2012
GREAT SOUTHERN TREE CONFERENCE

RESEARCH REPORT

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UNIVERSITY OF FLORIDA
Environmental Horticulture Department
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2013 Great Southern Landscape Field Days is coming!

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2012

The Great Southern Tree Conference (GSTC) has been a highly successful and critically important educational event coordinated by the Florida Nursery, Growers and Landscape Association (FNGLA) since its inception in 2000. The joint partnership among FNGLA, industry partners and the University of Florida/IFAS has served as a strong model for other programs. Over the last 11 years with the support of industry partners, more than $900,000 was raised to support both the GSTC conference and the IFAS research and hands-on education conducted at the outdoor demonstration site. Eighty percent of all partner dollars went directly to the research and the remaining 20% was invested in industry education.

When the program started, the concept of a cutting-edge educational event focused around an outdoor demonstration area was a unique and magical combination. The tree industry was booming and the industry's need for a better understanding of strong production techniques was critical to the quality of trees. A place to incorporate needed industry research with an educational experience made this conference second to none across the country.

While the industry has certainly changed in the last ten years, and is again being reshaped by the economy, FNGLA and the GSTC planning committee remain committed to educating the entire tree and supporting industry segments. Research and education continue to be the driving forces to safeguard the nursery and landscape industry and allows us to address new challenges to be faced over the next decade. We realize projects designed to benefit the entire industry may need to address new challenges. As we look into the future of the industry and this conference, we wish to broaden the conference's approach to appeal to a larger segment of the landscape profession.

The 2013 Great Southern Landscape Field Days creates a new venue for learning by borrowing from the decade-long highly-successful GSTC. With a solid foundation of applied science and research in tree production and usage, the next step will add a major focus on woody ornamental landscape plants. The Landscape Field Days will use the enormously effective hands-on format from the Tree Conference to demonstrate the modern horticultural approach and methods to growers, contractors, and landscape professionals. Major issues addressed will continue to include water, fertilization, sustainable design, efficient cultural strategies, and other topics as they emerge. As always, this new effort brings buyers and horticulture product users together with growers to deliver research-based horticulture to members of the profession.

Along with the 6 preceding reports (http://hort.ifas.ufl.edu/woody/great-southern-tree.shtml), this represents the very latest in tree research from Florida.

Please thank our 2012 Great Southern Tree Conference Partners

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Landscape Inspectors Association of Florida
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Great Southern Tree Conference: Effect of initial liner size and season of root pruning on live oak stability in a field nursery

Ed Gilman, Maria Paz and Chris Harchick, Environmental Horticulture, University of Florida
Gainesville, FL

Objective: Determine effects of live oak liner size and season of field root pruning on root system quality in field grown nursery stock after planting.

What we did: In February 2007, 120 Cathedral Oak® live oaks averaging 0.5" caliper were obtained in #3 Accelerator containers. The treatments were: (1) 40 trees planted directly into field soil; (2) 40 trees shifted into #10 Accelerators; or (3) 40 trees shifted into #15 Accelerators. Half of the trees (20 for each liner size) were root pruned when planting to the field or shifting to the larger container size. Trees were root pruned by cutting 2" deep into the side of the root ball in 5 equidistant places from the top of the root ball to the bottom. Tops on root pruned trees were washed for 10 seconds to expose and remove circling and potentially girdling roots on the top 1 to 2". The other half of the trees per treatment was not root pruned at field planting or shifting. The trees shifted into the #10 containers were planted into the field nursery October 2007, when the trunk caliper averaged 1". The #15 containers were field planted when the trunks reached a caliper of about 1.3" in January 2008. Root balls that were sliced when shifted were again sliced at planting into field soil, while those not pruned when shifted were not pruned when planted to field soil.

All trees were planted in the same field with 12 ft between rows and 8 ft between trees and were irrigated three times per day during the growing season through drip emitters. Trees in the field were root pruned in the following manner: 1) half were root pruned in the dormant season (Feb, Apr, Oct, Dec 08 and Feb, Apr 09); or 2) the other half were root pruned in the growing season (Apr, June, Aug, Oct 08 and Apr, June 09). At each root pruning, two 1/8 circumference sections opposite one another were cut with a sharp 12" long digging shovel starting 8" from trunk; each subsequent root pruning was about 1" farther from the trunk and rotated another 1/8 around circumference. Trees were fertilized three times a year with 115 g of 16-4-8 and were staked in November 2007 for #3 and #10, and at planting for #15. The experimental design was 3 liner sizes x 2 root pruning at shifting and field planting x 2 field root pruning seasons x 10 replicates = 120 trees.

Half of the trees for each treatment combination (5 trees in each of 12 treatment combinations = 60 trees) were dug with a 36 inch tree spade November 2009. Trees were lifted and placed back in the ground in the same hole. Trees were then rocked back and forth by one person three times in the north-south direction, then three times in the east-west direction to determine firmness. Root development was measured on these 60 trees December 2009 to show influence of root pruning strategies on root ball quality. Root data results can be found in the 2010 GSTC Report.

The other half of the trees left in the field (5 trees in each of 12 treatment combinations = 60 trees) were all moved in March 2010 with a 36 inch diameter tree spade without wire basket or burlap. Caliper and tree height was recorded. Once moved, trees were watered in by hand. Trees are now being irrigated every other day with periodic dry days to measure stress caused by water deficit. Water stress was measured April 18, April 28 and May 5, 2011. In September 2010 all trees were fertilized with 300 g of 20-0-8, and with 400 g of 20-0-8 on March and June 2011, and April 2012. Caliper and heights were recorded on September 2012. Trees were pulled until the trunk base tilted 5 degrees to test stability on April 2012. Moment was calculated as pulling force x distance between ground and pulling point. Trees were held for a minute at 5 degrees tilt, and distance from the trunk to dip point on leeward side measured (hinge point). When pull was released, final angle at the trunk base was recorded.

What we found as of November 2012: Initial liner size (Table 1), root ball slicing at planting, season of root pruning in the field nursery had no impact on tree caliper or tree height 30 months following landscape planting. There was also no impact of planting season or season of root pruning during production on tree stability 30 months after planting (data not shown). Water stress after landscape planting was not affected by either initial nursery liner container size or season of root pruning during production. Trees planted from #3 containers into the field nursery were the most stable 18 months after planting to the landscape (i.e. they required a larger stress and moment to pull them to 5 degrees trunk tilt) (Table 2). They also returned to the closest original angle of the trunk after testing for stability, when compared to the #10 and #15 trees (Table 2).

Table 1. Caliper and height 30 months after transplanting (September 2011) field nursery-grown live oaks initially planted from #3 (Feb 07), #10 (Oct 07) or #15 (Jan 08) containers.

Liner container size (beginning caliper)	Caliper (in)	Caliper increase 30 months after transplanting from field nursery (in)	Height (ft)	Height increase 30 months after transplanting from field nursery (ft)
#3 (0.5”)	5.1	1.9	20.9	5.7
#10 (1.0”)	4.9	1.9	20.5	6.1
#15 (1.3”)	5.1	2.0	20.9	6.2

[1]Means in a column with a different letter are statistically different at P < 0.05. Based on 20 trees per container size averaged across root pruning at planting and field root pruning season.

Table 2. Pulling moment to 5 degrees, hinge point and angle of field nursery-grown live oaks initially planted from #3 (Feb 07), #10 (Oct 07) or #15 (Jan 08) containers.

