

Proceedings of TREES AND PLANTING: GETTING THE ROOTS RIGHT

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Distinguishing Between Root System Architecture Changes and Planting Too Deep

Gary Watson and Angela Hewitt

The Morton Arboretum

Abstract

Trees can, and do, leave the nursery with roots too deep in the root ball. Alteration of the architecture of structural roots by nursery production systems is only beginning to be recognized as a possible major contributor to deep structural roots. During nursery production, the primary root of young seedlings is pruned during transplanting, leading to the formation of an adventitious root flare. If this adventitious root flare is more than a few inches below the natural location, and adjustments are not made during harvest from the nursery and replanting in the landscape, performance in the landscape will be reduced.

The depth of root systems of landscape trees has become a major topic of concern and discussion in the green industry. Though it is receiving more attention lately, the situation has not gone completely unnoticed in the past. Deep root problems of urban trees were documented by two research papers in the 1980's. Deep roots were reported on New York City trees and attributed to nursery practices prior to planting in the landscape (Berrang 1985). In a study of declining sugar maples in Wisconsin, *Fusarium* and *Phytophthora* diseases were found to occur frequently on the base of the trunk and buttress roots of trees with roots that were too deep (Drilias 1982). A relationship between the root depth and tree failure has been often noticed as well.

In the last five years, it has become more recognized, especially by arborists, that a substantial number of trees in urban landscapes have root systems that are too deep. This is based primarily on observation, with only minimal supporting data at this point (Table 1). Data from a 1989 study investigating the relationship between girdling roots and root depth indicated that about one-third

of the trees had structural roots more than 3 inches below the soil surface (current industry consensus of "too deep threshold" in average situations). None had died, and few were declining as a result. No data were taken that would have shown if the deep roots were reducing the vigor of the trees.

Data from a site planted in 2004 showed that the root systems of almost twice as many trees, nearly two-thirds, were more than 3 inches deep. Has the number of trees in the landscape with deep roots been increasing over the last 20 years, or is it just being noticed more? There is no way to know for sure from this limited information, but many arborists are convinced the situation has gotten worse, based on their own experience. Since the root depth measurements were taken after the trees were planted in both cases, we cannot be certain if the roots arrived on the site too deep in the root ball (Figure 1), or if mistakes were made in the planting process, or both.

The term most often used to describe deep roots is "planting too deep", but this only describes one of several causes. It is not just a problem of planting in the landscape. Trees can, and do, sometimes leave the nursery with the roots too deep in the B&B or container root ball. 'Deep structural roots' is a better description. Structural roots are the large woody roots giving characteristic

Table 1. Root system depth from two studies 15 years apart

Soil depth	1989	2004
0-3 inches	72%	37%
3-6 inches	22%	41%
6+ inches	6%	20%



Figure 1. This tree failed to survive transplanting because the roots were too deep. The root system was undersized because the roots were too deep in the root ball.

form and shape to the root system (Figure 2), and the depth of these roots is the real concern.

Trees can survive, and even thrive, in the nursery with deep roots because of the high quality, forgiving soils. When transplanted to a lesser-quality landscape site, the same tree will struggle, and may not survive. Site quality is a major factor in the survival and performance of trees with deep roots.

Some of the causes of deep roots are easily eliminated. Accumulation of soil around the base of the tree resulting from soil cultivation in the nursery was blamed for roots being too deep in the root ball more than 20 years ago. This does occur and the soil should be removed before the trees are dug (Figure 3).

Planting liners too deep can also cause the structural roots to be too deep. This has been a problem in both field-grown and containerized trees. Reasons given for this practice include hiding



Figure 2. Structural roots are the large woody roots giving characteristic form and shape to the root system.



Figure 3. Cultivation in the nursery can pile soil over the roots and must be removed before harvesting.

the graft union, cutback wound and resulting dogleg in the trunk (Figure 4), reduced need for staking, root stock sprout control, weed control, and carelessness. Such problems can be eliminated by educating the grower on how to produce a better product, and educating the consumer on how to demand a better product. The 2004 revision of the American Standards for Nursery Stock (ANSI Z60.1) addresses root depth for the first time. It states that for B&B trees, “soil above the root flare ... shall not be included in the ball depth measurement and should be removed.”

Alteration of the architecture of structural roots by nursery production systems is only beginning to be recognized as a possible major contributor to deep structural roots. In nature, the primary root emerges from the seed and grows down in response to gravity (Figure 5). When deteriorating growing conditions in deeper soils are encountered, penetration of the primary root will slow. This may



Figure 4. The graft union, cutback wound and resulting crook in the trunk should be visible liners are planted.

occur close to the surface in dense or poorly drained soils, or in species with weak primary roots, or somewhat deeper in strong taprooted species, and on well drained sites. When growth of the primary root slows, growth of the small lateral roots near the soil surface increases. As growth shifts, these lateral roots start to develop into the large, shallow, more-or-less horizontal roots that eventually form the root flare.

This natural sequence of events is altered in nursery production. Production of tree lining out stock (liners) in the nursery fields begins much the same way as in nature, with seeds sown on the surface (often in raised beds) and lightly covered with sawdust. Most species are grown for one season in these seedling beds. At the end of the first season, the seedlings are mechanically harvested and the primary root is pruned. We are now beginning to understand that location of this pruning cut is very important, as will be explained below. The seedlings are replanted in rows to grow liners, maintaining the same depth as in the seedling bed.



Figure 5. The primary root grows rapidly at first. When it's growth is slowed in deeper soils, laterals will begin to grow faster.

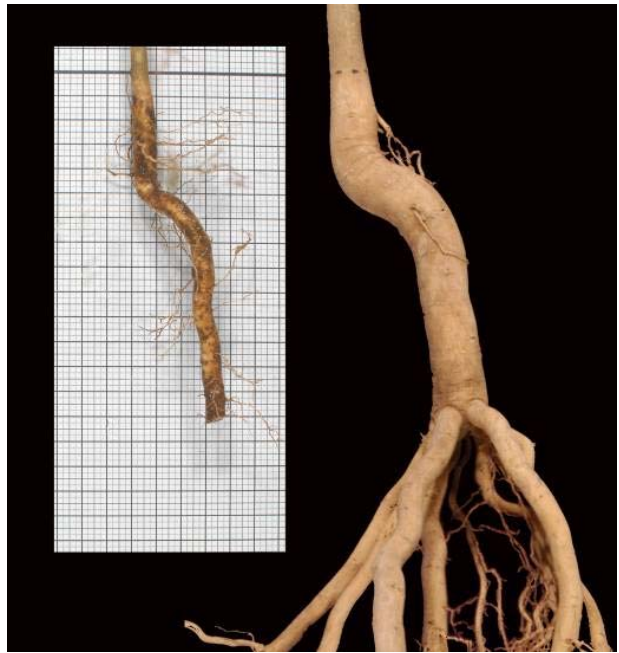


Figure 6. Regenerated roots from pruning cut.

The transplanting and pruning operations at the end of the first year are never experienced by trees in nature. How does the root system react to this process? When any root is cut, many roots are typically regenerated at the cut end. The primary root of a seedling is no exception. When the root-pruned seedling is replanted, the growing conditions in the soil around this cut end are ideal for root growth and the regenerated roots grow rapidly (Figure 6). Most of the shallow laterals do not persist. This could be from desiccation of the small lateral roots during storage and transplanting, or from dominance of the rapidly growing regenerated roots, or both.

The roots regenerated from the cut primary root are adventitious roots, induced by pruning. As the tree increases in size, they form what can be called an adventitious root flare several inches below the natural location for the root flare. (Figure 7) Sometimes a few laterals remain on the "root shank" (the remaining portion of the primary root above the adventitious root flare). The pattern seems to be set at time of seedling transplanting, but much more information is needed. We are still learning about the roles of species variation in young root systems.

Is this to say that nursery produced liners have roots that are inferior to those in nature? No! Non-transplanted tree root systems also seem to be far

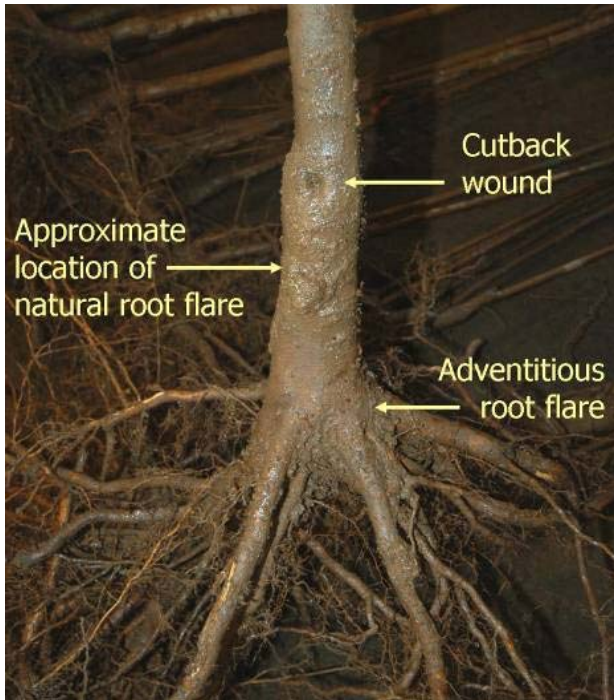


Figure 7- The distance between the ground line and adventitious root flare must be as small as possible.



Figure 8. Even when undisturbed, young root system may not seem likely to form good root flares

from perfect on average. (Figure 8) Trees with poor root systems may lose out in the competition with trees with better root systems in nature. Perhaps this is why all the trees in the forest have such nice root flares! Adventitious root flares could actually be more consistent than natural root flares, and well suited to a system where 90%, or more, of all plants are expected to survive. Further study is in progress.

The development of the structural root system on container-grown trees has not yet been formally studied, so we know even less about development of structural roots in this system. Preliminary observations indicate that there may be less of a tendency for adventitious root flares to form. In container production, growth of primary roots is usually stopped by air pruning, or wet soils in the bottom of the pot, rather than by mechanical pruning. (Figure 9) When the tip is killed, little regeneration will occur because of these same unfavorable conditions. This is a stark contrast to the ideal growth conditions for regeneration from the cut end in the field that may be encouraging development of an adventitious root flare. Each time the plant is repotted to a larger container, there is little disruption to the soil and roots. Damage to



Figure 9. Stopping primary growth by air pruning, may increase lateral root formation. (Photo credit – RootMaker Products Company, LLC)

the small laterals may be avoided. Stronger lateral roots seem to be developed as a result.

‘Getting the roots right’ is a problem that involves every aspect of the green industry, and everyone has to do their part to keep roots at the right depth.

- **Growers:** when planting liners, leave the crook and cutback wound exposed. If you plant too deep, you may be reducing the caliper measurement and the market price of the tree.
- **Landscape architects and designers:** specify the proper location of structural roots in the root ball, and after planting. Choose the trees in grower’s fields that are planted properly to avoid problems later. They will also be the most vigorous.
- **Landscape contractors:** locate the structural roots in the root ball before planting. This can be done by probing with a surveyor’s chaining pin or piece of wire. Plant the structural roots just below grade.
- **Arborists:** understand how an adventitious root flare develops, and when you find a young tree with roots a few inches deep, don’t assume that it is too deep.

We all need to educate consumers that the graft union is not a defect and should be seen above ground.

There is a great deal of work still to do. We have only scratched the surface so far. Research is underway by at least 10 locations around the country. You will see much more published over the next few years.

Literature Cited

Drilias, M., J. Kuntz, and G. Worf. 1982. Collor rot and basal canker of sugar maple. *J. Arboriculture* 8:29-33

Berrang, P., D.F. Karnosky, and B.J. Stanton. 1985. Environmental factors affecting tree health in New York City. *J. Arboriculture* 11: 185-189.

A Survey of the Lateral Root Depth of Ohio Nursery Trees

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Abstract

The average depth of lateral roots of trees growing in Ohio nurseries and stored in brokerage lots was 2.4 and 3.4 in. respectively. All trees surveyed had excess soil over the first order lateral roots according to published nursery standards. Methods of propagation and field years did not influence the depth of the first order lateral roots in nursery production fields or in brokerage lots. It is hoped that this research will raise awareness of the lateral root depth problem and prompt a change in nursery production and harvesting techniques.

Introduction

The root system of many trees in urban landscapes is too deep in the soil profile (Johnson and Hauer, 2000). As a result of the incorrect lateral root depth, urban trees exhibit nutrient deficiencies, poor growth and, in time, tree mortality following planting (Broschat, 1995; Browne and Tilt 1992; Smiley and Booth, 2000).

Several reasons have been suggested as the cause of the lateral root depth problem. Improper production and harvesting of nursery trees, improper planting of trees in landscapes and improper landscape maintenance techniques are all cited as possible causes of incorrect growing depth (Johnson and Hauer, 2000).

A survey was conducted to examine the contribution of nursery production and harvesting techniques on the lateral root depth problem. To determine the effect of production methods, the lateral root depth of Ohio nursery trees was measured. To examine the influence of harvesting techniques, the lateral root depth of harvested balled and burlapped nursery trees stored at brokerage lots was surveyed.

Materials & Methods

Nursery Grower Survey

The nursery survey was conducted during the summer and fall of 2004 on deciduous trees growing in Ohio nurseries. The nurseries included in the survey were members of the Ohio Nursery and Landscape Association and had annual sales in excess of \$1,500,000 (Anonymous, 2002). Only large nurseries were chosen to help ensure that a large diversity and quantity of trees would be available for the survey.

A study of the location of the nurseries revealed that the nursery growers were clustered in the Northeastern, Central and Southwestern portions of Ohio. Three nurseries were chosen at random within each of the three geographic regions for the survey.

In addition to nursery growers, methods of propagation and production years were also tested as possible factors influencing lateral root depth. To accomplish this, 10 trees were chosen at random that were propagated by budding, cutting, and seed and in their first and third year of production at each nursery. This sampling resulted in a total of 60 trees surveyed per nursery.

Lateral root depth was evaluated by determining the depth of the first order lateral root. A first order lateral root is defined as a root that forms at the junction of the trunk and root, grows parallel to the soil surface, composed primarily of woody tissue and is responsible for vertical stability of the tree.

The uppermost first order lateral root was located by probing the soil with a surveyors chaining pin. A surveyor's chaining pin is a 12 inch long metal rod that has a ring on one end and a point on the other end. The chaining pin was pushed into the soil immediately adjacent to the trunk until a

root was struck. The length of the pin below ground was recorded as the depth to the uppermost first order lateral root.

Nurseries were nested within geographic regions and tested using a likelihood ratio test. Within nurseries, propagation method and production year were treated as a 3X2 factorial sampling design.

Broker Survey

The broker survey was conducted during the spring of 2004 and the summer of 2005 on balled and burlapped deciduous trees stored in Ohio brokerage lots.

Brokers (or rewholesalers) were identified by interviewing nursery growers, municipal arborists and brokers. Three brokers were chosen again within the Northeastern, Central and Southwestern geographic regions used for the nursery grower survey.

In addition to broker, methods of propagation was also tested as possible factor influencing lateral root depth. To accomplish this, 10 trees were chosen at random that were propagated by budding, cutting and seed at each broker. This resulted in 30 trees of being measured at each brokerage lot.

As with the nursery grower survey, the depth of the uppermost first order lateral root was measured by probing the soil using a chaining pin.

Brokers were nested within geographic regions and tested using a likelihood ratio test. Within brokers, propagation was treated as a randomized complete block sampling design.

Results and Discussion

Nursery Grower Survey

Regional differences were not significant, thus all nurseries were analyzed together and not blocked by region. Two of the nine nurseries inspected did not have trees growing in their third year of production. Therefore the lateral root depth of only seven nurseries is reported.

The trees most frequently used in the nursery grower survey were honeylocust (*Gleditsia triacanthos*), red maple (*Acer rubrum*), and pin oak (*Quercus palustris*), representing budding, cutting and seeded methods of propagation, respectively.

The survey found a difference among nurseries in lateral root depth (Figure 1). The deepest lateral root depth was for trees growing in nursery 4 at 3.7 in. while the shallowest depth was 1.1 in. for nursery 7. The average depth of the uppermost root for all seven nurseries was 2.4 in.

The American standard for nursery stock (anonymous, 2004) state that for balled and burlapped deciduous trees “depth of the ball is measured from the top of the ball, which in all cases shall begin at the root flare. Soil above the root flare... shall not be included in ball depth measurement and should be removed.”

According to industry standards for nursery stock, there should be no soil above the root flare. The fact that nurseries had an average of 2.4 inches of soil over the uppermost first order lateral root would require removal of the excess soil during harvest to meet industry standards.

Comparison of the methods of propagation failed to show any difference in lateral root depth among trees grown from budding, cutting or seed (Figure 2). Likewise production year had no effect on lateral root depth (Figure 3).

Broker Survey

As with nurseries, regional differences were not significant, thus all brokers were analyzed together and not blocked by region. One of the nine brokers did not have trees representing all three propagation methods. Therefore the lateral root depth of only eight brokers is reported.

For the broker survey, honeylocust and Callery pear (*Pyrus calleryana*) were the two species most

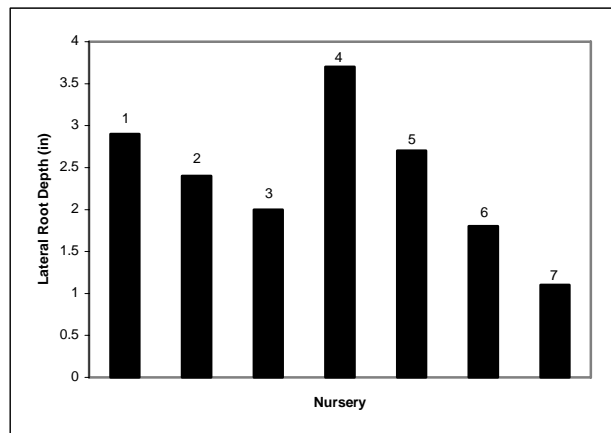


Figure 1. The effect of nursery source on the lateral root depth of Ohio nursery trees.

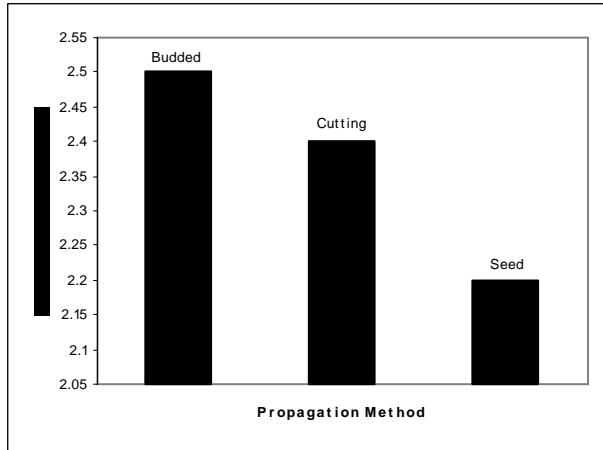


Figure 2. The effect of propagation method on the lateral root depth of Ohio nursery trees. frequently used and propagated by budding. The tree surveyed most often that was propagated by cutting was red maple. The trees most often utilized that were propagated by seed included red oak (*Quercus rubra*), swamp white oak (*Quercus bicolor*) and river birch (*Betula nigra*).

The survey found a difference among brokers in lateral root depth (Figure 4). The deepest lateral root depth found was for trees stored at broker 8 at 4.4 in. while the shallowest depth was 2.7 in. for brokers 3 and 5. The average depth of the uppermost first order lateral root for all eight brokers was 3.4 in.

All the trees surveyed had been harvested and were being offered for sale. All were too deep in the root ball according to industry standards and should have required that the excess soil be removed prior to sale by the broker in order to meet published industry standards.

