Research Reports

Planting Depth in Containers Affects Root Form and Tree Quality[1]

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Abstract

After 40 months in air root pruning containers, *Quercus virginiana* 'SDLN' Cathedral Oak® live oak planted 3.8 and 8.9 cm (1.5 and 3.5 in) deep from rooted cuttings had greater caliper than trees planted at 1.3 cm (0.5 in) below substrate surface. Trees in the 1.3 cm (0.5 in) deep treatment grew taller than all other trees except for those in the 3.8 cm (1.5 in) deep treatment. Most (80%) trees were graded as culls according to root evaluations in the Florida Grades and Standards for Nursery Stock. This resulted mostly from roots circling and crossing the top of the root ball in the #3 and/or #15 container sizes. Trees planted 6.4 cm (2.5 in) deep in #3s, then 6.4 cm deep in #15s, and 6.4 cm deep in #45s [19 cm (7.5 in) total depth] had fewer, smaller diameter, and deeper primary roots than trees planted at all other depths. The presence of a trunk flare and surface roots decreased with increasing planting depth indicating that these could be used as an indicator of primary root depth. Cathedral Oak® demonstrated the capacity to generate new roots above the primary flare roots only when rooted cuttings were planted into #3 containers. Trees adjusted their root systems by generating a new set of roots along the buried stem up to the substrate surface. Roots did not grow from the buried portion of the stem when trees in #3 containers were planted 6.4 cm (2.5 in) deep into #15 containers. In other words 75% or more of the primary structural roots were deflected by either the #3 or #15 container wall or both, indicating that most primary roots that emerged from the trunk did so when the tree was in the # 3 or #15 container within 22 months of planting from rooted cuttings. Roots often grafted when crossed or laid against other roots.

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

Significance to the Nursery Industry

Rooted cuttings of *Quercus virginiana* 'SDLN' Cathedral Oak® live oak in 5.7 cm (2.3 in) diameter liner pots planted deeply into #3 Accelerator® air root pruning containers generated roots from the stem near the substrate surface regardless of planting depth. However, older trees planted deeply did not develop roots from the stem resulting in severe root defects including buried root flare, circling roots, and stem girdling roots. Trees planted deeply into #3, into #15, and again into #45 containers had the most severe defects. Despite growing in air root pruning containers, most trees were graded as culls according to root evaluations in the Florida Grades and Standards for Nursery Stock. In most cases this was a result of circling roots at the #3 or #15 container sizes.

Introduction

Forestry professionals, fruit growers, and other horticulturists have debated the merits of deep planting versus

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planting at grade since the 1960s. Reasons suggested for planting trees below grade in field soil include increased stability (15), increased moisture for establishing trees (12, 24), simpler mechanical planting of forestry plots (11, 19), reduced damage from herbicide (17), reduced sprouting, and hiding the graft union on grafted trees (25). Most research was conducted on young seedlings planted into soil in forest restoration projects.

Depth of planting seedlings into field soil to about 6 cm (2.5 in) below original planting depth in the nursery had no significant effect on survival or tree height of newly planted conifers up to ten years after planting in a number of forest restoration studies (4, 12, 16, 22, 24). However, seedlings planted about 15 cm (6 in) below grade had reduced height and survival (4).

Switzer (23) found that deeply planted seedlings of *Pinus taeda* survival varied with soil conditions. Deep planted (one-half stem buried) seedlings had 95% survival in well-drained clay soil but only 70% survival in poor-drained clay and only 30% in poor-drained silt. Survival was even lower on poorly drained clay (20%) or silt (less than 10%) when seedlings were planted deeper (buried to terminal bud). Roots could be adapting to deep planting during this time as they adjust to soil with low oxygen content by growing toward the soil surface (9). In contrast, survival was 90–95% on all soil types when trees were planted at grade.

Some studies, many conducted on non-irrigated sites, reported increased height, caliper, or canopy growth of deeply planted seedlings. Deep planting (planted up to the terminal bud) of *Pinus elliottii* increased height after 2 years (22). Deep planting [5 cm (2 in) below nursery depth] of *Malus domestica* resulted in greater height but reduced blooms compared to planting at nursery depth (15) after 5 years. Deep planted *Picea glauca* [10 cm (4 in) below nursery level] grew significantly more in the first 2 years after planting compared to planting at grade. None of these studies reported on tree stability.