Container Size (beginning caliper)	Pulling stress to 5 degrees (kN/m^2)	Pulling moment to 5 degrees (kNm)	Rest angle (degrees)
#3 (0.5”)	33952 a[1]	5.9 a	1.2 b
#10 (1.0”)	29347 b	4.5 b	1.4 a
#15 (1.3”)	29208 b	4.9 b	1.5 a

[1]Means in a column with a different letter are statistically different at P < 0.05. Based on 20 trees per container size averaged across root pruning at planting and field root pruning season.

Great Southern Tree Conference: Effect of planting depth in containers and in the landscape on landscape performance after field planting Cathedral Oak® live oak.

Ed Gilman, Maria Paz and Chris Harchick, Environmental Horticulture, University of Florida
Gainesville, FL

Objective: Determine how planting depth in the root ball and planting depth in the landscape influence Cathedral Oak® live oak following landscape planting.

What we did: In July 2006, 144 Cathedral Oak® live oaks about 2.7” caliper were planted to a Bahia grass field in Citra, FL (20 miles south of Gainesville) from #45 containers. Twenty-four trees were planted on 50-foot centers and the remaining 120 trees were planted on 25-foot centers. Portions of the site were poorly drained. Trees were produced in containers from rooted cutting liners with the following planting depth treatments: (1) top-most root at soil level into #3, #15 and #45; (2) 2.5” below grade in #3 and #15, level into #45; (3) 4.5” below grade into #3 and #15, level into #45; or, (4) 2.5” below grade in #3, #15 and #45. Trees from each of these four depths in the containers were planted into the landscape at three different depths for a total of twelve treatment combinations. Landscape planting depths were: (1) 0”, media surface level with landscape soil; (2) 4” below grade; (3) 8” below grade. Half of the trees were root pruned at planting (trees were root pruned by cutting 4-5” deep into the side of the root ball in 5 equidistant places from the top of the root ball to the bottom using a sharp balling spade), whereas the other half was planted without root pruning. Following transplanting, all trees were mulched and irrigated with 34 gallons/day for approximately 2 ½ weeks. At the end of July 2006, irrigation was reduced to 7.5 gallons/day for two weeks. In mid-August 2006, irrigation was once more reduced to 7.5 gal every other day for 3 weeks and reduced further to 7.5 gal every three days for two weeks. Trees were fertilized April 2007 with 340 g of 12-2-14, 400 g of 16-4-8 in July 2008, and 800 g of 16-4-8 in July 2009. Caliper and height were measured in September 2011. Trees planted level with landscape soil and those planted 8” below grade were pulled until the trunk base tilted 1 degree to test stability on May 2012. Moment was calculated as pulling force x distance between ground and pulling point. Trees were held for a minute at 5 degrees tilt, and distance from the trunk to lowest point on the root-soil plate on leeward side measured (referred to as the hinge point). When the tree was released, final angle at the trunk base was recorded.

What we found as of November 2012: Trunk caliper and tree height five years after landscape planting were not affected by planting depth in the nursery container (data not shown). Tree height 5 years after planting appeared to be affected by landscape planting depth and root pruning at planting (Table 1 and 2). Trees that were planted into the landscape deeper were slightly shorter than those planted even with landscape soil probably because they were shorter at planting due to the deeper planting. Trees that were root pruned by slicing the root ball when planted into the landscape were slightly shorter than trees that were not root pruned. Although tree height was slightly affected by landscape planting depth and root pruning, the relative growth of all trees has been similar for all treatments. Trees planted at grade were more stable six years after landscape planting, than trees planted 8” below grade, expressed by a larger moment to pull them to 1 degrees trunk tilt (Table 3). The hinge point of trees planted at grade was also further from the trunk when compared to tree planted 8” below grade (Table 3), indicating better stability**.PILI Root pruning had no impact on stability (data not shown).**

Table 1. Caliper and height of live oak produced at different nursery planting depths 6 years after landscape planting at three different landscape planting depths.

Landscape planting depth	Caliper (in)	Caliper growth in 6 years (in)	Height (ft)	Height growth in 6 years (in)
Level (at grade)	6.28	3.42	19.8 a[1]	6.4
4” Below landscape surface	5.93	3.07	18.8 b	6.2
8” Below landscape surface	6.10	3.24	19.0 b	6.7

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 48 trees per treatment, averaged over nursery planting depth and root pruning treatment.

Table 2. Caliper and height of live oak that were root pruned or not root pruned at planting six years ago.

Root pruning	Caliper (in)	Caliper growth in 6 years (in)	Height (ft)	Height growth in 6 years (ft)
Yes	6.00	3.13	18.8 b[1]	6.1
No	6.20	3.35	19.6 a	6.7

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 72 trees per treatment, averaged over nursery and landscape planting depth.

Table 3. Pulling moment to 1 degree, hinge point and angle produced at different nursery planting depths 6 years after landscape planting at three different landscape planting depths.

Landscape planting depth	Pulling moment to 1 degree (kNm)	Hinge point[1] (in)	Rest angle (degrees)
Level (at grade)	8.3 a[2]	7.4 a	0.2
8” Below landscape surface	5.4 b	4.7 b	0.1

[1] Hinge point is distance from trunk to dip in the root-soil on the pulling (leeward) side of the tree.
[2] Means in a column with a different letter are statistically different at $P < 0.05$. Based on 12 trees per treatment, averaged over nursery planting depth and root pruning treatment.

Here is a correctly planted tree with substrate surface slightly above surrounding soil. Root pruning (white lines) at planting cut several inches inside the root ball all the way to the bottom of the root ball. This root pruning does not correct any defects further inside the root ball.

Great Southern Tree Conference: Effect of container type and root pruning on field growth and stability of 'Florida Flame' maple.

Ed Gilman, Maria Paz and Chris Harchick, Environmental Horticulture, University of Florida
Gainesville, FL

Objective: Determine impacts of container type and root ball shaving on root form on 'Florida Flame' maple.

What we did: In April 2008, 384 'Florida Flame' maple trees from liner containers were potted into eight different #3 container types with the top-most root planted at soil level. The container types are smooth sided (Nursery Supplies, Inc., Chambersburg, PA), SmartPot® (Root Control, Inc., Oklahoma City, OK), RootBuilder® and RootMaker® (Rootmaker® Products Company, LLC, Huntsville, AL), Fanntum™ (Fanntum Products, Inc., Statesville, NC), Florida Cool Ring™ (The Florida Cool Ring Company, Lakeland, FL), Airpot™ (Caledonian Tree Company, Ltd., Scotland) or Jackpot™ (Legacy Nursery Products, LLC, Palm City, FL), and were placed pot to pot. Substrate was 20: 60: 20 (New Florida peat: pine bark: sand, by volume) for RootMaker®, RootBuilder®, Fanntum™, Florida Cool Ring™ and Jackpot™ , and 50: 40: 10 (New Florida peat: pine bark: sand, by volume) for Airpot™, SmartPot® and smooth sided. Volume of substrate in each container was similar except the Jackpot™, which was about 15% smaller in volume than others. Trees were irrigated 3 times daily and were staked in May 2008. Root balls on 9 trees of each container were excavated November 2008 and root balls evaluated. In February 2009, 288 trees total of the #3 container types were shifted to the same type of #15 containers with the same substrate. The RootMaker® was replaced by RootTrapper® (a type of fabric container from the same manufacturer) since the largest size RootMaker® is #5, and will be referred as the RootTrapper® in this report. Before shifting into #15 containers, root balls on half of the trees of each container type were pruned in one of two ways: a) no root pruning, or b) shaving off the outer root ball, which removes the peripheral and bottom one inch of the root ball. The remaining 24 trees (3 for each container type) were planted directly into the ground, with the root ball intact and planted even with the soil.

