Root Ball Shaving Improves Root Systems on Seven Tree Species in Containers[1]

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Abstract

Established forest trees planted from small containers are less stable at the point where roots fork, bend or branch as a result of deflection by container wall, but less is known about the post-transplant impact of root deflections resulting from growing trees in large containers. We either root pruned by shaving off the periphery of the #3 container root ball as it was planted into the #15 container or did not root prune on 5 tropical and 2 temperate tree species. Shaving did not affect trunk caliper or tree height on the seven species tested under the conditions of this study. Shaving removed the entire outer and bottom 2.5 cm (1 in) of the root ball and reduced or eliminated culls on five of seven species. The largest diameter roots on trees in #15 containers that were not root pruned when shifted from #3 containers were kinked, descended down the container wall, or circled at the position of the #3 container. These root defects were largely missing on trees with root balls that were shaved of peripheral roots when shifted into #15 containers. The largest roots on shaved trees grew more-or-less straight radially from the trunk. Shaving the root ball periphery and bottom is recommended to improve root ball quality by reducing root ball defects.

Index words: stability, root defects, circling roots, descending roots, kinked roots.

Species used in this study: *Acer rubrum, Bursera simaruba, Delonix regia, Lysiloma latisaliqua, Quercus virginiana, Swietenia* I*mahogany, Tabebuia heterophylla.*

Significance to the Nursery Industry

Roots deflected by nursery container walls have been associated with tree instability for decades in the forestry industry. Instability can result in reductions in tree health, reduced lumber value, and fallen trees. This is less recognized and poorly understood in the horticulture profession where containers are much larger and nursery plants are much older than those used in reforestation efforts. There is evidence from the literature and from the current study that root systems can be improved with chemical and mechanical treatments. We found that shaving off all roots from the periphery of a #3 container prior to shifting to the #15 container dramatically reduced occurrence of circling and descending roots in the finished nursery stock. A reduction in circling roots and an increase in straight roots should lead to more stable and longer lived trees in the landscape.

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 (27, 31) roots on shade trees are deflected up, down, or around by container walls (18), and this can affect how roots grow out into forest (5) and landscape soil (23). Roots growing away from the trunk can also be deflected 180 degrees and grow back to and close to the trunk (12). Root systems on trees planted from containers often have more constricted, circling, and kinked roots that can lead to instability compared to naturally generated trees (5, 24). Naturally regenerated seedlings also had greater sinker root development emerging from horizontal lateral roots, and this can provide increased stability (17).

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Container dimensions, size, and container surface porosity can change root morphology for the better (3, 23, 28). Seedlings in air-pruning 5 cm (2 in) diameter containers had less packed roots, less spiraling roots, and fewer L-shaped roots (25). The authors noted that seedling grown trees in air-pruning containers produced less root defects than those grown in solid-walled containers, but they had slower root and canopy growth in the nursery due to the lateral air-pruning (25). Trees grew similarly regardless of root defects after planting into soil.

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, 9, 28). Others showed a reduction in root circling and root deflection downward in propagation container trays with copper hydroxide. This produced a root system similar to naturally regenerated trees resulting in identical post-planting stability between the two groups (8, 11). 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 on the interior of the root ball plug and fewer on the outside forming a 'cage' (26). 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. The same was true for Shumard oak (*Quercus shumardii* Buckl. (4). Lateral roots that emerged in the non-pruned, non-treated 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 resulting in a less stable tree following planting into the field (5).

Reported effects of mechanical root pruning in containers on root growth and morphology vary. One study showed that light cutting of circling roots of shrubs enhanced the amount of roots growing into substrate outside of the original root ball (6). In contrast Gilman et al. (13) showed that slicing #3 root balls top-to-bottom on Burford holly (*Ilex cornuta*

'Burfordii') at planting resulted in a redistribution of roots, not an increase in roots compared with non-pruned controls. Harris et al. (19) 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 trees had more main lateral roots (> 2 mm diameter) originating from the primary seedling radicle when compared to control. Krasowski and Owens (21) 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.

The objective of this study was to evaluate effects of removing all roots on the periphery and bottom of #3 container root balls on top and root growth in #15 smooth-sided black plastic containers.

