Production Method and Irrigation Affect Root Morphology of Live Oak[1]

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Abstract

Trees of live oak (*Quercus virginiana* Mill.) were container-grown (CG) or field-grown (FG) to a mean trunk diameter of 9.4 cm (3.7 in), transplanted into sandy soil, and established with frequent or periodic irrigation. Three years after transplanting, trees were harvested with a 1.5 m (60 in) diameter tree spade. Root number and root cross-sectional area was evaluated for all roots at the periphery of the tree-spade-dug root ball. Despite similar increases in trunk diameter, FG trees had greater root number and root cross-sectional area than CG trees. The greater root cross-sectional area occurred in roots 5–20 mm (0.2–0.8 in) in diameter at soil depths of 0–25 cm (0–9.8 in) and 75–100 cm (29.5–39.3 in). Irrigation frequency after transplanting had no effect on root number in FG trees. However, root number in CG trees was lower without frequent irrigation.

Index words: field-grown, container production, transplanting, root distribution, root diameter, soil depth, root number, balled and burlapped.

Significance to the Nursery Industry

Trees of live oak that received root pruning, fertilization, and irrigation in a field-grown nursery produced greater root cross-sectional area and root number, 3 years after transplanting, than container-grown trees. This might help FG trees establish more successfully in some landscape environments. FG trees also developed more roots deeper in the soil profile, which could increase survival and growth in dry or well-drained landscape soils. CG trees developed less root cross-sectional area in the top 25 cm (9.8 in) of soil than FG trees, which could make them more suited for planting near sidewalks. Sensitivity of CG trees to dry conditions immediately after transplanting might be responsible for a smaller number of roots. Therefore, irrigation after transplanting might be more important on CG than FG plants.

Introduction

Landscape trees are commonly produced in containers or are field-grown and balled and burlapped (B&B) when harvested. Limited research has compared root systems from these two production methods after transplanting. Blessing and Dana (3) found that after 16 weeks, field-grown (FG) Chinese juniper (*Juniperus chinensis* L.) had significantly greater new root dry weight than container-grown (CG), whereas there was no difference in shoot growth. In a similar experiment, there were no differences in root number or root dry weight between CG and FG white cedar (*Thuja occidentalis* L.) 40 days after transplanting (5). Using three species, Harris and Gilman (13) found that 10 weeks after transplanting, FG trees had greater root extension than CG trees. Laiche et al. (15) showed that 5 years after transplanting, height, caliper, and number of roots were not different between production methods for pecan [*Carya illinoensis* (Wang) K. Koch].

Rooting depth is largely influenced by cultural and environmental conditions (2). Research has shown that 99% of tree roots are found in the top 90 cm (35.4 in) of soil (4, 8). Laiche et al. (15) showed that roots of FG trees grew to a depth of 97 cm (38.2 in), significantly deeper than CG trees at 85 cm (33.5 in). The root system of FG trees of pecan had uniform root distribution, while CG trees had a denser root mass of circling, thicker roots. A deep root system could be beneficial in dry or well-drained soil since the lower soil layers dry out slower than surface layers (9), thereby making more water available to the plant. Deep roots are important for tree support and water absorption (7, 17). Deep root systems could become a disadvantage in poorly drained or compacted sites where such roots would not receive enough oxygen (10).

Irrigation could also be a factor in root distribution and size. Heilman et al. (14) suggested that accumulation of fine roots in the upper soil in hybrids of poplar (*Populus trichocarpa* (Torr. & Gray) x *Populus deltoides* (Marsh.)) was due not only to irrigation, but also to higher levels of organic matter and nitrogen in the upper soil horizons. Root biomass of seedlings of blue gum (*Eucalyptus globulus* Labill.) was greater in irrigated (daily irrigation from April to October) than non-irrigated seedlings 1 year after planting. All of this biomass was accounted for by roots 2–30 mm (0.08–1.2 in) in diameter (6). However, differences in root biomass between irrigated and nonirrigated treatments decreased with age, leaving no difference after 6 years. Gilman et al. (11) showed that 40 days after transplanting CG dwarf burford holly (*Ilex cornuta* Lindl. & Paxt. 'Burfordii Nana'), infrequent irrigation led to more root development from the bottom half of the root ball than the top half. Frequent irrigation encouraged root growth throughout the soil profile.