In November 2009, five trees of the #15 of each treatment combination (container type and root pruning – 80 trees total) were destructively harvested to evaluate root morphology. In February 2010, 10 trees for each treatment combination were shifted to the same type #45 containers with the same substrate. Roots were pruned before shifting following the same protocol described above. The remaining 48 trees (3 for each treatment combination) were planted directly into the ground, with the root ball intact and planted even with the soil in a randomized complete block design.

In May 2011, five trees of the #45 of each treatment combination were destructively harvested to evaluate root morphology. The rest of the trees (5 trees for each container type and root pruning combination) were planted into the landscape with the root ball intact and planted even with the soil in a randomized complete block design. In May 2011, trees planted from #3 containers into the landscape were pulled until the trunk base tilted 5 degrees to test stability. Moment was calculated as pulling force x distance between ground and pulling point. Trees were held for a minute at 5 degrees tilt, and distance from the trunk to dip point on leeward side was measured (the point of the maximum dip was called the hinge point). When pull was released, final angle at the trunk base was recorded as rest angle. These trees were compared with trees that were planted from propagation liners directly into the landscape on April 21, 2008, with no root manipulation. In April 2012, trees planted from #3 and #15 containers were pulled again following the same procedure as below. Caliper wasmeasured for all field trees on September 2012.

What we have found as of November 2012: Caliper of red maples planted into landscape soil was similar for each of the 8 container types for all sizes (Table 1) and root pruning treatment (data not shown). Tree stability 2 years after planting #3 and #15 containers into the landscape was not affected by container type (data not shown). Trees field-grown from liners in propagation containers had a dip point (distance from the trunk to the lowest point where root-soil plate sunk on the pull-side of the tree) further from the trunk when compared to trees planted from #3 and #15 containers (Table 2), which might indicate a larger root-soil plate. But trees planted from #3 containers were more stable, when compared to trees planted from liners and #15 containers (Table 2), expressed by a higher pulling moment to 5 degrees trunk tilt. This might be because #3 container trees have been in the ground longer than #15 container trees. For trees planted from #15 containers, the root pruned trees were a little more stable and were less tilted than trees that were not root pruned when potting from #3 to #15 (Table 3).

Table 1. Caliper and height in September 2012 of 'Florida Flame' maples planted to the landscape from #3 (Nov 2008), from #15 (Nov 2009) and from #45 (May 2011) containers.

Container type	#3 planted into landscape soil Caliper[1] (in)	#15 planted into landscape soil Caliper[2] (in)	#45 planted into landscape soil Caliper[3] (in)
Airpot™	3.4	3.6	4.4
Cool Ring™	4.3	3.8	4.4
Fanntum™	4.4	4.0	4.4
Jackpot™	4.0	4.0	4.3
RootBuilder®	4.0	3.8	4.2
RootTrapper®	4.3	4.0	4.3
SmartPot®	4.1	4.0	4.4
Smooth sided	4.1	3.9	4.5

[1]Based on 3 trees per container type (24 trees total). There were no differences among treatments.
[2]Based on 6 trees per container type averaged across root pruning treatment (48 trees total). There were no differences among treatments.
[3]Based on 10 trees per container type averaged across root pruning treatment (80 trees total). There were no differences among treatments.

Table 2. Pulling moment to 5 degrees, hinge point, and rest angle of red maple planted into landscape from liners (April 2008), from #3 (February 2009) and #15 (February 2010) container

Tree source	Pulling moment to 5 degrees (kNm)	Hinge point[1] (in)	Rest angle (degrees)
Liner	1.9 b[2]	8.7 a	1.0
#3	2.2 a	5.7 b	1.1
#15	1.7 b	6.0 b	1.1

[1] Hinge point is distance from trunk to dip in the soil on the pulling side of the tree.
[2] Means in a column with a different letter are statistically different at $P < 0.05$. Based on 3 trees per container type and 10 trees for field-grown liners.

Table 3. Pulling moment to 5 degrees, hinge point, and rest angle of red maple planted into landscape from #15 container, and shaved or not shaved when trees were planted from #3 into #15

Root pruning	Pulling moment to 5 degrees (kNm)	Hinge point[1] (in)	Rest angle (degrees)
None	1.6	5.9	1.2 a[2]
Shaved	1.7	6.1	0.9 b

[1] Hinge point is distance from trunk to dip in the soil on the pulling side of the tree.
[2] Means in a column with a different letter are statistically different at $P < 0.05$. Based on 3 trees per container type and 10 trees for field-grown liners.

Great Southern Tree Conference: Impact of tree size at planting, mulch and irrigation on 'Florida Flame' maple growth and anchorage

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Objective: Track growth, root characteristics, and stability of 'Florida Flame' maple planted in the landscape from various container sizes under two different irrigation and mulch treatments.

What we did: In February and March 2006, 16 red maples were planted into the landscape from #3, #25, #65 or #300 containers, for a total of 64 trees. Trees were irrigated daily from planting to the beginning of May 2006 (15 gallons per irrigation the first 3 weeks followed by 7 gallons thereafter for #300, 5 gallons for #65 and #25, and 2.5 gallons for #3). All irrigation was applied to the root ball only. This was followed with approximately 2 weeks of no irrigation. Irrigation resumed to every other day at the end of May 2006 with #300 receiving 18 gallons, #65 receiving 9 gallons, #25 receiving 6 gallons and #3 receiving 3 gallons of water each irrigation day. The weather remained dry so an exception to this schedule was made during 3 weeks in June, when irrigation was administered every day. Water was turned off in March 2007. In May 2007, half the trees (8) for each size were irrigated Monday, Wednesday and Friday. The other half of the trees (8) for each size were not irrigated ever again in the study. Also in May 2007 (one year after planting), half of the irrigated trees and half of the non-irrigated trees for each size were mulched up to the trunk with a 3" layer of shredded hardwood, while the other half was kept bare, with periodic applications of Roundup. Roundup was also used to keep mulched plots clean of weeds. Trees have not been fertilized since planting. Caliper measurements were collected for all trees in September 2011. On August 2011, all the mulched trees of all fours sizes were pulled to consecutive bending stresses of 10342, 13790, 17237, 20684 and 24132 kN/m^2 to evaluate lateral stability. Pulling all tree sizes to a constant bending stress was used to simulate exposure to a wind storm. Half of the pulled trees were irrigated, half were not. The tree was held in position at each stress while the root plate attributes were measured inside 5 degrees on either size of the axis of pull on the windward and leeward (the pull direction) side. The root plate attributes were: distance from the trunk to the lowest point on leeward side, leeward plate edge, highest point on windward side, and windward edge plate. The angle of the tree was also recorded at each stress to determine how much each tree was moving at the different simulated wind speeds. Following the pulls, roots were uncovered on the windward and leeward side of the trees using an air-spade. The diameter of the largest 5 roots on each side was measured 6-in from the original root ball, and used to calculate the cross sectional area (CSA) of each root and whether the root had been deflected. The CSA of all roots was added up and compared to the CSA of the trunk for each tree, calculated from the diameter of each tree one foot above the soil level.

