**Project title:** Improving establishment of container-grown landscape trees in the landscape

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**Project justification:**

Urban and community foresters and professional landscapers are increasingly reliant on container-grown trees for planting stock in addition to standard balled-in-burlap (B&B) trees. Compared to B&B trees, container-grown trees are lighter weight and can be planted over a longer planting season, which are key advantages for landscapers and for community tree planting programs that often depend on volunteers for planting. A major concern with container-grown trees, however, is that trees grown in standard plastic containers often develop circling roots during the nursery production cycle. Several approaches to remediating circling roots have been suggested including 'teasing' or pulling apart roots at planting, 'slicing' through the outer circling roots, and 'shaving' or removing all of the outer roots from the root-ball. In a recent trial at the MSU Horticulture Teaching and Research Center (HTRC), we planted 'Bloodgood' London planetrees in which circling roots were either shaved before planting or left untreated (control). After four growing seasons we excavated root systems of a subset of trees and evaluated root development. Shaving root systems prior to planting eliminated circling roots and increased new root growth outside of the original root-ball compared to trees that were planted without root modification.

Dr. Linda Chalker Scott (Washington State University) and the late Dr. Bonnie Appleton (Virginia Tech), among others, argue barerooting (removing all soil or container substrate) from B&B and container trees is the only means to uncover and remediate root defects at planting (Appleton, 2007; Appleton and Flott, 2009). Bare-rooting remains controversial, however, as it is labor-intensive and time consuming and few systematic studies have been conducted to evaluate its long-term benefits on root growth and development. Appleton and Flott (2009) compared growth and development of B&B red maple and willow oak trees that were bare-rooted prior to planting while dormant and during the growing season. They found no difference in any variables measured except that survival of willow oak trees decreased when planted bare-root during the growing season. In contrast, Chalker-Scott and Stout (2009) reported that bare-rooting containerized trees at transplanting enhanced new root growth of wax myrtle and arborvitae trees compared to trees that were planted with the root-ball undisturbed.

In this project we investigated the response of three common cultivars of shade trees (October Glory maple, columnar tulip poplar, and Bloodgood London planetree) to root modification at planting. The study provides comparative post-planting data on growth, physiology and root development of trees following shaving or bare-rooting. In addition, we will maintain the trees for periodic assessments (up to ten years) to provide a research platform for long-term evaluation of tree root growth responses.

**Objectives:**

1. Evaluate the effect of shaving and bare-rooting root-balls of container-grown trees on survival, growth, physiology, and root responses after transplanting

2. Determine if species vary in their responses to pre-plant root modification

3. Determine if response to root modification varies with time of planting.

**Accomplishments:**

We conducted two field experiments to examine the response of three species of container-grown trees to root modification treatments at different times in the growing season with the goal of improving root system development and transplant success.

Experiment 1: Spring planting. In May 2018, 32 container-grown trees of October Glory® red maple (*Acer rubrum* 'October Glory'), columnar tulip poplar (*Liriodendron tulipifera* 'Fastigiatum'), and Bloodgood London planetree (*Platanus x acerifolia* 'Bloodgood') (96 total) were transplanted to a field plot at the MSU HTRC. The experiment was installed as a 3 x 4 factorial of species (3) and root modification treatments (4) with eight replications (N=8). Trees of each species were randomly assigned one of four root-ball modification treatments. The root-ball modification treatments included: 1) Control – nursery container removed and planted without root modification (Photo 1A); 2) Shave – removal of the 3 cm periphery and bottom of the root-ball using a pruning saw (Photo 1B); 3) Bare-root airspade – removal of all container substrate using compressed air flow from a pneumatic air spade (Photos 2A and 2B), then any obvious root deformations, such as kinked or girdling roots, were removed with hand pruners; 4) Bare-root wash – root-balls were soaked in water approximately 12 hours prior to additional handling (Photo 2C), then, the following day, all container substrate was removed using a stream of water from a garden hose (Photo 2D) before removing any obvious root deformations using hand pruners.


Photo 1. Examples of root-ball treatments. A – Control treatment. B – Shave treatment.


Photo 2. Examples of root-ball treatments. A – Bare-root airspade treatment. B – Root-ball following removal of container substrate. C – Soaking root-balls for bare-root wash treatment. D – Bare-root wash treatment.

The trees were transplanted to a field block at the MSU HTRC and were planted in six rows, 2.7 m on center. For all treatments, the planting holes were backfilled with unamended backfill, and the trees were watered immediately after planting. We mulched all trees with a ring (1.5 m diameter) of ground blonde pine wood mulch to a depth of 8 cm (Photo 3).