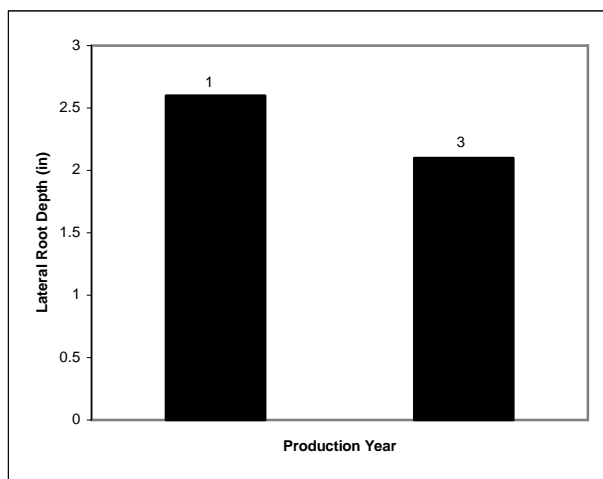


Figure 3: The effect of production year on lateral root depth of Ohio nursery trees.

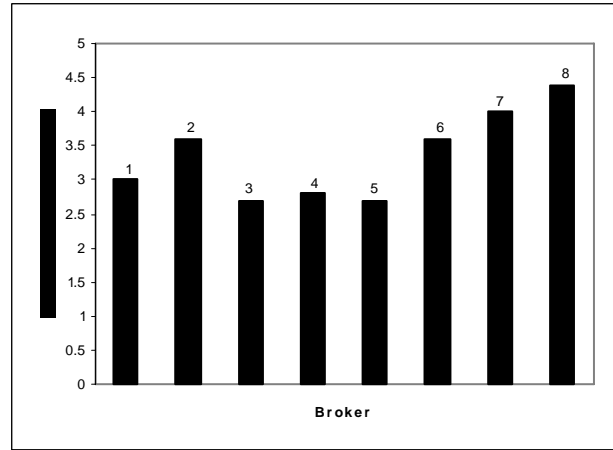


Figure 4. The effect of broker source on the lateral root depth of trees in Ohio brokerage lots.

As with the nursery survey there were no differences among budded, cutting and seeded trees in lateral root depth for the broker survey (Figure 5).

Literature Cited

Anonymous 2002. Ohio Nursery Stock Survey. The Ohio Nursery And Landscape Association. Westerville, OH.

Anonymous. 2004. American Standard for Nursery Stock ANSI Z60.1 – 2004. American National Standards Institute, Washington, DC. 113 pp.

Broschat, T. K. 1995. Planting Depth Affects Survival, Root Growth, and Nutrient Content of Transplanted Pygmy Date Palms. HortScience. 30(5): 1031-1032.

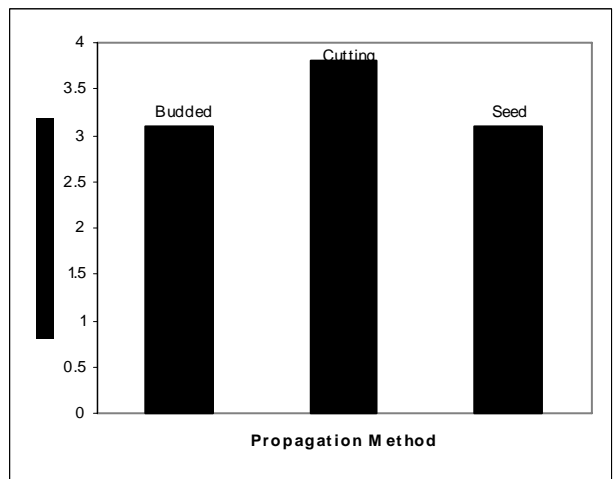


Figure 5. The effect of propagation method on the lateral root depth of trees in Ohio brokerage lots.

Browne, C. and K. Tilt. 1992. Effects of Planting Depth on Three Ornamental Trees. Southern Nurserymen's Research Conference Proceedings 37:123-125.

Johnson, G. R. and R. J. Hauer. 2000. A Practitioner's Guide to Stem Girdling Roots of Trees: Impacts on Trees, Symptomology and Prevention. U. of Minnesota Extension Bulletin BU-7501-S. 20pp.

Smiley, E. T. and D.C. Booth. 2000. Grown to Die? American Nurseryman March 15, 2000. p 48-50, 54 & 55.

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Nursery Tree Depth Projects

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Abstract

When selecting trees, a customer should be aware of the potential that excess soil will be present over the structural root system, and be able to determine the depth of planting, before leaving the nursery or garden center. This presentation will demonstrate the variation of soil depths on trees from twenty wholesale and retail nurseries.

A full length paper will be posted when available.

The Effect of Planting Depth on Tree Performance in the Nursery

Mark Jarecki, David Williams and Gary Kling

Graduate Research Assistant, Professor and Associate Professor of Horticulture, University of Illinois, respectively

Abstract

This study addresses the issue of planting depth of shade tree whips at the time of initial planting in the nursery, and how it affects tree survival, root growth, root architecture and caliper size. Three year old 7-9', bare-root liners of *Fraxinus americana* 'Autumn Purple', *Fraxinus pennsylvanica* 'Patmore', *Gleditsia triacanthos f. inermis* 'Shade Master', and *Acer platanoides* 'Emerald Lustre' were planted with the graft union 6" below the soil surface, at the soil surface, or at point where the trunk flare was at the soil surface. Prior to planting, the trees were selected so that the distance between the graft union and the trunk flare was consistent. Trunk caliper was measured 6 inches above the graft union and 6 inches above the soil surface. Over two growing seasons the caliper growth of the four taxa of trees studied was not affected by planting depth, whether measured 6 inches above the graft union, or 6 inches above the soil surface. It is thought that the quality of the soils were such that they overcame any affect due to differences in planting depths. These studies do not take into account the problems associated with highly disturbed urban soils.

Improper depth of a tree's root system due to improper planting is receiving increasing scrutiny as a possible problem affecting the performance of trees in the landscape. Growers, landscape contractors, arborists and those responsible for the short and long-term maintenance have reported a trend that some trees are too deep within the root ball. Although there is much anecdotal evidence to suggest that planting depth may adversely affect a tree's health, scientific evidence is limited. This study addresses the issue of planting depth of shade tree whips at the time of initial planting in the nursery and how it affects tree survival, root growth, root architecture and caliper size.

Experiment 1

Materials and Methods

The experiment was initiated in April of 2004. Three year old 7-9', bare-root liners of were donated by J.F. Schmidt & Sons Nursery of Boring, Oregon. Upon delivery the trees were covered with straw, kept moist, and stored in a cool area until planting.

Prior to planting on April 12, 2004, the trees were selected so that the distance between the graft union and the trunk flare was consistent, any broken or damaged roots were removed, and the lateral branches were pruned to two nodes. The root and tip pruned liners were planted at the university of Illinois Agricultural Experiment Station in Urbana, Illinois. The statistical design was a completely randomized design with 20 replications per treatment per species. The spacing was 12' within the rows 15' between the rows. Trees were staked with 10' sections of ½" galvanized conduit pipe. Weed control was by mechanical cultivation and any residual weeds removed by hand.

Trees assigned to the low planting depth were planted so that the graft union was 6" below the soil surface. Finished grade was considered the soil surface. Trees assigned medium planting depths were planted so that the base of the graft union was at finished grade. Trees assigned high planting depths were planted so that the point where the trunk flare began was the finished the grade.

Data was collected on caliper size for two growing seasons. Some of the trees will be harvested and planted into the landscape for a long term study of the effects of the original nursery planting depth on landscape performance.

Results

Figure 1 shows the trunk caliper of *Fraxinus americana* 'Autumn Purple' measured 6" above the graft union periodically from the time of planting over 500 days. Statistical analysis, LSD $p = .05$, of the data to data has revealed no significant differences between any of the treatments.

Figure 2 shows shows the trunk caliper of *Fraxinus americana* 'Autumn Purple' measured 6" above the soil surface periodically from the time of planting over 500 days. Statistical analysis, LSD $p = .05$, of the data to data has revealed no significant differences between any of the treatments.

Figure 3 shows the trunk caliper measured 6"

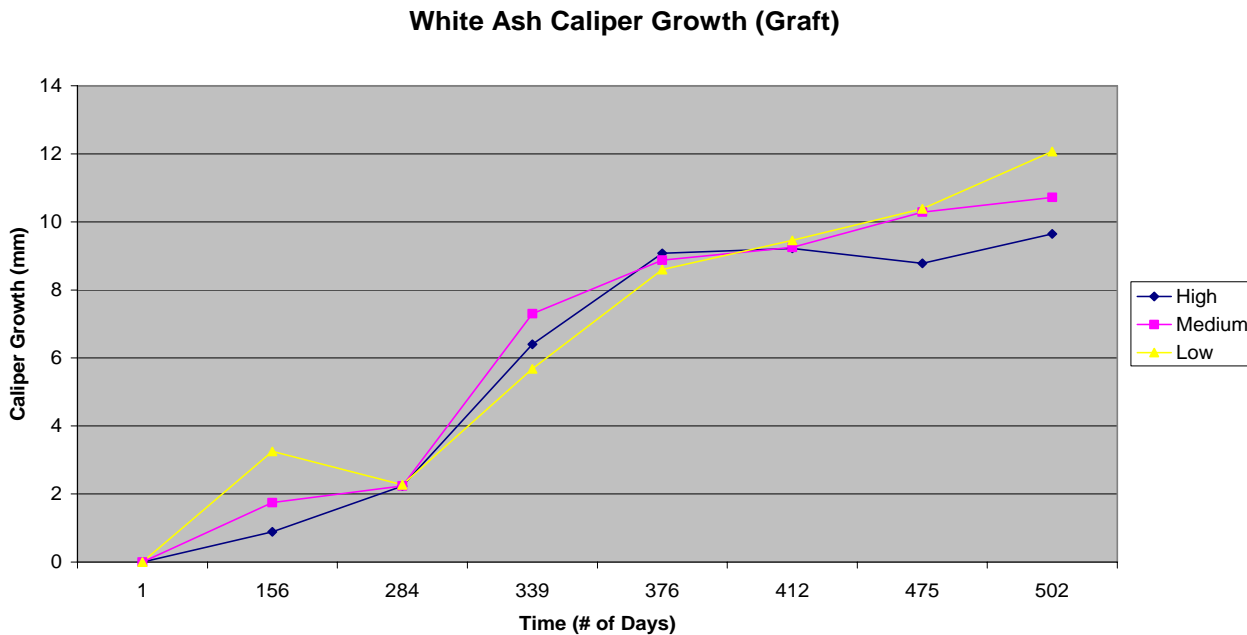


Figure 1. *Fraxinus americana* 'Autumn Purple' trunk caliper measured 6" above the graft union.

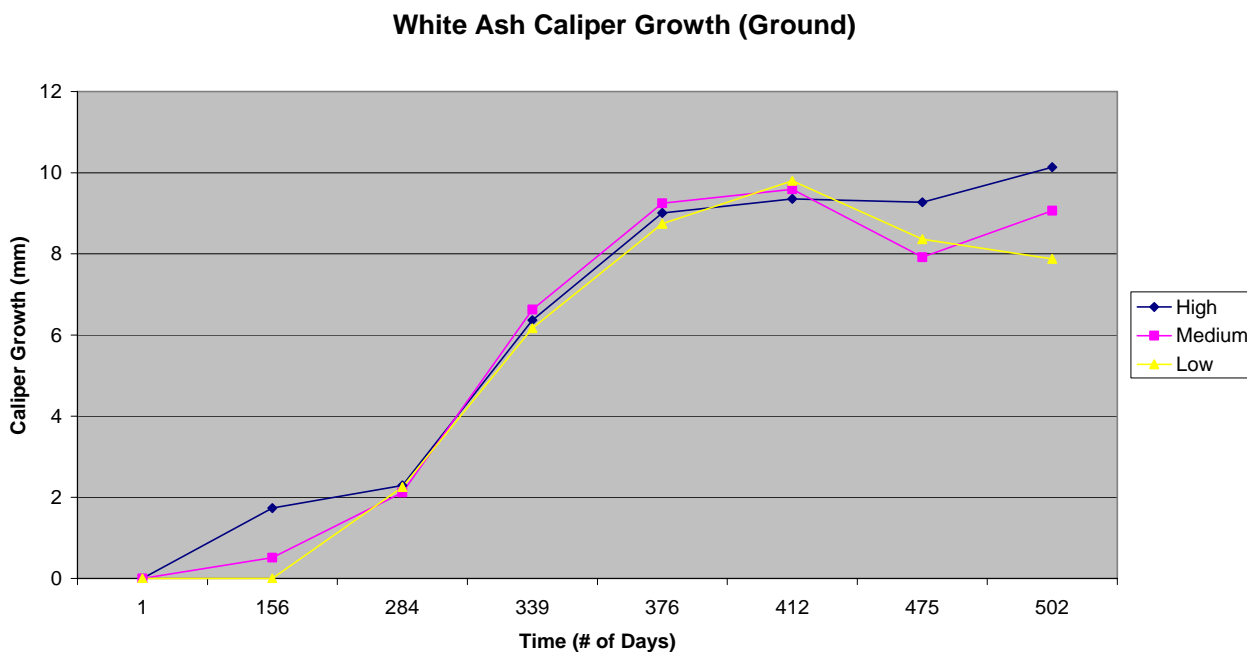


Figure 2. *Fraxinus americana* 'Autumn Purple' trunk caliper measured 6" above the soil surface.

above the graft union of *Fraxinus pennsylvanica* 'Patmore' periodically from the time of planting over 500 days. Statistical analysis, LSD $p = .05$, of the data to date has revealed no significant differences between any of the treatments.

Figure 4 shows shows the trunk caliper meas-

ured 6" above the soil surface of *Fraxinus pennsylvanica* 'Patmore' periodically from the time of planting over 500 days. Statistical analysis, LSD $p = .05$, of the data to date has revealed no significant differences between any of the treatments.

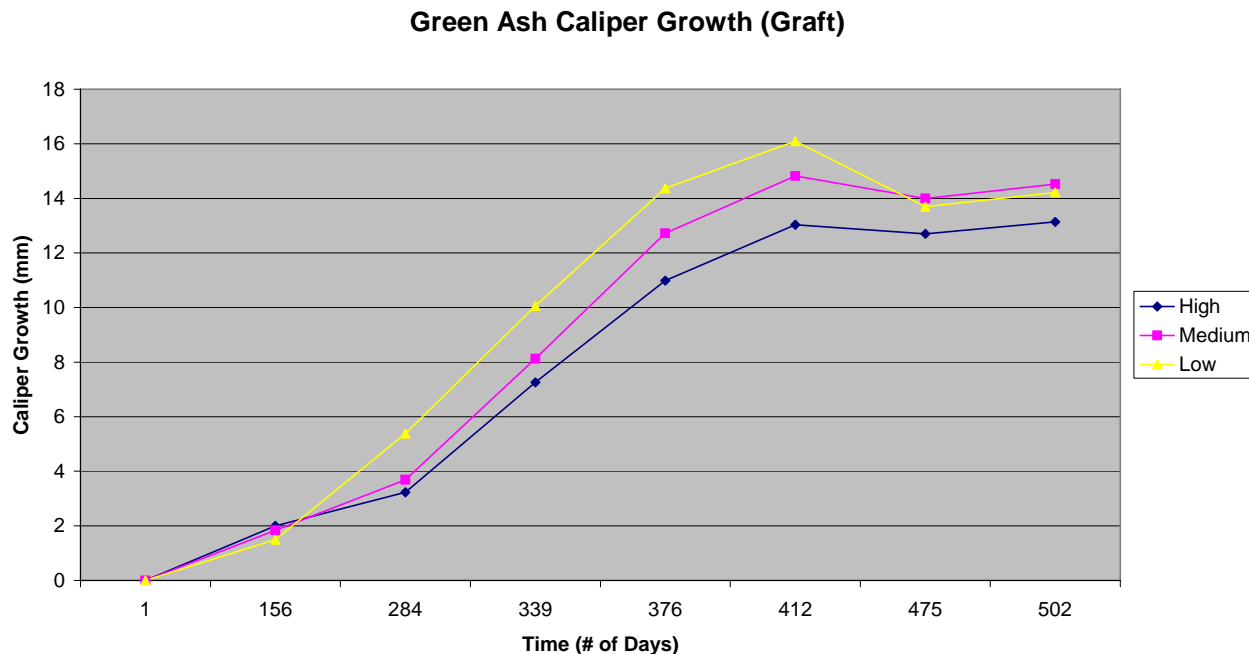


Figure 3. *Fraxinus pennsylvanica* 'Patmore' trunk caliper measured 6" above the graft union.

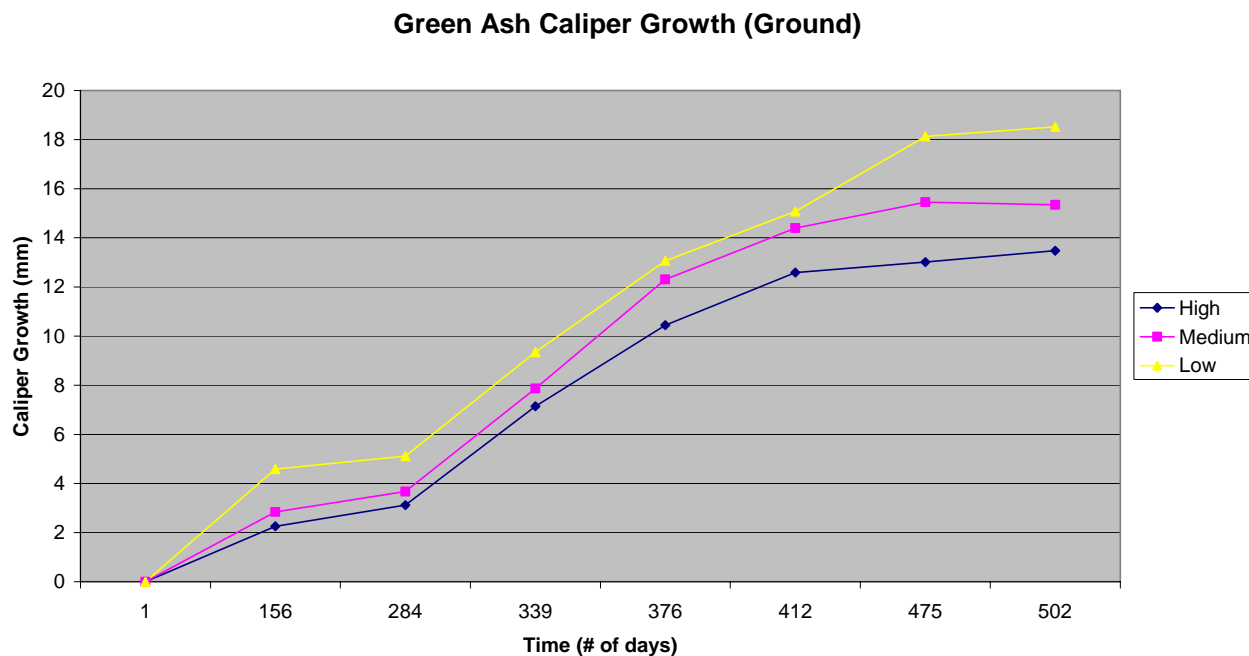


Figure 4 *Fraxinus pennsylvanica* 'Patmore' trunk caliper measured 6" above the soil surface.

Experiment 2

Materials and Methods

The experiment was initiated in April of 2004. Three year old 7-9', bare-root liners of *Gleditsia triacanthos f. inermis* 'Shade Master' and *Acer platanoides* 'Emerald Lustre' were planted by Hinsdale Nurseries.

The statistical design was a completely randomized design with 20 replications per treatment per species. The spacing was 12' within the rows 12' between the rows. Trees were maintained by the nursery and subject to the same conditions as trees of the same taxa in the nursery.

The trees were replanted to the following depths. Trees assigned to the low planting depth were planted so that the graft union was 6" below the soil surface. Finished grade was considered the soil surface. Trees assigned medium planting depths were planted so that the base of the graft union was at finished grade. Trees assigned high planting depths were planted so that the point where the trunk flare began was the finished the grade.

Data was collected on caliper size for two growing seasons. Some of the trees will be harvested and planted into the landscape for a long term study of the effects of the original nursery

planting depth on landscape performance.