It has been suggested that one of the reasons for unfavorable growth of some deeply planted seedling trees is a tendency for roots to circle, bend, or otherwise become deformed (18). Harrington and Howell (11) found that growth of *Pinus taeda* was significantly greater when trees were planted with straight roots rather than deformed or pruned taproots. In contrast, Seiler et al. (18) found that *Pinus taeda* and *Pinus strobus* with J-roots did not show reduced growth or increased water stress after three years when they were planted with the root collar at grade. After 5 years, Carvell and Kulow (4) found an upper layer of superficial roots had formed on *Pinus strobus* trees planted 15.2 cm (6 in) below grade and original roots were growing up toward the soil surface. It was not noted whether the upper network of roots was growing adventitiously from the trunk or whether it was a result of the roots below growing up toward the soil surface. Sparks (20) found that after 3 years, weakly developed lateral or brace roots on deeply planted *Carya illinoinensis* trees resulted in increased tilting or blowing over during a hurricane. Lyons et al. (14) found that after 2 years, *Malus domestica* were less likely to be shaken loose by wind when planted at nursery depth than when planted up to 20 cm (8 in) below nursery depth.

Few have studied planting depth in containers. After one year in above-ground containers, height of *Cornus florida* was significantly less on trees that were planted deeper than nursery depth (3, 6). Caliper of *Cornus florida* was greatest when planted at nursery level or 5 cm (2 in) below nursery level. Caliper was reduced when trees were planted at 10.1 or 15.2 cm (4 or 6 in) below nursery level. One year after planting in containers, survival of *Acer rubrum* and *Pinus virginiana* was reduced when planted at nursery level or at 15.2 cm (6 in) below nursery level. Trees planted at 5 or 10.1 cm (2 or 4 in) below nursery level had the greatest survival. *Quercus palustris* shoot growth was not affected by planting depth in #15 containers (J. R. Harris, personal communication).

Objectives of this experiment were to determine influence of planting depth in containers of rooted cuttings of *Quercus virginiana* Cathedral Oak® on root and top characteristics three years later.

Materials and Methods

Two-hundred-sixty-four *Quercus virginiana* 'SDLN' PP #12015 Cathedral Oak® rooted cuttings stuck 5–7 cm (2–3 in) deep into 5.7 cm (2.3 in) diameter 10 cm (4 in) tall Accelerator® containers in Summer 2002 were planted into #3 silver-colored Accelerator® pots (Nursery Supplies Inc., Fairless Hills, PA) early May 2003 filled with a 60 pine bark:40 peat:10 sand substrate (v:v:v) with pots touching each other. Enough container substrate was gently removed so we could position the point where the top-most root emerged from the trunk at 5 different depths as follows: 1) 1.3 cm (0.5 in) below the substrate surface, 2) 3.8 cm (1.5 in) below, 3) 6.4 cm (2.5 in) below, 4) 8.9 cm (3.5 in) below, or 5) 11.4 cm (4.5 in) below the substrate surface. This allowed us to determine if planting depth into #3 containers influenced ability to generate roots from the buried portion of the stem. Each depth treatment contained 44 trees, with the exception of the 6.4 cm (2.5 in) treatment which had 88 trees. Containers were placed on woven black plastic ground cloth typical of nurseries. 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 trees were potted into #15 Accelerator® pots without drainage holes in container bottom on 0.91 m (3 ft) centers and placed directly on soil. The finished #3 trees were well below [mean caliper 13 mm (0.5 in)] the standard (2) maximum caliper [19 mm (0.75 in)] for this container size. The top of the substrate in the #3 containers was placed even with the substrate surface in the #15 containers for all trees of each planting depth with the exception of half of the trees initially planted 6.4 cm (2.5 in) deep. The remaining half of the trees planted 6.4 cm (2.5 in) deep were planted another 6.4 cm (2.5 in) deep when potted into #15s, for a total of 12.7 cm (5 in) deep. This allowed us to determine if trees of this age retained the capacity to generate new roots from the buried portion of the trunk. Canopies were pruned to encourage a dominant leader in May 2004 and September 2004.

