Root Pruning and Transplant Success for Cathedral Oak® Live Oaks[1]

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Abstract

Trees that were root pruned regularly throughout the production period grew at a slower rate than trees that were not root pruned, but root pruning only in the last year of production did not affect trunk and canopy growth. Trees with root-pruning fabric installed under liners at planting grew at the same rate as trees without fabric during 39 months of field production. Hand spade root pruning throughout the production period increased the number of small diameter (< 3 mm) roots and decreased the number of large diameter roots in the root ball compared to trees that were not root pruned. Root pruning only in the last year of production reduced the number of large diameter roots but did not increase the number of small diameter roots. Fabric had no impact on the root system. Root pruning with a hand spade throughout production or only in the last year of production reduced water stress significantly in trees following digging compared to trees not root pruned during production. Root-pruning fabric installed under liners at planting reduced stress following digging 39 months later, but only on two of the days when water stress was measured.

Index words: tree transplanting, root ball, pruning fabric, water stress, *Quercus virginiana*.

Significance to the Nursery Industry

We found that root pruning Cathedral Oak® live oak (*Q. virginiana* 'SDLN' Cathedral Oak®, PP #12015) in a field nursery over two years (throughout production) reduced tree height 9%, trunk caliper 10%, and canopy width by 25%; whereas, root pruning only in the last year of production did not. Root pruning Cathedral Oak® only in the last year of production appeared to be most efficient, resulting in the largest trees with good root systems and only moderate stress after digging and excellent survival. However, these trees were challenging to root prune with a balling shovel because roots were thick and difficult to cut. To cut these large roots more easily, some growers now root prune using a tree spade. Cutting roots throughout the production period was easier because roots were smaller in diameter.

Introduction

Transplant stress and tree death can be costly to tree sellers and upsetting to their customers. Improving techniques for minimizing stress and maximizing survival are important for increasing canopy cover and improving efficiency in reforesting the urban landscape. In a study of irrigation effects on production of small diameter roots in the root ball, no differences were found between field grown live oaks receiving irrigation through a drip emitter and those receiving irrigation through a spray stake which distributed water over a 0.9 m (3 ft) diameter area (7). Irrigation volume also had no effect on the number or distribution of live oak roots inside the root ball. Since irrigation application had no apparent impact, we looked toward root pruning to improve root ball quality and enhance digging survival.

Live oak (*Quercus virginiana* Mill.) trees grown from seed or from cuttings (*Q. virginiana* Highrise®) in well-drained sandy nursery fields can sometimes produce large roots angled steeply down just below the trunk (8). The large roots can hinder harvesting the trees with a tree spade because the blades do not always cut through them. Extra labor is required to cut large roots with a shovel during harvest and can result in loose root balls or tree death in extreme cases. Large roots angled down sometimes produce only a few new roots following planting into a landscape with poor soil aeration (6). Some nursery trees produce large amounts of small diameter roots and some do not (13). Lack of small diameter roots on field grown trees has been associated with tree death in the days immediately following digging (8).

Morphological differences between root pruned and non root pruned trees include an increased ratio of small to large diameter roots (15) and a redistribution of larger roots to the top 1/3 of the root ball in live oak seedlings (7, 9). Since small diameter roots are thought to be more important for water and mineral absorption than larger roots, the proliferation of small roots after root pruning may help reduce water stress and increase survival after transplant (5, 11, 15). Stress after transplanting may be reduced by decreasing the leaf area that is transpiring as a result of root pruning (12). Sudmeyer et al. (14) also found an increase in small diameter roots of pines and eucalyptus in Australia on root pruned nursery stock.

Root pruning can reduce the cost of planting conifers with dominant taproots (10). Root pruning has also been used in the fruit crop industry to limit the growth of shoots (16). 'Wrenching' or lifting seedlings can reduce death by desiccation after transplanting for reforestation (11).

Gilman and Kane (5) hypothesized that post-transplant tree growth may be related to the distribution of roots among diameter classes within the root ball and that transplanted trees might benefit from treatments encouraging a high fine-root:coarse-root dry-weight ratio. Latter studies indicated that the larger coarse roots found on field grown trees might also be beneficial to transplant survival since trees from containers, with their abundance of fine roots, are more stressed following transplanting than field grown trees (4).

