Pruning Roots Affects Tree Quality in Container-Grown Oaks[1]

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Abstract

Height and trunk growth of *Quercus virginiana* 'SDLN' Cathedral Oak® tops was not affected by root pruning that occurred each time trees were potted into a larger container, beginning when rooted cuttings were planted into #3 containers. All trees produced in air root-pruning Accelerator® containers without mechanical root pruning produced enough circling roots to make them culls according to Florida and California standards for nursery stock. Removing root defects by pruning roots when trees are potted to the next larger size reduced culls from 100% to 40% of the crop and is recommended for quality tree production. Root pruning when trees were potted from one container size to the next size had no influence on the number of primary structural roots that grew directly from the trunk base. Root pruning had no impact on the number of roots that were deflected down. Waiting to root prune until #3 containers were potted into #15 containers did not increase the number of straight roots compared to non-pruned controls. Slicing the root ball edges vertically from top to bottom in several places appears to reduce circling roots capable of forming stem girdling roots. But slicing in the manner described in this study did little to reduce the descending root defects.

Index words: circling roots, root defects, adventitious roots, stem-girdling roots, root flare, trunk flare, root number, nursery stock quality, air root-pruning containers.

Species used in this study: Cathedral Oak® (*Quercus virginiana* Mill. 'SNDL' Cathedral Oak®).

Significance to the Nursery Industry

Air root pruning, copper hydroxide, and other systems designed to reduce root deformations in containers do not eliminate root defects; mechanical root pruning may remove more defects. Roots of *Quercus virginiana* 'SDLN' Cathedral Oak® live oak circled less when root balls were sliced top-to-bottom in six places each time trees were potted to a larger container size. This should reduce likelihood of formation of girdling roots and related health issues as the tree grows older. Tree stability may also improve with reduced circling, diving, and kinked roots. Slicing root balls did not eliminate all circling roots; removing the entire edge of the root ball each time trees are potted into a larger container size and when planting into the landscape may be necessary to effect removal of all root defects.

Introduction

Trees grown in containers develop root systems that are different from trees grown by other nursery production methods. Instead of spreading to their natural distance (37, 40) roots on shade trees are deflected up, down, or around by container walls (19), and this can affect how roots grow out into landscape soil (28). Roots growing away from the trunk can also be deflected 180 degrees and grow back to and close to the trunk forming a root kink (12). Compared with container-grown seedlings of the same age, naturally regenerated (i.e. trees resulting from seeds falling from nearby trees) *Pinus contorta* Douglas ex Louden seedlings were significantly taller and had a greater increase in leader height in each of the first two growing seasons (18). Root systems of container-grown seedlings had poorer lateral root symmetry and fewer main lateral roots after 12 years. Root systems on trees planted from containers also had more constricted, circling, and kinked roots. Naturally regenerated seedlings had greater sinker root development, and possessed self-grafted roots (18).

Container dimensions, size, and container surface porosity can change root morphology for the better (3, 28, 38). *Pinus radiata* D. Don seedlings in air-pruning 5 cm (2 in) diameter containers had less packed roots, less spiraling roots, and fewer L-shaped roots (32). The authors noted that tree seedlings in air-pruning containers produced less root defects than those grown in solid-walled containers, but also had slower root and canopy growth due to the lateral air-pruning (32).