In March 2005, all trees were potted into #45 Accelerator® pots without drainage holes in the container bottom on 1.8 cm (6 ft) centers with the top of the substrate in the #15 containers positioned even with the substrate surface in the #45 containers directly on soil. Finished #15 trees were well below [mean caliper 28 mm (1.1 in)] the standard (2) maximum caliper [38 mm (1.5 in)]. The trees planted 6.4 cm (2.5 in) deep in both #3s and #15s were planted another 6.4 cm (2.5 in) deep for a total of 19 cm (7.5 in) deep. All trees were pruned to a dominant leader May 2005 and in February and June 2006.

Trunk caliper 15 cm (6 in) from substrate surface and tree height from substrate surface to top bud were measured at the end of each growing season (October) and at the end of the study in June 2006; spread (mean of widest diameter and perpendicular to this) was measured 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. In September 2006, the following was evaluated by looking at the top of the undisturbed root ball surface: number of roots emerging directly from the trunk and presence of a trunk flare. 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), distance between media surface and the top of the root, evaluation of root system for step ten in Florida Grades and Standards for Nursery Stock (1), number of roots >10 mm diameter emerging from the trunk above the original top-most root when trees were planted into the #3 container, and number of roots that grew straight from the trunk without deflection from #3 or #15 container.

Trees were arranged in Gainesville Florida (USDA hardiness zone 8b) in a randomized complete block design (44 blocks) with single tree replicates of each treatment in each block. Data was analyzed using SAS to perform one way randomized complete block design ANOVA.

Results and Discussion

Caliper in the first 18 months following planting (2004 data) was larger for trees 3.8 cm (1.5 in) deep than for trees planted 11.4 and 12.7 cm (4.5 and 5.0 in) deep, or 1.3 cm (0.5 in) deep; there was no height difference among planting depths in 2004 (Table 1). Thirty months after planting (2005 data) trunk caliper in all planting depths was similar except the shallowest and the deepest planted trees had smaller caliper than trees planted 3.8 cm (1.5 in) deep. Trees planted 3.8 cm (1.5 in) deep were also taller than trees planted at all other depths excepting those planted 1.3 cm (0.5 in) deep. Furthermore, trees planted 1.3 cm (0.5 in) deep were taller than trees planted 6.4 cm (2.5 in) deep and those planted 19 cm (7.5 in) deep [6.4 cm (2.5 in) deep in #3s followed by 12.7 cm (5 in) in #15s and 19 cm (7.5 in)in #45s]. Despite these statistical differences there were few meaningful differences in top growth among planting depths. Brown and Tilt (3) and Fare (6) found that top growth was not affected by planting depth in containers except for *Cornus florida* which grew slower at deeper planting depths. Giblin et al. (7) found that two of four species grew less caliper when planted in containers 15 cm (6 in) deep than at grade; there was no effect from planting depth on the other two species.

After 40 months (2006 data), trees planted 3.8 and 8.9 cm (1.5 and 3.5 in) deep had a larger caliper than trees planted at 1.3 cm (0.5 in) below grade. In turn, trees in the 1.3 cm (0.5 in) depth treatment grew taller than all other trees except for those in the 3.8 cm (1.5 in) depth treatment. Overall, caliper of trees planted with the first root within 1.3 cm (0.5 in) of the substrate surface grew slowest in the first 18 months after planting but then these trees grew at the same rate as other planting depths. Despite trees receiving irrigation up to 3 times daily May through September, slower growth early of very shallow planted trees may have been due to the roots becoming too dry for a short time after potting into the #3 containers. Perhaps this could be overcome with more frequent irrigation. Shallow planted trees remained slightly yet significantly taller over the entire study, perhaps due to their initial shallower planting depth.

Trees planted at 1.3, 3.8, and 8.9 cm (0.5, 1.5, and 3.5 in) deep had wider canopy spreads than trees planted 19 cm (7.5 in) deep [6.4 cm (2.5 in) deep in #3s followed by 12.7 cm (5 in) in #15s and 19 cm (7.5 in) in #45s]. Moreover, trees planted at a depth of 3.8 and 8.9 cm (1.5 and 3.5 in) were wider than trees planted 6.4 and 11.4 cm (2.5 and 4.5 in) deep. Trees planted at a depth of 3.8 cm (1.5 in) below grade demonstrated the highest likelihood of grading [according to steps 1 through 9 in Florida Grades and Standards, (1)] as either a Florida Fancy or Florida #1 (Table 2). Both grades are considered acceptable in most municipal landscape codes in Florida and parts of the southeastern United States, and they meet the guidelines for California and Illinois which are the only other states with published nursery stock specifications. Trees planted 6.4, 8.9, and 11.4 cm (2.5, 3.5, and 4.5 in) deep exhibited the highest variability in grade. Planting

Table 1. Cathedral Oak® trunk and canopy growth following planting in containers at different depths.