Results

Figure 5 shows the trunk caliper of *Gleditsia triacanthos f. inermis* 'Shade Master' measured 6" above the graft union periodically from the time of planting over 500 days. Statistical analysis, LSD $p = .05$, of the data to data has revealed no significant differences between any of the treatments.

Figure 6 shows shows the trunk caliper measured 6" above the soil surface of *Acer platanoides* 'Emerald Lustre' periodically from the time of planting over 500 days. Statistical analysis, LSD $p = .05$, of the data to data has revealed no significant differences between any of the treatments.

Figure 7 shows the trunk caliper of *Acer platanoides* 'Emerald Lustre' measured 6" above the graft union periodically from the time of planting over 500 days. Statistical analysis, LSD $p = .05$, of the data to data has revealed no significant differences between any of the treatments.

Figure 8 shows the trunk caliper of *Acer platanoides* 'Emerald Lustre' measured 6" above the soil surface periodically from the time of planting over 500 days. Statistical analysis, LSD $p = .05$, of the data to data has revealed no significant differences between any of the treatments.

Honey Locust Caliper Growth (Graft)

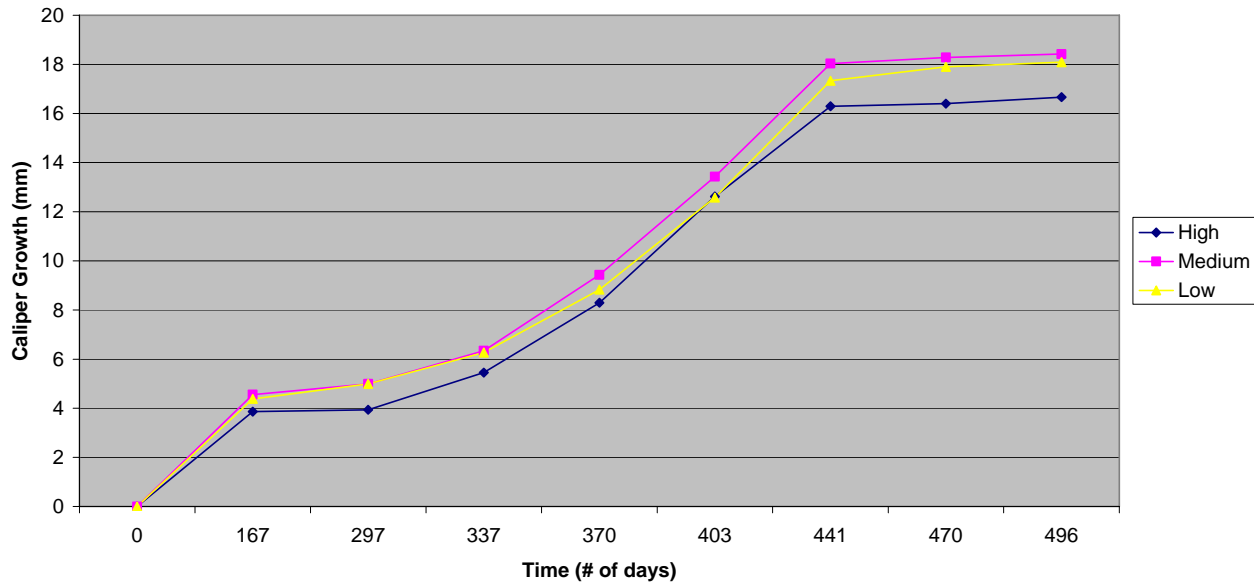


Figure 5. *Gleditsia triacanthos f. inermis* 'Shade Master' trunk caliper measured 6" above the graft union.

Honey Locust Caliper Growth (Ground)

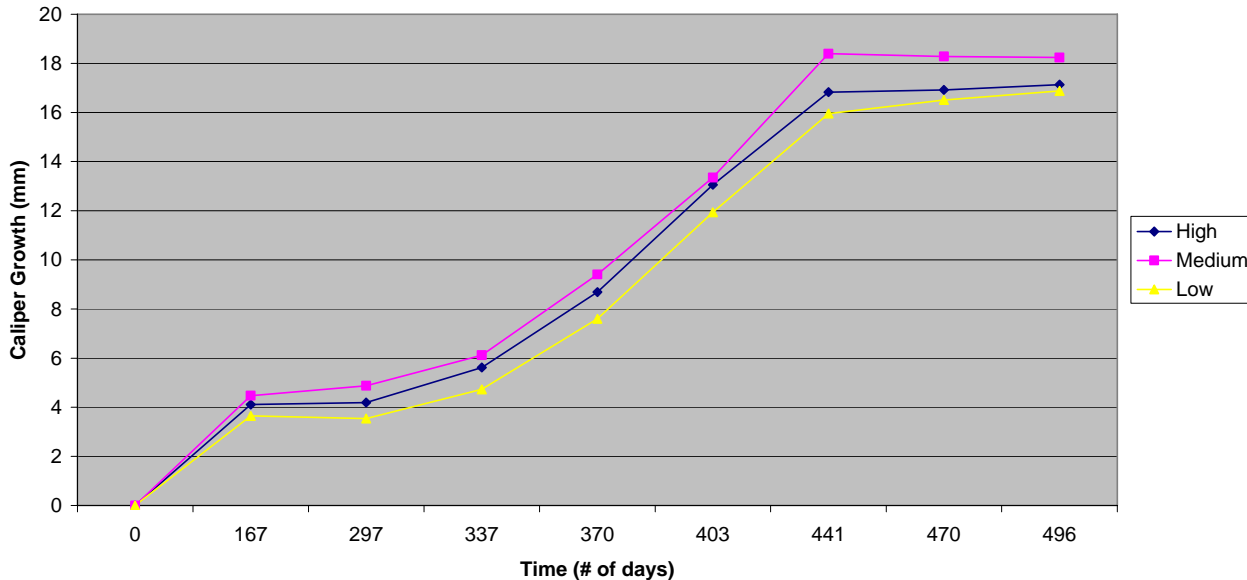


Figure 6 *Acer platanoides* 'Emerald Lustre' trunk caliper measured 6" above the soil surface.

Norway Maple Caliper Growth (Graft)

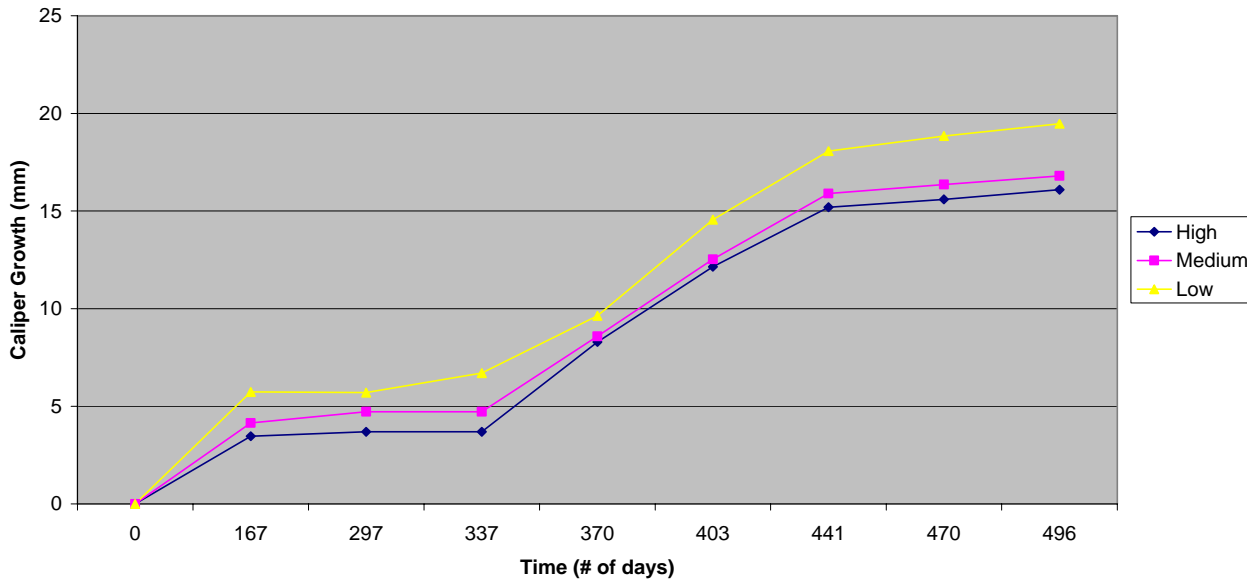


Figure 7. *Acer platanoides* 'Emerald Lustre' trunk caliper measured 6" above the graft union.

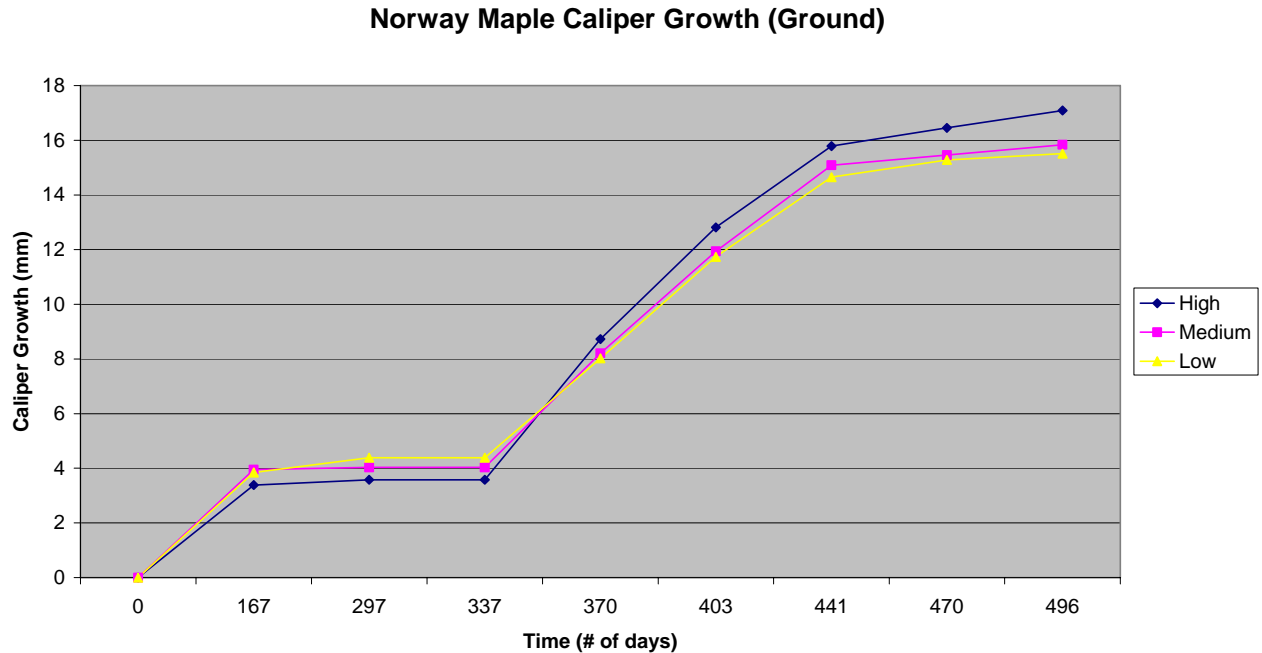


Figure 8. *Acer platanoides* 'Emerald Lustre' trunk caliper measured 6" above the soil surface.

Discussion

Over two growing seasons the caliper growth whether measured 6" above the graft union or 6" above the soil surface of the four taxa of trees studied was not affected by planting depth. The soils at both planting sites had high organic matter and are considered to be highly production prairie soils. They both are characterized as having good water holding capacities. Even though the trees were irrigated as needed the two summers during the study were relatively dry. It is thought that the quality of the soils were such that they overcame any affect due to differences in planting depths.

These studies do not take into account the problems associated with highly disturbed urban soils. Most of the anecdotal evidence presented is based on observations made on highly disturbed soils with poor structure for plant growth. These results should not be interpreted to indicate that planting depth would have no affect on the growth of trees growing on soils not well suited for plant growth. These studies though preliminary and short term-in-nature do not support the accusation that trees planted deep will not grow properly.

Planting Depth and Cultural Practices

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Abstract

A series of studies were initiated to investigate the effect of planting depth and various production and transplant practices on the initial establishment of container-grown trees and shrubs in the landscape. These studies confirm that the container-grown trees transplanted with the root collar, or main structural roots, below grade are subject to adverse effects on survival, growth, and physiological processes during establishment. Adverse effects were demonstrated on several species, particularly those sensitive to poorly drained soils with root collars located as little as 7.6 cm (3 in) below grade. In some cases, planting above grade by similar depths improved growth of trees over that of those planted either at or below grade. Interactions with cultural practices such as the thickness of mulch applications and soil amendments were also documented. Studies investigating several other production and transplant practices which may potentially interact with planting depth during landscape establishment of container-grown trees remain in progress.

Introduction

Each year millions of container-grown trees and shrubs are planted in landscapes world-wide. Many factors can impact the initial establishment, as well as long-term development of these trees. Some factors are from the production system used to grow the tree, such as circling roots in containers (Watson and Himelick, 1997). Others are the result of techniques used during the physical planting of the tree in the landscapes, while still others center around maintenance practices implemented after the actual planting of the tree. However, in many cases, the successful establishment and long-term growth of a tree in the landscape is a result of interactions among multiple factors.

One of the practices receiving increased scrutiny during recent years is that of how deeply the root flare, also known as the root-to-shoot transition, root collar, or origin of the first of the primary structural roots, is placed in the planting hole. In nature, trees often develop a spreading trunk flare, sometimes manifesting itself as a broad basal plate (Figure 1). However, trees planted in the landscape may be placed substantially below the surface resulting in a telephone pole-like base to the trunk. The fate of the deeply planted root system is usually unknown, but in recent years has become a suspect in tree failures. In general, trees are planted with the trunk flare deeper than would have occurred if the seedling germinated in place either by accident, as a result of practices used during production or transplanting, or by intent. Intentional below grade planting of trees has occurred primarily for one of three reasons. Trees, particularly some species of palms [family *Arecaceae* Schultz (*Palmae*)], are sometimes intentionally planted at different depths to achieve a uniform height to the canopy in formal planting designs. More commonly, trees are sometimes planted below grade in



Figure 1. *Fagus grandiflora* basal plate

an attempt to reduce windthrow during establishment or to reduce the need for staking. Finally, trees are occasionally planted with the root flare deeper than grade in an attempt to avoid root growth conflicts with components of the man-made infrastructure in the landscape.

Most reports of tree responses to planting depth are based on anecdotal information. Little information on planting depth of trees is presently available in the scientific literature based on replicated, peer-reviewed studies (Arnold *et al.*, 2005; Broschat, 1995; Browne and Tilt, 1992; Gilman and Grabosky, 2004). Even less information is available on the interactions of cultural practices with planting depth (Arnold *et al.*, 2005; Gilman and Grabosky, 2004). The purposes of the work described in this paper were to investigate interactions among species responses to planting depths and cultural practices such as pine bark mulch applications and soil amendments.

Materials and Methods

Study 1: Planting Depths and Mulch Thickness.

Two tree species, *Koelreuteria bipinnata* Franchet (bougainvillea goldenraintree, hypoxia intolerant) and *Fraxinus pennsylvanica* Marshall (green ash, hypoxia tolerant), were chosen for their differential responses to soils with poor internal drainage resulting in hypoxic or anoxic conditions (Arnold, 2002). Trees of both species were produced on site at the Texas A&M University Nursery/Floral Field Laboratory (College Station, TX) to ensure that the root collars were at the surface of the container substrate. Seeds were germinated in flats, graded for uniform root systems and then carefully transplanted to the 9.3 L (#3) black plastic containers to maintain the root collar at the surface of the substrate. Seedlings were grown in an outdoor container nursery utilizing a commercial pine bark based substrate (3 pine bark : 1 peatmoss : 1 coarse builders sand by volume). Trees were staked and trained to a central leader.

Each species was transplanted to adjacent field plots on 27 April 2001 (*K. bipinnata*) or 1 May 2001 (*F. pennsylvanica*). *Koelreuteria bipinnata* (84 trees) and *F. pennsylvanica* (120 trees) were established on 0.91 m (3 ft) within row and 3.1 m (10 ft) between row spacings in Brazos County, TX. Field plots

contained a Boonville Series, Boonville fine sandy loam, fine, montmorillic thermic ruptic-vertic albaqualfs (pH 9.1, bulk density 1.51 g·cm⁻³, 61% sand, 11% clay, 28% silt) underlain at a 15.2 to 30.5 cm (6 to 12 in) depth with a hard clay pan. Final planting depths placed the root collars 7.6 cm (3 in) below grade, at grade, or 7.6 cm (3 in) above grade. The excised native soil was used as backfill during planting. Soil in the bottom of the holes was tamped to preclude subsidence and maintain the desired planting depth. Soil water potential was monitored using tensiometers (Model 2725 JetFill Tensiometers, Soil Moisture Equipment Corp., Santa Barbara, CA) inserted to a 15.2 cm (6 in) depth. Trees were irrigated daily for the first four weeks using drip tape (T-Tape[®], T-Systems Intl. Inc., San Diego, CA) at 10 psi to maintain moisture in the transplanted rootballs and afterwards when soil water potential reached -1.5 kPa (-15 bars) in non-mulched control plots. The drip tape was located above the mulch.

In factorial combinations with the three planting depths, four mulch thickness treatments were established (Figure 2). A 0.74 m² (8 ft²) area around each tree was mulched to a depth of 0, 7.6, 15.2, or 22.9 cm (0, 3, 6, or 9 in) with a mixed particle size commercial shredded pine bark mulch. Mulch treatments were separated between plants via two 0.61 m (2 ft) long double stacked 10 cm (4 in) tall CCA-treated landscape timbers. Mulch was replenished in the spring and fall of each year to maintain the desired treatment levels. Three sets of plants with one of each mulching thickness treatment



Figure 2. Factorial combinations of planting depths and pine bark mulch treatments on *Koelreuteria bipinnata* and *Fraxinus pennsylvanica*.

were randomly chosen to monitor soil water potentials adjacent to the rootball. Soil water potential in mulch treatments was monitored throughout the first growing season.

Both species remained in the field under irrigation for two years after planting. This is within a time frame in which the trees should have been well established in USDA plant hardiness zone 8b (Gilman, 1997). After the second year, the *K. bipinnata* study was terminated due to low survival of some treatments. During the third growing season, irrigation was not provided to *F. pennsylvanica* to assess if these plants were fully established. Height, trunk diameters at 15 cm (6 in) above the soil surface, survival, and the percentage of the canopy exhibiting stress symptoms (chlorosis, marginal necrosis, and/or premature leaf senescence) were measured at transplant to the field and at the end of each growing season.

Each species was treated as a separate experiment. The statistical design was a randomized complete block design consisting of a factorial of three planting depths x four mulching thicknesses for each species. In the experiment with *F. pennsylvanica*, there were ten blocks containing a single plant replication of each treatment combination, whereas with *K. bipinnata* there were eight blocks. Data were analyzed using the general linear models procedures in the SAS System for Windows, Release 8.01 (SAS Institute, Inc., Cary, NC).

Study 2: Testing a Wider Range of Species.

During spring and summer 2002, five species of trees and shrubs were propagated and grown in an outdoor container nursery in 9.3 L (#3) black plastic pots as previously described. *Fraxinus pennsylvanica*, and *Platanus occidentalis* L. (sycamore) were grown from seed, while *Lagerstroemia indica* L. x *Lagerstroemia fauriei* Koehne 'Basham's Party Pink' (crapemyrtle), *Nerium oleander* L. (oleander), and *Vitex agnus-castus* L. 'LeCompte' (vitex) were propagated from cuttings. In May 2003, all five species were transplanted to a field site in College Station, Texas, as described in the previous study, but without mulch, by placing the root collars for seedlings, or first lateral root for cuttings, 7.6 cm (3 in) below grade, at grade, or 7.6 cm (3 in) above grade. Tree height, trunk diameter, cross-sectional trunk area at 15 cm (6 in) above the soil surface, and

shrub height, canopy spread and cross-sectional trunk area were measured for three growing seasons. For trees/shrubs with multiple trunks, cross-sectional areas were calculated by totaling the calculated area for each stem using individual stem diameters. A canopy index (height x spread perpendicular and parallel with the row) was calculated as a pseudo-volumetric estimate of the canopy size.