Little research has been conducted on post-planting root morphology of evergreen angiosperms. This experiment was therefore designed to compare root morphology of field-grown live oak (*Quercus virginiana*) with that of container-grown trees 3 years after transplanting.

Materials and Methods

Sexually propagated FG trees of live oak were planted in November 1987 in a central Florida nursery in 3-liter (#1)

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containers and were drip irrigated, fertilized regularly, and root pruned a minimum of once yearly. FG trees were dug in January 1992 with a 1 m (40 in) tree spade in accordance with industry standards (1). Root balls of 10 randomly chosen trees were placed in treated burlap and wire baskets. These trees were held at the nursery until May 1992, when they were shipped 21.7 km (35 miles) to the planting site in Gainesville, FL (USDA hardiness zone 8b). At another central Florida nursery, sexually propagated CG trees were grown above ground in a bark, sand, and peat medium. In May 1992, 10 of these trees were shipped 37.3 km (60 miles) to the planting site in 245 liter (65 gal) containers. All 20 trees were transplanted in May 1992 into a Millhopper sand (loamy, siliceous, hyperthermic Grossarenic *Paleudults*) on 6 m (20 ft) centers. The plot was laid out in a randomized complete block design of 10 blocks, each containing one tree from each production method. Mean trunk diameter, 15 cm (6 in) above the soil, was 8.9 cm (3.5 in) and 9.9 cm (3.9 in), for CG and FG trees respectively. Cypress mulch was applied around the base of each tree to a 1.8 m (6 ft) by 1.8 m (6 ft) square area to a depth of approximately 9 cm (3 in).

All 20 trees received 76 liters (20 gal) of irrigation daily for 2 weeks after planting, after which trees received either frequent or periodic irrigation. On the frequent irrigation schedule, five trees from each production method received irrigation daily weeks 3–22, then every other day from weeks 23–27. No irrigation was applied to these trees after week 27. On the periodic irrigation schedule, five trees from each production method were watered every other day from weeks 3–6, every third day from weeks 7–13, then weekly through week 18. Irrigation was discontinued after week 18 on trees irrigated periodically. Trees were grown for 3 years after transplanting, and were fertilized three times yearly at a rate of 1.4 kg (3 lb) of nitrogen/92.9 m^2 (1000 ft^2)/year. Trunk diameter was measured at planting and in June 1995.

In June 1995, all 20 trees were severed at ground level. Mean trunk diameter was 15.1 cm (6 in) and 17.3 cm (6.8 in) for CG and FG, respectively. Root systems were dug with a mechanical tree spade, which harvested a conical root ball measuring 1.5 m (60 in) wide by 1.0 m (40 in) deep. Root balls were placed upside down to allow for easy access to the roots. They were divided into four depth classes: soil surface to 25 cm (9.8 in) deep, 25–50 cm (9.8–19.7 in) deep, 50–75 cm (19.7–29.5 in) deep, and 75–100 cm (29.5–39.3 in) deep. All harvested roots were grouped by diameter into seven classes: 3–5 mm, > 5–10 mm, > 10–15 mm, > 15–20 mm, > 20–25 mm, > 25–30 mm, and > 30 mm. Roots ≥ 3 mm (0.12 in) that intersected the perimeter of each root ball were counted and cut 3 cm (1.2 in) back from the perimeter. Using the cut portion of the root, a clean cross-section was traced onto vellum paper from which the root cross-sectional area was calculated with a Delta T area meter (Decagon Instruments, Pullman, WA). Root balls were divided into four random vertical quadrants and root number counted in each quadrant.

Data were analyzed using SAS general linear model analysis of covariance procedures (16) to adjust means because trunk diameter at transplanting was slightly (but significantly) greater for FG trees. This procedure provided means for root cross-sectional area and root number adjusted for differences in initial trunk diameter. Means were compared using least square means from the general linear models procedure.

Results and Discussion

Production method and soil depth each had a significant effect on root cross-sectional area, as did the interaction between the two (Table 1). FG trees had greater root cross-sectional area than CG trees in the 0–25 cm (0–9.8 in) and 75–100 cm (29.5–39.3 in) soil depths (Fig. 1). Root cross-sectional areas of FG trees varied greatly over the soil depth, whereas, CG trees had no difference in root area at depths between 0 and 75 cm (29.5 in) (Fig. 1). The 50% greater total root cross-sectional area of FG trees was accounted for in the 0–25 cm (0–9.8 in) and 75–100 cm (29.5–39.3 in) soil depth. Laiche et. al. (15) also found that FG trees had deeper root systems than CG trees.

