. 50/50 placement was half inside and half outside the container.

[x] Means with the same letter within columns are not significantly different at a = 0.05 as determined by Fisher's Protected LSD.

Site 2. The inside and 50/50 irrigation treatments were replicated for both species at a second site. Soil in this site was a Myakka fine sand with an impervious hard pan about 0.7 m (2.3 ft) below the surface. Myakka sand is classified as a sandy, siliceous hypertermic Aeric Haplaquods with bulk densities of 1.45 to 1.6 g/cm^3, available water capacity of 0.02 to 0.15 in/in and 2 to 5% clay (9). This site was about 72 km (45 miles) east northeast of site 1.

Tree height and trunk caliper at 15 cm (6 in) above the soil were measured periodically on all trees at both sites throughout 1991 and 1992 until trees were harvested. During fall and early winter of 1992, five trees from each species per treatment were randomly selected and lifted from the soil at each site. Roots outside of the fabric container were excised and fabric removed. Soil was washed from the root ball and the trunk severed near soil level. Washed root balls were then stored at 3C (37F) in open polyethylene bags until root analysis. Roots at the perimeter of root balls were cross-sectioned and separated into diameter classes of 5–10 mm (0.2–0.4 in), >10–15 mm (>0.4–0.6 in), >15–20 mm (>0.6–0.8 in), >20–25 mm (>0.8–1.0 in) and >25–30 mm (>1.0–1.2 in). Total root cross-sectional area was calculated in each class. Roots within each root ball were removed and separated into 0–2 mm (0–0.08 in), >2–5 mm (>0.08–0.2 in) and >5–10 mm (>0.2–0.4 in) diameter classes. Roots were dried at 70C (158F) to a constant weight and dry weight determined.

Final tree heights and calipers were analyzed as a split plot for each species with factor (fertilizer and irrigation) as the main plot and placement (inside, 50/50, outside) as the subplot for trees at Site 1. Root dry weights and perimeter cross-sectional surface area were analyzed as a randomized design separately for each root diameter class within a species and factor. Final height, trunk caliper and root dry weights, and cross-sectional root areas were analyzed separately for each species as a split plot design; where field site was the main plot (site 1 and site 2) and irrigation placement the subplot.

Results and Discussion

Tree growth—elm. At field site 1, interaction of factor and placement was not significant for final elm height or final trunk caliper (data not shown), but main and subplot effects were significant for height (Table 1). Fertilizer had a larger influence on elm height than irrigation. Placing a factor 50/50 produced taller trees than either inside or outside placement. Placing a factor 50/50 produced larger trunk calipers than inside placement, which were larger than those receiving outside placement (Table 1).

Elm trees grown at field site 2 had larger ($\alpha = 0.05$) trunk calipers (51.7 mm; 2.0 in) at harvest than those grown at field site 1 (49.0 mm; 1.9 in). Within field site 2, there were no differences in final height or caliper between elm trees grown with irrigation inside or 50/50. Yet, when the two sites were analyzed together, tree height responded oppositely to placement at each field site (Table 2).

Tree growth—oak. Interactions of factor and placement were not significant for final growth measurements of live oak at field site 1 (data not shown). Placement did not affect

Table 2. Effects of soil type (field site) and irrigation placement on final Chinese elm tree height.

Irrigation placement	Tree height (m) Field site 1[z]	 Field site 2
Inside[y]	2.8b[x]	3.19a
50/50	3.16a	2.96b
Within site	*[w]	ns

[z] Field site 1 was an Apopka fine sand while field site 2 was a Myakka fine sand.

[y] Placement of irrigation in relation to perimeter of the in-ground fabric container. 50/50 placement was half inside and half outside container.

[x] Means with the same letter are not significantly different at a = 0.05 as determined by Fisher's Protected LSD within rows and columns.

[w] *, ns signify signficant differences of 0.05 or not significant, respectively.

Table 3. Effects of fertilizer and irrigation placement on final tree height and trunk caliper of live oak at field site 1.