<u>Experiment 2: Summer planting.</u> In July 2018, an additional subset of 27 trees (nine trees of each cultivar) were transplanted from the pot-in-pot nursery to a plot adjacent to Experiment 1 at the MSU HTRC. The experiment design for Experiment 2 was the same as experiment 1 except N=3 for each species x treatment combination, and the bare-root airspade treatment was eliminated due to lack of acceptable trees available from the nursery and trees in this treatment had poor survival in Experiment 1.

Photo 3. Field planting following installation in May 2018. All trees were mulched shortly after the photo was taken.

<u>Assessments</u> At the time of planting we recorded the length of time to install each tree, including the time for root modification and planting time. We also collected, dried, and weighed roots that were removed during the root modifications. We assessed survival, growth, leaf water potential, SPAD chlorophyll index, and photosynthetic gas exchange for two growing seasons (2018 and 2019) following transplanting. At the end of the second growing season (fall 2019), we destructively harvested a subset of half of the trees in Experiment 1 to determine above- and below-ground biomass. We did not harvest trees from Experiment 2 due to low replication and poor overall survival. For each tree harvested, we measured leaf, shoot, and trunk dry biomass. Root systems were harvested with a mechanical tree spade. We removed soil and residual container substrate from the roots using a pneumatic air-spade. We separated roots into those inside the original container root-ball and those outside the root-ball (Photo 4). Roots were further separated into fine roots (<5 mm) and coarse roots (>5 mm), dried, and weighed.

Photo 4. Example excavated root system of *P. x acerifolia*; dashed line indicates perceived outline from the original nursery container.

Results Root modifications increased the average installation time of each tree. Shaving added 6 to 10 minutes to the installation time relative to the untreated control depending on species. Bare-root – washing was the most time-intensive treatment and added 39 to 65 minutes, depending on species. Bare-rooting – airspade added 18 to 37 minutes for each tree (data not shown).

Leaf scorch assessed at the end of the first growing season after spring transplanting was affected by species and root modification (Table 1). Root modification increased leaf scorch for tulip poplar and red maple trees. Bare rooting of tulip poplar increased the incidence of severe scorch compared to the untreated control trees. Nearly all trees (67% or more) bare-rooted before the summer planting had severe die-back.

**Table 1.** Mean leaf scorch rating and percent of trees with extreme (ranking ≥ 3) leaf scorch rating of trees of three species subjected to four root modifications: control (no root manipulation), shave (outer 3 cm of roots removed), bare-root (BR) airspade (all container substrate removed using an airspade, then root defects manually removed), or bare-root (BR) wash (all container substrate removed using the stream of water from a garden hose, then root defects manually removed) on September 21, 2018.

| | **Mean scorch (0-4; 0 = no scorch, 4 = dead)** | | | **% with extreme scorch (rating ≥ 3)** | | |
|---|---|---|---|---|---|---|
| Treatment | *A. rubrum* | *L. tulipifera* | *P.* x *acerifolia* | *A. rubrum* | *L. tulipifera* | *P.* x *acerifolia* |
| Control | 0.50ab | 0.38a | 0.25a | 12.5a | 0.0a | 0.0a |
| Shave | 0.00a | 1.63ab | 0.13a | 0.0a | 37.5ab | 0.0a |
| BR-Airspade | 1.75b | 3.63c | 0.63a | 37.5a | 87.5c | 0.0a |
| BR-Wash | 1.75b | 2.88bc | 1.38a | 25.0a | 62.5bc | 0.0a |

Means within a column followed by the same letter are not different at $P<0.05$ level. Mean separation by Tukey's HSD.

Survival was excellent (87.5% or higher) for all red maples and planetrees planted in May, regardless of treatment (Fig. 1). Survival of tulip poplar trees, in contrast, was affected by root modification. Only one of the eight tulip poplar trees that were bare-rooted with the air-spade was still alive at the end of the first growing season. Overall, survival for spring-planted tulip poplar trees that were bare-rooted was 50%. In the July planting block, all tulip-poplars that were bare-rooted died.

The effect of bare-rooting on leaf scorch and survival was associated with increased tree stress immediately after planting. Bare-rooting reduced pre-dawn leaf water potential of tulip poplars and planetrees measured one week after planting, compared to trees in the control or shave groups (data not shown). For red maples, bare-rooting with the air-spade reduced pre-dawn leaf water potential compared to all other treatments. Leaf water potentials were similar among root modification treatments for the rest of 2018 and throughout the 2019 growing season. This suggests that the water status of trees with modified root systems achieved an equilibrium by reducing whole-tree water loss as functional leaf area was reduced by leaf scorch and crown die-back. This hypothesis is also supported by leaf-level gas exchange rates (net photosynthesis and stomatal conductance), which were similar among treatments within each species throughout both growing seasons (data not shown).