Study 3: Live Oak Planting Depth and Soil Type.

Documentation of the effects and/or repercussions of planting depths and modifications of the planting site are important to enhanced tree growth and survival. In this preliminary pilot study we compared tree responses to planting depths as influenced by alternation of soils characteristics by the use of amendments. The site at the Texas A&M University Nursery/Floral Field Laboratory chosen for the study was characterized by a heavy clay loam (Zack Series, Zack-urban land complex, fine, montmorillonitic, thermic, udic paleustalfs) with poor internal drainage, which served as the control treatment. The soil treatments consisted of the native soil, incorporation of one-third by volume of the top 23 cm (9 in) of soil with composted organic matter (peat) or a coarse builders sand to alter the physical composition of the native soil, or a 15 cm (6 in) tall raised bed on top of the native soil that was filled with sandy topsoil. Fungal and bacterial colony forming units were determined for each soil type.

Quercus virginiana P. Miller (live oak) which were grown in 11 L black plastic containers (obtained from Greenleaf Nursery, El Campo, TX) were transplanted at either 7.6 cm (3 in) above grade, grade, or 7.6 cm (3 in) below grade. The split plot design consisted of two trees per planting depth (subplot factor) randomly distributed within each of the four soil treatments (main plot factor). There were three replications of each soil plot (Figure 3). Soil bulk density, pH, biotic activity, and soil moisture content were quantified. Leaf tissue samples were analyzed for chlorophyll content. Net photosynthetic rate (Pn) and xylem water potentials (Ψ) were monitored on a quarterly basis. Plants were excavated nine months after planting to determine the extent of root growth. Height and



Figure 3. Soil amendments study plots prior to tilling.

trunk diameter were recorded at the beginning and end of the study. Visual shoot ratings were determined on a scale ranging from 0 (dead) to 5 (dense canopy of dark green leaves) at the end of the study.

Results and Discussion

Study 1: Planting Depths and Mulch Thickness.

The magnitude of the differential responses between the hypoxia-tolerant *F. pennsylvanica* and the hypoxia-intolerant *K. bipinnata* was substantial. Planting below grade reduced the survival of *F. pennsylvanica* after three years in the field (Figure 4). Corroborating Gilman and Grabosky (2004), who found little impact of planting below grade during the first few months on *Quercus virginiana*, both species which tolerate periodically wet soils, we saw little response to planting depth in the first

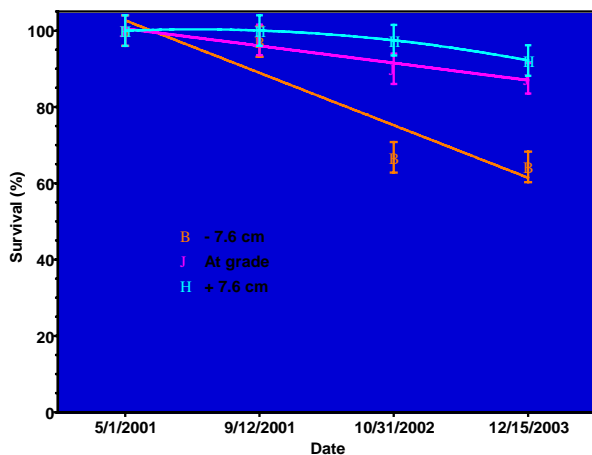


Figure 4. Survival of *F. pennsylvanica* in response to planting depth over three years in the landscape.

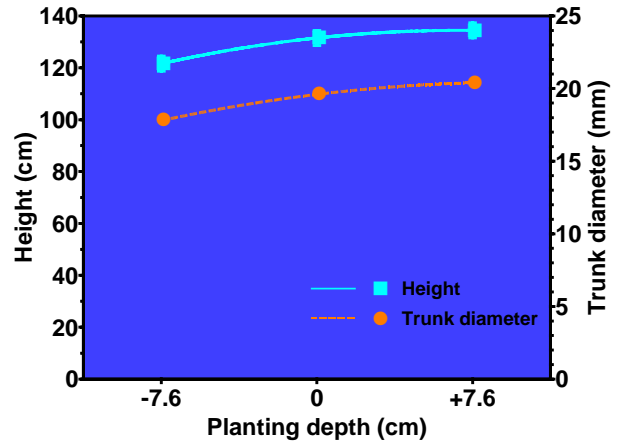


Figure 5. Planting depth effects on height and trunk diameter of *F. pennsylvanica* after three years.

year on *F. pennsylvanica*. However, planting only 7.6 cm (3 in) below grade reduced *F. pennsylvanica* survival by about 40% after 3 years. Height and trunk diameter growth of surviving *F. pennsylvanica* were reduced slightly compared to above or at grade planting (Figure 5). Mulch thickness had minimal effects on the response of *F. pennsylvanica* to planting depth in this study.

Koelreuteria bipinnata had a more dramatic response to planting on this site, particularly when planted below grade (Figure 6). Although survival was decreased substantially after two years for even those trees at or above grade, deep planting exacerbated the problem, resulting in the death of the vast majority (90.6%) of *K. bipinnata* planted below grade within 2 years. Mulching with even a 7.6 cm (3 in) thicknesses of pine bark mulch also reduced survival (by as much as 50.5%) of *Koel-*

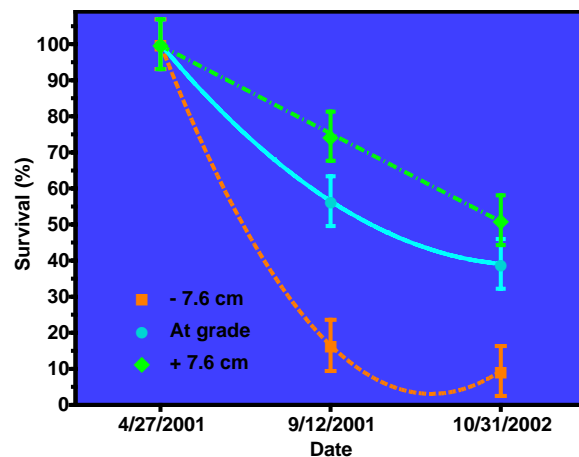


Figure 6. Survival of *K. bipinnata* planted at a range of planting depths over two years in the landscape.

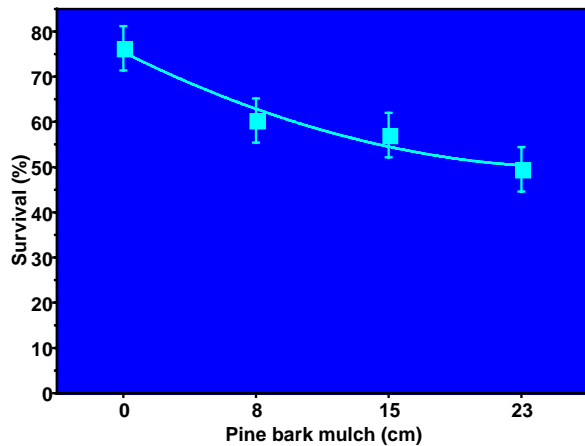


Figure 7. Survival of *K. bipinnata* after two years in the landscape in response to various pine bark mulch thicknesses across planting depths.

reuteria bipinnata (Figure 7) across all planting depths.

Study 2: Testing a Wider Range of Species.

Three year survival was nearly 100% for all species when planted at or above grade, however, when planted below grade, survival was reduced for all species but *V. agnus-castus* (data not presented). Although planting above grade did not affect survival rates, except for *P. occidentalis* (data not presented), cross-sectional trunk area growth was greater for all species when planted above grade compared to the same species planted below grade (Figure 8). Trunk cross-sectional areas of crapemyrtle, oleander, and sycamore were greater when planted above grade than at grade (Figure 8). Conversely, below grade planting decreased the cross-sectional area of surviving *L. 'Basham's Party Pink'*, *F. pennsylvanica*, *N. oleander*, and *V. agnus-castus* compared to planting at grade (Figure 8). Those *N. oleander* which did survive increased little in canopy volume if planted below grade, while those planted above grade grew better than those planted at grade (Figure 9). This data shows the same pattern of response as observed for *F. pennsylvanica* in previous studies (Arnold *et al.*, 2005), but also illustrates the wide variation in species responses to planting depth and that the pattern of response varies depending upon the measure of survival or growth process observed. On this soil type-climate over a three year period covered in each of the two studies, growth and/or survival was

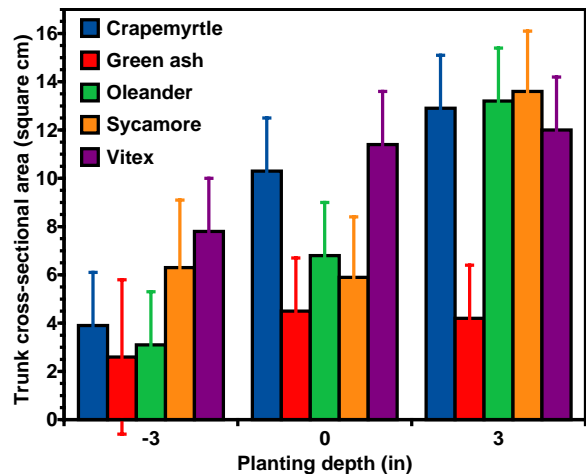


Figure 8. Cross-sectional trunk area (means ± standard errors) of five species planted at various depths in the landscape.

reduced on all species tested in studies 1 and 2 when trees were planted as little as 7.6 cm (3 in) below grade. This is in contrast to the results of Gilman and Grabosky (2004) and some of the species tested by Browne and Tilt (1992), in which survival or growth of some species did not appear to be impacted by planting below grade, in some cases even deeper planting than was tested in this study. Some of these differential results might be explained by the shorter duration of Gilman and Grabosky's study. Results from the present study showed minimal impacts during the first year after transplanting which was reported by Gilman and Grabosky. Differences might be the result of a substantially heavier soil on the Texas site than the sandy soils on Gilman and Grabosky's Florida site.

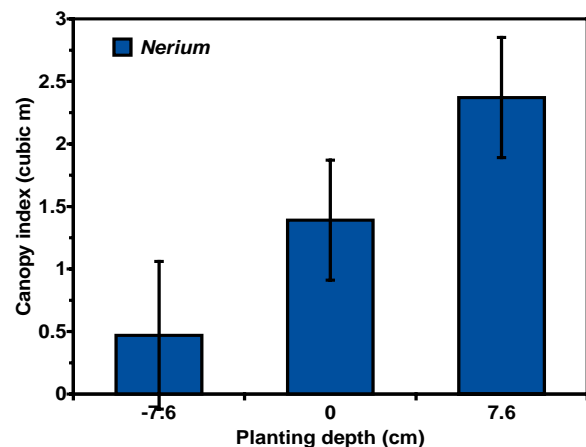


Figure 9. Canopy growth (means ± standard errors) of *Nerium oleander* in response to planting depth in the landscape.

The soil type was not reported for Browne and Tilt's work, which make it difficult to identify if differences were soil related or may simply represent species variable responses.

Study 3: Live Oak Planting Depth and Soil Type.

Soil treatments did result in a change in some physical and chemical properties of the soils relative to the original soil on the site (Figure 10). Growth of *Q. virginiana* was variable within the short time frame of this pilot study. Planting *Q. virginiana* below grade reduced the shoot quality ratings in all soil treatments (Figure 11). Unlike the results with the species included in the two studies discussed above, planting *Q. virginiana* above grade reduced shoot quality to a similar extent as planting too deeply (Figure 11), except for trees grown in raised beds. This may have been due to drying of the exposed rootballs and/or the effects of strong

winds. Trees in this study were transplanted in mid-summer when daily high temperatures were consistently in the mid-30°C (mid-90°F) or greater range for several months. Thus, the potential for drying or wicking of moisture from the exposed rootballs of plants planted above grade was greater than at cooler times of the year. However, it is interesting to note that there were no adverse effects of the exposed rootballs in the prior studies presented here and there was no advantage to covering the exposed rootball with pine bark mulch, suggesting that wicking of moisture does not appear to be a major issue for establishment of container-grown trees if irrigation is provided. Severe winds from thunderstorms required straightening and restaking of some of the above grade plants shortly after planting. This suggests that it is important to firmly stake those plants planted above grade as they may be more prone to

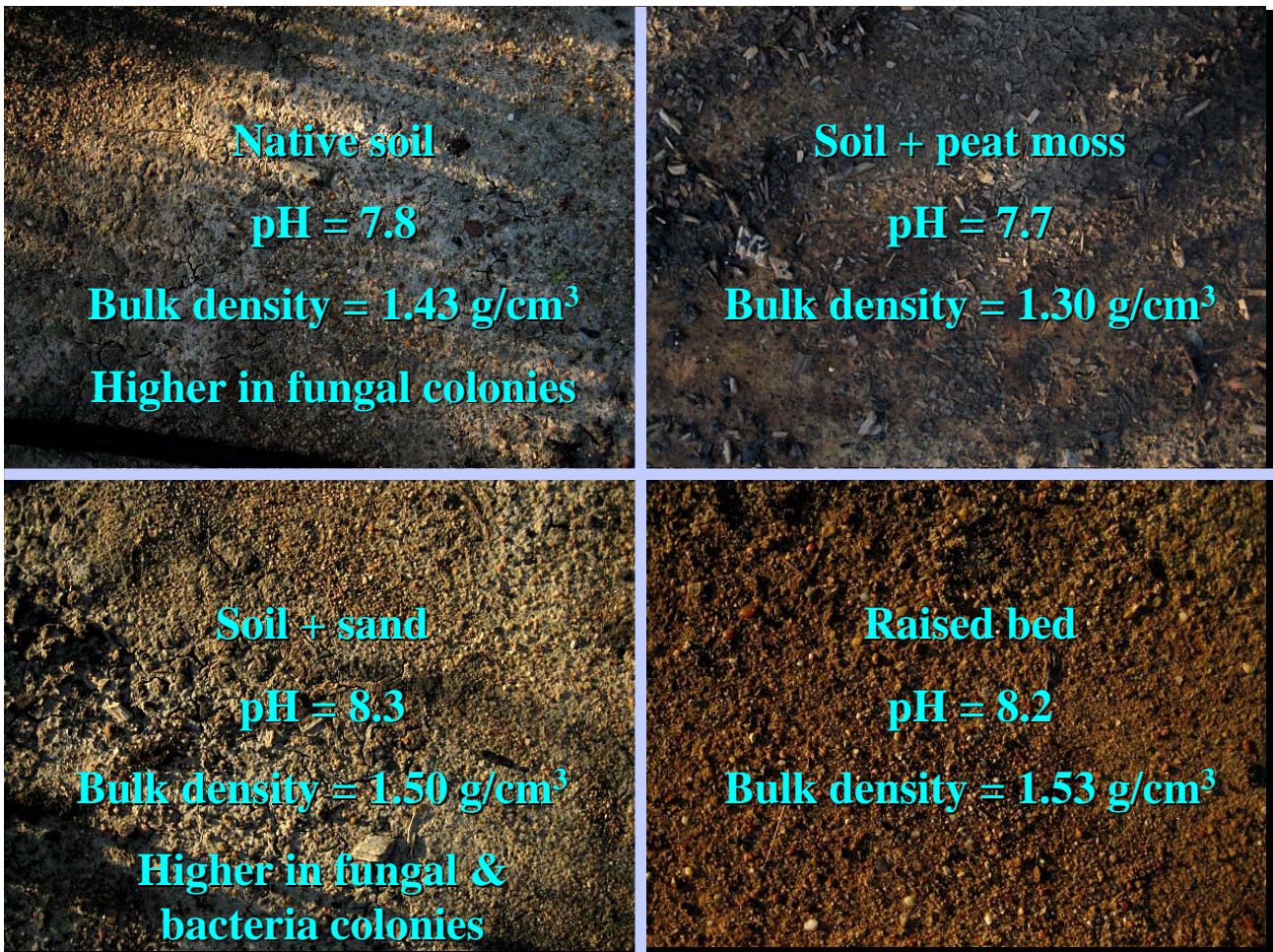


Figure 10. Selected characteristics of the four soil types used in the pilot study to test influences of soil characteristics on responses of *Q. virginiana* to planting depths.

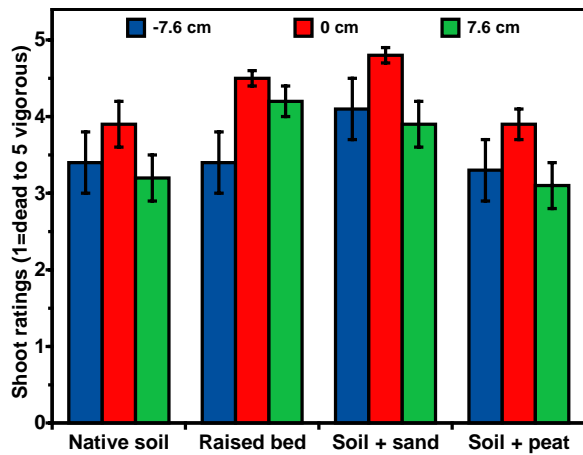


Figure 11. Crown quality (means ± standard errors) of *Q. virginiana* grown in four soil types at three planting depths.

windthrow during initial establishment.

Trees grown in raised beds exhibited less negative mid-day Ψ in spring than trees in the other soil treatments (Figure 12). Likewise, Pn of trees planted below grade in raised beds was not significantly different from trees planted at grade in the native soil, whereas those trees planted below grade in all other treatments had reduced Pn compared to the at grade trees in the native soil (data not presented).

For trees planted at grade, root system quality was best in raised beds, intermediate in the amended plots, and poorest in the native soil (Figure 13). A similar pattern was present for trees planted above grade, except that those in the native soil did not differ from those in the peat amended soil (Figure 13). However, root system quality of trees planted below grade was lower than those

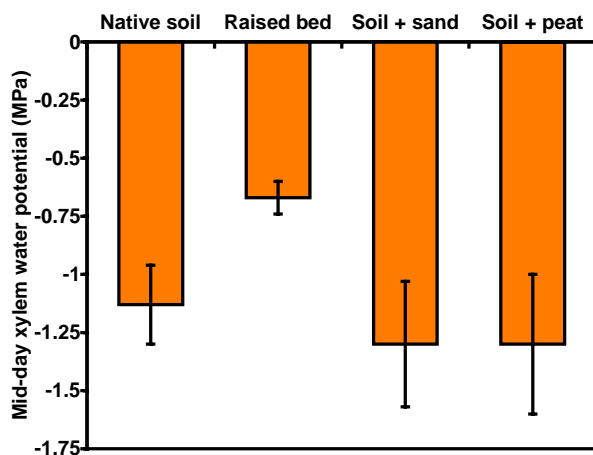


Figure 12. Xylem water potentials (means ± standard errors) for *Q. virginiana* grown in four soil treatments.

planted at grade for all soil treatments (Figure 13) and was lower than those planted above grade for all except those planted in peat amended or the native soil.

The results of this pilot study suggest that planting in raised beds ameliorated the adverse effects of deep planting on Pn, Ψ , and visual quality ratings of container-grown *Q. virginiana*. Root quality was most improved by raised beds and amending the native soil with 30% by volume sand or peat moss resulted in intermediate responses.

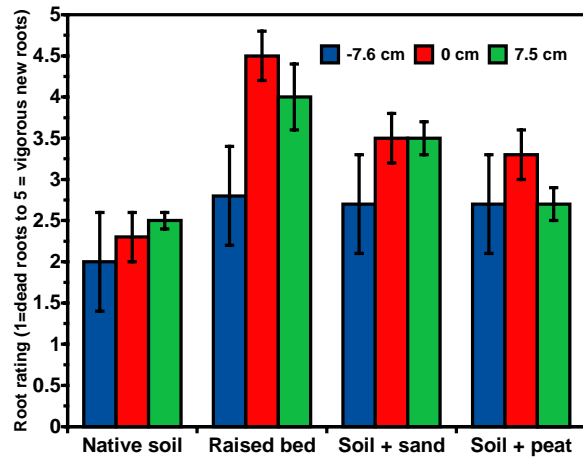


Figure 13. Root system quality (means ± standard errors) of *Q. virginiana* grown in four soil types at three planting depths.