Our objectives in this study were to compare the effects of hand spade root pruning and root-pruning fabric on 1) morphology of the root system of field grown, cutting propa-

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Table 1. Schedule and placement for hand spade root pruning.

Date and location of root pruning	Distance from trunk at which roots were pruned	Root pruning treatment: Root pruning throughout production[z]	Root pruning treatment: Root pruning in last year of production (2004)
September 4, 2002 NE-SW[y]	20–23 cm (8– 9 in)	x	
December 3, 2002 NW-SE	23–25 cm (9–10 in)	x	
April 23, 2003 N/S	25–28 cm (10–11 in)	x	
July 10, 2003 E/W	28–30 cm (11–12 in)	x	
October 27, 2003 NE/SW	30–33 cm (12–13 in)	x	
February 12, 2004 NW/SE	33–36 cm (13–14 in)	x	x
April 12, 2004 N/S	33–36 cm (13–14 in)	x	x
July 13, 2004 E/W	33–36 cm (13–14 in)	x	x
October 12, 2004 NE/SW	33–36 cm (13–14 in)	x	x

[z]Trees planted August 2001.

[y]Abbreviations indicate compass direction. Hand spade root pruning was accomplished by slicing a square-tipped balling shovel 36 cm (14 in) long into the soil at an angle similar to that of a mechanical tree spade. Cuts were one-eighth circumference segments (12.5% of circumference each, totaling 25% circumference) at each root pruning date.

gated live oaks (*Quercus virginiana* Cathedral Oak®), 2) tree growth in the nursery, and 3) digging stress after transplanting.

Materials and Methods

Treatments. On August 7–8, 2001, thirty #1 (3.7 liter) liners of Cathedral Oak® live oak (*Q. virginiana* 'SDLN' Cathedral Oak®, PP #12015) were planted at the University of Florida Great Southern Tree Conference research site in Alachua County, FL (USDA Hardiness Zone 8b), on 1.8 m (8 ft) centers within rows and 3.6 m (12 ft) between rows in a sandy soil (Arrendondo sand) and grown for 39 months. At planting, #1 liner root balls were sliced from top to bottom about 2.5 cm (1 in) deep in four places around the plant to sever any potentially circling roots that could cause girdling as they expanded. No soil was placed over the root balls at planting.

Six treatments were applied to trees during the 39-month field production period. They included 1) fabric under root ball plus hand spade root pruning during the last year of production (2004), 2) fabric under the root ball plus hand spade root pruning multiple times during production, 3) fabric under the root ball and no hand spade root pruning, 4) no fabric under root ball plus hand spade root pruning during the last year of production (2004), 5) no fabric under the root ball plus hand spade root pruning multiple times during production, 6) no fabric under the root ball and no hand spade root pruning. Experimental design was a randomized complete block design with 2 (fabric vs. no fabric) × 3 (root pruning treatments) = 6 total treatments with 5 blocks totaling 30 trees.

A 30.5 × 30.5 cm (12 in^2) proprietary knit fabric of interlocking polyester fibers, designed to prevent enlargement of openings (Rootmaker Products Company, LLC, Huntsville, AL), was placed horizontally directly under the #1 liners at planting. Hand spade root pruning was accomplished by slicing a square-tipped balling shovel 36 cm (14 in) long into the soil at an angle similar to that of a mechanical tree spade. See Table 1 for a description of the root pruning schedule. Each pruning consisted of two one-eighth circumference segments (12.5% of circumference each, totaling 25% circumference). The bottom of the hand spade did not reach far enough into the soil to intersect opposite slices; therefore, roots growing directly under the trunk were not cut.

Each tree was irrigated using one drip emitter (Toro-Ag DBK 08 E-2 emitter, 8 liters/hr at 25 psi, Toro Agricultural Irrigation, El Cajon, CA) throughout production. Growing season daily irrigation volume [11.4 liters (3 gal)] was split into three applications (morning, noon and mid-afternoon) beginning in late March or early April, and dormant season irrigation was delivered in one application to total 3.8 liters (1 gal) per day beginning in late November. All trees were staked at planting to 2.5 m (8 ft) tall solid galvanized steel rods 8 mm (5/16 in) diameter. Staking was adjusted and maintained as needed to develop a straight central trunk to the top of the tree.

