Impacts of Wire Basket Retention and Removal on Whole Tree Stability and Long-term Growth[1]

Richard J. Hauer[2], Andrew K. Koeser[3], Jason W. Miesbauer[4], Jeff Edgar[5], and David Kleinhuizen[6]

Abstract

When balled-and-burlapped trees are planted, a decision must be made regarding whether the wire basket, burlap, and other packing materials should be removed (completely or partially) or retained. While past research has failed to show a significant impact of either approach with regard to initial growth and establishment, many professionals still question whether a decision to leave the wire basket intact at planting will have longer-term impacts to tree health and stability. In this study, we revisit two nursery trials first initiated in 2011 and 2012 to assess the impact of burlap folding, and full wire basket removal, partial removal, or retention on tree growth and root anchorage five to six growing years after planting. We found that neither stem caliper (min $P = 0.249$) nor twig elongation (min $P = 0.297$) differed among removal treatments with the Norway maple (*Acer platanoides* L.) and 'Skycole' honeylocust (*Gleditsia triacanthos* L. var. *inermis*) trees used in this study. Similarly, we were unable to detect any differences in rooting strength among the removal treatments tested (min $P = 0.154$). These results serve as further evidence that wire baskets are not a cause of early tree mortality or instability.

Index words: Arboriculture, biomechanics, growth and longevity, nursery production, static-pull test, transplanting, transplant shock.

Species used in this study: Norway maple *(Acer platanoides* L.); 'Skycole' honeylocust (*Gleditsia triacanthos* L. var. *inermis*).

Significance to the Horticulture Industry

Wire baskets have played a critical role in the mechanization of field-grown nursery tree production. Despite their prevalence, there is still a lack of industry consensus regarding what should happen to this packing material (and other materials like burlap) at planting. In this study, we found no differences in tree survival or growth five to six years after transplanting when trees were planted with wire baskets intact, partially removed or fully removed and treated burlap folded or unfolded. Moreover, wire basket removal or retention did not influence rooting strength when trees were pulled to assess whole-tree anchorage. This paper adds to the small, but growing body of literature that directly addresses best practices for planting balled-and-burlapped trees.

Introduction

The period of time associated with planting and establishment is one of the most challenging in an urban tree's life (Hilbert et al. 2019). For balled-and-burlapped trees, root loss, water stress, rootball disruption, and changes in below- and above-ground environment all contribute to a period of increased likelihood of mortality and decreased growth known as "transplant shock" (Koeser et al. 2009, Struve 2009, Levinsson 2013). Among the list of potential stressors associated with balled-and-burlapped tree transplanting, one persists despite a general absence of evidence to support its validity. This is the belief that failure to remove at least some of the packing (i.e., wire basket, burlap, twine) will hinder establishment or even lead to premature tree death (Appleton 2015).

Many opinions, conjecture, and popular thought exist on whether to remove or not to remove wire baskets, burlap, and twine at planting (Appleton and Floyd 2004, Cregg 2009, Kuhns *undated*, Weigel 2019, Gilman 2020). While professional opinions differ, the research on the topic has remained relatively consistent. The first peer-reviewed work on the subject was an observational account by Lumis and Struger (1988). In this brief article, the authors excavated 11-year old willow (*Salix* spp.) to document the regrowth of vascular tissue over wire from a basket wire which was partially girdling the roots (Lumis and Struger 1988). Four years later, Goodwin and Lumis (1992) conducted a controlled greenhouse experiment where they used floral wire to girdle (fully or partially) potted green ash (*Fraxinus pennsylvanica* Marshall) grafted plants, hackberry (*Celtis occidentalis* L.) seedlings, as well as hybrid poplar (*Populus angulata* × *plantierensis*) liners. For the first two species, the researchers found no significant difference in growth (whole-plant dry weight) when comparing the partially and fully girdled treatments against the ungirdled control (Goodwin and Lumis 1992). Similarly, the authors failed to detect differences in caliper and whole-plant dry weight for the hybrid poplar tested (Goodwin and Lumis 1992). While an improvement from the earlier work, Goodwin and Lumis (1992) were quick to point out that it might be difficult to draw parallels between

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[2]Professor, College of Natural Resources, University of Wisconsin-Stevens Point, 800 Reserve Street, Stevens Point, Wisconsin, 54481, United States. Corresponding Author: rhauer@uwsp.edu.