Adverse impacts of high soil bulk density did not appear to be related to the observed responses (Figures 10 & 13). For *Q. virginiana*, planting at grade generally produced the best quality plants while planting below grade usually reduced quality ratings. Results of above grade planting were somewhat mixed. This was the only study presented here in which the authors did not grow the container nursery stock used in the experiment. This made it more difficult to determine where the true structural roots and transition from shoot to root tissue was located. The trees were also somewhat larger in relation to the container size than would be considered optimal. Hence, this study is being redone over a longer time with *Taxodium distichum* (L.) Richard seedlings (more tolerant to poor drainage to improve survival, thus reducing missing data points) grown in containers on-site by the authors.

Conclusions

Studies conducted herein demonstrate the potential adverse effects of planting container-grown tree and shrubs even slightly below grade. Differential species responses can be severe, resulting in poor survival and growth. In some instances, planting above grade or modifying soil characteristics can result in improved growth relative to planting at or below grade. Excessive mulching may also contribute to the detrimental effects of deep planting, depending upon the species and soils involved. Interactions with many other production and transplant practices need to be evaluated to more fully understand how to produce and establish the highest quality woody landscape plants. Studies to this end are currently underway investigating planting depth interactions with soil characteristics, irrigation regimes, nursery production practices, and seasonality of the processes.

Literature Cited

Arnold, M.A. 2002. Landscape plants for Texas and environs, second edition. Stipes Publ. L.L.C., Champaign, Illinois p. 1088.

Arnold, M.A., G.V. McDonald, D.L. Bryan. 2005. Planting depth and mulch thickness affect establishment of green ash and bougainvillea golden-raintree. *J. Arboriculture* 31:163-170.

Broschat, T. 1995. Planting depth affects root growth and nutrient content of transplanted pygmy date palms. *HortScience* 30:1031-1032.

Browne, C. and K. Tilt. 1992. Effects of planting depth on three ornamental trees. *Proc. Southern Nurserymen's Res. Conf.* 37:123-125.

Gilman, E.F. 1997. Trees for urban and suburban landscapes. Delmar Publ., Albany, NY. pp. 662.

Gilman, E.F. and J. Grabosky. 2004. Mulch and planting depth affect live oak (*Quercus virginiana* Mill.) establishment. *J. Arboriculture* 30:311-317.

Watson, G.W. and E.B. Himelick. 1997. Principles and practice of planting trees and shrubs. International Society of Arboriculture, Savoy, Ill. p. 199.

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Should Potting Depth Be a Concern with Container-Grown Trees?

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Abstract

Potting depth of ornamental trees during production can effect plant growth as well as plant quality. The growth response of 'Autumn Flame' red maple (*Acer rubrum* L.), 'Brandywine' Red maple (*Acer rubrum* L.), 'Autumn Brilliance' serviceberry (*Amelanchier arborea* x *A. grandiflora* (Mich. f.) Fern.), 'Green Vase' zelkova (*Zelkova serrata* (Thunb.) Mak.), and 'Cherokee Princess' dogwood (*Cornus florida* L.), potted at predetermined depths of 0, 5.1, 10.2 and 15.2 cm (0, 2, 4, and 6 inches) from the base of the trunk flares, was monitored. During a 2-year production cycle, plant height and caliper growth was not affected by potting depth of most selections, with the exception of 'Cherokee Princess' dogwood. Shoot and root growth of dogwood were reduced at potting depths greater than 10.2 cm. Root and shoot dry weight of others selections were similar among potting depths. The root systems on most tree selections, regardless of potting depth, had completely amassed the volume of the containers, with no visual signs of root rot or disease. These findings suggest that pine bark substrate used in container production has a similar effect as mulch in landscape plantings and caused no unfavorable plant response to most species, with the exception of dogwood.

Introduction

Planting depth of ornamental trees has become a point of discussion among arborists, growers and landscapers. Some arborists have raised concerns about an increased number of landscape trees in which the root system was potted too deeply in the growing container, or buried in the soil of a balled and burlapped root system, and speculate that this may be the reason for poor landscape performance. Others suggest that the problem starts in the production phase and compounds during landscape installation if planted too deep.

In the ornamental plant industry, many clonal selections are propagated by budding or grafting which may cause a slight dogleg in the lower trunk on young trees. Over time, the increase in trunk growth eliminates the dogleg. With today's specialized nursery equipment, many bare root transplants are available one to two years after budding, with trunk diameters exceeding 1-inch, and developed scaffold branching. Halcomb (2003) concluded several reasons that lead to plants being planted too deep: 1) to hide the bud union or crook from a cut-back liner, 2) to help the plant stand up and prevent blow-over, especially with the large transplants or 3) because more moisture is available deeper in the soil or container substrate.

The planting or potting depth scenario may stem from guidelines provided during the 1960s and 1970s. A common practice was to plant apple trees to the bud union regardless of the height of the bud, or to plant the bud union a little below the soil surface to protect it from cold injury (Carlson, 1981). Peach tree buds ranged from 13 to 18 cm above the trunk flare (Lyons and Yoder, 1981) and buds were used as a planting guide and placed below the soil surface when transplanted into orchards. Parry (1974) suggested planting clonal rootstocks such as Malling 7 and East Malling 26 up to 15 cm deeper than nursery depths to promote anchorage and performance, and as an alternative to staking.

Container production of ornamental trees has increased in the last few years due to the landscape industry's demand for quality plants year around, the ease of producing container plants compared to balled and burlapped plants, and the availability of large plastic containers. In the Tennessee nursery industry, container-grown trees have increased in

the production phase due to the pressure of the Federal Imported Fire Ant Quarantine. All root systems, whether with balled and burlapped plants or container grown plants, must be treated with a mandatory pesticide prior to shipping out of the quarantine. It is much easier and less costly to treat a container grown plant than a balled and burlapped plant. This experiment monitored plant growth and performance of bare root tree liners in which the root systems were potted at various depths in a container grown nursery production system.

Methodology

Acer rubrum L. 'Autumn Flame', *Acer rubrum* L. 'Brandywine', *Acer rubrum* L. 'October Glory', *Amelanchier arborea* x *A. grandiflora* (Mich. f.) Fern. 'Autumn Brilliance' serviceberry, *Cornus florida* 'Cherokee Princess' and *Zelkova serrata* (Thunb.) Mak. 'Green Vase', were selected as uniform bare root transplants from a wholesale nursery. Autumn Flame maple transplants were branched, with an average height of 8 feet and trunk diameter of 0.9 inches. Brandywine and October Glory averaged 7.2 and 6.9 feet tall with 0.8 and 0.6 inches trunk diameter, respectively. Autumn Brilliance and Cherokee Princess averaged 4.6 and 4.8 feet in height with trunk diameters of 0.4 and 0.6 inches, respectively. The 'Green Vase' zelkova transplants were 9 feet tall with an average trunk diameter 1.2 inches and well branched.

Forty liners of each species were divided into four groups of ten plants. Each group represented potting depths of 0, 2, 4, or 6 inches from the trunk flare. A paint marker was used to mark the depths on the trunk to ensure during potting that the correct depth was maintained (Figure 1). Plants were placed in a pot-in-pot system and grown for two years using standard nursery practices.

Results and discussion

With the exception of Cherokee Princess dogwood, height and caliper growth was not affected by potting depth during the 2-year test (Figure 2 & 3).

During year 1, mortality occurred with three Autumn Flame and four Zelkova liners potted at 0 cm. Due to an unusual windy spring, tree liners, along with the supporting stakes, were blown out



Figure 1. Yellow paint mark visible at top of substrate.

of the container several times and root systems were exposed for short periods. These liners were well branched and root establishment in the container had not occurred. A common nursery practice is to plant tree liners deep in the container substrate to hold liners in place during transport from the potting shed to the growing location and cm. Due to an unusual windy spring, tree liners, along with the supporting stakes, were blown out of the container several times and root systems were exposed for short periods. These liners were well branched and root establishment in the container had not occurred. A common nursery practice is to plant tree liners deep in the container substrate to hold liners in place during transport

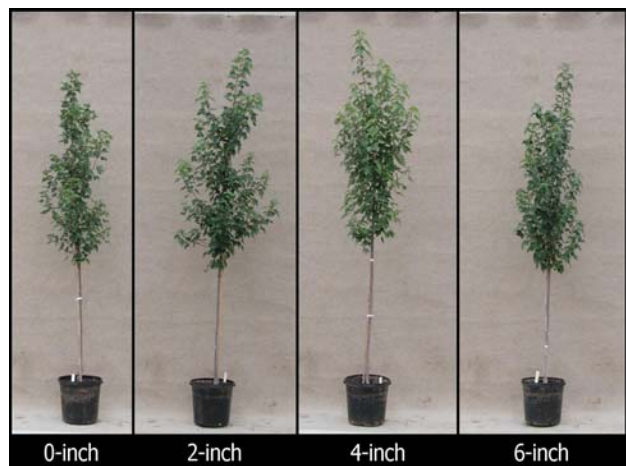


Figure 2. *Acer rubrum* 'October Glory' at the end of the 1st growing season showing similar growth of plants potted 0, 2, 4, and 6 inches above the trunk flare.

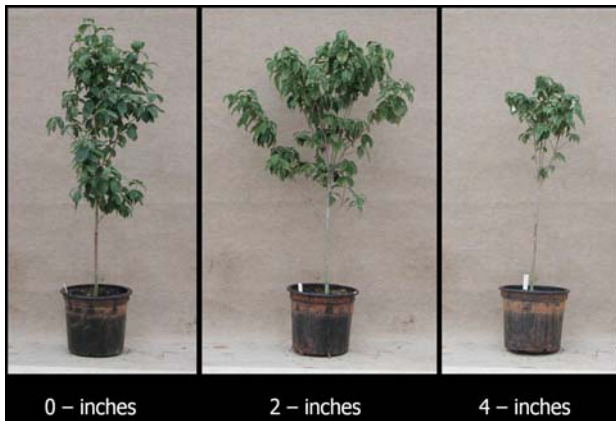


Figure 3. *Cornus florida* 'Cherokee Princess' at the end of the 2nd growing season showing growth differences of plants potted 0, 2 and 4 inches above the trunk flare.

from the potting shed to the growing location and to prevent liners from blowing over or out of the container during windy conditions.

During harvest, no roots were observed originating from the trunk portion that was buried in the container substrate. Subsequently, there was no additional anchorage gained from adventitious roots on the main stem.

The root systems, however, had completely amassed the entire volume of the container. There were no visual signs of root rot or decay. Plants placed 6 inches deeper than the trunk flare had a tremendous amount of roots circling in the bottom fourth of the container. When potted, the root system of these liners had been sitting on the bottom of the container. However, the root system had grown upward and had filled the entire container volume with roots when potted at 2, 4 and 6 inches above the trunk flare (Figure 4).

Costello and Day (2004) reported that in landscape settings fill soil adversely affected plant growth and vigor unless the fill was a porous material that allowed oxygen to the roots. The pine bark substrate used in container production has a low bulk density range between 0.19 and 0.24 g/cc (Yeager, et. al, 1997) and provided an environment conducive to root growth. In field production or landscape settings, bulk density can range from 1.0 to 2.0 g/cc in clay loam to sandy loam soils (Brady, 1974). In addition, plants in container production are grown in an enriched environment with adequate nutrients and water applied as needed.

It is a standard landscape practice to mulch plants with 5.1 to 7.6 cm (2 to 3 inches) with a



Figure 4. *Acer rubrum* 'Brandywine' roots from plants potted at 2 and 6-inches above the trunk flare.

porous organic material over the existing container surface, or over the root system of a balled and burlapped plant. Mulching adds aesthetic value, but more importantly, reduces soil surface temperature. Potting bare root liners 2 to 3 inches deeper than the trunk flare in a container is similar to the practice of landscape mulching and created no unfavorable plant response with the plant selections in this test.

Optimal water and nutrition were provided to maintain healthy active growth of the plants in this



Figure 5. Monitoring photosynthesis in a long term evaluation of plants used in this study.

study. Further research is needed to determine if potting depth in container production adversely affects the root and shoot growth of other species and to conduct a long-term evaluation of plant performance after installation into a landscape setting.

Literature Cited

Brady, N.C. 1974. *The Nature and Properties of Soils*. 8th ed. Macmillan Publ. Co., Inc., New York.

Carlson, R.G. 1981. Apple rootstocks, recommendation and the International Dwarf Fruit Tree Association. *Virginia Fruit* LXIX (3):55-58.

Costello, L.R. and S.D. Day. 2004. A new look at the impact and management of fill soil around trees. *Arborist News* 13(4):25-29.

Halcomb, M. 2003. Nursery Field Production. 19 Oct. 2004. <http://www.utextension.utk.edu/hbin>

Lyons, C.G., Jr. and K.S. Yoder. 1981. Poor anchorage of deeply planted peach trees. *HortScience* 16(1):48-49.

Parry, M.S. 1974. Deeper planting as an alternative to staking. Rpt. E. Malling Res. Sta. for 1973. 175 pp.

Yeager, T.H., C. H. Gilliam, D. Fare, A. Niemiera, T. Bilderback and K. Tilt. 1997. *Best Management Practice Handbook: Guide for Producing Container-Grown Plants*. Southern Nurserymen Association, Marietta, Georgia. 69 pp.

What happens when container grown trees are planted deeply? An example from studying the live oak (*Quercus virginiana*) cultivar Cathedral Oak™

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Abstract

We planted cutting propagated live oak at 6 different depths in containers. Caliper in the first 18 months following planting was larger in trees planted 1.5 in deep, than in trees 0.5 in, 3.5 in and 4.5 in deep. Slowed growth by the very shallow planted trees (0.5 in) may have been due to the roots drying out or heating up for a short time after potting into the #3 containers. Height was not affected by planting depth. However, by the time the crop was finished, 3.5 years after planting, there were no differences in caliper (2.7 in) or height (11.4 ft) among planting depths. Cathedral Oak™ planted at all depths developed adventitious roots along the stem above the top-most root present at the initial planting. The only group that did not develop adventitious roots were those initially planted 2.5 in deep in #3 containers, then another 2.5 in deep in #15 and again 2.5 in deep in #45 containers. This indicated that the ability to develop adventitious roots is lost at a very young age. The take home message is that only very young trees of this cultivar develop adventitious roots.

Introduction

Growers producing trees in containers face a number of conditions that differ from those who sell field grown trees. For example, nursery production of container grown trees can require multiple repottings as trees outgrow their pots and need additional space. Each time the tree is potted up, new opportunities arise for roots to become buried or desiccated and to develop circling or girdling habits (Arnold, et al. 2005; Gilman et al 2003). Studies of container production have found morphological changes in roots, including circling roots and root deflection, but the effects of planting depth

in container-grown nursery stock have received less attention (Gilman et al. 2003; Arnold 1996; Gilman 2001).

Survival of transplanted trees in the landscape depends in part on starting with a well-developed fibrous root system with few circling roots and quickly forming new roots (Harris et al. 2003). New adventitious roots develop in some tree species in response to flooding or deep planting (Kozłowski and Pallardy 1997; Gilman et al. 2003; Yamamoto et al. 1995). Plant hormones that initiate adventitious roots in hypoxic conditions may be used to encourage roots on cutting propagated cultivars.

Although survival in the landscape is the real test of successful tree production, research to understand production techniques can improve the likelihood of survival for container grown trees. Guides for landscape tree planting consistently describe problems arising from planting root balls improperly, such as digging the planting hole too deeply and covering the root ball with soil (Watson & Himelick 2005; University of Minnesota Extension Service website 2000; Kansas State University website; Gilman: University of Florida website). Yet forestry researchers investigating planting depth often report *increased* survival or growth for deeply planted small seedlings of conifer species, especially in sandy soil or during drought conditions (South et al. 2001; VanderSchaaf and South 2003; Schwan 1994). While in a very wet year, survival was poor for cuttings of green ash (*Fraxinus pennsylvanica*) planted 3 inches deep (Kennedy 1977), recent work comparing planting depth of flood tolerant and intolerant species found deep

planting less problematic for the species adapted to wetland habitats (Arnold et al. 2005).

Although instructions for planting caliper-sized landscape trees generally recommend planting at or above soil grade, many seedling-sized trees planted in reforestation efforts survive as well or better with deep planting depending in part on soil conditions. For example, southern pines planted deeply on well-drained to droughty soils survive better than ones planted shallowly, while the opposite was found for wet sites (Schwan 1994). Wetland species adapted to flooding and hypoxic root environments can thrive with deep planting and may develop adventitious roots in response to ethylene or auxins (Yamamoto, et al 1995; Yamamoto & Kozlowski 1987). These roots could encourage survival of newly transplanted trees sufficiently to warrant the application of growth stimulating hormones at transplant time (Scagel et al 2000). Perhaps small seedling-sized trees can adapt better to deep planting than larger trees typically used in landscape sites.

In this study, we follow growth of Cathedral Oak™ cultivars of live oak (*Quercus virginiana* Mill.) for over two years through transitions from liner to #45 container to understand more about the effects of planting depth on container grown trees. The objective of this study was to demonstrate how planting depth can influence tree height, caliper and quality during production of Cathedral Oak™ in containers.

What we did

In May 2003, 220 cutting propagated Cathedral Oak™ 5.7 cm (2.25 in) liners were planted into #3 ACCELERATORS™ (these air-root pruning plastic containers are designed to reduce root circling). The point at which the top-most root met the trunk was placed at 5 different depths as follows: 0.5 to 0.75 in below the media surface, 1.5 in below, 2.5in below, 3.5in below, or 4.5 in below the media surface. All treatments were fertilized regularly with 20-20-20 Peters 200 ppm N 300 ml per pot and irrigated with drip irrigation appropriate for each pot size. We pruned canopies so trees developed a central leader.

In May 2004, all trees were potted into #15 ACCELERATORS™. The top of the media in the #3 containers was placed even with the media surface in the #15 containers. An additional group of trees planted 2.5 in deep into #3s were planted another 2.5 in deep when potted into #15s, for a total of 5 in deep. We measured caliper and height in October 2004. All trees were potted up into #45 ACCELERATORS in March 2005. Trees planted 2.5 in deep into #3s and #15s were planted another 2.5 in deep when potted into #45s, for a total of 7.5 in deep. We pruned tree canopies in May 2005.

What we've learned so far

Caliper in the first 18 months following planting was larger in trees planted 1.5in deep, than in trees 0.5 - 0.75 in, 3.5 in and 4.5 in deep (Table 1).

Table 1. Effect of liner planting depth on growth of live oak

		November 2003	May 2004	October 2004	July 2005
Caliper	(in)				
A	0 to 3/4" deep	0.39	0.51	1.02	1.60
B	1.5" deep	0.43	0.57	1.13	1.67
C	2.5" deep	0.41	0.55	1.10	1.62
D	3.5" deep	0.39	0.52	1.07	1.62
E	4.5" deep	0.38	0.51	1.04	1.60
H	2.5" liner to 3 gal, 3 to 15, 15 to 45	0.39	0.49	1.05	1.60
Height	(ft)				
A	0 to 3/4" deep	2.55	3.29	6.62	9.25
B	1.5" deep	3.15	3.81	6.86	9.63
C	2.5" deep	2.80	3.63	6.65	9.23
D	3.5" deep	2.75	3.59	6.66	9.25
E	4.5" deep	2.69	3.34	6.44	9.03
H	2.5" liner to 3 gal, 3 to 15, 15 to 45	2.70	3.18	6.42	8.83

Thus overall, caliper decreased with increasing planting depth, except that trees planted with the first root within .75 in of the surface grew slowest. This slowed growth by the very shallow planted trees may have been due to the roots drying out or heating up for a short time after potting into the #3 containers. Height was not affected by planting depth.