Planting depth of top root[z] [cm (in)]	2004 caliper (cm)	2004 height (m)	2005 caliper (cm)	2005 height (m)	2006 caliper (cm)	2006 height (m)	2006 spread (m)
1.3 (0.5)	2.59[y]c[x]	2.01	5.23b	3.50ab	6.22b	3.93a	1.72ab
3.8 (1.5)	2.90a	2.09	5.56a	3.556a	6.53a	3.81ab	1.75a
6.4 (2.5)	2.79ab	2.03	5.46ab	3.32c	6.35ab	3.78b	1.65bc
8.9 (3.5)	2.70abc	2.03	5.31ab	3.40bc	6.50a	3.72b	1.76a
11.4 (4.5)	2.62bc	1.97	5.38ab	3.35bc	6.38ab	3.69b	1.65bc
19.0[w] (7.5)	2.67bc	1.96	5.26b	3.31c	6.38ab	3.72b	1.59c

[z]Top root means the root that was the top-most root when the rooted cutting was planted into the #3 container.

[y]Means based on 44 trees per treatment.

[x]Means in a column followed by different letters are statistically different at $P < 0.05$ by Duncan's multiple range test.

[w]19 cm (7.5 in) depth obtained by positioning the point where the top-most root emerged from the trunk 6.4 cm (2.5) deep into #3 containers, 6.4 cm deep into #15 containers and 6.4 cm deep into #45 containers.

Table 2. Percentage of Cathedral Oak® by grade[z] of live oak planted at 6 depths.

Planting depth of top root[y] [cm (in)]	Florida Fancy (Best)	Florida #1 (Acceptable)	Florida #2 (Unacceptable)	Cull (Unacceptable)	Root cull (%)
1.3 (0.5)	11[x]	81[x]	6[x]	2[x]	80[w]
3.8 (1.5)	7	91	2	0	100
6.4 (2.5)	26	72	2	0	80
8.9 (3.5)	16	77	7	0	100
11.4 (4.5)	24	65	9	2	40
19[v] (7.5)	5	90	5	0	80

[z]Florida Grades and Standards for Nursery Stock (Anonymous 1998).

[y]Top root means the root that was the top-most root when the rooted cutting was planted into the #3 container.

[x]Based on 44 trees per treatment.

[w]Percent of trees graded as root culls based on 5 trees per treatment.

[v]19 cm (7.5 in) depth obtained by positioning the point where the top-most root emerged from the trunk 6.4 cm (2.5) deep into #3 containers, 6.4 cm deep into #15 containers and 6.4 cm deep into #45 containers.

Table 3. Cathedral Oak® surface root characteristics following planting in containers at different depths.

Planting depth of top root[z] [cm (in)]	% trees with root flare	Mean number of surface roots per tree[y]	% primary roots originating above original top root
1.3 (0.5)	100	2.0a[x]	3.3
3.8 (1.5)	100	2.0a	35.7
6.4 (2.5)	80	0.8b	56.4
8.9 (3.5)	20	0.2bc	94.7
11.4 (4.5)	40	0.8b	100.0
19.0[w] (7.5)	0	0.0c	100.0

[z]Top root means (5 trees per treatment) the root that was the top-most root when the rooted cutting was planted into the #3 container.

[y]Surface root means roots >10 mm diameter visible on the substrate surface without washing away substrate.

[x]Means (of 5 trees per treatment) in a column followed by different letters are statistically different at $P < 0.05$ by Duncan's multiple range test. Data based on 5 trees per depth treatment.

[w]19 cm (7.5 in) depth obtained by positioning the point where the top-most root emerged from the trunk 6.4 cm (2.5) deep into #3 containers, 6.4 cm deep into #15 containers and 6.4 cm deep into #45 containers.

depth of rooted cuttings into #3 containers did not appear to affect root quality according to step ten in Florida Grades and Standards (Table 2).