Tree root length on the outside surface of the root ball can be reduced, at least for a time, by growing trees in containers coated with copper (8, 17, 38). Others showed a reduction in root circling and root deflection downward in propagation container trays with copper hydroxide producing root systems similar to naturally regenerated trees resulting in identical stability between the two groups (8, 9). Rooting cuttings in copper treated containers resulted in a greater percentage (40%) of roots emerging from the top one-third of the plug compared to trees grown in containers not treated with copper (18%); there were also more roots in the interior of the root ball plug and fewer on the outside forming a 'cage' (35). Gilman and Beeson (16) did not find this in *Ilex cassine*, L. Krasowski (25) found chemically root pruned *Pinus contorta* seedlings had more symmetrical root systems than controls, and root deflection was reduced. Lateral roots were more evenly distributed throughout the root ball in both chemically and mechanically pruned *Pinus contorta* than in the solid-walled, untreated control. Lateral roots that emerged in the unpruned, untreated control after seedlings were installed in the field were located primarily at the bottom of the original plug; this is considered a defective root system (25). Copper treatments of inner container walls were also reported to increase shoot growth (4) and root growth (3) of seedlings compared to untreated controls when planted into the field. In contrast, on typical landscape-sized trees, Gilman et al. (14) found similar root form on trees grown in copper treated

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or standard black plastic containers five years after planting. Despite reducing the length and amount of circling roots on the outer edge of the root ball, trees grown in containers treated with copper still develop circling roots (28).

Container grown trees planted in a nursery or landscape sometimes develop lateral roots on only two or three sides on the plant (24). This can lead to uneven root distribution in the landscape (34). Marler and Davies (29) reported that root circling and kinks on container grown citrus were responsible for uneven root development following planting. Roots that do not grow directly away from the trunk because they are deflected by the container wall can lead to tree instability. For example, Scots pine (*Pinus sylvestris* L.) planted from 75 ml containers (Paperpot FH 408) had less stability in the soil 7–9 years after planting than naturally regenerated trees (27). Authors attributed this to the spiraling roots developed in the propagation container.

The effects of manual root pruning of container-grown plants has resulted in varied responses on root growth and morphology. One recent study showed that light cutting of circling roots of shrubs enhanced the amount of roots growing into substrate outside of the original root ball (7). In contrast Gilman et al. (17) showed that cutting Burford holly (*Ilex cornuta* 'Burfordii') roots at planting resulted in a redistribution of roots, not an increase in roots compared with non-pruned controls. Harris et al. (20) reported root pruning treatments [5, 10, or 15 cm below soil) on pin oak (*Quercus palustris* Münchh.) liners in containers did not significantly affect total root length following planting, but root pruned treatments had more main lateral roots (> 2 mm diameter) originating from the primary seedling radicle when compared to control. Krasowski and Owens (26) found that root systems in mechanically pruned *Picea glauca* (Moench) Voss produced greater root growth than control or chemically root pruned treatments despite a smaller root ball at planting.

Existing lateral roots positioned close to the soil surface were invigorated and grew faster when tap root growth was blocked by placing the taproot into a small plastic cone; lateral roots grew only slightly faster than non-pruned controls when the tap root was pruned instead of blocked because new roots were generated at the cut end of the tap root (39). This has been attributed on young seedlings to carbon moving to the cut end of the tap root when no lateral roots are present or to the lateral roots when lateral roots are present. Removing the tap root tip of more mature seedlings (with existing lateral roots in the upper section of the root zone) resulted in an immediate increase in the radioactive carbon accumulation in the upper lateral roots (6).

Since most of the cited research was conducted on small seedlings, the objectives of this experiment were to determine influence on root system quality and top growth from cutting roots of landscape-sized trees in containers.

Materials and Methods

Eighty-eight *Quercus virginiana* 'SDLN' PP #12015 Cathedral Oak® rooted cuttings stuck into 5.7 cm (2.25 in) diameter Accelerator® (Nursery Supplies Inc., Fairless Hills, PA) containers in Summer 2002 were planted into #3 silver-colored Accelerator® containers filled with a 60 pine bark:40 peat:10 sand substrate (v:v:v) in early May 2003. Accelerator® containers are designed with holes in the sides to reduce circling roots. Enough substrate was gently removed from the 5.7 cm (2.25 in) Accelerator® to position the top-most root that emerged from the trunk 38 mm (1.5 in) below the substrate surface in the #3 container. Root defects (circling, ascending, descending or kinked roots) were cut with a hand pruner on half the liners (44) as they were potted into the #3 containers; defects were not cut on the other half (44 liners). Roots were cut just proximal (toward the trunk) to the point where they made an abrupt turn up, down, or around the container, or just proximal to the point where a 'J' root turned. Containers rested directly on field soil and were placed so container edges touched each other (pot-to-pot). Canopies were pruned in July 2003 and September 2003 to encourage a dominant leader. All trees were sprayed for powdery mildew once in October 2003. Low volume irrigation and controlled-release fertilizer was supplied identically to each container throughout the study to promote normal growth and health in the nursery.