[3]Associate Professor, Department of Environmental Horticulture, CLUE, IFAS, University of Florida Gulf Coast Research and Education Center, 14625 County Road 672, Wimauma, Florida, 33598, United States.

[4]Research Arborist, The Morton Arboretum, 4100 Illinois Route 53, Lisle, Illinois, 60532, United States.

[5]Owner, Silver Creek Nurseries, Inc., P.O. Box 1988, Manitowoc, Wisconsin, 54421-1988, United States.

[6]President, Hardwood Creek Nursery, Inc., 18431 Henna Avenue North, Forest Lake, Minnesota, 55025-3610, United States.

the findings of their study (conducted on very young specimens over the course of one growing season) and the potential health impacts associated with wire basket girdling on maturing trees.

More recently, Koeser et al. (2015) conducted a controlled experiment in two commercial nursery environments, assessing the impact of wire basket removal (full and partial) and retention on the short-term health and survival of larger-caliper 5 to 9 cm (2 to 3.5 in) Norway maple (*Acer platanoides* L.) and 'Skycole' honeylocust (*Gleditsia triacanthos* L. var. *inermis*) trees. In this study, the authors failed to detect any significant differences in survival, twig growth, or caliper growth after two to three growing seasons (Koeser et al. 2015). Similarly, Klein et al. (2019) failed to detect differences in survival and growth for 45 'Autumn Purple' white ash (*Fraxinus americana* L.) trees subjected to two levels of wire basket and burlap removal (i.e., intact or full removal) or spade transplanting (i.e. no packing materials used) after nine years.

The aim of this study was to revisit the trees from the Koeser et al. (2015) study and quantify the effects of removing all, some, or none of the wire basket, twine, and burlap that cover soil of tree root balls over a longer period of time. We set out to determine if the growth of landscape trees differ with different treatments that replicate three common approaches to removing materials that cover root balls. We also tested if the stability of trees after establishment (e.g., five to six growing seasons post planting) differed when subjected to static pull testing.

Materials and Methods

Study sites. Two locations were used to test the effect of a full, partial, and no removal of balled-and-burlapped packing materials (e.g., wire basket, twine, and untreated burlap; see Koeser et al. 2015). Both study locations were commercial tree nurseries in the upper Midwest (United States) with differing soil textures and climates. The first study site was located in Manitowoc, WI (lat. 44° 5′ N, long. 87° 39′ W, USDA Hardiness Zone 5b) and was planted on June 28, 2011. The second study site located in Forest Lake, MN (lat. 45° 17′ N, long. 92° 59′ W, USDA Hardiness Zone 4b) was planted on May 10, 2012. These locations were selected to provide an intentional spatial and temporal variability (with planting and harvest dates staggered over seasons) to capture contrasting growing environments. Soils were a Keowns very fine sandy loam (USDA 2019) in Wisconsin (3.2% OM and 7.3 pH) and a Lino variant loamy fine sand (USDA 2019) in Minnesota (1.5% OM and 6.2 pH). After planting, trees were monitored for five (Manitowoc) or six growing seasons (Forest Lake) before being destructively pull tested to gauge rooting strength. The final measurements occurred on September 25, 2015 at the Manitowoc, WI site and on May 30, 2018 at the Lake Forest, MN site.