Trees were fertilized using soluble 16 N–4 P_2O_5 –8 K_2O throughout production applied at a rate of 65 g per tree in January 2002, 210 g in May 2002, 300 g in July 2002, and 400 g in October 2002. Thereafter in 2003 and 2004, 400 g was applied in March, June, and August or September. Fertilizer was distributed on the surface at each application to the approximate area of a 91 cm (36 in) diameter root ball.

The leader and canopy of each tree was pruned in May 2002, April and October 2003, and April and October 2004. Shoots were pruned to develop and maintain a dominant central leader and to establish scaffold branches spaced at least 15.4 cm (6 in) apart. Branches in the lower 1.5 m (5 ft) of the trunk that were growing up into the tree canopy were shortened. All other lower branches on the trunk were left intact during production until October 2004, when all branches on the lower 1.5 m (5 ft) of trunk were removed. These branches varied in diameter to a maximum of 2.54 cm (1 in). One

Table 2. Number of days after transplanting that water potential was measured (between noon and 1 pm) and the numbers of hours since trees were last irrigated before the water potential measurement.

No. of days after transplant	No. hours since irrigation
5	<1
9	<1
23	4
24	28
30	24
31	48
32	72
38	96
50	72

Table 3. **Mean growth rate of Cathedral Oak® grown with and without fabric installed under the liner at planting and with and without mechanical root pruning during field production. Trees were arranged in a randomized, complete block design in a 2 (fabric) × 3 (root pruning) factorial with 5 blocks (30 trees total).**

Treatment	Caliper cm (in)	Tree height m (ft)	Canopy width m (ft)
Fabric under liner	8.1 (3.2)	4.6 (15.0)	1.9 (6.2)
No fabric under liner	8.4 (3.3)	4.5 (14.8)	1.9 (6.3)
Not root pruned	8.4 (3.3)a[z]	4.7 (15.5)a	2.2 (7.1)a
Root pruned only in 2004	8.6 (3.4)a	4.6 (15.2)a	2.0 (6.7)a
Root pruned throughout production	7.6 (3.0)b	4.3 (14.0)b	1.6 (5.1)b
ANOVA			
Source of variation		**Significance**	
Fabric vs. no fabric	NS	NS	NS
Root pruning	$p < 0.0001$	$p < 0.007$	$p < 0.0001$
Fabric × root pruning	NS	NS	NS

[z]Within columns, means followed by different letters are significantly different ($p < 0.05$).

person pruned all trees throughout in the study. Final caliper, canopy spread, and total tree height were measured in November 2004.

Digging procedure and measurements. To compare the effects of root pruning on digging survival and stress, four complete blocks of 6 trees (4 × 6 = 24 trees total) were dug with an 81 cm (32 in) hydraulic tree spade (for trees root pruned throughout production) or a 91 cm (36 in) diameter hydraulic tree spade (for all other trees in the study) on November 14, 2004. The tree spade size corresponds to the American National Standards Institute Z60.1-2004 nursery stock standard (1). All 24 trees were then moved within the same field about 15 m (50 ft) from the original site. For 22 days, we irrigated transplanted trees every hour on the hour from 7:00 am until 6:00 pm, a typical procedure among wholesale tree nurseries digging live oak. Trees received 19 liters (5 gal) of water over a 10 minute period each time they were irrigated. After transplanting, we measured stress periodically for 50 days using a pressure bomb (Soil Moisture Inc, Santa Barbara, CA). After 23 days, transplanted trees were allowed to dry for several hours to several days before measuring stem water potential. To increase the water stress during the next three weeks, we gradually increased the number of hours or days since irrigation before measuring water potential (Table 2).