The three way interaction, production method × irrigation × soil depth, was significant (Table 1) only because at the 25–50 cm (9.8–19.7 in) soil depth, root cross-sectional area for FG trees receiving frequent irrigation was less than FG trees irrigated periodically (data not presented). This represented the only significant irrigation effect on root cross-sectional area. Gilman et. al. (11), using dwarf burford holly,

Table 1. Analysis of covariance for root cross-sectional area of live oak in response to production method, irrigation, soil depth, and root diameter.

Source of variation	Significance
Production method	**[z]
Irrigation	NS
Production method x irrigation	NS
Soil Depth	**
Irrigation × soil depth	NS
Production method × soil depth	**
Production method × irrigation × soil depth	*
Root diameter	**
Irrigation × root diameter	NS
Production method × root diameter	**
Production method × irrigation × root diameter	NS
Soil depth × root diameter	**
Irrigation × soil depth × root diameter	NS
Production method × soil depth × root diameter	NS
Production method × irrigation × soil depth × root diameter	NS

[z]NS, *, ** Nonsignificant or significant at p ≥ 0.01 or 0.001, respectively.

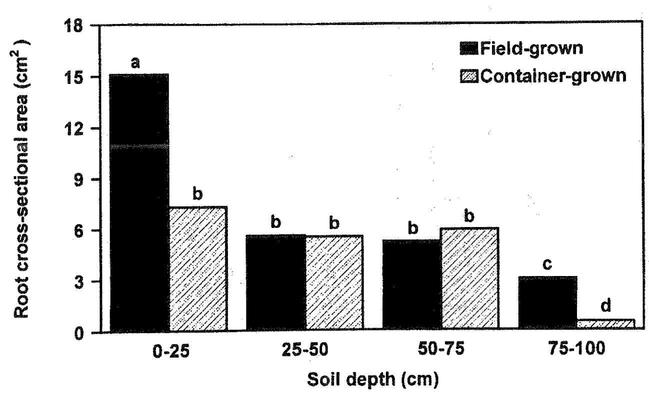

Fig. 1. Effect of production method and soil depth on root cross-sectional area of live oak. Values with the same letter are not significantly different according to least square means procedure at p ≥ 0.01.