Most (80%) trees grown in accordance with the outlined protocols in this study were culls according to step ten in the Florida Grades and Standards for Nursery Stock. This means that most trees had at least one root (but in most cases several roots) in the top half of the root ball greater than one-tenth the trunk diameter circling more than one-third of the trunk. In most cases this was a result of roots meeting the #3 and/or #15 container wall and growing around the container perimeter perpendicular to gravity. Some roots grew straight down after striking the container wall as previously found in Accelerators® (Marshall and Gilman, 1998). These root defects are concerning because they could develop into stem girdling roots (7) and stress, kill or cause instability in trees (26). This should be addressed aggressively in future research and production protocols.

Trees planted 6.4 cm (2.5 in) deep in #3s, then 6.4 cm (2.5 in) deep in #15s, and 6.4 cm (2.5 in) [(19 cm (7.5 in) total depth] in #45s had fewer, smaller diameter, and deeper

Table 4. Cathedral Oak® primary root growth[z] following planting in containers at different depths.

Planting depth of top root[y] [cm (in)]	Number of primary roots	Number of straight primary roots	Primary root diameter (mm)	Distance between substrate surface and primary root (cm)
1.3 (0.5)	6.0a[x]	0.8a	23.4a	4.01a
3.8 (1.5)	5.6a	0.8a	22.2a	4.06a
6.4 (2.5)	8.0a	2.0b	22.0a	4.60ab
8.9 (3.5)	7.6a	2.0b	18.9ab	4.80b
11.4 (4.5)	7.4a	1.0ab	20.3a	4.90b
19[w] (7.5)	1.4b	0.2a	16.3b	6.32c

[z]Primary roots >10 cm diameter growing from the trunk in the top 7.6 cm (3 in) of substrate.

[y]Top root means the root that was the top-most root when the rooted cutting was planted into the #3 container.

[x]Means (of 5 trees per treatment) in a column followed by different letters are statistically different at $P < 0.05$ by Duncan's multiple range test. Data based on 5 trees per depth treatment.

[w]19 cm (7.5 in) depth obtained by positioning the point where the top-most root emerged from the trunk 6.4 cm (2.5) deep into #3 containers, 6.4 cm deep into #15 containers and 6.4 cm deep into #45 containers.

Fig. 1. Cathedral Oak® rooted cutting planted 11.4 cm (4.5 in) deep into a #3 container 12 months ago. Note generation of new roots along the buried portion of the stem. The top-most roots when the rooted cutting was planted into this #3 container can be seen about half way into this root ball (see arrow). Roots are beginning to deflect down and around pot edge.

primary roots in the top 7.6 cm (3 in) of substrate than trees planted at all other depths (Tables 3 and 4). Whereas other planting depth treatments had primary roots at or near the substrate surface, the top 7.6 cm (3 in) of substrate on these trees was almost devoid of roots (data not shown). Unlike other planting depths trees planted 6.3 cm (2.5 in) deep at each pot up had roots growing over the root flare close to the trunk after being deflected by the container wall. Lack of roots growing from the buried portion of the trunk also occurred for *Malus domestica* where roots were found in the top 5.1 cm (2 in) of soil only in the shallow planted treatments (15). This contrasted somewhat with Fare (6) who found that roots of deeply planted trees of various cultivars filled the entire container including the top portion despite being planted 15 cm (6 in) deep. However, no oaks were evaluated in that study. In addition to the surface roots reported by Fare (6) our deepest planted trees also had a concentrated mass of roots at the bottom of the container.

The presence of a trunk flare and visible surface roots on our oaks decreased with increasing planting depth (Table 3) indicating that these could be used as an indicator of planting depth in containers. Percentage of primary flare roots originating from the stem in the top 7.5 cm (3 in) of the #45 container at the end of the study that originated above the top-most root present on the rooted cutting increased with planting depth. This indicated capacity to generate adventitious roots post-planting into the #3 container.