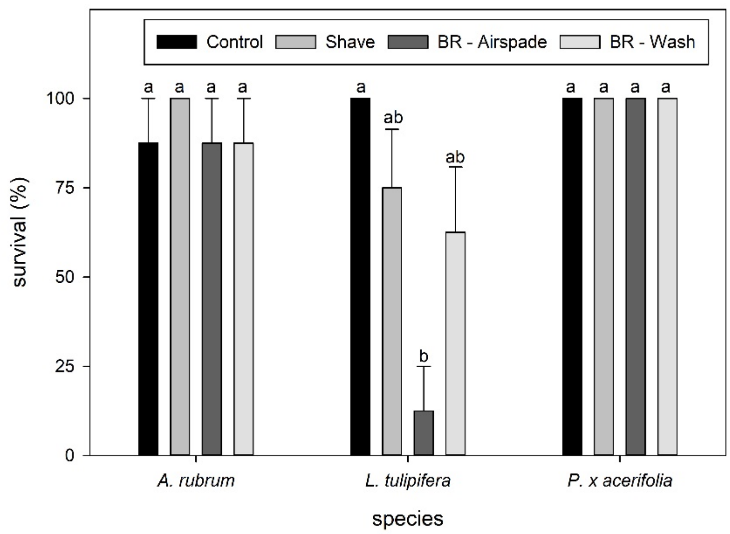


Figure 1. Mean survival (%) of trees of three species subjected to four root modifications: control (no root manipulation), shave (outer 3 cm of roots removed), bare-root (BR)-airspade (all container substrate removed using an airspade, then root defects manually removed), or bare-root (BR)-wash (all container substrate removed using the stream of water from a garden hose, then root defects manually removed). Means within a species followed by the same letter are not different at P<0.05 level. Mean separation by Tukey's HSD.

Mean total above-ground biomass varied among root modification treatments and species when trees were harvested after two growing seasons (data not shown). For red maple trees, all root modifications reduced biomass relative to the control trees. Bare-root–Wash reduced biomass of tulip poplar trees compared to trees in the control or shave group. Root modification did not affect total biomass of planetrees. Root biomass outside the original root-ball, an indication of root egress into backfill soil after transplanting, did not differ among root modification treatments. However, bare-rooting reduced the proportion of circling roots compared to the control trees for all species. Shaving reduced the proportion of circling roots compared to control trees for tulip poplar and planetrees.

Publications and presentations


Rouse, R.P. 2020. Improving establishment of container-grown deciduous shade trees. M.S. Thesis Michigan State University.

Rouse, R.P & B. Cregg. (in preparation) Improving root systems of container-grown trees through pre-plant root modification: shaving and bare-rooting. *Urban Forestry and Urban Greening*.

Rouse, R.P. 2019. Improving root systems of container-grown trees through pre-plant root modification: shaving and bare-rooting. Arboriculture Society of Michigan, February 2019, Lansing, MI.

Rouse, R.P. 2019. Improving root systems of container-grown trees through pre-plant root modification: shaving and bare-rooting. International Society of Arboriculture Conference and Trade Show, August 13, 2019, Knoxville, TN.

Cregg, B.M. & Rouse, R.P. 2019. Improving root systems of container-grown trees through pre-plant root modification: shaving and bare-rooting. Bartlett Tree Research Laboratories. Oral presentation delivered to the research staff at Bartlett Tree Research Laboratories, August 2019, Charlotte, NC.

Rouse, R.P. 2020. Improving transplant success of container grown trees. Michigan Nursery and Landscape Association Great Lakes Trade EXPO, January 25, 2020, Lansing, MI.

**Impacts:**

This investigation is one of the first systematic studies to examine the effect of bare-rooting container grown trees at planting. This practice is recommended by social media sites and popular press outlets despite the absence of evidence-based supporting information. This study demonstrated that bare-rooting and shaving can improve root system quality by reducing the number of circling roots. However, bare-rooting increased tree stress immediately after transplanting in May 2018, resulting in leaf scorch in red maple and tulip poplar and increased mortality in tulip poplar. Moreover, nearly all trees that were bare-rooted before planting in July had severe leaf scorch and all the tulip poplar trees that were bare-rooted died. These results indicate that response to bare-rooting is species-specific. Arborists and landscapers that are interested in adopting the technique to improve root quality should avoid trees that are known to be difficult to transplant bare-root (e.g., oaks, hackberry, tulip poplar, hornbeam, hop hornbeam) and transplant trees when they are dormant, when possible.

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**Summary statement**

Modifying the root systems of container-grown shade trees by shaving or bare-rooting can improve subsequent root system development; however, tree responses are strongly dependent on species and time of planting. Arborists and landscapers interested in adopting these practices should avoid species that are difficult to transplant bare-root (e.g., oaks, hackberry, tulip poplar, hornbeam, hop hornbeam) and avoid extensive root removals when planting trees that are not dormant.