In early May 2004, all 88 trees were potted using a fresh batch of the same substrate formulation into #15 Accelerator® containers resting directly on field soil and were placed 0.9 m (3 ft) apart. Trees were well below ANSI Z60.1 maximum caliper [19.0 mm (0.75 in)] and height [2.1 m (7.0 ft tall)] for the finished crop in this container size (#3) (2). The top of the substrate in the #3 containers was placed even with the substrate surface in the #15 containers for all trees. Root defects adjacent to the trunk including circling and kinked roots in the top 2.5 cm (1 in) of the root ball were again cut if needed on the 44 trees that previously had root defects removed; few trees needed this because they were previously root pruned. Twenty-five randomly chosen trees from the group whose root defects were not cut when potted into #3 containers had root defects removed in a similar manner when potted into #15 containers. Root defects were not removed on the remaining 19 trees. In addition to the defects close to the trunk that were removed from the top of the finished #3 root balls, the top edge and sides from top to bottom of the root ball of all root-pruned trees was cut 5 cm (2 in) deep radially in 6 equidistant places. For all trees at each repotting, substrate was removed to the point where the top-most root emerged from the trunk and then planted even with the top of the substrate. Canopies were pruned in May 2004 and September 2004.

In March 2005 all 88 #15 containerized trees were potted into #45 Accelerator® containers resting directly on field soil using a fresh batch of the same substrate formulation. Trees were placed 1.8 m (6 ft) apart. Trees were well below maximum caliper [5 cm (2 in)] and height [3.7 m (12 ft)] for a #15 container (2). The top of the substrate in the #15 containers was placed even with the #45 substrate surface. Trees that were previously root pruned had the top surface of the root ball cut radially and the sides in 6 equidistant places about 4 cm (1.5 in) deep prior to planting. All trees were canopy pruned in May 2005 and in February and June 2006.

Trunk caliper and tree height were measured at the end of each growing season (October) and at the end of the study in June 2006; spread was measured only in June 2006. All trees were graded according to the Florida Grades and Standards for Nursery Stock (1) steps one through nine in September 2006. Roots >10 mm diameter [measured 7.6 cm (3 in) from the trunk] in the top 7.6 cm (3 in) of substrate [if the top surface of the root was in the top 7.6 cm (3 in) then it was measured] on five trees in each treatment were separated from substrate with high speed air and water. The following was measured on each tree: maximum diameter of the root and diameter perpendicular to maximum diameter (these were averaged and reported as a mean), evaluation of the entire root system for step ten in Florida Grades and Standards for Nursery Stock, number of primary roots > 10 mm (0.4 in) diameter emerging from the trunk, number of primary roots that grew more-or-less horizontally straight from the trunk without deflection from the #3 or #15 container, number of primary roots that were deflected down at the position of the #3 or #15 container, number of primary roots circling at the position of the #3 or #15 container sizes.

Trees were arranged in a randomized incomplete block design with single tree replicates of treatments in each block. Data were analyzed using SAS to perform one way randomized complete block design ANOVA.