Materials and Methods

Temperate trees. In April 2008, 40 #3 (12.5 liter) Air-Pot (Caledonian Tree Company, Ltd. Edinburgh, Scotland) container-grown *Acer rubrum* L. 'Florida Flame' maples on their own roots and 40 *Quercus virginiana* Mill. Cathedral Oak® live oaks on their own roots were potted into #15 (51 liter) smooth-sided black plastic containers. Rooted cuttings from Cherry Lake Tree Farm (Groveland, FL) were planted into the #3 Air-Pot containers 14 months previously. The #3 nursery stock had a trunk caliper [trunk diameter 15 cm (6 in) from ground] of 16.8 mm (0.7 in) for maples and 14.0 mm (0.6 in) for oaks, and a height of 2.4 m (7.8 ft) for maples and 1.6 m (5.4 ft) for oaks, which was within standard size guidelines (2). Twenty trees of each species were root pruned by shaving about 2.5 cm (1 in) from the outer periphery and bottom of #3 root balls before shifting into the #15 containers. Roots were shaved from the root ball using a sharp digging shovel (Fig 1). Removed roots were as large as 8 mm (0.3 in) diameter. The other twenty trees of each cultivar were shifted without disturbing the root balls.

Treatments were arranged in a randomized complete block design with one replicate of both treatments in each of 20 blocks. The maple plot was adjacent to the oak plot. Trees were spaced 1.8 m (6 ft) in rows 3 m (10 ft) apart and irrigated three times daily after shifting into #15 containers as per standard practice for container production in warm climates. Shoots were actively growing when trees were root pruned; shoots on most shaved trees wilted during daylight hours for several days. Branches were pruned once to develop a dominant leader and the trunk was staked straight in June 2008.

Fig. 1. Shaving the periphery and bottom of the #3 root ball with a sharp blade removed roots from the outer 2.5 cm (1 in) of the root ball prior to shifting into a #15 container (top). Seven months later, roots in the #15 container on shaved trees were oriented mostly away from the trunk in a radial manner (left). Roots on trees not shaved remained circled at the position of the #3 container with few roots growing into the #15 substrate.

In October 2008, substrate from containers was removed with a stream of water to expose roots on ten randomly selected blocks of maples for a total of 20 trees. Root ball data collected included: root ball quality ratings (where 1 = poor root ball quality with many deflected roots and 5 = excellent root ball quality with mostly straight roots), diameter of the largest 5 primary mother roots growing from the trunk [measured 10 cm (4 in) from the trunk], number of roots greater than 2 mm growing into the #15 substrate, diameter and angle (in relation to each of the 5 primary roots) of the 3 largest branch roots that grew from the point where each of the 5 largest primary roots met the #3 container wall, whether the root system (evaluated at the position of the #3 root ball) was considered a cull based on Florida Grades and Standards for Nursery Plants (1), number of branch roots oriented +/– 25 degree azimuth in relation to the primary roots (these were considered straight roots), number of branch roots > 2 mm diameter (up to a total of 3 per primary root) that grew from the point where each of the 5 largest primary roots met the #3 container in the following manner: circled or grew down at an angle < 45 degrees to the horizontal at the position of the #3 container, grew down at an angle of > 45 degrees at the position of the #3 container, kinked back toward the trunk at an angle greater than 90 degrees in relation to the primary root, grew up toward the surface at the position of the #3, grew in a fan-like manner out into the #15 substrate. Trunk caliper and height of all trees were measured in October 2008. Ten oaks of both shaved and not shaved were excavated in January 2009 in the manner described above for maples.

Tropical trees. In May 2008, ten #3 (10 liter) smooth-sided black plastic container-grown *Bursera simaruba* L. (gumbo limbo), *Lysiloma latisiliqua* L. (Lysiloma), *Swietenia mahogany* L. (mahogany), *Delonix regia Bojer* (royal poinciana), and *Tabebuia heterophylla* DC. (pink tabebuia) were potted into the same type #15 containers as temperate trees. Seed grown liners were planted by Arazoza Brothers Corp. (Miami, FL) into the #3 smooth-sided containers 10 to 14 months previously depending on species. The #3 nursery stock was within standard size guidelines (1). Five trees of each species were root pruned by shaving about 2.5 cm (1 in) from the outer periphery and bottom of #3 root balls before shifting into #15 smooth-sided containers. Roots were shaved from the root ball using a sharp digging shovel. The other 5 trees of each species were shifted without disturbing the root balls.