Root ball dissection procedure and measurements. All transplanted trees were raised with a tractor between 50–60 days following transplanting to measure roots in the root ball. Roots growing outside the root ball were discarded. Soil was gently washed from the root systems with a stream of water. The number of roots intersecting the edge of the root ball in each of four diameter classes (3 to 5 mm, 5 mm to 1 cm, 1 to 2 cm, and > 2 cm) was recorded. Washed, intact root systems on 18 trees (3 complete blocks) were marked at 27 cm (10.7 in) below the soil surface, half the depth of the deepest root ball. The root system was divided into an upper and lower portion along this line, placed in separate bags by diameter classes (< 3 mm and ≥ 3mm), and dried at 70C (158F) for 7 days. Root dry weight was recorded by diameter class.

Data analysis. Analysis of variance was performed using SAS statistical software (SAS Institute Inc., Cary, NC). A significance level of $P < 0.05$ was used for all analyses. Duncan's Multiple Range Test was used to compare means.

Results and Discussion

Top growth in the nursery. Trees with fabric under the liner grew at the same rate as trees without fabric (Table 3). Trees that were root pruned throughout the production period grew 10% less caliper and height and 25% less canopy width than trees that were not root pruned. Trees that were root pruned

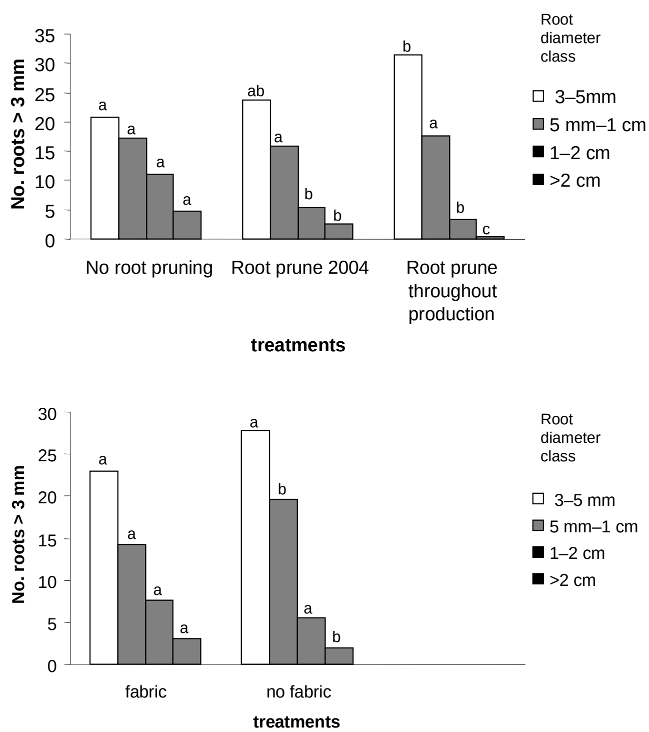

Fig. 1. **Mean number of roots (greater than 3 mm diameter) in each root diameter class for three root pruning treatments (top). Mean number of roots in root balls of trees grown with and without fabric installed under the liner at planting (bottom). Note: Within a root diameter class, different letters above the bars indicate significant differences ($p < 0.05$). Interaction between fabric and root pruning treatment was not significant.**