Results and Discussion

Final tree caliper and height were not affected by root pruning that occurred each time trees were potted into a large container beginning when rooted cuttings were planted into #3 containers. Similarly, growth was not affected when we waited to remove root defects when trees were potted from #3 into #15 containers (Table 1). Some of the roots pruned on finished #3 trees were up to 8 mm (0.3 in) diameter. Reported effects of manual root pruning in containers on top growth of container-grown plants vary in the literature. Some authors found reduced canopy growth following transplanting into the field when container-grown seedlings were root pruned (3, 5). Persson (33) found that mortality rate of *Pinus silvestris* L., and *Pinus contorta* Douglas ex Louden was not significantly different compared to control or between treatments when plants were treated with one or two mechanical root pruning treatments [light (35% root mass removed) or heavy (70% root mass removed) root pruning], but height and root collar diameter were reduced in the more heavily root pruned treatment. Gilman and Anderson (15) determined that root pruning field-grown live oak reduced top growth by about 12%. In contrast, Krasowski and Owens, (26) reported that *Picea glauca* (Moench) Voss seedlings in mechanically pruned treatments had greater above ground growth after 3 growing seasons than other treatments. Others reported no difference in shoot growth in response to root pruning container-grown plants (20, 25). This may have resulted from the more-or-less continuous and rapid growth of live oak during the growing season, and our irrigation and fertilization regime which was sufficient to sustain shoot growth following root pruning. Perhaps on other species and in cooler climates where growth is slower results would be different.

All trees produced in these air root-pruning Accelerator® containers without mechanical root pruning produced enough circling roots to make them culls according to Florida Grades and Standards for Nursery Stock (1). This is the only standard in the United States that quantifies root defects other than planting depth on nursery trees (2). In a related study 80% of Cathedral Oak® trees planted in containers were culls without root pruning (13). Removing root defects by pruning roots when trees are potted to the next larger size reduced culls from 100% (Figure 1A) to 40% (Figure 1B) of the crop (Table 2) and is recommended for quality tree production; but a 40% cull rate seems very high suggesting that we need a better root pruning system than slicing the sides of the root ball. Others found that manual root pruning of seedlings grown in containers reduced root defects (21, 22) and produced more symmetrically distributed lateral roots (25). Trees should be removed from containers before defects redevelop following root pruning**.** For example, planting container-grown *Pistacia chinensis* Bunge. into the field more than 35 days following root pruning in the container reduced the number of acceptable root systems due to root kinking (21).

Number of primary structural roots (roots > 10 mm diameter) that originated in the top 7.6 cm (3 in) of the root ball ranged from 5 to 8 per tree (Table 2). Others found similar number of main structural roots on a variety of tree species (10, 30). This suggests that most of the main structural roots were already formed on these four-year-old trees. Roots on Cathedral Oak® continue to emerge from the trunk after rooted cuttings were planted into #3 containers (13) so it is not surprising that removing root defects on rooted cuttings was no more beneficial than waiting to the next larger container size.

Root pruning when trees were potted from one container size to the next size had no influence on the number of primary structural roots that grew directly from the trunk base (Table 2). Root pruning had no impact on the number of roots that were deflected down. However, more primary roots (4.2) grew straight to the edge of the #45 container when roots were pruned each time plants were potted to the next container size compared to not pruning (1.2) (Table 2). Waiting to root prune until finished trees in #3 containers were potted into #15 containers did not increase the number of straight roots compared to non-pruned controls indicating that earlier mechanical intervention (root pruning) resulted in a greater number of straight roots. In agreement with others (22) removing root defects at each pot up appears essential to improve root system quality. Pulling tests combined with surveys following storms have shown that tree stability can be compromised when structural roots are not straight (36, 27). The influence of root defects on shade tree stability needs further attention.

Table 1. Effect of root defect removal on growth of Cathedral Oak® live oak in containers.

	Caliper cm			Height m		
Root defects removed[z]	**2004**	**2005**	**2006**	**2004**	**2005**	**2006**
not in #3, not in #15, not in #45[y]	2.52	5.08	6.22	2.01	3.40	3.74
not in #3, yes in #15, yes in #45	2.67	5.26	6.33	1.94	3.26	3.68
yes in #3, yes in #15, yes in #45	2.57	5.21	6.30	1.94	3.28	3.69

[z]Root defects were cut (yes) or not when potting into #3, #15 and #45 containers. Roots were cut just proximal to the point where they made an abrupt turn up, down, or around the container, or just proximal to the point where a 'J' root turned.