Treatments were arranged in a randomized complete block design with one replicate of both treatments in each of 5 blocks. Each species was in its own plot adjacent to other species. Trees were spaced 1.1 m (4 ft) in rows 1.8 m (6 ft) apart and irrigated three times daily after shifting into #15 containers as per standard practice for container production in warm climates. Branches were pruned twice to develop a dominant leader and the trunks staked straight in June 2008. In November 2008, substrate from the containers was removed with a stream of water to expose roots on all 10 trees of all 5 species (total 50 trees). Roots were measured in the manner described above for temperate trees. Trunk caliper and height of all trees were measured in November 2008.

Data analysis. Data were analyzed for each species separately with t-test in SAS version 9.1 ($P < 0.05$). Root count data and root rating were analyzed using the PROC GENMOD in SAS for Poisson distributions, and treatments compared using the CONTRAST statement after log transformation of data. Culls were analyzed using Fisher's Exact Test as a binomial and expressed as a percentage generated from the PROC FREQ tables. Other percentages were normally distributed so no transformation was needed.

Results and Discussion

No trees of any species died or died back during the course of the study. Trunk caliper and height were not affected by root pruning for any of the 7 species tested (Table 1), despite severe wilting for several days following shaving on some trees. Others also reported that the shoots and trunk of trees grew similarly after cutting (by slicing the root ball top-to-bottom) and teasing roots away from the periphery of container root balls (4, 15, 22). Direct comparisons are difficult to make between studies but shaving the root ball likely removed more of the root system than slicing and teasing in these other studies because shaving severed every root that reached the outside periphery of the #3 container root ball. This demonstrates as others have shown (15) that container grown shade trees receiving regular irrigation can recover from severe root pruning without slowing their shoot growth. On the other hand, field grown trees typically grew slower following root pruning (14), probably because it is more difficult in many field nurseries to deliver the irrigation necessary to keep all roots moist.

Shaving maple root balls reduced culls from 100% for non root pruned trees to 40% for trees with shaved root balls (Table 1), the same as previously reported for slicing *Quercus virginiana* root balls top-to-bottom at each shift to the next container size (15). Shaving maple root balls before shifting into #15 containers resulted in a higher root rating which meant they had more straight roots than trees not shaved (Table 1). Eighty percent or more of tropical trees excepting gumbo limbo were culls and root rating was lower if root balls were not shaved when shifted (Table 1). In contrast, none of the tropical trees of any species that were shaved were graded as culls indicating a dramatic improvement in quality in response to shaving (Fig 1). The position of the #3 container on most trees that were not shaved was clearly visible when roots were washed of the #15 container substrate because many large roots were circling and growing nearly straight down 12 cm (4.7 in). This was the precise position of the #3 container. The large percentage of culls for non-shaved trees indicates that the #3 container can be a source of serious root defects.

Shaving increased the number (on 5 of the 7 species) and reduced mean diameter (on 4 of the 7 species) of branch roots > 2 mm diameter that grew into the substrate of the #15 container compared to trees that were not shaved (Table 2). Branch roots on shaved trees grew from the severed root ends that resulted from shaving the #3 root ball periphery and from intact roots on the interior of the root ball. Branch roots on non-pruned trees grew from the interior of the root ball and less frequently from the outer surface of deflected roots. The mean angle of departure of the 3 largest branch roots from each of the 5 largest primary roots that was severed in the shaving treatment was significantly reduced on all species compared to trees that were not root pruned (Table 2). The angle of departure of the largest branch root was also reduced in shaved trees (data not shown). This indicated that the largest diameter roots were growing in a

Table 1. **Caliper, height, percent culls, and root rating for seven tree species in #15 containers root pruned in spring 2008 by shaving the outer 2.5 cm (1 in) of the root ball or not root pruned before shifting from #3 containers.**