Although rooting depths vary greatly by species, in general, roots are concentrated in the upper 30 cm of soil. Root growth and activity are diminished in low oxygen concentrations (Kozłowski & Pallardy 1997) and soil oxygen is reduced as depth increases (Drew 1990). We found negative effects of planting at the shallowest depth for Cathedral Oak, with best results when roots were 1.5 inches below soil grade. Growth diminished at incrementally deeper levels. Browne and Tilt (1992) found similar results for red maple, with reduced height growth at zero and six inch planting depths while trees planted two and four inches deep grew taller. Flood tolerant species adapted to wetland conditions, including periodic hypoxia, may benefit from deeper planting if soils in transplanted landscapes are subject to drying conditions.

Cathedral Oak™ planted at all depths developed adventitious roots along the stem above the top-most root present at the initial planting. The only group that did not develop adventitious roots were those initially planted 2.5 in deep in #3 containers, then another 2.5 in deep in #15 and again 2.5 in deep in #45 containers. This indicated that the ability to develop adventitious roots is lost at a very young age. The take home message is that only very young trees of this cultivar develop adventitious roots. New roots arising from the root/stem interface of lacebark elms (*Ulmus parvifolia*) have been correlated with increased growth of two-year old container grown trees (Whitcomb 1986). The cultivar in this study is propagated by cuttings rather than seeds, but Cathedral Oak™ was selected in part because of its rooting capacity. For oaks, both acorn burial by wildlife and natural germination patterns lead to below ground root collars and associated buds (Ward & Brose 2004). Adventitious roots found on our cutting propagated trees may reflect the pattern of root and shoot development of seedlings.

Conclusions

Trunk caliper developed more slowly on this cultivar of live oak as planting depth in containers increased. There was no effect of planting depth on tree height growth.

Literature Cited

Arnold, M.A. 1996. Mechanical correction and chemical avoidance of circling roots differentially affect post-transplant root regeneration and field establishment of container-grown Shumard oak. *J. Amer. Soc. Hort. Sci.* 121:258-263.

Arnold, M. A., G. V. McDonald, and D. L. Bryan. 2005. Planting depth and mulch thickness affect establishment of green ash (*Fraxinus pennsylvanica*) and bougainvillea goldenraintree (*Koelreuteria bipinnata*). *J. Arboric.* 31: 163-170.

Browne, C. and K. Tilt. 1992. Effects of planting depth on three ornamental trees. *Southern Nursery Association Research Conference Proceedings* 37: 123-125.

Drew, M.C. 1990. Sensing soil oxygen. *Plant Cell Environ* 13: 681-693.

Gilman, E.F. nd. Roots too deep in the root ball. <http://hort.ifas.ufl.edu/woody/planting/rootgrowth/deep.htm>

Gilman, E. F. 2001. Effect of nursery production method, irrigation, and inoculation with mycorrhizae-forming fungi on establishment of *Quercus virginiana*. *J. Arboric.* 27: 30-39.

Gilman, E. F., J. Grabosky, A. Stodola, and M. D. Marshall. 2003. Irrigation and container type impact red maple (*Acer rubrum* L.) 5 years after landscape planting. *J. Arboric.* 29: 231-236.

Harris, R. W., J. R. Clark, and N. P. Matheny. 2003. *Arboriculture: integrated management of landscape trees, shrubs, and vines*, 4th edition. Prentice Hall, Inc. Upper Saddle River, New Jersey.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service. nd. *Tree*

planting depth: rooting out the problem.
www.oznet.ksu.edu/

Kennedy, H. E., Jr. 1977. Planting depth and source affect survival of planted green ash cuttings. Research Note SO-224. USDA Forest Service Southern Forest Experiment Station. New Orleans, Louisiana.

Kozlowski, T.T. and S. G. Pallardy. 1997. Physiology of woody plants, 2nd edition. Academic Press, San Diego, California.

Scagel, C. F., R. G. Linderman and R. K. Scagel. 2000. Ten-year growth and survival of Douglas-fir seedlings treated with plant growth regulating substances at transplant. Can J. Forestry Research 30: 1778-1787.

Schwan, T. 1994. Planting depth and its influence on survival and growth: a literature review with emphasis on jack pine, black spruce, and white spruce. NEST Technical Report TR-017. Canadian Ministry of Natural Resources. Ontario, Canada.

South, D. B., J. L. Rakestraw, and G. A. Lowerts. 2001. Early gains from planting large-diameter seedlings and intensive management are additive for loblolly pine. New Forests 22: 97-110.

University of Minnesota Extension Service. 2002. A practitioner's guide to stem girdling roots of trees. BU-07501. www.extension.umn.edu

VanderSchaaf, C. L. and South, D.B. 2003. Effect of planting depth on growth of open-rooted *Pinus elliottii* and *Pinus taeda* seedlings in the United States. Southern African Forestry Journal 198: 63-73.

Ward, J. S. and P. H. Brose. 2004. Mortality, survival, and growth of individual stems after prescribed burning in recent hardwood clearcuts pp 193- 199 *In*: D.A. Yaussy, D.M. Hix, R.P. Long, and P.C. Goebel (Editors). Proceedings. 14th Central Hardwood Forest Conference; March 16-19, 2004; Wooster, OH. Gen. Tech. Rep. NE-316. Newtown Square, PA: U.S. Department of Agriculture. Forest Service. Northeastern Research Station.

Watson, G. and E. B. Himelick. 2005. Best management practices: tree planting. International Society of Arboriculture. Champaign, Illinois.

Whitcomb, C. E. 1986. Landscape plant production, establishment, and maintenance. Lacebark Pubs. Stillwater, Oklahoma.

Yamamoto, F. and T. T. Kozlowski. 1987. Regulation by auxin and ethylene of responses of *Acer negundo* seedlings to flooding of soil. Environ. Exp. Bot. 27: 329-340.

Yamamoto, F., T. Sakata and K. Terazawa. 1995. Physiological, morphological and anatomical responses of *Fraxinus mandshurica* seedlings to flooding. Tree Physiology 15: 713-719.

The Effects of Soil Depth on the Long-term Health and Frequency of Storm Damage to Trees in the Upper Midwest

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Abstract:

In a long-term, 9 year study, 180 sugar maple (*Acer saccharum*) and 180 littleleaf linden (*Tilia cordata*) bare root trees were field-planted in a complete, randomized block design. The treatments consisted of planting with 0 inches, 5 inches (12.7 cm) and 10 inches (25.4 cm) of soil over the uppermost first-order lateral roots. Tree mortality was high the first year. Through 2006, mortality was greater with increased planting depth and greater for sugar maple than littleleaf linden. Stem encircling roots (SERs) of littleleaf linden increased significantly at 5 and 10 inches deep by 2006. There was no difference for sugar maples. Stem girdling roots (SGRs) generally increased with time and planting depth, but significant differences were uncommon. Only littleleaf linden planted 5 inches deep had greater sucker formation.

A second study investigated the practice of trees being placed deeply in containers to prevent windthrow and excessive lean on pot-in-pot produced whitespire birch (*Betula platyphylla x japonica* 'Whitespire'), green ash (*Fraxinus pennsylvanica*), Spring snow crabapple (*Malus* 'Spring Snow'), and swamp white oak (*Quercus bicolor*). There were no significant increases in windthrow occurrences at the zero planting depth. Root volume trended downward as planting depth increased. Green ash and the swamp white oak had significantly better caliper growth at the 0 centimeter planting depth, as compared to the 15 centimeter planting depths.

Surveys of 3-9 inch dbh street trees conducted to determine condition, depth of soil over roots, and frequency of SERs and SGRs. Species surveyed were sugar maple (*Acer saccharum*), green ash (*Fraxinus pennsylvanica*), littleleaf linden (*Tilia cordata*), hackberry (*Celtis occidentalis*), and honeylocust (*Gleditsia triacanthos*). For most species, the greatest number of SERs and SGRs occurred 3-4 inches deep. Fifty percent of the hackberry and honeylocust trees had lateral roots within the top two inches of soil. Fifty percent of the sugar maple, green ash and littleleaf linden trees did not have roots in the top 4 inches of soil.



Long Term Planting Depth Study

The study is designed as a 9 year study, initiated in 2000.

Methods

The treatments consisted of planting with 0 inches, 5 inches (12.7 cm) and 10 inches (25.4 cm) of soil over the uppermost first-order lateral roots. One third of the blocks was randomly selected and harvested every 3rd year. The first harvest was in 2003, second in 2006.

Data was collected annually. At the end of the growing season:

- Caliper (growth rate) is recorded for each of the trees.

At the beginning of the growing season:

- Winter damage or dieback is determined for each tree, then removed.
- Suckers from the previous season are counted and removed.



Fig. 2. Using an air knife to harvest the trees in 2003.

- Other items noted: stem damage, insect and disease pressure, and herbicide damage

2003 Harvest. An air knife was used to remove the soil down to and around the root systems. Root systems were then cut roughly 8 inches away from the stem to complete the removal of the tree from the ground. At this time, the root systems were evaluated for stem encircling (SERs) or stem girdling roots (SGRs). The root systems were then washed and photographed against a 5 centimeter square grid.

2006 Harvest. Trees were mechanically spaded out of the ground and the soil was then removed with an air knife. Root systems were then evaluated as per the 2003 harvest.

Observations through October 2006.

While there are some interesting trends there are only a couple of significant conclusions can be drawn from the data collected thus far.

During the first season there was an effort to keep the field fully stocked. So, adjusted total tree number (Table 1) reflects the true number of trees that were planted. This number presented to



Fig. 3. A tangential stem encircling root

demonstrate the difficulty in getting the maples initiated, especially at the 5 and 10 inch deep treatments.

There were no statistically significant differences or trends in caliper or annual dieback for either species (data not shown).

Sugar maple showed no relationship between sucker formation and planting depth treatments. Littleleaf lindens, however, showed a significant relationship at 5 inches in both the 2003 and 2006 data (Table 2).

Sugar maple showed no statistically significant increase in stem encircling roots (SERs) at any depth, though there was a consistent trend to increase with depth and time. SERs of littleleaf linden increased significantly at 5 and 10 inches deep by 2006 (Table 3).

Stem Girdling Roots (SGRs) were recorded within 6 inches of the main stem. Only 1 littleleaf linden had any SGRs in 2003. There was a general trend for SGRs to increase in number with time and depth in both species, but only number of SGRs on littleleaf linden at 5 inches was significant by 2006 (Table 4). Figure 4 shows an example of a gridling



Fig. 4. A stem girdling root.

Table 1. The relationship between mortality and planting depth.

* Mortality Data:	<i>Acer saccharum</i>			<i>Tilia cordata</i>		
	Through 2003	2006		Through 2003	2006	
Planting Depth	Losses	Adjusted Total Trees / Mortality Rate	% Alive	Losses	Adjusted Total Trees / Mortality Rate	% Alive
0 Inches	28	true n = 80 for 35%	70	11	66 / 17%	60
5 Inches	62	true n = 112 for 55%	60	2	62 / 3%	90
10 Inches	85	true n = 135 for 63%	35	8	64 / 12.5%	70

Table 2. The relationship between sucker formation and planting depth.

Harvest Data:	<i>Acer saccharum</i>			<i>Tilia cordata</i>		
	Occurrence of root suckering 2003	Occurrence of root suckering 2006	Significant / Trend Through 2006	Number of suckers 2003 (mean)	Number of suckers 2006 (mean)	Significant / Trend Through 2006
0 Inches	1; on 1 tree	9; on 3 trees	No / No	4.8	16.4	No
5 Inches	4; on 1 tree	6; on 1 tree	No / No	10.25	27.4	Yes / Yes
10 Inches	0	3; on 3 trees	No / No	2.4	20.4	No

Table 3. The relationship between stem encircling roots and planting depth.

Harvest Data:	<i>Acer saccharum</i>			<i>Tilia cordata</i>		
	% of trees with SERs		Significant / Trend	% of trees with SERs		Significant / Trend
Planting Depth	2003	2006		2003	2006	
0 Inches	4.2	7	No	11.7	17	No / No
5 Inches	12	17	No	29.0	61	Yes / Yes
10 Inches	18	28	No / Yes	41.7	64	Yes / Yes

Table 4. The relationship between stem girdling roots and planting depth.

Harvest Data:	<i>Acer saccharum</i>		<i>Tilia cordata</i>	
	Occurrence of SGRs	% of trees with SGRs	Occurrence of SGRs	% of trees with SGRs
Planting Depth	2003	2006	2003	2006
0 Inches	0	0	0	0
5 Inches	0	8	1 at 25% of stem	28 - Sig. from 0"
10 Inches	0	14	1 at 30% of stem	14 - Trend from 0"

root on one of the littleleaf lindens.

Pot-in-Pot production and Planting Depth Study

This investigation focused on the practice of trees being placed deeply in containers to prevent wind-throw and excessive lean.

Methods

In June of 2002, 60 bare root *Betula platyphylla x japonica* 'Whitespire', *Fraxinus pennsylvanica*, *Malus* 'Spring Snow', and *Quercus bicolor* 360 bare root trees were out-planted in a pot-in-pot production field in a commercial, wholesale nursery (Fig. 5) in a complete, randomized block design. The nursery's standard practices were followed with one exception - staking was avoided when possible. Irrigation and fertilization were provided by onsite nursery staff per standard operating procedures. The treatments consisted of planting with 0 cm, 5 cm, 10 cm and 15 cm of soil over the uppermost first order lateral roots. The roots were pruned at the beginning of the study to remove broken and damaged roots and to fit #10 containers.

The study took place over 4 months terminating in early October. During those four months, data relating to tree lean was collected on a weekly basis, using a plumb-bob and a centimeter gauged ruler (Fig. 6).

Also noted during the weekly visits was the occurrence of socketing, death of trees, drainage problems and wind-throw (Fig. 7). An on site Watch Dog® weather station recorded wind speeds during the 4 months of the experiment.

Stem caliper was taken during the initial pot-up at 6 inches above the first order roots. The final caliper was taken at 6 inches above the soil line, as is standard nursery practice for trees of this size. Another important part of the data set is root volume. Root volumes were determined by water displacement, at pot-up and at harvest.

Discussion and Conclusions

The choice of *Quercus bicolor* for this study became somewhat problematic. The root systems were locked-in solid, but the stems became limber as the growing season progressed. The photo in Fig. 8 was taken in August and several oaks were



Figure 5. Trees were out-planted in a pot-in-pot production field in a commercial wholesale nursery.



Fig. 6. Tree lean was measured using a plumb-bob and a centimeter gauged ruler.



Figure 7 Measuring root volume by water displacement. This was done at pot-up and at harvest.



Fig. 8. The stems of swamp white oak were very limber and required staking. subsequently staked.

Straightening. Standard nursery practice is to straighten or stake the trees that are leaning until the roots “lock” in to the container media. The nursery that we were working with indicated that this is typically a 4 to 6 week period of weekly visits. This study demonstrated that there was no significant change required to the standard practice if the trees were planted at the proper depth (Fig. 9).

Windthrow. There were no significant increases in windthrow occurrences at the zero planting depth (data not shown).

Root Volume. Based on root volume, it appears that the ‘Spring Snow’ crabapples and the green ash liked the deep planting (Fig. 10). An explanation - the crab apples were extremely prolific and filled the containers, while the green ash put on a phenomenal amount of adventitious roots (Fig 12). However, looking at the root volume ‘percent change’ overall the trend was downward as planting depth increased.

Caliper. (Fig. 12) - Again, note that the crab

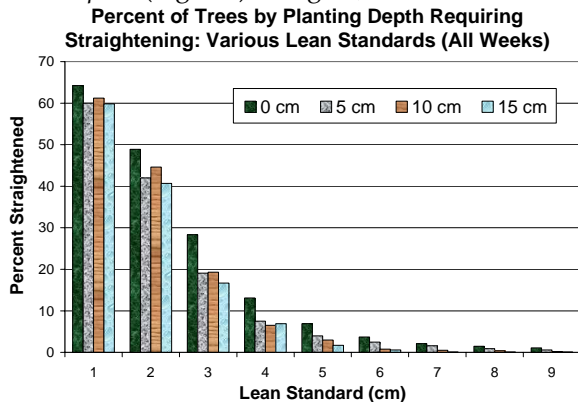


Fig. 9 There was no change required to the standard staking practice when trees were planted at the proper depth.

Percent Change in Root Volume by Species and Planting Depth

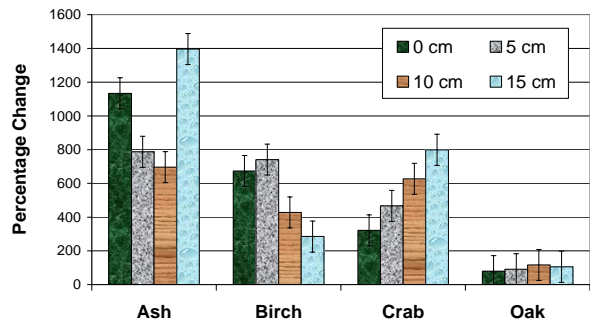


Fig.10. The relationship between root volume and planting depth



Fig. 11. Before and after shots of two root systems. *Top left:* Green ash planted 10 cm deep. *Top right:* Same green ash at the end of the study. *Bottom left:* Whitespire birch to be planted 15 cm deep. *Bottom right:* Same whitespire birch at the end of the study.



Fig. 12. Green ash produced a large number of adventitious roots.

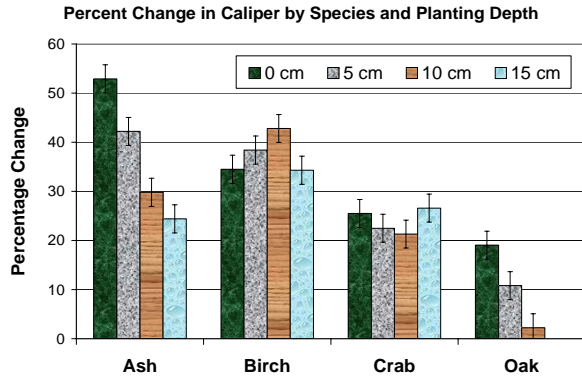


Fig. 13. The influence of planting depth on caliper growth.

apples and the birches didn't show statistically significant differences amongst the planting depth treatments. However, the green ash and the bicolor oak had significantly better caliper growth at the 0 centimeter planting depth as compared to the 15 centimeter planting depths.

Frequency of Buried Root Systems: Relationship to stem and canopy condition, and frequency of stem encircling/girdling roots

Methods

In this study, surveys of landscape trees were conducted to determine depth of soil over roots, frequency of stem encircling roots (SERs) and stem girdling roots (SGRs). The cities were selected based on: street tree inventories, adequate sample size of the chosen species in 3-9 inch d.b.h. class, and permission granted to perform root collar examinations in public spaces. Species surveyed were sugar maple (*Acer saccharum*), green ash (*Fraxinus pennsylvanica*), littleleaf linden (*Tilia cordata*), hackberry (*Celtis occidentalis*), and

Minneapolis	1997	<i>Acer saccharum</i>
	1999	<i>Fraxinus pennsylvanica</i>
	1999	<i>Tilia cordata</i>
Rochester	2001	<i>Celtis occidentalis</i>
Saint Paul	2004	<i>Gleditsia triacanthos</i>



Fig.14. The thinning canopy on this Norway maple is the result of stem girdling roots (SGRs).

honeylocust (Gleditsia triacanthos).

Root collar examinations were performed to get information on SERs and SGRs. SERs are roots that are encircling the stem but are not yet compressing or maybe not even touching the stem. SGRs are roots that are compressing the stem.

Discussion and Conclusions

The following figures represent frequency information collected during the field surveys and subsequent root collar examinations of five tree species. The data reflects only frequencies, not severity. For instance, for trees that were found to have SGRs at a 3 inch depth, the figure only relates the number of trees in each species that had SGRs. These figures do not illustrate the severity of the SGRs, i.e., the percent of the stem circumference that was compressed by SGRs.