Study plants. Two commonly planted shade tree species, 'Skycole' honeylocust (*Gleditsia triacanthos* L. var. *inermis*) and Norway maple (*Acer platanoides* L.), were selected for comparison in this study. Both species were field grown and harvested as balled-and-burlapped stock using standard tapered wire baskets constructed from 10.5 gauge wire following nursery standards at the time of the study start (ANLA 2004). Norway maple were 5.0 cm to 6.5 cm (2.0 in to 2.5 in) in caliper at the Wisconsin site and 7.5 cm to 9.0 cm (3.0 in to 3.5 in) in caliper at the Minnesota site at the time of planting. Honeylocust were 5.0 cm to 6.5 cm (2.0 in to 2.5 in) in caliper at the time of planting. A 76-cm (30-in) diameter wire basket was used to transplant the honeylocust at both sites and the Norway maple at the Wisconsin site. The larger Norway maple at the Minnesota site was placed in 91-cm (36-in) diameter wire baskets during transplanting. The wire hole size for the 76 cm basket was 15.2 cm (6 in) tall by 15.2 cm (6 in) wide, basket height was 45.7 cm (18 in), with a 43.2 cm (17 in) bottom rung and 76.2 cm (36 in) top rung (model 30 CBT, Dayton Bag & Burlap, Dayton, OH). The wire hole size for the 91 cm basket were 15.2 cm (6 in) tall by 21.0 cm (8.25 in) wide, basket height was 61 cm (24 in), with a 40.6 cm (16 in) bottom rung and 91.4 cm (36 in) top rung (model CBV-36CG, Cherokee Manufacturing, South St Paul, MN). Natural burlap was 0.37 $kg{\cdot}m^{-3}$ (10 $oz{\cdot}yd^{-3}$) weight treated with copper sulfate <0.2% (Cherokee Manufacturing, South St Paul, MN). Trees were dug from and planted in the same soil type at each study location.

Experimental treatments. Sixty (60) trees in total were used for this study. At each site, 15 trees per species were randomly assigned one of three treatments for 5 replications per treatment. The treatments were as follows: 1) wire basket and natural burlap fully intact (intact); 2) top third of the wire basket removed and the natural burlap cut and folded down as low in the planting hole as possible (partial removal); and 3) wire basket completely removed and natural burlap folded down in the hole below the root ball (full removal) (Koeser et al. 2015). For all treatments, any twine wrapped around the base of the trunk was removed to prevent stem girdling. When planting trees in the full removal treatment group, the bottom of the basket was removed prior to placing the tree in the planting hole. This left the sides of the tapered basket intact to support the root ball until the tree was completely situated in the bottom of the planting hole. The remaining wire basket was then removed and the burlap was loosened and folded down to the bottom of the hole. All trees were assessed to ensure the root-stem transition zone (RSTZ) was planted at or slightly above the final soil grade to avoid issues of deep planting.

Planting holes were dug with a tree spade attached to a skid steer (Wisconsin site) or u-blade attached to a skid steer (Minnesota site). Before planting, these holes were widened with a hand shovel to a width of 1.5 times the root ball diameter to allow access for wire basket removal and burlap loosening as noted above. Trees were transported from their harvest location to the planting holes via forks attached to a skid steer. Final soil backfilling was done by shovel and the soil was tamped lightly to reduce air gaps. Trees were later watered by hand to wet the soil and no supplemental irrigation occurred during the study.

Growth measurements. Stem caliper was measured above the graft union at 15.2 cm (6 in) from the ground.

Caliper was initially measured with a digital caliper and the mean of two measurements (North-South and East-West) used, and later (last two years of study) caliper measurements were taken with a diameter tape. The caliper measurement location was marked annually with a waxed pen or black Sharpie pen. Annual elongation was measured for three twigs on each tree from terminal shoots of the lowest three sun-exposed main branches and the mean of these values were used for analysis. Growth measurements were taken at or near the end of each growing season.

Static pull testing. Static pull tests are a standard method and were conducted to evaluate the effect of wire basket removal or retention on tree stability (Peltola 2006). To measure tree tilt, an inclinometer (model DOG2 MEMS, TE Connectivity, Schaffhausen, Switzerland) was secured to the tree base at a height of 15 cm (6 in), directly above the root flare. A 2,268 kg (5,000 lb) capacity winch was secured to earthmoving equipment available onsite and used to exert the pulling force needed for the pull tests. A sling was then hitched around the tree at a height of 1.4 m (4.6 ft) and the winch was positioned at a uniform distance from the tree. A 4,536 kg (10,000 lb) capacity load cell (SSM2-N5-10K; Interface Inc., Scottsdale, Arizona, U.S.) was secured in-line between the sling and winch cable to measure the force required to pull the trees to 1° of tilt. After the first pull, the tension on the winch cable was released and trees were allowed to return to their initial resting position as indicated by the inclinometer. Pull tests were repeated two more times for a total of 3 pull tests. All inclinometer and load cell readings were sampled at a rate of 20 Hz using a 16-bit data acquisition system (National Instruments Corporation, Austin, TX, U.S.) while being observed and archived on a laptop computer running engineering software (LabView v.13.0.1, National Instruments Corporation, Austin, TX, U.S.). Relative differences in rooting stress were compared in terms of bending stress. Bending stress (σ) was calculated using the equation:

$$\sigma = 32 \mathrm{Pl} \cos\theta / \pi \mathrm{D}^3 \qquad \text{(Eq. 1)}$$

where P = the force (averaged over 3 pulls) required to reach 1 degree of inclination, θ = the angle of winch cable from horizontal, l = trunk length from the ground to the height of sling attachment, and D = trunk diameter measured 15 cm above ground level (height of inclinometer attachment, which was directly above the root flare).

Design and analysis. At each location, trees were grouped by species and planted in rows on an approximate 3 m (10 feet) spacing. The three treatments were arranged by species grouping in a completely randomized design. Final caliper growth was analyzed separately for each species using Analysis of Covariance (ANCOVA) with initial caliper, site, and treatment included as covariates (R Core Team 2018). Similarly, twig elongation was analyzed separately using ANCOVA with site, treatment, and growing season as covariates. Bending stress was assessed as a linear regression using the lm() function in R (R Core Team 2018). The data from the Minnesota site was initially modelled separately as soil moisture data was collected at this location, but not at the Wisconsin site. After initial

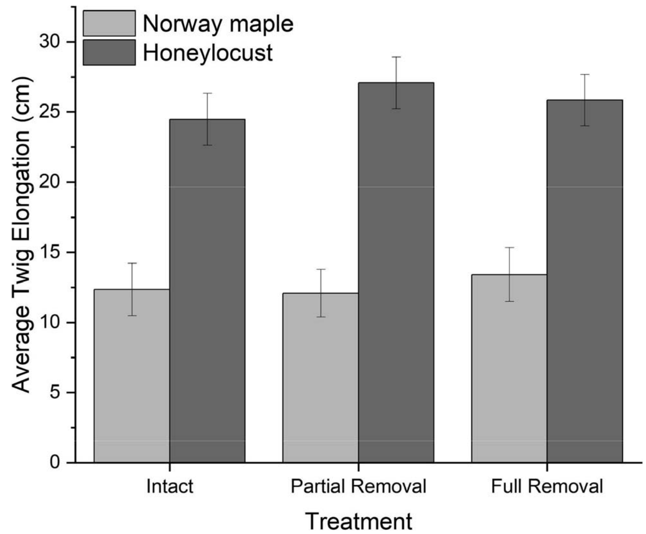

Fig. 1. Average twig elongation for 'Skycole' honeylocust (*Gleditsia triacanthos* L. var. *inermis*) and Norway maple (*Acer platanoides* L.) trees grown under three transplanting treatments: intact (wire basket and balled-and-burlapped packing materials were not removed), partial removal (removal of the top third of the packaging materials), and full removal (all packaging materials removed). Bars represent standard error, honeylocust n=30 and Norway maple n=26.

analysis showed soil moisture did not influence the analysis (P = 0.262), the covariate was dropped and all data was pooled together for both sites. Our final model for bending stress included species and treatment as covariates (site was dropped given non-significance). All underlying assumptions for the statistical models used were assessed using residual plots and met. All decisions were made at an $\alpha = 0.05$ level of type I error.

Results and Discussion

We used tree growth and stability (as assessed through a pull test) to attempt to elucidate any differences among treatments. Over the course of the study, we found no evidence of differences among treatments for any of our responses (e.g., twig elongation, caliper growth, and bending stress). All honeylocust trees survived at both sites. Rodent-induced mortality occurred on Norway maple in Minnesota (1 tree) and Wisconsin (3 trees). Average annual twig elongation was similar for all three treatments for honeylocust ($P = 0.2971$) and Norway maple ($P = 0.7821$, Fig. 1). Honeylocust (25.8 cm; 1.1 SE) had greater twig elongation than with Norway maple (12.7 cm, 1.1 SE). Twig elongation differed by site for the honeylocust trees ($P < 0.0001$) but not the Norway maple ($P = 0.2545$). Honeylocust trees had 35% greater mean twig elongation in Minnesota (29.7 cm, 1.5 SE) than in Wisconsin (21.9 cm, 1.4 SE). The measurement season was also significant for both species ($P < 0.0001$), with reduced twig elongation being observed in the two to three years following transplanting.