Species	Root ball shaved	Caliper (mm)	Height (ft)	% Culls[z]	Root rating[y]
Temperate					
Red maple	No	37.7	11.5	100a	2.0b[x]
	Yes	36.6	11.1	40b	4.3a
Live oak	No	27.9	8.0	50	2.7
	Yes	26.5	7.8	30	3.1
Tropical					
Gumbo Limbo	No	45.5	7.3	20	2.8b
	Yes	44.2	7.6	0	4.4a
Lysiloma	No	32.1	7.7	80a	1.8b
	Yes	27.0	7.0	0b	4.2a
Mahogany	No	33.1	8.5	80a	1.2b
	Yes	33.0	8.0	0b	4.6a
Royal poinciana	No	38.0	7.6	80a	1.2b
	Yes	30.7	6.7	0 b	4.8a
Pink tabebuia	No	35.1	6.5	100a	1.0b
	Yes	33.0	6.3	0 b	4.6a

[z]Based on Florida Grades and Standards for Nursery Plants (Anonymous 1998); a cull results when one or more roots greater than 10% of the trunk caliper circles more than one-third around the top half of the root ball. Trees were graded at the position of the #3 container.

[y]1 = poor quality root ball with many deflected roots, 5 = excellent quality root ball with abundant non-deflected, straight roots.

[x]Means for a species in a column with a different letter are statistically different at $P < 0.05$. Based on 10 trees per species × treatment combination, 40 trees total for temperate trees; 5 trees per species × treatment. combination, 50 trees total for tropical trees. There were no differences in caliper and height measurements.

more radial, straight manner away from the trunk than on non-pruned trees.

The largest roots are particularly important in holding trees erect, and it is important that these roots be as straight as possible to reduce wind-throw (10, 20, 25). A significantly larger portion of new branch roots in the #15 substrate on shaved trees of 6 of 7 species were growing nearly straight (at an angle of less than 25 degrees in relation to the primary root) compared to non-pruned trees (Table 2). Angle of three largest branch roots in relation to the main root was less for shaved trees of all species tested compared to non-pruned trees. This indicated that roots of shaved trees were growing in a more radial nearly straight orientation from the trunk, not deflected and turned as in trees that were not shaved when

Table 2. **Root ball characteristics for seven tree species in #15 containers root pruned by shaving the outer 2.5 cm (1 in) of the root ball or not before shifting from #3 containers.**

Species	Root ball shaved	Primary root[z] diameter (mm)	Number of branch roots >2 mm[w]	Mean branch root[y] diameter (mm)	Largest branch root diameter (mm)	Largest branch root diameter as percent of primary root diameter (%)	Angle[x] of three largest branch roots to primary root (degs)	Number of primary roots with straight[v] branching roots
Temperate								
Red maple	No	15.3a[u]	26b	7.0a	9.2a	60	74a	1.1b
	Yes	11.5b	47a	4.5b	5.4b	47	32b	3.9a
Live oak	No	12.9	37b	7.7a	10.3a	80	62b	2.5
	Yes	13.3	47a	6.1b	8.1b	61	51a	2.4
Tropical								
Gumbo Limbo	No	16.3	15	9.7a	11.6	71	75a	1.2b
	Yes	14.5	34	6.4b	8.5	59	39b	3.4a
Lysiloma	No	12.3	17	7.3	9.3	76	59a	1.4b
	Yes	9.4	18	5.8	6.4	68	28b	3.8a
Mahogany	No	13.1	17b	9.9	11.3	86	77a	0.6b
	Yes	12.6	33a	6.4	8.0	64	39b	3.6a
Royal poinciana	No	14.7	7b	7.8	10.2	69	78a	1.2b
	Yes	11.4	22a	5.8	7.2	63	36b	3.6a
Pink tabebuia	No	16.8	22b	11.1a	13.9a	83	72a	1.0b
	Yes	14.2	43a	7.1b	8.6b	61	25b	4.6a

[z]Mean diameter of the 5 largest primary roots growing directly from the trunk base.

[y]Mean diameter of the three largest roots growing into the #15 substrate from each of the 5 primary roots at the edge of the #3 container.