Cathedral Oak® demonstrated the capacity to generate new roots above the primary flare roots only when rooted cuttings were planted into #3 containers (Fig. 1). Trees adjusted their root systems by generating a new set of roots along the buried stem up to the substrate surface. Although trunk flare was less prominent in the deeper planted trees (Fig. 2a) than on shallow planted trees (Fig. 2b), there were primary roots just under the substrate surface on most trees, even on those planted 11.4 cm (4.5 in) deep into the #3 containers (Table 3, Fig. 2a). Young seedlings of *Picea glauca* (21) and *Acer rubrum* (10) produced adventitious roots along the buried stem as well. Although roots on our oaks grew from the buried

Fig. 2a. Cathedral Oak® rooted cutting in a #45 container planted 11.4 cm (4.5 in) deep 40 months ago. Note root flare and presence of primary roots just under the substrate surface. These roots were generated along the buried portion of the stem when the rooted cutting was planted into the #3 container. There was one root growing over the primary roots (see arrow). Roots are deflected down and around the #3 and #15 pot edge.

Fig. 2b. Cathedral Oak® rooted cutting planted 1.3 cm (0.5 in) deep 40 months ago. Note root flare and presence of primary roots just under the substrate surface. Most roots deflected down or around when they contacted the #3 or #15 container wall.

Fig. 2c. Cathedral Oak® planted 6.4 cm (2.5 in) deep into #3s, and 6.4 cm (2.5 in) deep into #15s and 6.4 cm (2.5 in) deep into #45s [19 cm (7.5 in) total depth] resulted in roots circling over flare roots. No primary roots were generated in the top 10.2 to 12.7 cm (4 to 5 in) of substrate. Substrate surface is indicated by arrow. Note all the roots growing over primary roots that could become stem girdling roots.

portion of the stem while trees were in the #3 containers at all planting depths, mean distance between substrate surface and top of the roots was greater for the deeper planting depths but only by 9 mm (0.4 in) (Table 4).

It is imperative to point out that roots did not grow from the buried portion of the stem when trees in #3 containers [mean trunk diameter 13 mm (0.5 in)] were planted 6.4 cm (2.5 in) deep into #15 containers. This is a problem because roots from below grew up from deeper in the container and over the primary flare roots (Fig. 2c). Fare (6) also found that new roots did not grow from the buried portion of the stem when 1–3 cm (0.4–1.2 in) trunk diameter liners of several common shade tree cultivars were planted into #15 containers. In contrast Giblin et al. (7) and Gilman (8) found that *Fraxinus pensylvanica* generated adventitious roots along the buried portion of the approximately 2.5 cm (1 in) diameter trunk on trees planted deeply indicating that some riparian trees retain this adventitious capacity. Although planting deep into the #15 or #45 containers appears to be problematic, planting depth appears less crucial for Cathedral Oak® rooted cuttings potted into #3 containers.

Number of primary structural roots >10 mm diameter that originated in the top 7.6 cm (3 in) of the root ball ranged from 5.6 to 8.0 per tree (Table 4). Less than about 25% of these grew straight out from the trunk; these roots were not deflected by the #3 or the #15 container walls. Therefore, it is likely that these were generated from the trunk after planting into #45 containers. In other words 75% or more of the primary structural roots were deflected by either the #3 or #15 container wall, or both. Primary roots were deflected down, up, and/or around the container edge. This indicates that most primary roots that emerged from the trunk did so when the tree was in the # 3 or #15 container within 22 months of planting from rooted cuttings. Others have found that most main roots on trees developed within the first 3 to 7 years after seed germination (5). If most primary main roots are generated when trees are still in the container permanent root defects may remain with the tree. Tree stability can be compromised when structural roots are deflected (13, 20).

Roots often grafted when they crossed over or touched other roots. Roots that circled at the #3 or #15 container size sometimes grafted to other roots. Sometimes these other roots were growing more or less straight out from the trunk above the deflected root. Root grafting might help mitigate the potential negative health effects from circling roots (26) on this cultivar of live oak. Most trees had one or more small diameter woody roots growing from deformed primary roots deflected by the #3 or #15 container wall (Fig. 2b). These small diameter roots typically originated from the point where the primary roots deflected downward, and they grew more-or-less straight to the edge of the #45 without being deflected. This characteristic might eventually help the tree overcome the potential downsides of circling (10) or diving roots on Cathedral Oak® if they grow to become large and woody. Longer term studies are continuing to determine this.

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