As with twig elongation, mean caliper growth did not differ by treatment for honeylocust (P = 0.2486) (Fig. 2) or Norway maple (P = 0.6120) (Fig. 3) during the study

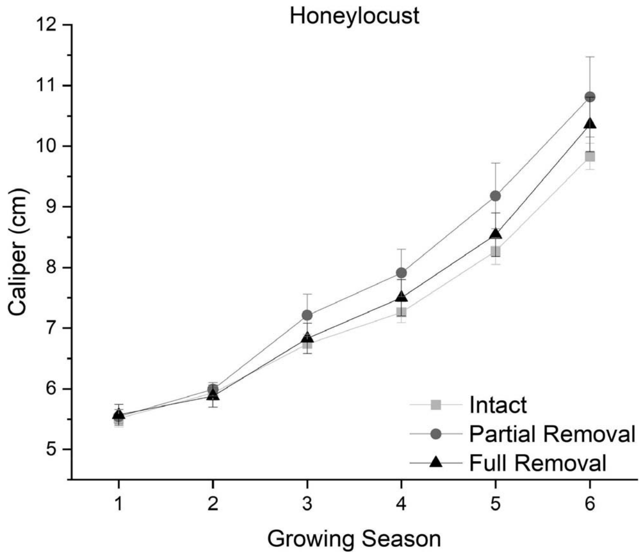

Fig. 2. **Change in stem caliper for 'Skycole' honeylocust (*Gleditsia triacanthos* L. var. *inermis*) trees grown under three transplanting treatments: intact (wire basket and balled-and-burlapped packing materials were not removed), partial removal (removal of top third of packaging materials), and full removal (all packaging materials removed). Bars represent standard error, n=30.**

period. Honeylocust caliper increased from 5.54 cm (0.08 SE) at the end of the first season to 9.83 cm (0.22 SE) at the end of the sixth season. Average caliper for the Norway maple trees increased from 7.40 cm (0.32 SE) at the end of the first season to 16.47 cm (0.32 SE) at the end of the sixth season. A significant ($P < 0.0001$) site difference occurred which was the result of one additional growing season at the Minnesota site. However, no significant interaction was detected between site and treatment for honeylocust ($P = 0.4314$) or Norway maple ($P = 0.5509$).

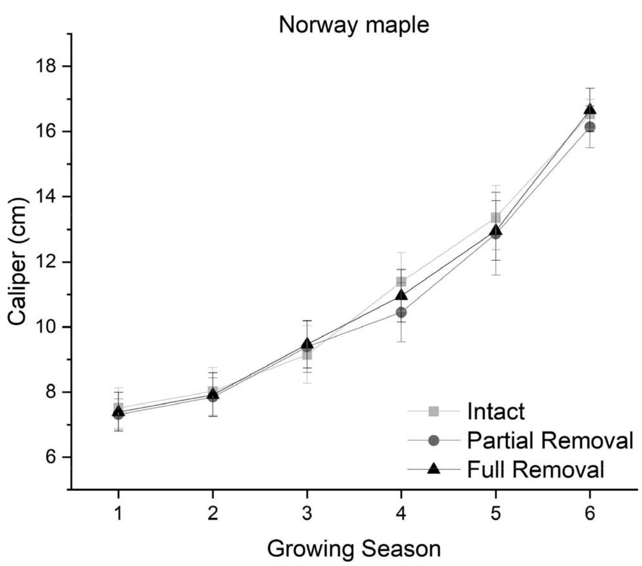

Fig. 3. **Change in stem caliper for Norway maple *(Acer platanoides* L.) trees grown under three transplanting treatments: intact (wire basket and balled-and-burlapped packing materials were not removed), partial removal (removal of top third of packaging materials), and full removal (all packaging materials removed). Bars represent standard error, n=26.**