What we found as of November 2012: Mulch and irrigation had a small or negligible growth enhancing effect on caliper 6 years after planting (Table 1 and 2). Except in the first three years when the largest trees grew slowest, trees appeared to grow in trunk caliper at the same rate regardless of initial tree size, with the larger tree sizes retaining greater calipers (Figure 1).

There was no effect of irrigation on stability of trees (data not shown). Trunk angle during pulling tests increased with container volume for all bending stresses (Figure 2). Trees from smaller containers were better anchored to landscape soil than those from larger containers probably due to having higher root CSA, lower trunk to root CSA ratios, and fewer roots deflected (Table 3). Roots in the leeward root-soil plate on trees planted from the 2 smallest containers pushed down against mineral landscape soil outside the root ball when pulled (Figure 3). These same roots for the 2 largest containers pushed against decomposing organic substrate of the planted root ball causing them to sink (Figure 3).

Table 1. Caliper (in) and caliper growth in five years (in) for mulched and non-mulched trees averaged over #3, #25, #65 and #300 container trees.

Mulch	Caliper (in)	Caliper growth in 6 years (in)
Yes	7.43 a[1]	4.02 a
No	6.84 b	3.49 b

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 32 trees per treatment.

Table 2. Caliper (in) and caliper growth in five years (in) for irrigated and non-irrigated trees averaged over #3, #25, #65 and #300 container trees.

Irrigation	Caliper (in)	Caliper growth in 6 years (in)
Yes	7.30 a[1]	3.89
No	6.98 b	3.62

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 32 trees per treatment.

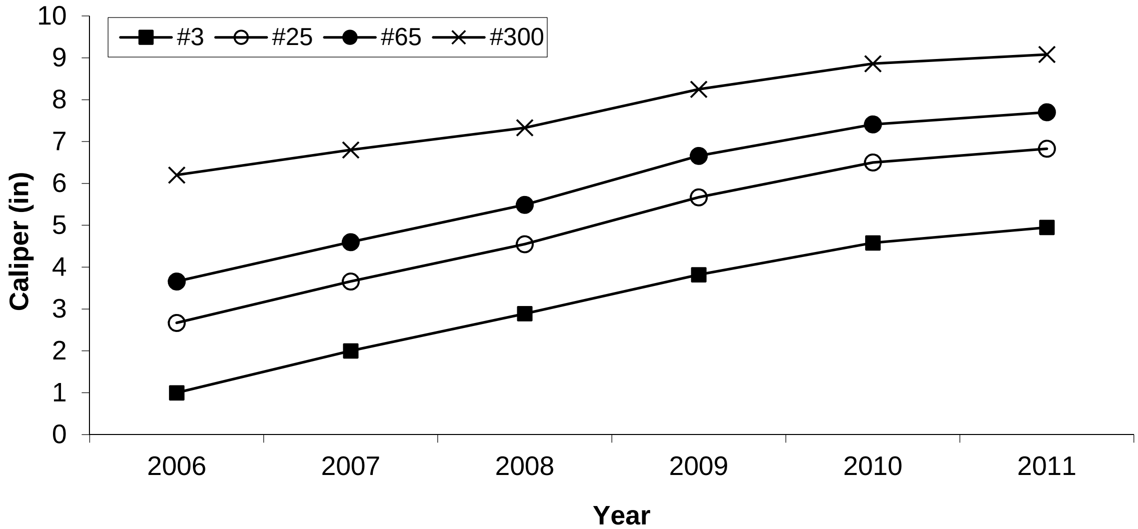

Figure 1. Caliper (in) of 'Florida Flame' maples from September 2006 to September 2010 planted from #3, #25, #65 and #300 containers.

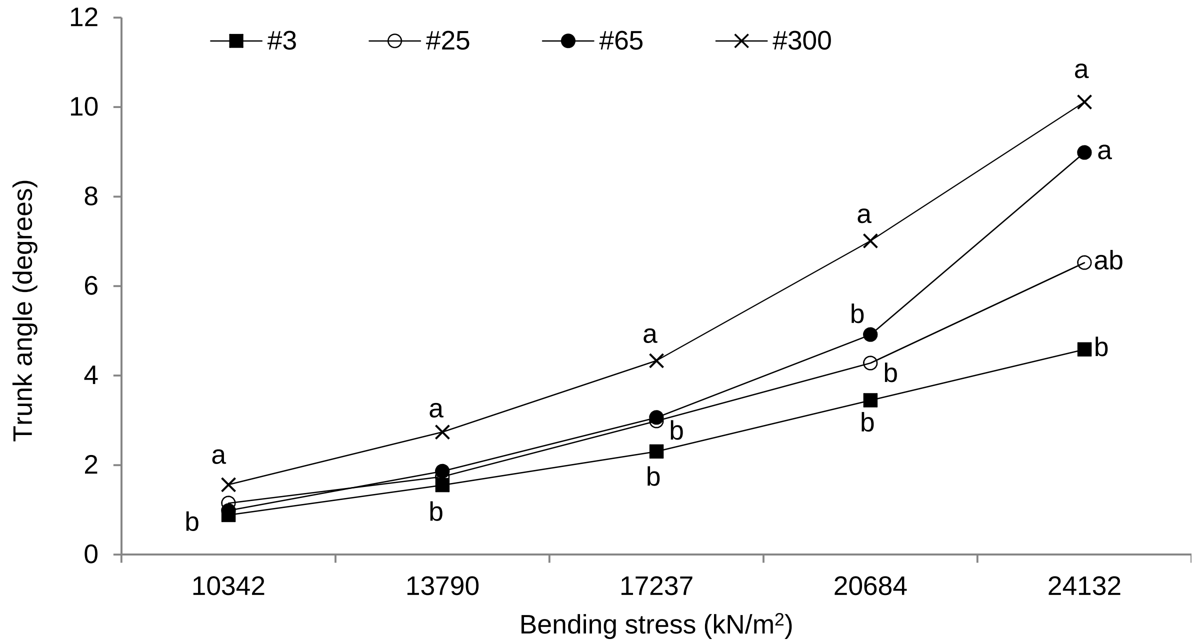

Figure 2. Trunk angle at five applied bending stresses of trees planted from 4 container volumes. Different letters within a bending stress indicate significant difference in angle (based on 8 trees per treatment, averaged across irrigation).

Table 3. Trunk and root cross sectional area[z] for trees planted into soil 6 years earlier from 4 nursery container volumes.

Container volume	Trunk cross sectional area (cm^2)	Root cross sectional area (cm^2)	Trunk CSA: root CSA	Percent of 5 largest roots not deflected (%)[y]
#3	155 d[1]	114 a	1.7 b	94 a
#25	267 c	96 a	4.2 b	53 b
#65	321 b	32 b	11.3 ab	12 c
#300	459 a	39 b	18.4 a	0 c

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 16 trees per treatment averaged across irrigation and mulch treatments.