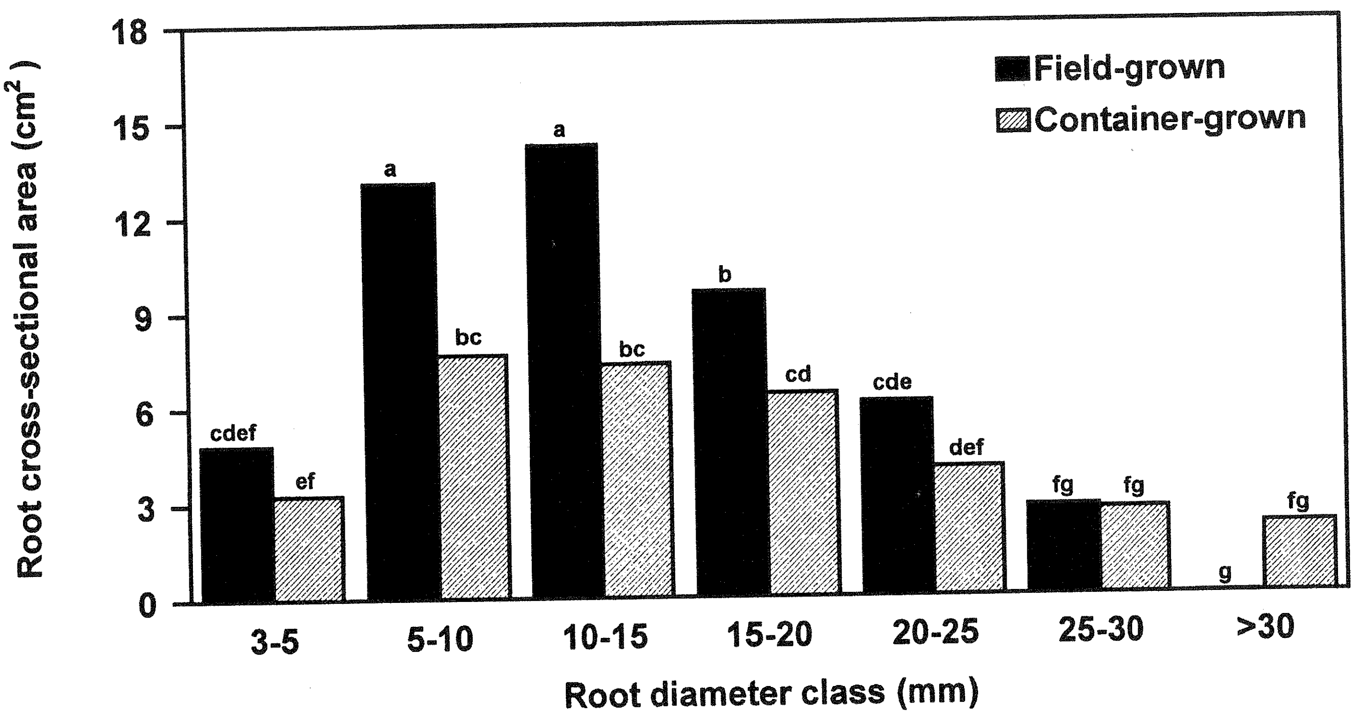

Fig. 2. **Effect of production method and root diameter class on root cross-sectional area of live oak. Values with the same letter are not significantly different according to least square means procedure at $p \geq 0.01$.**

showed a similar pattern of increased rooting deeper in the soil profile with infrequent irrigation. Research on trees of apple (*Malus* (Mill.) 'Laxton's Superb' / M 2) showed that irrigation increased root weight at 0–15 cm (0–5.9 in) soil depth but was reduced at 15–30 cm (5.9–11.8 in) depth (12). Under our soil conditions, frequent irrigation appeared to have caused a root response similar to irrigated trees in Goode and Hyrycz's (12) experiment, while our trees irrigated periodically reacted more like their nonirrigated trees. Irrigation increased the below-ground total biomass several years after planting; however, the effect often decreases over time (6). Fabião (6) found that after 6 years the below-ground total