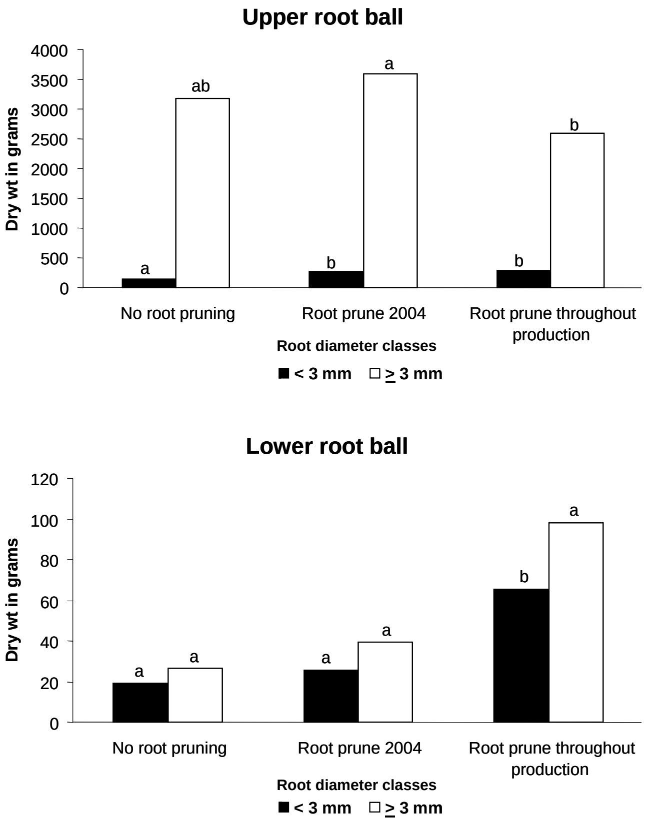

Fig. 2. Mean dry weight of roots in upper and lower root balls in pruning treatments. Upper root ball included all roots in the upper 27 cm; lower root ball included all roots below this point. Note: Within a root diameter class, different letters above the bars indicate significant differences among treatments (p < 0.05). Scale differs on upper and lower y-axes.

only in 2004 grew at the same rate as trees not root pruned (Table 3). Other studies also reported slow growth or no difference in growth in response to root pruning (2, 12).

Morphology of the root system. After 39 months of production, we found no differences in the dry weight of roots in either the upper or lower root ball, when comparing trees growing with and without root-pruning fabric (data not shown). This contrasts with results from a similar study showing that fabric under the liner, in conjunction with hand spade pruning, retarded development of large diameter deep roots and encouraged more shallow roots on Highrise® live oaks and live oak propagated from seed (7). Unlike the many deep roots on Highrise® without fabric, these shallow roots on Cathedral Oak® were easily cut with regular root pruning four times annually during production. The relatively shallow rooting of Cathedral Oak® in the current study may account for the lack of significant differences in dry weight between trees with fabric and those without fabric.

Installing root-pruning fabric under the #1 liner at planting reduced the number of roots 5–10 mm diameter and slightly, but significantly increased roots > 2 cm diameter (Fig. 1, bottom). Installation of fabric had no impact on root weight (data not shown).

Hand spade root pruning throughout the production period increased the number of small diameter (3–5 mm) roots and dramatically decreased the number of large diameter roots in the root ball compared to not root pruning (Fig. 1, top). Root pruning only in the last year of production (2004) also reduced the number of large diameter roots but did not increase the number of small diameter roots.

Root pruning throughout production or only in the last year of production increased the root dry weight of small diameter (< 3 mm) roots in the upper half of the root ball com-