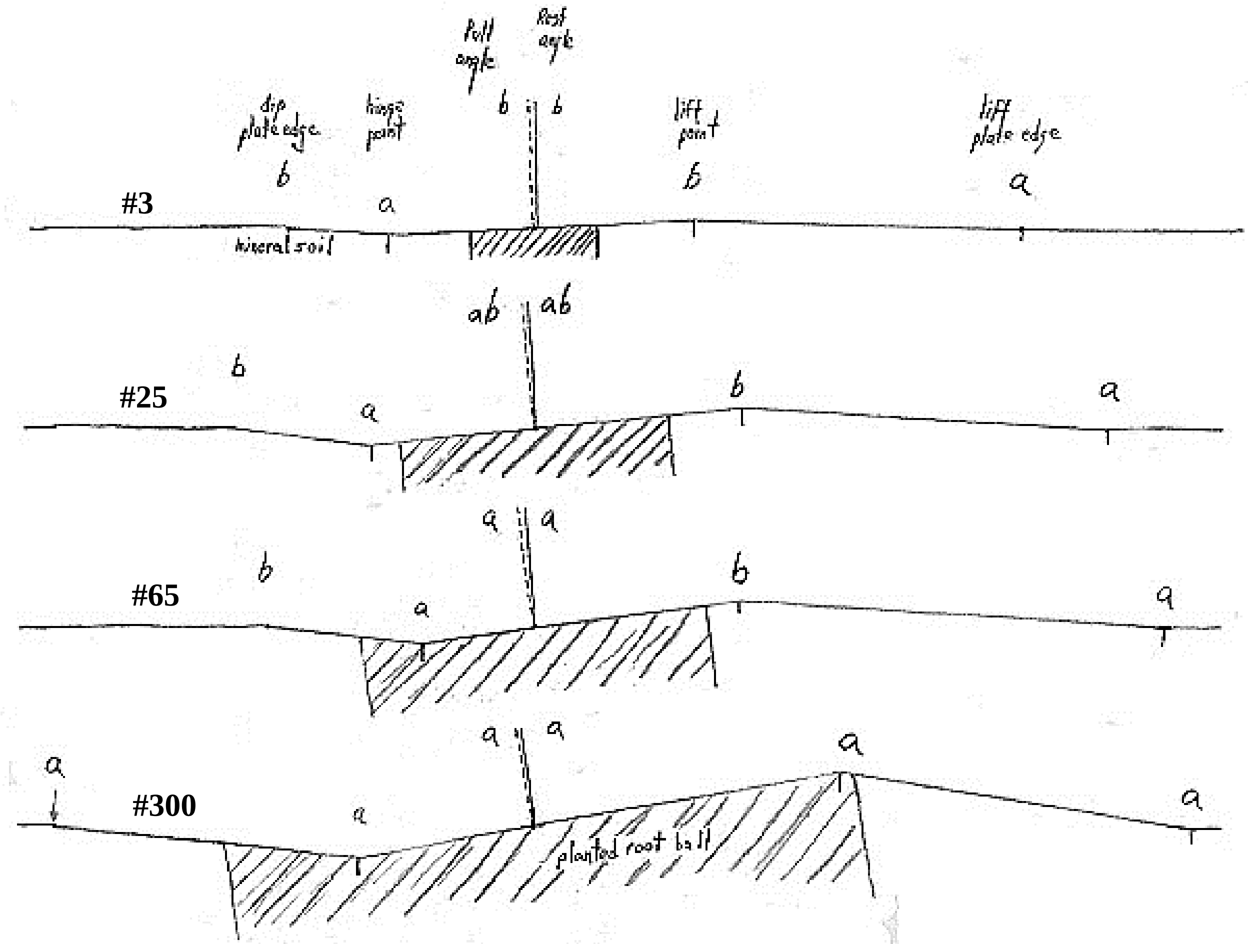

Figure 3. Leeward root-soil plate edge, leeward hinge point, pull angle under stress, rest angle following pull, windward lift point, and windward (lift) plate edge for trees planted 6 years earlier from 4 container volumes and pulled with a winch to 24132 kN/m^2 bending stresses. Different letters in a column for each attribute indicates significant difference.

Conclusions: Despite the increasing water stress with container volume, growth rates were identical for the 3 smallest container volumes the first 6 years after planting. Greater resistance to horizontal trunk displacement and overturning was associated with abundant roots that radiated straight from the trunk. Planting from smaller containers increased the root CSA outside the root ball per unit trunk CSA and they grew in mineral landscape soil which helped trees become anchored better than trees planted from larger containers whose large roots mostly remained in the original container volume. Unlike the larger trees, those planted from the smallest containers retained the capacity to generate a root system similar to that found in nature (Lyford and Wilson 1964). This capacity appeared to diminish as red maple trees were retained in the nursery by shifting them to increasingly larger container volumes. The result was diminished anchorage due primarily to reduced root CSA growing from the container root ball and into landscape soil, lower root-soil plate mass, and the deflected nature of the main structural roots.

Great Southern Tree Conference: Impact of root pruning techniques on post-planting growth in the landscape of red maple and live oak.

Ed Gilman, Maria Paz and Chris Harchick, Environmental Horticulture, University of Florida
Gainesville, Florida

Objective: Demonstrate the effects of removing all roots on the outer one inch of #3 container root balls on top and root growth of red maple and live oak.

What we did: In April 2008, 40 #3 container-grown 'Florida Flame' maples and 40 Cathedral Oak® live oaks were potted into #15 containers. Twenty trees of each species were root pruned by shaving about one inch from the outer root ball and bottom from #3 Airpots before shifting into #15 smooth sided pots. The other twenty trees were potted without disturbing the root balls. Trees were irrigated three times daily and pruned and staked in June 2008. In September 2008, ten maples of each treatment were destructively harvested to dissect the root balls. Root ball data was collected and results included in the 2009 GSTC Report. Twenty trees of each species (10 per treatment) were planted in the field in November 2008 for the maples and January 2009 for the live oaks, to compare tree stability in the landscape resulting from root pruning treatment against no root pruning. When the trees were in containers, north was marked on all trees and the mark was placed either north or south when field planting, to test whether heat from direct sun exposure on the south side of container affects root distribution and tree stability after landscape planting. Trees are being watered three times a week and were fertilized with 200 g of 16-4-8 on March and June 2009, and 400 g of 20-0-8 on March and May 2010, and March and June 2011 and 2012. Trees were pulled until the trunk base tilted 5 degrees to test stability on August 2009, 2010 and 2011 for the maples, and October 2009, 2010 and 2011 for the live oaks. Moment was calculated as pulling force x distance between ground and pulling point and results included in the 2010 GSTC Report. Tree caliper and height were collected September 2012.

What we found as of November 2012: Tree caliper and heights in #15 containers were not affected by root pruning during container production for either species (2008 GSTC Report). For maples, shaving root balls reduced culls, produced higher quality root balls and a greater number of lateral roots. For live oaks, root ball shaving also improved root ball quality and increased number of roots growing out into the #15 substrate (2009 GSTC Report). Root pruning as trees were shifted from #3 into #15 containers had no effect on caliper and height three years after landscape planting (Table 1). Bending moment required to tilt trunks to 5 degrees one, two and three years after landscape planting was not affected by root pruning during production (2010 GSTC Report). Orientation at planting (i.e., the side of the tree facing north in the nursery planted to the north vs. planting the north side facing south) in the landscape has had no effect on parameters measured (data not shown).