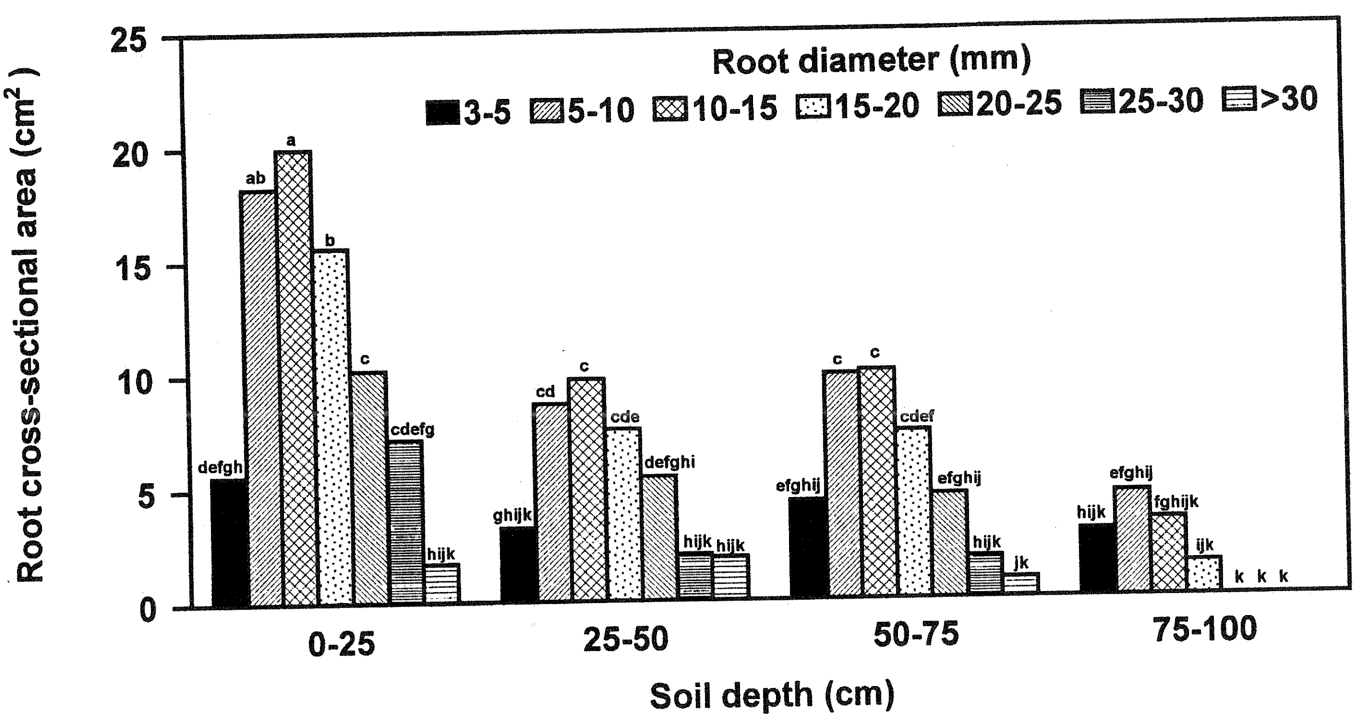

Fig. 3. **Effect of root diameter class and soil depth on root cross-sectional area of live oak. Values with the same letter are not significantly different according to least square means procedure at $p \geq 0.01$.**

Table 2. Adjusted least square means and analysis of covariance for mean root number of live oak in response to production method, irrigation, and quadrant.

Treatment	Mean root number
Field-grown	216.5a[x]
Container	137.2b
Field-grown/frequent irrigation	209.2a[y]
Field-grown/periodic irrigation	223.9a
Container/frequent irrigation	152.2b
Container/periodic irrigation	122.6c
Source of variation	**Significance**
Production method	**[z]
Irrigation	NS
Production method × irrigation	*
Quadrant	**
Irrigation × quadrant	NS
Production method × quadrant	NS
Production method × irrigation × quadrant	NS

[x,y]Values with the same letter are not significantly different according to least square means procedure at $p \geq 0.01$.

[z]NS, *, ** Nonsignificant or significant at $p \geq 0.01$ or 0.001, respectively.

biomass of irrigated trees was similar to nonirrigated trees, although there were differences after 1 and 2 years.

More than two-thirds (69.3%) of the total root cross-sectional area over all treatments resulted from roots 5–20 mm (0.2–0.8 in) in diameter (Fig. 2). The only significant differences in root cross-sectional area between FG and CG trees were in these same size classes, accounting for the significant production method × root diameter interaction (Table 1). Root cross-sectional area in these classes was greater than in the other diameter classes only in the 0–25 cm (0–9.8 in) soil depth (Fig. 3), accounting for the soil depth × root diameter interaction. This coincides with the overall increase in root cross-sectional area in the 0–25 cm (0–9.8 in) soil depth shown in Fig. 1. Therefore, much of the difference between the 0–25 cm (0–9.8 in) soil depth and other depths can be accounted for with roots 5–20 mm (0.2–0.8 in) in diameter. There was a more uniform distribution of root cross-sectional area among root diameters deeper in the soil.

FG trees generated a greater number of roots than CG trees 3 years after transplanting (Table 2). There was an interesting production method × irrigation interaction. Although FG trees under frequent or periodic irrigation had similar root numbers, CG trees had fewer roots with periodic irrigation than with frequent irrigation. Perhaps the plant compensated for reduced root number by increasing root size, causing, overall root cross-sectional area to remain the same. Laiche et al. (15) found that after 5 years there was no difference in root number of CG and FG trees of pecan. Quadrant was significant indicating that roots were not distributed uniformly around the trees. In other words, root number in at least one quadrant was greater than in the others. Lack of uniformity or lack of symmetry was significant for both production methods. Other researchers have also noted lack of symmetrical root distribution (18).

Greater root area at shallow soil depths in FG trees could be seen as a disadvantage in urban conditions where shallow roots often lift sidewalks and pavement. On the other hand, increased root area deeper in the soil on FG trees could lead to increased tolerance of drought conditions. Perhaps roots deflected down the container walls remain at the bottom accounting for the smaller root area at the shallow soil depths for CG trees, however, more research on a variety of species in different soil types needs to be conducted before these conclusions could be drawn.

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