Figure 15 represents the field survey results for depth of soil over the first main order roots for five different tree species, as determined by root collar examinations. For each increment of soil depth, i.e., one inch, the frequency of trees in each species that

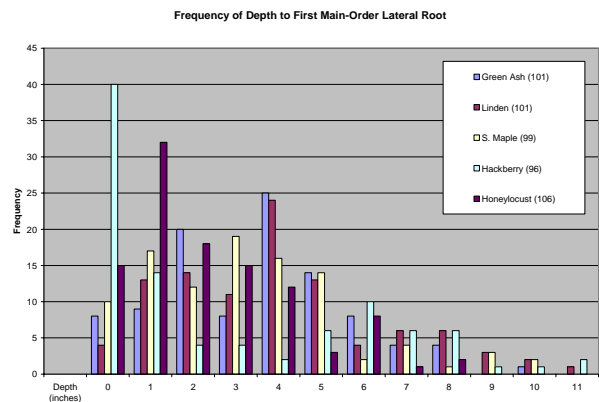


Fig. 15. Depth to uppermost lateral root.

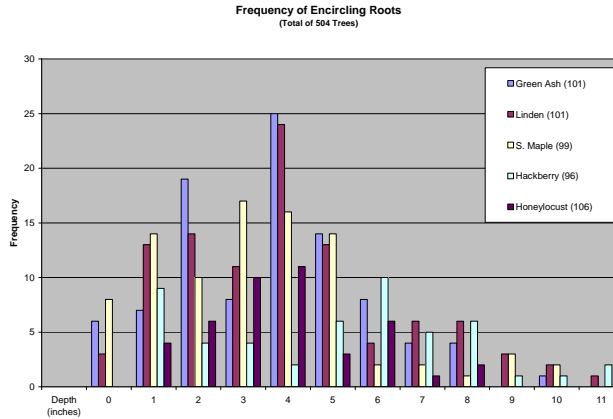


Fig. 16 The frequency of SERs by depth interval for each species.

was found to have that amount of soil over the roots is recorded in the bars. So, out of the 101 green ash that were included in the field surveys, 40 had 0 to less than 1 inch of soil, and 14 had at least 1 inch but less than 2 inches of soil over their first, main order roots.

Figure 16 illustrates the number of each tree species at each interval of soil depth over the first main order roots that was found to have woody roots encircling the stems, a.k.a., stem encircling roots or SERs. SERs were defined as woody roots with a diameter of at least 5 mm, growing tangentially or encircling the stem and were located within 6 inches of a tree’s stem. Further, SERs were not necessarily contacting or compressing stem tissue.

Figure 17 illustrates the frequency of trees at the various soil depths that had SGRs, that is, roots that were compressing stem tissues. For those lindens that were found to have at least 4 but less

than 5 inches of soil over their first main order roots, 14 of 24 (refer to Fig. 15, frequency of lindens that had 4 inches of soil over their roots) had SGRs.

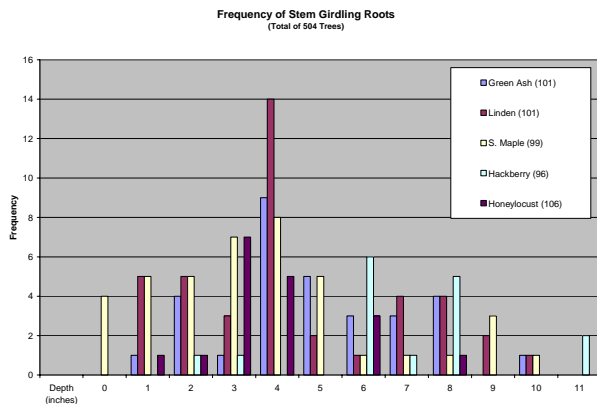


Fig. 17 The frequency of SGRs by depth interval for each species

Effects of planting depth on landscape tree survival and girdling root formation

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Abstract

Deep planting resulted in loss of 50% of the 15-cm and 31-cm deep-planted Yoshino cherries in the first two years, whereas all the control cherries survived. Short-term survival of red maples was not affected by planting depth. Deep-planted trees had far fewer roots in the upper soil layers than properly-planted trees one full year after transplant for both species. Control maples had 14 ± 19 % of their trunk circumference encircled by girdling or potentially-girdling roots; this number rose to 48 ± 29 % and 71 ± 21 % for 15-cm and 31-cm deep-planted maples, respectively. There were no treatment-related differences in girdling root development in the cherries. Deep planting can predispose trees to transplant failure and girdling root formation.

Introduction

Root collar burial at transplant positions much of the tree's root system in deeper soil layers where access to water, nutrients, and oxygen may be restricted. Anecdotal evidence suggests that root collar burial predisposes trees to transplant failure and girdling root development, but little scientific research has been performed to evaluate these claims (Broschat 1995; Gilman and Grabosky 2004).

The objective of the present research was to examine the effect of planting depth on the health, survival and root development of two popular landscape trees, red maple (*Acer rubrum*) and Yoshino cherry (*Prunus x yedoensis*). Trees were transplanted with their root flares at grade, 15 cm (6 in) below grade or 31 cm (12 in) below grade. A combination of above- and below-ground meas-

urements was used to characterize tree responses to root collar burial.

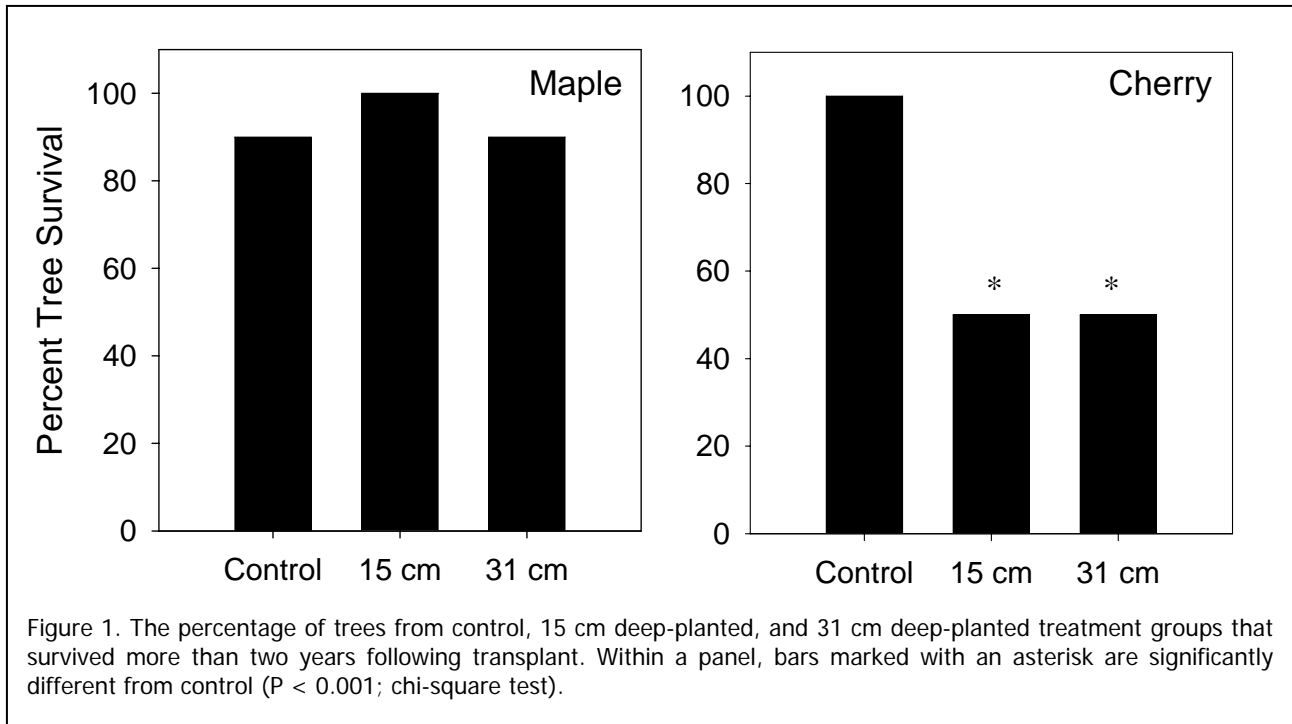
Experimental Design

The experiment was performed in a half-acre open-field in the Roland Schoenike Arboretum in Clemson, South Carolina. The soil was an eroded Cecil sandy loam, and the site exhibited a 10% slope. Two-inch caliper balled-and-burlapped 'October Glory' red maples (*Acer rubrum*) and Yoshino cherries (*Prunus x yedoensis*) were obtained from a local nursery. Thirty trees of each species were planted in a randomized complete block design, consisting of ten replicate blocks within which two species and three planting depth treatments were randomly arranged.

Planting depths included control (planted with the root flare at grade), 15 cm (6 in) deep-planted (planted with the root flare 15 cm below grade) and 31 cm (12 in) deep-planted (planted with the root flare 31 cm below grade). Replicate blocks were laid out as rows perpendicular to the direction of the slope. Above- and below-ground growth data were collected for four years following transplant to assess tree survival, performance and girdling root development (for full description of methods, see Wells *et al.* 2006).

Results

Deep planting had a strong negative effect on the short-term survival of Yoshino cherries. Two years after transplanting, 50% of the 15-cm and 31-cm deep-planted cherries had died, whereas all the control cherries had survived (Figure 1). Short-



term survival of maples was not affected by planting depth. After two years, no further tree mortality was observed in either species.

In May 1997, six months after transplant, there were no treatment-related differences in the lengths of individual shoots or the areas of individual leaves for either species. However, 31-cm deep-planted trees of both species had significantly lower leaf chlorophyll content as estimated by SPAD

meter readings (Table 1). None of the maples showed visible signs of stress at this time, but the 31-cm deep-planted cherries were rated significantly higher than the controls for defoliation, chlorosis and leaf curl (Table 1).

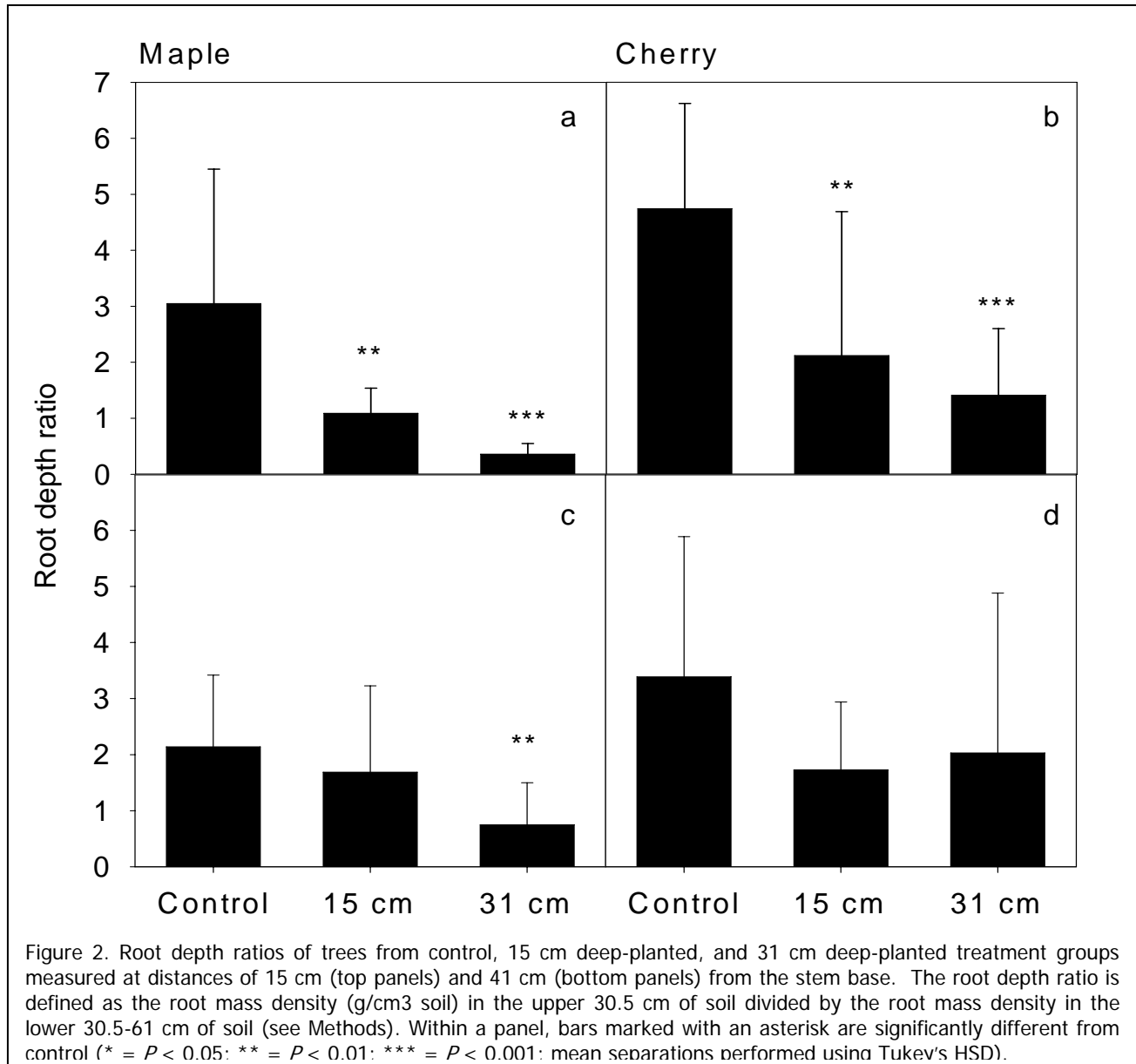
In December 1997, one year after transplant, the maples had significantly higher root mass densities (RMD) than the cherries (1.75 ± 0.98 vs. 1.02 ± 0.81 mg root cm^{-3} soil; $P < 0.0001$; Table 2), but planting

Table 1. Mean values for aboveground measurements and visual ratings taken 5 months after transplant (May 1997) and root measurements taken 12 months after transplant (December 1997). Within a row and species, treatment means followed by different letters are significantly different at $P < 0.05$.

	Maple			Cherry		
	Control	15 cm	31 cm	Control	15 cm	31 cm
<u>Measurements</u>						
Shoot length (cm)	4.9 ^a	6.3 ^a	4.8 ^a	13.2 ^a	13.7 ^a	14.7 ^a
SPAD meter	36.1 ^a	36.2 ^a	34.0 ^b	37.1 ^a	35.7 ^{ab}	34.5 ^b
Leaf area (cm^2)	35.4 ^a	35.2 ^a	36.7 ^a	10.7 ^a	11.8 ^a	11.5 ^a
Root mass density ¹	1.8 ^a	1.9 ^a	1.5 ^a	1.1 ^a	1.1 ^a	0.8 ^a
Root depth ratio ¹	2.6	1.4	0.6	4.1	1.9	1.7
<u>Visual Ratings (0 to 3 scale)²</u>						
Shoot tip dieback	1.5 ^a	1.3 ^a	1.3 ^a	0.4 ^a	0.7 ^a	0.9 ^a
Defoliation	0.0 ^a	0.0 ^a	0.0 ^a	0.8 ^a	1.3 ^{ab}	1.6 ^b
Poor leaf color	0.1 ^a	0.1 ^a	0.1 ^a	1.3 ^a	1.8 ^{ab}	2.1 ^b
Leaf curl	0.0 ^a	0.0 ^a	0.0 ^a	1.4 ^a	2.1 ^{ab}	2.4 ^b

¹ Values averaged across both distances from the trunk, i.e. 16 cm and 41 cm

² 0 = condition is not present; 3 = condition is severe

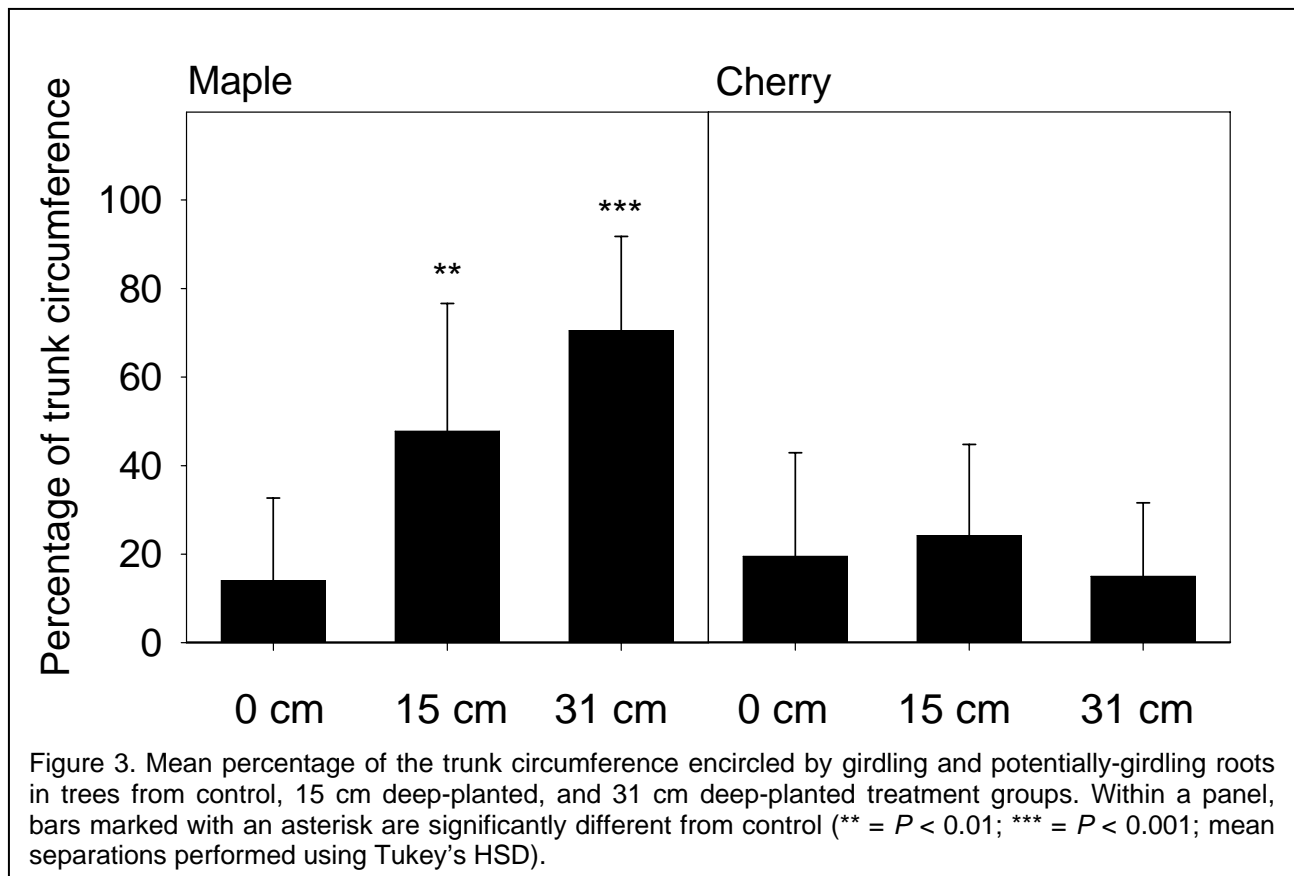


depth treatments had no effect on RMD.

Although planting depth had no effect on the total mass of roots present in the top 61 cm of soil, it had a strong effect on the depth distribution of this root mass (Figure 2; Table 1). Within the original root ball diameter, the root depth ratio (RDR) of properly planted maples was 3.05 ± 2.41 . This indicates that the root mass per cubic cm of soil was approximately 3 times greater in the upper 30.5 cm of soil than in the 30.5-61 cm depth. RDR declined markedly with planting depth to 1.09 ± 0.45 for 15-cm deep-planted maples and 0.36 ± 0.19 for 31-cm deep-planted maples. Similar significant decreases in RDR with planting depth were observed in the

cherries (Figure 2). Thus, deep-planted trees had far fewer roots in the upper soil layers than properly-planted trees one full year after transplant.