Conclusion: Shaving off root defects from the outer periphery of the root ball when trees were shifted from #3 to #15 containers in the nursery removed root defects without compromising growth (4 years) or stability 3 years) after planting into the landscape. When planting into the landscape, tree do not need to be positioned in the same compass direction as they were grown in the nursery.

Table 1. Caliper and height four years after landscape field planting of 'Florida Flame' maples and Cathedral Oak® live oaks root pruned by shaving the outer inch of the root ball or not root pruning when shifted from #3 to #15 container. #15 containers were planted into landscape without root pruning.

Species	Root pruning in nursery	Caliper[1] (in)	Height[1] (ft)
Maples	No pruning	4.7	23.3
	Root ball shaving	4.5	22.5
Live Oaks	No pruning	4.9	21.9
	Root ball shaving	4.9	21.5

[1] Based on 10 trees per species x root pruning combination (40 trees total). There were no differences among treatments.

Great Southern Tree Conference: Root defect removal and mulch effects on landscape performance of elm and maple.

Ed Gilman, Maria Paz and Chris Harchick, Environmental Horticulture, University of Florida
Gainesville, Florida

Objective: Determine how planting depth in containers, root defect removal when planting, and mulch over root balls affects landscape performance of landscape planted elms and maples.

What we did: In February 2008, 40 elms and 40 maples were planted in the landscape from #45 smooth-sided containers raised from cuttings. Cuttings were potted into #3 Airpots either with the top-most root even with the surface or 2.5" deep; then they were shifted to #15 Airpots even with the surface or another 2.5" deep; then they were shifted into smooth-sided #45 containers even with the substrate surface. Before planting into the landscape, ten trees of each planting depth and species (40 trees total) were air spaded to expose the root flare. Roots growing over the root flare were removed to the edge of the root ball. Time required to air spade and remove root defects was recorded for each tree. The other twenty trees of each species were left untouched. Trees were planted into the landscape with the top of the root ball an inch or two above surrounding landscape soil. Mulch 4" deep was applied around the root ball but not over the root ball on half the trees; the other half of the trees were mulched up to the trunk. There are a total of 8 treatments (2 planting depths in containers x 2 root removal treatments x 2 mulch treatments) combinations for each species, with 5 replicate trees for each treatment. All trees are being irrigated three times a week. Trees were fertilized with 400 g of 16-4-8 on March and June of 2008 and 2009, and with 400 g of 20-0-8 on March and May 2010, and March 2011. All trees were staked with the Terra Toggle root ball stabilization system in June 2008, which was removed in June 2009. Trees were pulled until the trunk base tilted 5 degrees to test stability on February 2012. Moment was calculated as pulling force x distance between ground and pulling point. Trees were held for a minute at 5 degrees tilt, and distance from the trunk to dip point on leeward side measured (hinge point). When pull was released, final angle at the trunk base was recorded. Tree caliper was collected September 2012.

What we found as of November 2012: Trees of both species that were planted deeply in the container took much longer to remove substrate and root defects at planting than trees planted at the appropriate depth in containers (2010 GSTC Report). Maple trunk caliper four growing seasons after landscape planting was not affected by planting depth in the nursery container, root removal treatments or mulch treatment after planting (data not shown). Elm caliper increase in four years was affected by the placement of mulch over the root ball (Table 1). Trees with no mulch placed over the root ball have grown slightly (15%) more in caliper than those with mulch over the root ball (Table 1). This difference in caliper growth is small (less than half an inch), but it will be interesting to see how trees keep growing. Thus far, the different treatments haven't had an effect of tree stability on maple (data not shown). The hinge point of elms during pulls was affected by removing roots growing over the root flare prior to field planting (Table 2). Those that were root pruned have a hinge point further out from the trunk than those that were not root pruned which could translate into better stability in coming years (Table 2). Neither moment to 5 degrees nor rest angle of tree were affected by the different treatments (data not shown).

Conclusion: Keeping mulch off the root ball surface had no detrimental effects on trees in the first 43 months after planting, in fact those with no mulch on the root ball grew 15% more. Mulch placed over the root ball did not improve growth or health on elm or maple trees, and it seems to be hindering caliper growth on elms. Planting trees deeply in the root ball in the nursery makes it very difficult to plant trees correctly into the landscape due to the enormous amount of roots growing over the flare. These must be removed at planting.

Table 1. Effect of placement of mulch over the root ball or not on caliper of elms 55 months after planting.

Mulch over root ball at planting	PILI caliper is too small? Maybe switched with growth? YES! fixed Caliper 55 months after planting(in)	Caliper growth 55 months after planting (in)
Yes	4.9	2.3 b[1]
No	5.1	2.6 a

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 20 trees per treatment

Table 2. Pulling moment to 5 degrees, hinge point, and rest angle of elm with or without removal of roots growing over the root flare prior to planting into the landscape

Root removal	Pulling moment to 5 degrees (kNm)	Hinge point[1] (in)	Rest angle (degrees)
Yes	5.2	8.3 a[2]	1.5
No	4.7	6.9 b	1.5

[1] Hinge point is distance from trunk to dip in the soil on the pulling side of the tree.
[2] Means in a column with a different letter are statistically different at $P < 0.05$. Based on 20 trees per treatment

Substrate removed from top of root ball exposed roots so root defects could be removed. Roots that were kinked, circled, diving or crossing roots were removed to the first major roots shown above. This required 12 minutes per tree. Exposed roots were not damaged by sun after planting.

Roots were cut and removed if they circled over the major flare roots. Note the two visible cuts above. Another set of trees was planted without removing root defects (those trees are not pictured here).

Great Southern Tree Conference: Container planting depth, root shaving and landscape planting depth effect on Miss Chloe® magnolia landscape performance

Ed Gilman, Maria Paz and Chris Harchick, Environmental Horticulture, University of Florida
Gainesville, Florida

Objective: Determine how planting depth in containers, root ball shaving when planting, and landscape planting depth affects landscape performance of recently planted Miss Chloe® magnolia.

What we did: In September 2008, 48 Miss Chloe® magnolias were planted in the landscape from #45 smooth-sided containers raised from cuttings. Cuttings were potted into #3 Airpots either with the top-most root even with the surface or 2.5” deep; then they were shifted to #15 Airpots even with the surface or another 2.5” deep; then they were shifted into smooth-sided #45 containers even with the substrate surface. When planted into the landscape, half of the trees were either planted 2 inches above the soil surface, or 4 inches below the soil surface. After the trees were set in the ground, half of each of the treatment combinations was either planted with no root shaving, or the root balls were shaved before completely filling the landscape planting hole. Root balls were shaved by edge pruning to remove approximately 2 inches of the outer edge of the entire root ball. There are a total of 16 treatments (4 planting depths in containers x 2 landscape planting depths x 2 root shaving treatments) combinations, with 3 replicate trees for each treatment. Trees were mulched immediately after planting with mulch to the trunk. Trees that were planted high were mulched with 2 inches of mulch on the root ball and 4 inches outside the ball, while those planted deep, had 4 inches of mulch over ball and outside the ball. All trees are being irrigated once a day. Trees were fertilized with 400 g of 16-4-8 on November 2008, and March and June of 2009, and with 400 g of 20-0-8 on March and May 2010, March and June 2011, and April 2012. Radius of the root system was measured by gentle excavation on May and November 2009 and compared to tree canopy radius to determine root to shoot ratio, and reported in the 2011 GSTC Report. Trees were pulled until the trunk base tilted 5 degrees to test stability on January 2012. Moment was calculated as pulling force x distance between ground and pulling point. Trees were held for a minute at 5 degrees tilt, and distance from the trunk to dip point on leeward side measured (hinge point). When pull was released, final angle at the trunk base was recorded. Caliper and height were collected September 2012.