	Height (m)	Trunk caliper (mm)
Main effect		
Fertilizer	2.22	37.8
Irrigation	2.49	41.1
	**[z]	ns
Subplot effect[y]		
Inside	2.52	42.9a[x]
50/50	2.36	38.2b
Outside	2.21	37.4b
	ns	*

[z] *, **, ns signify significant differences of 0.05, 0.01 or not significant; respectively.

[y] Placement location of either fertilizer or irrigation in relation to perimeter of the in-ground fabric container. 50/50 placement was half inside and half outside container.

[x] Means with the same letter within columns are not significantly different at a = 0.05 as determined by Fisher's Protected LSD.

tree height (Table 3). However, averaged over placement treatments, irrigation had a larger influence on tree height than fertilizer. Differences in trunk caliper occurred as a function of placement independent of factor (Table 3). Placement of either factor inside the container resulted in the largest calipers, with 50/50 and outside placement producing similar trunk calipers (Table 3).

Concentrating irrigation to inside the fabric container did not increase caliper or height growth compared to 50/50 placement at field site 2 (data not shown). There were no significant differences in height or trunk caliper of oaks between sites or among placements.

Harvested roots for Chinese elm. At field site 1, neither fertilizer nor irrigation placements resulted in differences in perimeter root cross-sectional areas (data not shown). However, at field site 2, concentrating the irrigation inside the fabric container (2148 mm^2; 3.3 in^2) increased ($\alpha = 0.05$) the perimeter root cross-sectional area in the >5–10 mm (0.2–0.4 in) class compared to 50/50 placement (1124 mm^2; 1.7 in^2). Field site did not influence perimeter root cross-sectional area within any diameter class (data not shown). However, when averaged over sites, perimeter root cross-sectional area in the >5–10 mm^2 (0.2–0.4 in^2) diameter class was larger with inside irrigation placement (1829 mm^2; 2.8 in^2) than with 50/50 placement (1240 mm^2; 1.9 in^2).

Fertilizer placement inside the fabric container at field site 1 increased ($\alpha = 0.01$) fine root mass in the 0–2 mm (0–0.02 in) class (52.15 g) compared to 50/50 (22.30 g) and outside (16.59 g) placement. Root mass in the >2–5 mm (>0.08–0.2 in) class was nearly doubled with inside placement compared to the other two placements, but was not significantly different ($\alpha = 0.08$; data not shown). Root dry mass in the larger root diameter classes was similar among treatments.

At field site 1, less root dry mass in the 0–2 mm (0–0.08 in) and >2–5 mm (>0.08–0.2 in) diameter classes ware harvested when irrigation was limited to outside the fabric container compared to inside or 50/50 placement (Table 4). There were no differences among other root diameter classes and root cross sectional area classes (data not shown). At field site 2, concentrating irrigation to within the fabric container produced more ($\alpha = 0.05$) harvested root mass within the >2–5 mm (>0.08–0.2 in) class (82.2 g) and >5–10 mm (>0.2–0.4 in) class (98.7 g) than 50/50 placement (57.9 and 66.5 g, >2–5 mm and >5–10 mm classes, respectively).

Comparisons of root dry weight within root diameter classes revealed several differences between field sites. More ($\alpha = 0.05$) fine roots in the 0–2 mm (0–0.08 in) class were harvested at field site 2 (46.2 g) compared to field site 1 (32.6 g). In the >2–5 mm (0.08–0.2 in) class, root mass was

Table 4. Effect of irrigation placement on root dry mass in the fabric container for Chinese elm 'Drake' at field site 1.

Placement[z]	Root dry mass (g) Root diameter class 0–2 mm	 >2–5 mm
Inside	32.8a[y]	42.2a
50/50	32.4a	51.6a
Outside	11.6b	21.1b

[z] Placement location of either fertilizer or irrigation in relation to perimeter of the in-ground fabric container. 50/50 placement was half inside and half outside the container.

[y] Means with the same letter within columns are not significantly different at a = 0.05 as determined by Fisher's Protected LSD.