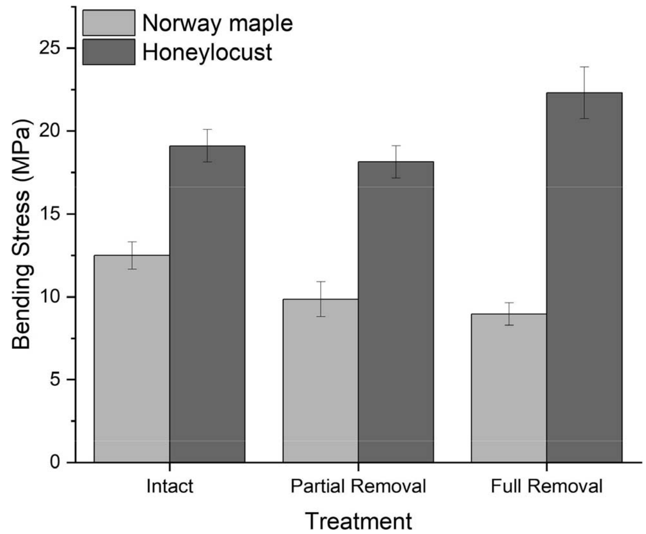

Fig. 4. **Average bending stress for 'Skycole' honeylocust (*Gleditsia triacanthos* L. var. *inermis*) and Norway maple *(Acer platanoides* L.) trees pulled to one degree inclination. Trees received one of three transplanting treatments: intact (wire basket and balled-and-burlapped packing materials were not removed), partial removal (removal of the top third of the packaging materials), and full removal (all packaging materials removed). Bars represent standard error, honeylocust n=30 and Norway maple n=26.**

The full multiple regression ($F(3, 52) = 17.73$, $p < .001$, $AdjR^2 = .65$) showed no effect of removal treatments. Neither partial removal ($P = 0.154$) nor full removal ($P = 0.997$) offered any discernible benefit over our intact treatment with regard to bending stress (i.e., rooting strength). Similarly, no site-related differences in bending stress were detected ($P = 0.922$). The bending stress for honeylocust pulled to 1 degree was greater than that of the Norway maple ($P < 0.001$; Fig. 4).

Findings from this study offer additional empirical observation of the effect of retention (intact) or partial-to-full removal of balled-and-burlapped packing materials on the survival and stability of transplanted trees. We found that regardless of treatment, tree growth measured through twig elongation and stem caliper were similar. Our findings are consistent with our earlier results (Koeser et al. 2015) in which the growth of these same trees was assessed for the first two to three growing seasons after planting. It is also in line with the research by Klein et al. (2019) who found no difference between partial, or full removal of balled-and-burlapped packing materials nine years after planting. This study and the work of Koeser et al. (2015) and Klein et al. (2019) studied angiospermous trees. We do not know if coniferous trees will respond similarly to results from this current study.

It is possible that if this study or others (Lumis and Struger 1988, Goodwin and Lumis 1992, Klein et al. 2019) were allowed to progress for a longer period (e.g., 1 to 2 decades or more) that an effect could occur. This is a valid and testable argument and we know of no controlled multi-decade studies on this question. The fear that wire can girdle tree roots and that tree root penetration is affected by burlap are presented as justification for removing balled-and-burlapped packing materials in order to enhance transplant growth and survival (Kuhns 1997, Appleton and Floyd 2004). However, we believe that is not the case based on Lumis and Struger (1988) who found root embedding of wire baskets after 7 years in "Tristis' weeping willow trees. Similarly, Kuhns (1997) observed that Norway maple roots were able to penetrate burlap. As the years following transplanting are generally considered some of the most tenuous in a tree's life (Hilbert et al. 2019), the results of this and other studies on wire basket removal may ultimately be indicative of longer-term survival.