What we found as of November 2012: Landscape planting depth had a negligibly effect on trunk growth and height growth in the three years after planting (Table 1). Root ball shaving that removed roots from the periphery of the root ball at planting statistically decreased growth in trunk caliper (0.1 inch) and height (0.9 ft) in the 4 years after planting, but the difference may be of little practical importance (Table 2). Trees that we planted high were more stable in the landscape than trees planted deeply (Table 3), since it required a greater moment to pull trees to 5 degrees trunk tilt. The hinge point is also farther out than the trunk for trees planted high when compared to those planted deeply, but those planted deep are closer to the original angle of the tree before the pull (Table 3). Shaving the outer edge of the root ball of Magnolia made the trees 12% less stable in the landscape, expressed by a smaller moment to 5 degrees (Table 4). The shaved trees also had a higher degree of tilt after pulling, but had no effect on hinge point (Table 4).

Conclusion: Root ball shaving to reduce root defects when planting #45 containers southern magnolia into the landscape did not impact root system expansion into landscape soil, but it slightly reduced top growth and stability of Magnolia the first 4 years after planting. Planting deeply into the landscape appears to slow establishment rate slightly in the first few months after planting in this well-drained soil and reduces stability, but then trees grew similarly regardless of landscape planting depth. Planting depth into nursery containers had no impact on growth after planting into the landscape. Results may have been different in a soil than drains poorly, or for a different species of tree.

Table 1. Effect of landscape planting depth on caliper and height of Miss Chloe® magnolia three years after planting

Landscape planting depth	Caliper (in)	Caliper growth in 4 years (in)	Height (ft)	Height growth in 4 years (ft)
2 inches high	5.0 a[1]	2.2	19.5	8.2 b
4 inches deep	4.8 b	2.2	19.5	8.9 a

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 24 trees per treatment averaged across root pruning at planting and planting depth in containers.

Table 2. Effect of root shaving treatment on caliper and height of Miss Chloe® magnolia four years after planting

Root shaving	Caliper (in)	Caliper growth in 4 years (in)	Height (ft)	Height growth in 4 years(ft)
Yes	4.9	2.1 b[1]	19.2	8.1 b
No	5.0	2.2 a	19.8	9.0 a

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 24 trees per treatment averaged across root pruning at planting and planting depth in containers.

Table 3. Pulling moment to 5 degrees, hinge point, and rest angle of Miss Chloe® magnolia planted high or deep in the landscape

Landscape planting depth	Pulling moment to 5 degrees (kNm)	Hinge point[1] (in)	Rest angle (degrees)
2 inches high	6.7 a[2]	7.0 a	1.1 a
2 inches deep	5.4 b	4.6 b	0.8 b

[1] Hinge point is distance from trunk to dip in the soil on the pulling side of the tree.
[2] Means in a column with a different letter are statistically different at $P < 0.05$. Based on 24 trees per treatment averaged across root pruning at planting and planting depth in containers.

Table 4. Pulling moment to 5 degrees, hinge point, and rest angle of Miss Chloe® magnolia root shaved or not prior to landscape planting

Root shaved	Pulling moment to 5 degrees (kNm)	Hinge point[1] (in)	Rest angle (degrees)
Yes	5.7 b[2]	6.0	1.0 a
No	6.4 a	5.7	0.9 b

[1] Hinge point is distance from trunk to dip in the soil on the pulling side of the tree.
[2] Means in a column with a different letter are statistically different at $P < 0.05$. Based on 24 trees per treatment averaged across root pruning at planting and planting depth in containers.

Shaving the root ball at planting (see root pruning spade cutting roots from outer 2 inches of root ball) reduced root defects without negative impacts on survival or health. There was a slight reduction in growth as a result of this root pruning the first four years after landscape planting.

Great Southern Tree Conference: Impact of length in nursery containers on Miss Chloe® magnolia, 'Florida Flame' maple and Allée® elm quality.

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Gainesville, Florida

Objective: Demonstrate the impact of the time magnolias, maples and elms are left in #3 and #15 containers in the nursery on subsequent root quality on finished trees in #45 containers and field performance.

What we did: In February 2007, eighty liners of each species (Miss Chloe® magnolia, 'Florida Flame' maple and Allée® elm) were potted into #3 black nursery containers. Thirty two (32) elms died from freezing damage and subsequent water stress. Twenty magnolia and maples, and twelve elms were: (1) potted June 2007 into #15 after 4 months in #3, and then potted Feb 2008 into #45 after 8 months in #15; or (2) potted Sept 2007 into #15 after 7 months in #3, and then potted July 2008 into #45 after 10 months in #15; or (3) potted Nov 2007 into #15 after 9 months in #3, and then potted Nov 2008 into #45s after 12 months in #15; or (4) potted Feb 2008 into #15 after 12 months in #3, and then potted April 2009 into #45 after 6 months in #15. Trees were finished in #45 containers in October 2009, when 5 trees of each treatment were harvested and root balls dissected for data collection. Root balls were not pruned when shifted to a larger container and were planted even with the substrate in the larger container.

In May 2010, the remaining trees were planted in the landscape. Twenty elms were planted into the landscape with root balls undisturbed and planted even with the landscape soil. For the magnolias and maples, the root balls of half of the trees for each species were either: 1) left intact; or 2) after placing in the planting hole, the balls were shaved with a balling shovel to remove approximately 2 inches of the outer periphery of the entire root ball. All trees were planted even with the landscape soil. All trees are being irrigated every other day (three times a day on these days). Trees were fertilized with 800 g of 20-0-8 in June 2010, and 400 g of 20-0-8 in March and June 2011. Caliper and height for all trees were collected September 2012. Trees were pulled until the trunk base tilted 5 degrees to test stability in November 2011. Moment was calculated as pulling force x distance between ground and pulling point. Trees were held for a minute at 5 degrees tilt, and distance from the trunk to dip point on leeward side measured (hinge point). When pull was released, final angle at the trunk base was recorded.

What we found as of November 2012: Caliper and height growth on elms and magnolias planted into the landscape was not affected by time spent in either size nursery container (Table 1). However, maples that spent less time in #3 and #15 and more time in #45 had smaller calipers when compared to those that spent similar times in these sizes, but all are increasing in caliper at a comparable rate (Table 1). Maple height growth 28 months after landscape planting was least for trees that spend the most time in #3 and the least time in #45 containers (Table 1). Caliper and height growth on maples and elms was not affected by root pruning at landscape planting (data not shown). Caliper and caliper growth of root pruned magnolia trees was smaller 28 months after planting, but these differences are of less than half an inch (Table 2). Magnolia height was not affected by root pruning at the time of landscape planting (Table 2).

The length of time magnolia and elms spent in the various container sizes did not impact stability (anchorage), hinge point, or rest angle immediately following pulling the trunk to 5 degrees. Maples that spent the least time in the #3 and #15 and the most time in the #45 containers required less moment to pull them to 5 degrees tilt when compared to the other retention times (Table 3). This indicates that maples that spent more time in #45 were less stable in the landscape than those that spent less time in #45. Root pruning had no effect on stability for maple and magnolias (data not shown). This project is ongoing, and trees will be pulled again to evaluate landscape stability or anchorage.