Table 5. Effect of fertilizer placement on root dry mass in the fabric container for live oak at field site 1.

Placement[z]	Root dry mass (g) Root diameter class >10 mm	 Total
Inside	167.2a[y]	239.6a
50/50	77.6b	145.5b
Outside	47.0b	95.2b

[z] Placement location of either fertilizer or irrigation in relation to perimeter of the in-ground fabric container. 50/50 placement was half inside and half outside the container.

[y] Means with the same letter within columns are not significantly different at a = 0.05 as determined by Fisher's Protected LSD.

similar between field sites with 50/50 placement, but was nearly double at field site 2 (82.2 g) compared to field site 1 (42.2 g) when irrigation was entirely inside the container. For root diameters >10 mm (>0.4 in), more ($\alpha = 0.05$) roots were harvested at field site 1 (267.7 g) than field site 2 (160.4 g). Total harvested root dry mass was also greater at field site 1 (449.3 g) than at field site 2 (359.4 g).

Harvested roots for live oak. Applying fertilizer only within the fabric container increased ($\alpha = 0.01$) root mass in the >10 mm (>0.4 in) class and total root dry mass within the root ball compared to other placements at field site 1 (Table 5). However, fertilizer placement had no effect on harvested fine roots (0-5 mm; 0–0.2 in) for live oak (data not shown). Root perimeter cross-sectional surface area in the >20–25 mm (>0.8–1.0 in) class was also greater ($\alpha = 0.05$) than other treatments with fertilizer placement inside (data not shown). Irrigation placement failed to produce any differences in root mass or perimeter surface area class between field sites (data not shown).

Trees grown in the less well-drained soil at field site 2 had more roots in the 0–2 mm (0–0.8 in) and >2–5 mm (>0.08–0.2 in) diameter classes averaged over irrigation placements (15.0 g and 27.4 g, respectively) than trees grown at field site 1 (4.8 g and 15.4 g, respectively). There were no differences in root dry mass due to placement effects, nor were there differences in root perimeter cross-sectional areas between sites.

For Chinese elm, fertilizer placement had more influence on tree shoot growth than irrigation placement. The 50/50 placement of both fertilizer and irrigation produced the tallest trees and largest trunk diameters compared to the other fertilizer-irrigation combinations. Although this placement produced only half the dry root mass in the 0–2 mm (0–0.8 in) diameter class as inside fertilizer placement, root masses in other diameter classes were similar. Thus, 50/50 placement of both fertilizer and irrigation resulted in maximum shoot growth and good root development within the harvested root ball. In other studies, increased transplant survival was associated with larger amounts of fine root mass (0–5 mm; 0–0.2 in) in the transplanted root balls (3, 10), as was higher post digging tree quality (1).

In contrast to elm, irrigation placement had a greater effect on live oak height than fertilizer placement. Another study also noted that oaks were generally unresponsive to fertilizer rate changes (11). Largest caliper increases and greatest total root mass occurred when both irrigation and fertilizer were concentrated inside the fabric container during the first 2 years of production. Relative to the other placement treatments, this placement did not increase harvestable fine root mass (roots 0–2 mm; 0–0.08 in diameter), but stimulated greater shoot growth. Greater shoot growth probably accounts for greater total root ball dry mass and perimeter root cross-sectional areas of larger roots. During the last interval between growth measurements, growth rates of trees with irrigation placement outside appear to have surpassed that of those with inside placement. We suggest, therefore, that the irrigation be expanded to a larger area after the end of the second growing season.

For both species, fine root mass was greater in trees growing at field site 2 than at field site 1. Field site 2 had a heavier, finer-textured soil with a shallow impervious hard pan. For root diameters 5 mm (0.2 in) or less, the increase in root mass was generally independent of irrigation placement. With greater harvestable fine root mass, post-harvest survival might be greater and transplant shock less for trees grown in the finer-textured sands (1, 5). Differences in soil types may explain some of the variability in postharvest survival rates among tree farms.

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