[x]Vertical or horizontal angle (whichever was greater) of departure of the 3 largest diameter branch roots at the position of the #3 container wall growing from the 5 largest primary roots into #15 substrate.

[w]Number of roots > 2 mm diameter growing into the substrate of the #15 container.

[v]Number of primary roots (up to 5) in the #3 substrate with at least one branch root growing into the #15 substrate +/– 25° azimuth relative to the primary root.

[u]Means for a species in a column with a different letter are statistically different at $P < 0.05$ based on Student's t-test. Based on 10 trees per species × treatment combination, 40 trees total for temperate trees; 5 trees per species × treatment combination, 50 trees total for tropical trees.

shifted into #15 containers. Brass et al. (7) found that red maple trees growing in chemically (copper hydroxide) pruned 23 liter (6 gal) containers grew more roots into the substrate of the larger 51 liter (13.5 gal) container than non-treated trees. Krasowski and Owens (20) found that root systems in mechanically pruned *Picea glauca* (Moench) Voss produced more root growth outside the original root ball than control or chemically root pruned treatments despite a smaller root ball at planting. Increased number and cross-sectional area of lateral roots on naturally regenerated and planted forest trees has lead to a more stable tree following planting of small forest seedlings (5, 9). Further testing is required to fully understand stability attributes of shade trees planted from these much larger containers used in the current study.

Fewer roots circled (on all species tested) or grew down (2 of 7 species tested) at the position of the #3 container on shaved trees (Table 3). Fewer roots kinked back toward the trunk on 2 species tested (maple and gumbo-limbo) as a result of shaving the root ball. More new branch roots of shaved trees on all species tested were oriented radially away from the trunk in a fan-like pattern from the cut root ends than on non root pruned trees (Table 3, Fig 1). The turned, circling and deflected roots of trees that were not shaved when shifted to larger containers in the current study have been associated with instability in conifers planted from much smaller containers (9, 25). Roots growing tangent to the trunk such as circling or kinked roots have also been associated with tree

Table 3. Number of primary roots[z] producing branch roots (> 2 mm diameter) in various orientations at the former position of the #3 container 7 months following planting into the #15 container for seven tree species pruned by shaving the outer 2.5 cm (1 in) of the root ball or not root pruned before shifting from #3 containers.

Species	Root ball shaved	Root orientation at #3 container wall			
		Circling[y]	Kinked[x]	Down[w]	Fan[v]
Temperate					
Red maple	No	2.5a[u]	0.9a	3.1a	1.8b
	Yes	0.0b	0.2b	0.9b	4.8a
Live oak	No	2.7a	0.4	2.3	2.7b
	Yes	1.2b	0.1	1.4	4.6a
Tropical					
Gumbo Limbo	No	3.2a	0.6a	1.4	1.4b
	Yes	0.2b	0.0b	0.6	5.0a
Lysiloma	No	2.2a	0.4	2.0	2.0b
	Yes	0.0b	0.0	1.0	5.0a
Mahogany	No	2.6a	0.0	2.4a	1.0b
	Yes	0.4b	0.0	0.0b	5.0a
Royal poinciana	No	3.6a	0.4	1.2	0.6b
	Yes	0.2b	0.0	0.0	5.0a
Pink tabebuia	No	2.0a	0.4	2.0	1.4b
	Yes	0.0b	0.0	0.0	5.0a

[z]The 5 largest diameter primary roots were measured.

[y]Branch roots were deflected and grew in a circle at the position of the #3 container wall.

[x]Branch roots were deflected by container wall at an angle of more than 90 degrees so they grew back toward the trunk.

[w]Branch roots were deflected straight down at the position of the #3 container wall.

[v]Branch roots grew into 15 substrate out away from the trunk +/– 90° (180 degrees total) azimuth relative to the primary root.

[u]Means for a species in a column with a different letter are statistically different at $P < 0.05$ based on t-test. Based on 10 trees per species × treatment combination, 40 trees total for temperate trees; 5 trees per species × treatment combination, 50 trees total for tropical trees.

decline and death several years after planting (32). Further investigations are needed to evaluate the stability and health of shade trees planted from different production methods including containers, bare-root, and balled-and-burlapped field grown trees.