When planting trees, there are many considerations beyond the debate with removing packing materials. Planting depth is perhaps of greater concern (Miesbauer et al. 2019). Tree planting with the RSTZ below the soil surface may result in tree roots growing toward the soil surface and resuming lateral growth at a direction away from or towards the tree stem. A root that encircles a tree stem can later through stem and root growth result in girdling and tissue compression, resulting in tissue dysfunction (Hudler and Beale 1981). The effect of dysfunction from stem girdling roots can lead to the gradual decline of trees one to two decades post planting and whole tree failure for damaged and decayed stem tissue (Johnson and Hauer 2000, Arnold et al. 2007, Gilman et al. 2010, Watson and Hewitt 2012, Harris et al. 2016). Post-transplant watering is also vital to plant survival and establishment (Gilman 2001, Gilman et al. 2013). Post-transplanting tree watering led to greater tree survival and greater root growth in *Quercus virginiana* Mill. Removal of burlap is suggested as it can wick water away from the rootball. However, no research is known to substantiate this claim and this topic should be studied (Gilman 2020).

If packing materials are removed, then staking a tree might be needed. Staking a tree might also be needed for trees without packing material removal. Interestingly, the removal of packing materials resulted in several trees that had full or partial removal of packing material to partially lean during a moderate wind storm approximately 18 m/s (40 mph) in strength a few days post planting in the Minnesota experiment. The trees were straightened and no effect on the experiment was observed. But this observation suggests a BMP for planted trees is to stake those that had packing materials removed. There are many ways to stake a tree (Appleton et al. 2008). A basic premise is the tree should still retain some stem movement and staking materials attached to the tree stem should not lead to stem girdling.

Root severing can affect tree stability and Smiley (2008) found in willow oak (*Quercus phellos* L.) that when root severing occurred at least 3 times the stem diameter or more away on one side, there was no difference in the force required to move a trunk to 1° of tilt. In this study trees had roots severed at approximately 5 to 7.5 times the stem diameter away when harvested (data not shown). Except for the initial wind tilting post planting at one site, tree roots then grew for 5 to 6 years and when subjected to static mechanical force, only a difference in tree species was detected. Gilman and Wiese (2012) found the cross-sectional area of roots was correlated with greater stability. They also found that correcting root defects (e.g., circling roots) was important to promote tree stability in container-raised trees two years following planting. This study used balled-and-burlapped harvested trees that were planted as bare root liners with no known circling root issues and trees were harvested and soil removed so the RSTZ was at the surface. Observation of several root systems lifted with a u-bladed at the end of the experiment showed no visual observations of root defects. The burlap was also well decomposed with little material observed at the end of the experiment.

The root system configuration of the species in this study differ in rooting depth. Honeylocust have a wide spreading and deep rooting habit that profusely branches (Blair 1990). By comparison, Norway maple has a shallow root system (Gilman and Watson 1993). Thus, this fact may explain the difference with Norway maple trees requiring less force to pull to 1° of tilt. At the soil surface, both honeylocust and Norway maple had similar trunk flare diameter (Hilbert et al. 2020).

Results from this study will likely not put to rest whether a practitioner should remove packing materials at planting and by not doing such leads to premature plant death. The results from this study showed no difference regardless of treatment. These findings are also consistent with three other studies that showed the same result. Tree planting specifications should clearly describe what is to be done. Point in case is whether to remove packing materials or not. One could argue that the length of this study and others cited in this paper were too short and perhaps a different finding after several decades would result. Clearly our study was not designed to answer that question, but addressed the effects during establishment and within a few years after transplant establishment occurred. The installation and development of a controlled study is recommended to address and answer this generational question. But until then, we know of no controlled studies that have shown that removing or retention of packing materials is detrimental to plant establishment, growth, and survival. We are not discounting the belief of practitioners that a tree with a wire basket not removed has a lower long-term survivability relative to trees that removal occurred. But we are saying that the results to date do not support such anecdotal beliefs. We also argue if this is the case then this anecdotal conclusion would likely and commonly result in tree death above normal mortality with landscape trees. Interestingly, the authors of this paper differ in the opinion on to remove or not remove wire baskets at planting. The results of this study also offered no evidence to change one's practice. Rather it raised an important point that in science, colleagues with differing opinions can use a scientific method to test beliefs that ultimately are tested with the scientific method.

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