Conclusions: Pruning roots at planting to remove defects had little impact on growth or lateral stability in the first 28 months after planting into the landscape for all three tree species tested. Maples retained in

#45 size containers for the longest time period were less stable 28 months after planting into the landscape than maples retained for a shorter time period in #45 containers. However, stability for the other two species tested was not impacted by retention time in the various container sizes.

Table 1. Caliper and height of elms, maples and magnolias grown for different time periods in #3, #15, and #45 containers, 16 months after planting into landscape field soil (May 2010).

Treatment (retention time in containers)	Caliper (in)	Caliper growth in 28 months (in)	Height (ft)	Height growth in 28 months (ft)
		Elms		
4 mo #3; 8 mo #15; 20 mo #45	4.3	1.3	20.3	5.1
7 mo #3; 10 mo #15; 15 mo #45	4.4	1.3	19.8	5.4
9 mo #3; 12 mo #15; 11 mo #45	4.3	1.4	20.3	4.3
12 mo #3; 14 mo #15; 6 mo #45	4.5	1.6	20.8	5.4
		Maples		
4 mo #3; 8 mo #15; 20 mo #45	4.6 b[1]	1.5	23.2	6.8 ab
7 mo #3; 10 mo #15; 15 mo #45	5.4 a	1.8	24.0	7.2 ab
9 mo #3; 12 mo #15; 11 mo #45	5.3 a	1.9	24.4	8.5 a
12 mo #3; 14 mo #15; 6 mo #45	4.9 ab	1.5	22.6	6.1 b
		Magnolias		
4 mo #3; 8 mo #15; 20 mo #45	4.6	1.7	18.4	5.8
7 mo #3; 10 mo #15; 15 mo #45	4.4	1.6	17.9	5.7
9 mo #3; 12 mo #15; 11 mo #45	4.3	1.5	17.1	4.8
12 mo #3; 14 mo #15; 6 mo #45	4.7	1.8	17.4	5.5

[1]Means in a column within species with a different letter are statistically different at $P < 0.05$. Based on 10 trees per treatment for magnolia and maple averaged across root pruning, and 5 trees per treatment for elm.

Table 2. Caliper and height 28 months after planting into landscape field soils (May 2010) of magnolias that were root pruned at planting or not.

Root pruning	Caliper (in)	Caliper growth in 28 months (in)	Height (ft)	Height growth in 28 months (ft)
Yes	4.3 b[1]	1.5 b	17.4	5.2
No	4.7 a	1.8 a	18.0	5.7

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 20 trees per treatment averaged across time in pot.

Table 3. Pulling moment to 5 degrees, hinge point and rest angle of maples (elm and magnolia were not affected) grown for different time periods in #3, #15, and #45 containers pulled to 5 degrees 18 months after planting into the landscape.

Treatment	Pulling moment to 5 degrees (kNm)	Hinge point[1] (in)	Rest angle (degrees)
4 mo #3; 8 mo #15; 20 mo #45	1.89 b[2]	7.6	1.0
7 mo #3; 10 mo #15; 15 mo #45	3.45 a	7.8	1.0
9 mo #3; 12 mo #15; 11 mo #45	3.26 a	7.5	1.0
12 mo #3; 14 mo #15; 6 mo #45	2.89 a	8.4	1.1

[1] Hinge point is distance from trunk to dip in the soil on the pulling side of the tree.
[2] Means in a column within species with a different letter are statistically different at $P < 0.05$. Based on 10 trees per treatment averaged across root pruning.

Great Southern Tree Conference: Influence of propagation tray type, container type and root pruning on mahogany.

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Gainesville, Florida

Objective: Determine impact of propagation tray type and time in tray on root development and stability of mahogany.

What we did: In February 2009, seeds of mahogany were germinated in either smooth tray or Elle pots. In July 2009, the seed-sowed mahoganies from each propagation type were shifted to either a smooth #1 pot or a Pioneer #1 pot. In September 2010, the trees were shifted to either a smooth #3 or a Pioneer #3, keeping trees in the same container type as they were in #1. The outer edge of the root balls was shaved or cut from half of the trees when they were potted from a #1 to a #3 for each treatment combination. In April 2011, ten trees of each treatment were planted into field soil with the root balls intact and even with the landscape soil. Trees were watered daily and fertilized with 65 g of 20-0-8 a week after planting and 120 g of 20-0-8 on June 2001. Caliper and heights were recorded at planting and on September 2011. In November 2001, all trees were pulled to simulate a wind event at a height of 8.25 inches to a bending stress of 13790 kN/m^2 to test tree stability. Angle at this bending stress was recorded for all trees, as well at the rest angle a minute immediately after the pull. Root balls were then dug up and characterized.

What we have found as of November 2012: Root pruning liners as they were shifted into #1 containers had no effect on mahogany growth, stability or root characteristics of root balls in the nursery or after landscape planting (data not shown). Propagation tray had a slight effect on mahogany (Table 1). Mahogany propagated in Elle pots grew in caliper a little more and had straighter roots than those propagated in smooth trays. The #1 and #3 container type had more of an effect on mahogany (Table 2 and 3). Those grown in smooth container were slightly larger than those grown in Pioneer pots, but the ones in Pioneer pots increased slightly more in caliper (Table 2). Mahoganies grown in Pioneer pots were more stable in the 9 months after landscape planting than those from smooth container, expressed by a much greater angle at pull and greater rest angle after pull (Table 2). The mahoganies grown in Pioneer pots might be more stable because they have more straight roots and a better quality root ball when compared to smooth containers (Table 3). Although trees from smooth containers had larger roots, more of these roots were deflected downward and around by the container (Table 3).

Table 1. Caliper increase, rest angle and 5 largest root characteristics of mahogany propagated in two different tray types

Tray type	Caliper increase (mm)	Rest angle after pull	Downward angle 5 largest roots (degs)	Cross-sectional area of the 5 largest roots deflected by liner (mm^2)
Elle	15 a	8.5 a[1]	44 b	72 b
Smooth	12 b	6.1 b	52 a	301 a

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 36 trees per treatment averaged across tray type and root pruning.

Table 2. Mahogany growth and angle at pulls grown in two different #1 and #3 container types

Container type	Caliper (mm)	Caliper increase (mm)	Height (cm)	Trunk angle during pull	Rest angle after pull
Pioneer	26.8 b[1]	14.1 a	195 b	17.7 b	4.1 b
Smooth	28.6 a	12.6 b	209 a	27.2 a	10.5 a

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 36 trees per treatment averaged across tray type and root pruning.

Table 3. Root ball characteristics of mahogany grown in two different #1 and #3 container types

Container type	No. straight roots	% Cull	% Trunk circled	Root symmetry (1-5)	Start angle 5 largest roots	Total CSA 5 largest roots (mm^2)	% 5 largest roots deflected
Pioneer	8.4 a[1]	8.3 b	15.3 b	4.5 a	30.4 b	1308 b[z]	22.8 b
Smooth	1.0 b	64.9 a	65.0 a	1.6 b	64.5 a	1531 a	94.1 a

[1]Means in a column with a different letter are statistically different at $P < 0.05$. Based on 36 trees per treatment averaged across tray type and root pruning.

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