[y]Nineteen, 25 and 44 trees were in each treatment, respectively.

Fig. 1A. **Live oak root system currently in a #45 container that was never root pruned when potted from one container to the next larger size. Large primary roots were deflected by the #15 container wall.**

Fig. 1B. **Live oak root system currently in a #45 container that was root pruned each time tree was potted to the next larger container size. Note that there were more straight roots and fewer deflected roots on root pruned trees than those not root pruned. Despite root pruning some deflected roots are apparent at the #3 and #15 container sizes.**

Previous studies have clearly shown that containers with copper hydroxide treated walls (4), air root pruning containers (28), and shallow-wide containers (31) reduce root circling. This has lead to an abundance of container types designed to reduce circling roots. But no containers appear to eliminate root defects (28). Few have discussed the role that descending or ascending roots play in growth in containers or growth, root form and stability following planting to the landscape. Mickovski and Ennos (30) showed that trees with fewer straight roots led to instability in storms. Marshall and Gilman (28) showed that Accelerator® air-root pruning containers caused an increase in number of descending roots compared to smooth-sided containers probably due to the corrugated sides. Some arborists report that trees with shallow lateral roots that are deflected downward by container sides fell over in the 2004 and 2005 hurricanes (11). Horsley (23) showed that new roots are generated primarily near the cut end of a root and grew more-or-less in-line with the orientation of the cut root. When cut at the point a few mm before they make a sharp turn downward or around the trunk, new roots will form and grow in more-or-less the same direction as they did before hitting the container wall (23). This is probably the reason more straight roots were generated on our trees that were root pruned each time they were potted to the next larger container size. Root pruning container-grown trees needs much more attention as descending, ascending and circling roots appear to be common and can become a serious root defect contributing to instability and poor health.

Slicing the root ball edges from top to bottom in several places as we did in this study appears to reduce circling roots. This is best represented by the dramatic reduction in culls from 100% in the non-pruned root balls to only 40% in the sliced root balls (Table 2). This is likely to reduce the amount of roots capable of forming stem girdling roots. However, slicing did little to reduce the descending root defects (Table 2). Perhaps the entire outside edge of the root ball should be removed at each pot up so all descending, ascending, and circling roots are cut. Some of the new roots generated following this treatment should grow more-or-less straight out away form the trunk and improve stability in the container and in the landscape.

Table 2. Effect of root defect removal on primary[z] root form of Cathedral Oak® live oak in containers.

Root defects removed[y]	% culls[x]	No. primary roots	No. primary roots to edge of container[w]	No. primary descending roots[v]	No. primary circling roots[u]
not in #3, not in #15, not in #45	100	5.9a	1.2a	3.2a	3.2a
not in #3, yes in #15, yes in #45	40	5.5a	2.2ab	4.0a	1.8b
yes in #3, yes in #15, yes in #45	40	6.3a	4.2b	3.2a	1.8b

[z]Primary roots are roots > 10 mm diameter growing directly from the trunk measured 3 cm from the trunk.
[y]Root defects were cut (yes) or not on five trees of each treatment when potting into #3, #15 and #45 containers. Roots were cut just proximal to the point where they made an abrupt turn up, down, or around the container, or just proximal to the point where a 'J' root turned. Means calculated on 5 trees in each treatment.
[x]Culls according to Florida Grades and Standards for Nursery Stock (1); based on five trees per treatment.
[w]Number of roots > 10 mm diameter 3 cm from trunk base that reached the container edge without reducing noticeably in diameter at the position of the #3 or the #15 container.
[v]Primary roots deflected down at an angle greater than 45 degrees at either the position of the #3 or the #15 container.
[u]Primary roots circling at the position of the #3 or #15 containers.

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