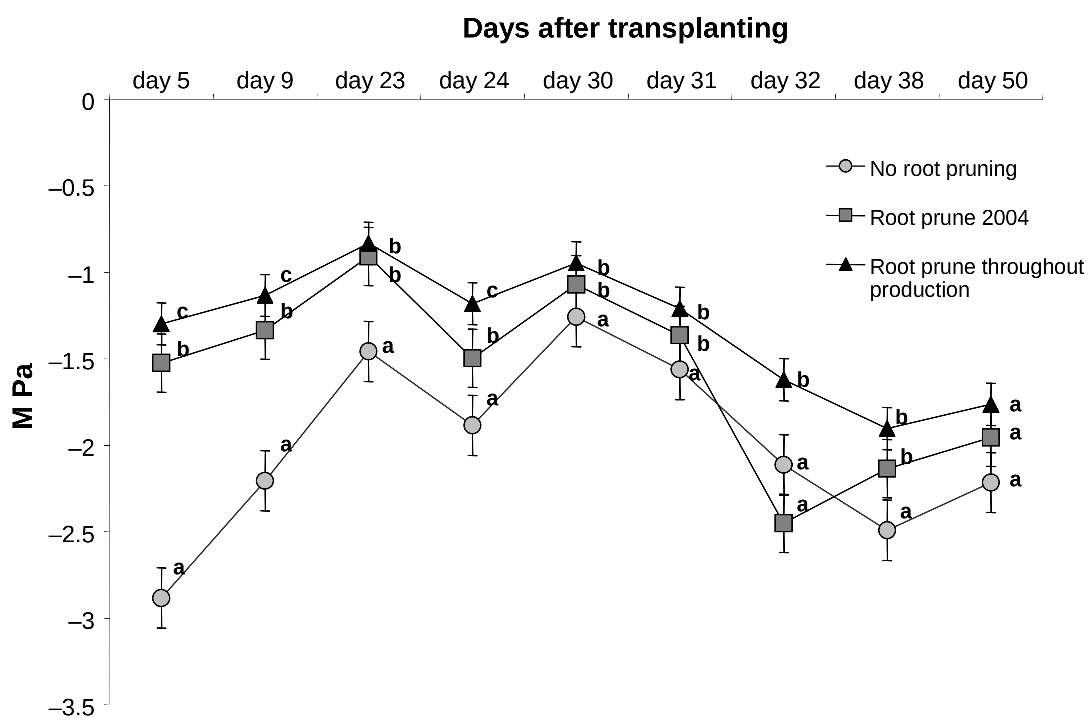

Fig. 3. Mean (with standard error bar) water potential (MPa) averaged across root-pruning fabric by root pruning treatment (8 trees per treatment) as an indicator of stress among transplanted trees in the nursery. Note: Within each day, means with different letters indicate significant differences (p < 0.05) among treatments.

pared with no root pruning (Fig. 2). Root pruning throughout production reduced large diameter root weight compared to root pruning only in the last year. Root pruning throughout the production period increased small diameter root weight in the lower portion of the root ball. Root pruning only once had no effect on dry weight of roots in the lower root ball (Fig. 2).

According to Kozlowski and Pallardy (11), injury to roots encourages branching and growth of new roots. Although we found that many roots grew from just behind the root pruning cut, some roots grew from 15 cm (6 in) or more behind the cut. Other studies have found that roots can originate from at least 10 cm (4 in) behind a root pruning cut (9). Along with increasing the distance between the trunk and the root pruning cuts each time we root pruned (Table 1), this explains the increase in fibrous roots we found within the root ball in response to root pruning. This study adds evidence to support the use of root pruning to encourage fibrous roots within the root ball.

Digging survival and stress. Root pruning with a hand spade throughout production or only in the last year of production, either with or without fabric, reduced water stress significantly in trees following digging compared to trees not root pruned during production (Fig. 3). Based on another study where trees that were not root pruned during production were stressed near the lethal level immediately following digging (2), many trees that were not root pruned in this study would have died if not irrigated ten times each day following digging. The extra effort required to root prune nine times during production resulted in reduced stress only in four of the nine stress measurement dates compared to trees root pruned only four times in the last year of production. While statistically significant, the reduction in stress may not be meaningful to growers because the difference in stress in the weeks following digging was small.

Root-pruning fabric installed under the liner at planting reduced stress following digging 39 months later, but only on two of the days when water stress was measured (data not shown). Results from a similar study (8) from 1997–2000 showed that the fabric under the liner retarded development of large diameter deep roots and encouraged more shallow roots on live oak acorn propagated trees. These shallow roots could be cut easily with regular root pruning four times annually during production. These trees survived the harvesting process better than traditionally root-pruned trees in the summer and winter dig (7). We did not find that fabric under the liner resulted in better survival in the current study with Cathedral Oak® probably because roots were fairly shallow on Cathedral Oak®.

Eventually, trees in all treatments acclimated to transplant stress and no xylem potential differences were found by day 50 (Fig. 3). Root pruning multiple times during production resulted in the least stress after digging, but trees were considerable smaller than trees root pruned only during the last year of production. Apparently less water would be needed to keep root pruned trees alive.

Trees survive droughts more easily with a densely branching root system than if their root systems rarely branch (11). It is probably not efficient nor necessary to root prune Cathedral Oak® throughout production since stress in the trees that were root pruned only in the last year was well below the level necessary to kill live oak (3). In the current study with Cathedral Oak®, we found no improvement in survival with fabric under the liner, possibly because roots were fairly shallow on Cathedral Oak®. The results of this study and others add support to the hypothesis that more small diameter roots coupled with fewer large diameter roots improves the likelihood of tree survival after transplant (8, 13). However, because hurricane force winds blew down 2-year-old trees in greater numbers if this same fabric was installed beneath them (Michael Marshall, Marshall Tree Farm, verbal communication), installation of root-pruning fabric under field grown live oak liners might not be warranted in regions that experience these winds.

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