Cutting roots by shaving the periphery of the root ball when shifting from a #3 to a #15 container had no impact on primary root diameter on any species except red maple (Table 2). Shaving had no impact on the ratio diameter of the largest branch root to primary root diameter (Table 2). Ortega et al. (25) and Dunn et al. (11) found that deflection by the #3 container wall did not appear to stop or even slow root growth; the container wall only redirected growth. Rarely did roots on non-pruned trees fan out into the #15 substrate at the point where a primary root turned down or circled as did roots on shaved trees (Table 2, Fig 1). Sharp turns in primary and main lateral roots create a weakness in the root system and have been associated with instability in forest trees planted from small containers (10).

More roots > 2 mm diameter growing into the #15 substrate appeared to be positioned closer to the surface (although this was not measured) than roots of trees that were not shaved. This was especially noticeable on oaks and all subtropical species, less so on maples. Thaler and Pages (30) showed that pruning the tap root on young germinating seedlings resulted in a slight but significant increase in root growth near the top of the soil profile. Krasowski (20) showed that chemically and mechanically root pruned seedlings in 3 cm (1.3 in) diameter containers grew more roots closer to the surface that untreated control trees. Harris et al. (19) also showed that more lateral horizontal roots were produced on liners that were root pruned.

Restricting development of downward growing roots along the wall of the 3 cm (1.3 in) diameter container with copper resulted in more surface roots and better stability following planting compared to trees growing in pots not treated (8, 20). It is not clear whether encouraging more surface roots that occurred on the much larger sized containers in the current study will result in better stability. Long term testing is needed to evaluate this. However, straight roots have been associated with better stability following planting (25), and there were more straight roots on all 7 tree species that received root ball shaving when shifted to a larger container size in the current study.

The two different #3 container types may have influenced the effectiveness of the shaving treatment, although our study was not designed to test this. Tropical trees were grown in smooth-sided containers, and most circling and deflected roots were clearly visible on the periphery of the root ball. Svensen et al. (29) also found that most roots growing in smooth-sided pots were on the periphery on tropical trees and shrubs as did Ortega et al. (25) and others on temperate conifers. Therefore it was unlikely tropical trees as a group differed from temperate trees in response to the container. Since most root defects appeared at the periphery, shaving the tropical tree root balls likely removed most of these circling and descending roots. In contrast, maples and oaks were grown in Air-Pot containers with hundreds of indents and holes in the side. These containers were designed to reduce the occurrence of roots at the root ball periphery. Some deflected maple and oak roots in these Air-Pots were visible on the outside periphery, but many were not visible because they were positioned slightly back from the periphery inside the substrate. Brass et al. (7) and Struve (28) found that root balls became denser when grown in chemically root pruning containers by reducing root growth on the periphery of the root ball. Air-Pots appear to have caused a similar effect, and further study is underway to test this hypothesis. Some of these root defects farther inside may not have been removed when root balls were shaved so they retained their original deflected position. This could explain why shaving appeared to be more effective on trees in the smooth-sided containers (the tropical trees).

More research is clearly needed to explain this since there are few reports characterizing root form in large containers. Root defects on smooth-sided containers may be easy to remove with mechanical root pruning (shaving and slicing the root ball periphery) because defects form at the extreme edge of the container (4, 5, 11) where they are easily shaved off. It could be more difficult to remove defects from container types that force the defects further inside the substrate (16).

Treating the interior plastic container surface with copper is a time-tested, effective method of reducing root growth on the periphery of container root balls. Its effect lasts about one year in a #5 to a #15 container before roots begin to grow on the periphery (7, 23). Certain container types have also been associated with reduced root defects at the root ball periphery (16, 23). Shaving the root ball periphery appears to be a useful technique to reduce or eliminate root defects, or it can be used in conjunction with copper and air-pruning, or when plants cannot be shifted from containers at the most optimal time due to market conditions or other circumstances. Root system quality improved dramatically by removing roots that grew down, around, and up the wall of a container root ball by shaving the periphery and bottom of the root ball when shifting to a larger container.

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