In December 2000, root collar excavations revealed that deep planting had a significant impact on girdling root development in the red maples (Figure 3). Control maples had $14 \pm 19\%$ of their trunk circumference encircled by girdling or potentially-girdling roots; this number rose to $48 \pm 29\%$ and $71 \pm 21\%$ for 15-cm and 31-cm deep-planted maples, respectively. There were no treatment-related differences in girdling root development in the cherries.



Discussion

In most forest trees, the majority of fine roots are located in the top 15 cm of soil where mineral nutrients and rainfall are most abundant (Kozłowski and Pallardy 1997). At greater soil depths, oxygen partial pressures may also fall below those needed to support root respiration, growth and nutrient uptake (Kozłowski 1985; but see MacDonald *et al.* 2004). The root balls of deep-planted trees in our study were placed below the top 15 cm of soil at the time of transplant. Lower SPAD meter readings of deep-planted trees six months post-transplant indicated that such root system burial did indeed cause measurable tree stress. However, only in the cherries was this stress serious enough to produce visual symptoms and significant tree mortality.

We did not measure oxygen partial pressures in the soil, but site characteristics lead us to suspect that flooding and anoxia may have played an important role in initial deep planting stress. The site exhibited a 10% slope, and, following heavy rain events, significant runoff and pooling of water in the lower portions of the site was observed. In

flooded or waterlogged soils, aerobic conditions may extend only a few centimeters beneath the soil surface (Taiz and Zeiger 2002). Under such conditions, trees with the majority of their root system below 15 cm would be subjected to severe anoxia. Yoshino cherry, in particular, is known to be intolerant of flooding (Rowe and Beardsell 1973; Jacobs and Johnson 1996).

Infection by pathogenic fungi such as *Phytophthora* is encouraged under flooded or poorly-drained conditions (Wilcox 1993). However, tests at our site showed no relationship between treatment or slope position and the sporadic incidence of *Phytophthora* infection in the planting (data not shown).

Maples were better able to tolerate deep planting than cherries in the short term. Surprisingly, this greater tolerance was not related to more rapid re-establishment of a normal root depth distribution. One full year after transplant, the root distribution of the deep-planted maples was not different from that of deep-planted cherries and was still strongly skewed toward the lower soil profile.

Although the maples appeared to recover well from initial deep planting and transplant stress, air spade excavations indicated that deep planting may have set the stage for future problems with stem-girdling roots. It is unclear why deep planting should predispose trees to girdling root formation. Stem-girdling roots are known to form at transplant when lateral root growth is stimulated by the severance of major structural roots radiating from the stem base (Watson *et al.* 1990). This effect is particularly pronounced in maples whose laterals tend to emerge at right angles to their parent roots. Roots that grow vertically towards the soil surface following deep planting may be more likely to assume a girdling orientation, particularly if they tend to grow along the oxygen-rich interface between the deeply-planted trunk and the bulk soil.

Although deep-planted maples showed substantial girdling root development, it is not yet clear whether these girdling roots will persist and cause long-term damage to the trees. There is evidence to suggest that girdling roots of red maple, while numerous following transplant, may not persist long enough to cause serious damage (Watson *et al.* 1990). Follow-up measurements at our site will shed light on the degree to which early girdling root formation causes long term injury in red maple.

In conclusion, our results support the hypothesis that deep planting can predispose trees to transplant failure and girdling root formation. While the effects of deep-planting will certainly vary with species and site conditions, the few extra minutes needed to identify a tree's root collar and place it at grade could mean the difference between its survival and failure in the landscape.

References Cited

Broschat, T. 1995. Planting depth affects survival, root growth, nutrient content of transplanted pygmy date palms. Hortscience 30: 1031-32.

Gilman, E. F. and Grabosky, J. 2004. Mulch and planting depth affect live oak establishment. Journal of Arboriculture 30: 311-316.

Jacobs, K. A. and Johnson, G. R. 1996. Ornamental cherry tolerance of flooding and *Phytophthora* root rot. Hortscience 31(6): 988-991.

Kozlowski, T.T. and Pallardy, S.G. 1997. Physiology of Woody Plants, Second edition. Academic Press. San Diego, CA.

Kozlowski, T.T. 1985. Soil aeration, flooding, and tree growth. Journal of Arboriculture 11 (3): 85-96.

MacDonald, J.D., Costello, L.R., Lichter, J.M., and Quickert, D. 2004. Fill soil effects on soil aeration and tree growth. Journal of Arboriculture 30(1): 19-26.

Rowe, R.N. and Beardsell. 1973. Waterlogging of fruit trees. Horticultural Abstracts 43(9): 533-548.

Taiz, L. and Zeiger, E. 2002. Plant Physiology, Third edition. Sinauer Associates, Inc. Sunderland, MA.

Watson, G.W., Clark, S. and Johnson, K. 1990. Formation of girdling roots. Journal of Arboriculture 16(8): 197-202.

Wells, CE, Townsend, KS, Caldwell, JD JHam, DL, Sherwood, Michael and E. Thomas Smiley. 2006. Effects of planting depth on landscape tree survival and girdling root formation. Arboriculture and Urban Forestry 32: 303-309.

Wilcox, W.F. 1993. Incidence and severity of crown and root rots on four apple rootstocks following exposure to *Phytophthora* species and waterlogging. Journal of the America Society of Horticultural Science 118(1): 63-67.

Buried Trunks: How Deep Planting Affects Trunk Tissue, Adventitious Rooting and Tree Growth

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Abstract

Changes in soil grade are a common disruption and are thought to reduce the likelihood that trees will reach maturity and remain healthy and productive. In these studies, we examined the role of soil grade changes in tree growth, survival, and physiological function. Soil grade effects are primarily a result of two situations: when trees are planted too deeply in the landscape, or when building or road construction occurs near existing trees. In the first experiment described here, 15 container-grown Turkish hazelnut trees (*Corylus colurna*) were planted either at grade, 6 in (15 cm) below grade, or 12 in (30 cm) below grade into a silt loam soil. Trees were grown for five years and then root collars were excavated on two replicates of each below-ground treatment. All trees were subjected to flooding stress by being irrigated to soil saturation for approximately six weeks. Treatments did not affect trunk diameter growth during the six years of the experiment. One 12 in (30 cm) deep tree died after flooding stress. All trees experienced decline in photosynthetic rates during the flooding, but preliminary data suggest that this decline may have proceeded more slowly for trees with excavated root collars and those planted at grade. Implications for girdling roots are discussed. The second experiment continues a long-term evaluation of the effects of spreading C horizon fill soil over the root zones of white oak (*Quercus alba*) and sweetgum (*Liquidambar styraciflua*) trees. Root zones were either left uncovered, covered with 8 in (20 cm) of fill soil, or covered with fill soil and compacted. Within fill treatments, soils was either piled against trunks, or kept away from trunks. After approximately ten years, treatments have not affected trunk diameter growth. Bark of some oak trees appears to be decaying, but bark biopsies revealed only saprophytic fungi. Preliminary assessment of oak tree ring width indices indicate that trees continue to grow well.

Root-collar Excavations and Deeply Planted Turkish Hazelnut Trees

Nature of Work

We planted 15 container-grown (#15) Turkish hazelnuts (*Corylus colurna*) into one of three treatments: planted at grade, planted with the root collar 6" below grade, and planted 12" below grade (completely randomized design). The experiment was installed in 1999 in Blacksburg, Virginia in a Groseclose silt loam soil on a very slight slope. Trees were grown for 5 years and then two of each treatment randomly selected and their root collars excavated with a compressed air tool. Excavations created a bowl shape approximately extending 2 to 2.5 feet away from the trunk. Water stress, especially soil hypoxia, is thought to be a primary contributor to tree stress from deep planting. To increase the stress experienced by the experimental trees, a flooding regime was instituted for approximately 6 weeks in late summer of 2004. Soils were kept saturated through continuous micro-spray irrigation during this time. Photosynthesis was monitored approximately twice a week immediately before, during, and immediately after flooding using a Li-Cor 6400 gas exchange analyzer. Photosynthesis rates were measured on two leaves for each tree and averaged. Trunk caliper was monitored throughout the experiment.

Growth and Morphology

Deep planting did not affect caliper growth after 6 years (Figure 1). One 12" deep tree at the lower end of the slope died after flooding. Bark of excavated trees appeared unaffected by soil contact. No change in taper or swelling was observed. No

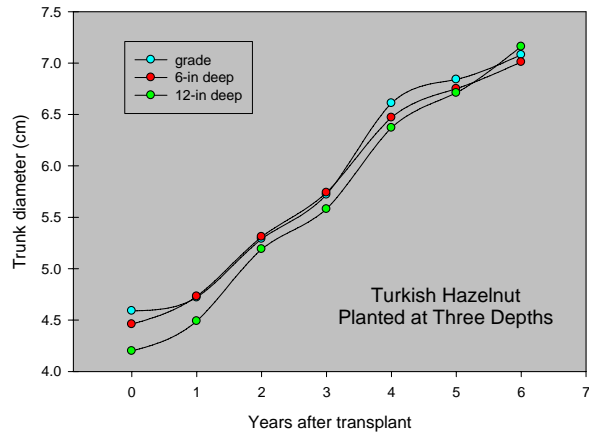


Figure 1. Caliper growth of Turkish hazelnuts from planting to 6 years. Each circle represents the mean of 5 trees.

adventitious roots were observed. One root on one 6" deep tree grew upwards adjacent to the trunk. More information on root architecture will be available at the conclusion of the long-term portion of this experiment.

Flooding Stress Test

Root collar excavations did appear to offer some short-term protection from the stress associated with flooding for both the 6" and 12" deep treatments. Photosynthesis rates appeared to be higher for excavated trees during the first week of flooding than for non-excavated trees. All trees eventually defoliated and photosynthesis measurements were therefore impossible. Consequently, no difference among treatments in "recovery" from flooding stress was observed.

Discussion

Deep planting did not impair establishment of Turkish hazelnuts in well-drained soil. There is no indication that deep planting has had a detrimental effect on tree growth during the 6-year period of this study. Turkish hazelnut is reputed to be intolerant of hypoxic soils, and, in fact, completely defoliated during the flooding stress test in our experiment. The death of one 12" deep tree in the lower part of the experimental plot suggests that wet soils brought about by the combination of deep planting and flooding may increase tree mortality. Deep planting may predispose trees to suffer from this type of stress by locating their root systems closer to the water table. Root collar excavations

may confer some benefit to deeply planted trees. However, the present experiment indicates such benefit is slight and does not address soil drainage issues that may be affected by placing roots in deeper soil layers. Further research would help clarify when excavating root collars is helpful, and why.

Long-term Effects of Soil-bark Contact in White Oak and Sweetgum

Nature of Work

Our second study concerned long-term evaluation of 154 white oaks (*Quercus alba*) and 293 sweetgum (*Liquidambar styraciflua*) buried under construction fill. Groups of trees in two stands in Patrick County, Virginia were subjected to one of three treatments: fill (F), 8" of C Horizon soil was placed around trees; compacted fill (CF), 8" of soil placed around trees and compacted with a sheep's foot compactor; and a control (C), no fill. An additional sub-treatment was imposed on F and CF trees—half of these trees had soil pulled away from the trunks (AWAY), and half had soil against trunks (AGAINST).

The oaks were planted in the late 70s and treatments imposed in 1996. These were not vigorous trees. The sweetgums were planted in the early 80s and treatments were applied in 1997. These trees were large and of average vigor. All treatments were kept weed free with herbicides. For a full description of the experimental design, see Day et al. 2001 (citation at end of report).

We are currently revisiting these trees with two objectives: 1) has any change in growth pattern occurred after nine years that was not evident after three? 2) how has the bark been affected by the AGAINST treatments when compared to the AWAY treatments? We are using tree ring analysis to give us a better understanding of growth patterns. Physical measurements of bark characteristics on the oak trees, including bark depth and softness, are underway. In addition, biopsies of 12 trees with buried trunks (6 of each species) were taken to attempt to isolate pathogenic fungi. Outer bark was removed with a sterile chisel, inner bark was sterilized and a sample taken with a cork borer and placed in a sterile jar. Samples were kept chilled and later placed on agar and fungi present were

grown out. The bark of these gum trees was excavated, probed, and visually assessed. There did not appear to be any affect on bark tissues of sweetgum trees from soil contact. Therefore we are focusing our energies on the oak trees and may revisit the gums at a later date.

Tree Growth

Initial tree ring assessment indicate that all oak trees experienced a growth rate increase after treatments were applied—presumably because competing herbaceous and woody plants were removed from all plots. Visual assessment indicates no difference between treatments in growth rate (Figure 2). Ring widths have been measured and cross-dated and a full analysis will be conducted in winter 2005-6. Diameter measurements in June 2005 indicate no changes in tree growth due to treatment for either oaks or gums (data not shown).



Figure 2. Growth rings through 2005 show no signs of tree decline in either controls or trees with compacted fill against the trunks. Arrows indicate when treatments were

Bark Response

Visually, bark on many F and CF oak trees appears blackened and rotting (Fig. 3). Biopsies indicated no fungi present on gum trees. Three fungi were identified on oak trees—all saprophytic. These included species of *Penicillium*, *Trichoderma*, and *Pestalotia*.



Figure 3. Buried trunk on white oak displaying signs of bark decay above the soil line. Insects are attracted to the bacterial flux.

Discussion

Saprophytic fungi are decomposing bark tissues. This decay has been quite slow and at this point there is no indication of corresponding decline in the trees. There has been no indication of pathogenic fungi to date. Because it is more difficult to confirm that something is NOT present, than it is to confirm its presence, we will expand our biopsy sampling. In another site or with another species, it is possible that decomposing bark may predispose a tree to infection by pathogens, but that is not indicated here.

Conclusions

Ten years ago, when we were planning the installation of the construction fill experiment described above, our conception of the affects on trees of buried root systems was very different from what it is today. We were very concerned that more than 20 cm of compacted fill soil might outright kill the white oak trees and make any treatments meaningless. We were concerned that underlying soil layers might remain waterlogged and anaerobic. We expected massive root die-offs that would manifest themselves as greatly increased soil respiration. With the Turkish hazelnut tree experiment, we expected rotted trunks and reduced growth. None of these events occurred and we have had to reevaluate our concepts of tree response to buried root systems.

The results of these experiments support the conceptual framework below. Further research will

either confirm, or require us to adjust, this framework as we develop Best Management Practices for buried trees.

- Damage to trees from deep planting or fill may occur very slowly. A buried tree may also be predisposed to damage from occasional stresses it could otherwise endure—in particular, years of exceptionally high rainfall. The long-term prognosis for any tree must include these considerations.
- Bottomland species are more likely to be tolerant of some of the conditions created by deep planting or burial by construction fill—for example, soil against the trunk and deep burials where adventitious roots may be an advantage.
- Roots are able to grow up into fill or existing soil of at least 8 inches, and probably much more. If this soil is of acceptable quality for tree roots, stress to trees should be relatively little *from this source*. This is not say that a tree with fill or deeply planted may not be stressed by other associated factors, such as wet trunks or disrupted drainage regimes.
- Construction fill is typically associated with other tree-damaging events, such as root severance and severe site compaction that may result in rapid tree decline, regardless of other damage.
- Bark on larger trees may be unaffected by soil contact (more likely in bottomland trees or trees on well-drained sites) or slowly begin to decay (upland trees). Long-term effects are not known.
- An accurate assessment of any deeply planted tree or fill-buried tree must include the following components: tree species, soil quality and layers, history of root severance, current drainage regimes.

Literature Cited

Day, S.D., J.R. Seiler, D.W. Smith and R.E. Kreh 2001. Overlaying compacted or uncompacted construction fill has 0 negative impact on white oak and sweetgum growth and physiology. Canadian Journal of Forest Research. 31:100-109.

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Root Collar Excavation for Urban Landscape Trees

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Abstract

Soil against the trunk of a tree is a serious problem that needs to be addressed by professional arborist and members of associated green industries. This problem leads to premature death or mechanical failure of many trees. While the best treatment is prevention, root collar excavation is a practical solution when prevention has not succeeded and should be done by arborists, landscapers and nurserymen whenever they are responsible for the health of the tree.

In the landscape, when there is soil against the trunk of a tree above the buttress roots, the trunk bark is more prone to infection by some diseases, infestation by certain insects, mechanical damage and physiological degradation. Any or all of these situations can lead to the premature decline and death of the tree or shrub.

There are many sources for the excess soil ranging from soil moved against the trunk in the nursery, to deep planting, to excess fill soil from nearby construction. The most common diseases associated with soil against the trunk are *Armillaria* and *Phytophthora* (Figure 1). These are both common root diseases that tend to kill trees much faster when they infect the root collar area. The best



Figure 1. *Phytophthora* canker on crab (*Malus*) associated with soil against the trunk.

known insect that preferentially attacks buried trunk is the pine root collar weevil. Soil it self may directly damage the trunk through girdling (girdling soil) when radial growth is inhibited by the soil. Soil can also hold large amounts of water against the bark. The majority of trees do not have bark that has evolved to resist this constant wetting.

In our early studies on this problem we found that a typical “professionally” planted tree in the ground for about two year, on average, had about five inch of soil and/or mulch above the buttress roots (Table 1). More recent studies have found that the problem is no less frequent and is not limited to North America (Figure 2).

In studies at the Bartlett Tree Research Laboratory, we have found rapid decline and death of white pine (*Pinus strobus*) with six inches of soil against the trunk. When willow oak (*Quercus phellos*) whips were planted six inches deep, mortality rates were 30% after four years. Control trees planted with their buttress roots at grade had a loss

Table 1. Average depth (inches) of soil and mulch above the buttress roots of professionally planted trees in landscapes about two years old.

	Charlotte	Long Island	Cape Cod
Ave. Soil	2.5	6.2	2.1
Ave. Mulch	2.5	0.7	3.3
% Girdling	20	14	13
Number	200	67	150



Figure 2. Soil above the buttress roots and against the trunk in Florence, Italy.

rate of about 5%. There is no question that soil against the trunk will lead to decline and premature death of many species of trees.

Our post-hurricane studies have found that trees with buried root collars were more susceptible to root related failure. Of the root related failures studied after hurricane Fran in the Raleigh area of North Carolina we found that 33% had soil above the buttress roots. Of similar size trees of the same species that survived the hurricane only 8% had soil in that area (Figure 3).

From these and other studies we conclude that having soil against the trunk above the buttress roots is not only a serious health risk for a tree but can also be a serious safety concern for all those who are around the tree.



Figure 3. Root failure of an elm in North Carolina associated with fill soil applied over thirty years prior to the hurricane related failure

Obviously the best solution for root collar problems is planting the tree properly and not moving soil against the trunk as it matures. We know that this is not what actually occurs in the landscape. So arborists are faced with the problem of correcting root collar problems on a daily basis. The solution that is available is root collar excavation, the removal of soil from above the buttress roots of the tree.

In experiments on Japanese black pine on Long Island where soil was removed or left against the trunk of declining tree we have found many dramatic improvements in tree condition on the excavated trees. In addition we found a significant reduction in the occurrence of winter injury on the excavated trees.

Since those early days in the study of the cause, occurrence, distribution and treatment of root collar problems, root collar excavation has become a standard treatment done by professional arborists worldwide. This treatment was originally done with shovels and small hand tools. When faced with larger excavations and multi-tree jobs, most arborists now prefer the use of supersonic air tools for excavation. These tools rapidly remove excess soil, leaving the exposed roots intact. Better decisions can be made on which roots to remove and which to leave when the trees are air excavated.

What Is Found Below The Ground: The Tree's Response to Deep Planting

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Abstract

Root excavations of thousands of trees over the past 14 years have shown consistent patterns of root growth and structure when trees are planted deep. These root growth patterns are discussed as well as the species specifics in root response to planting depth.

A full length paper will be posted when available.

Getting the Roots Right: The Structural Root Depth Best Management Practice

Gary Watson

The Morton Arboretum

Abstract

An industry-wide working group has developed a Best Management Practice (BMP) on structural root depth to aid in the interpretation and implementation of current knowledge in the industry as a guide for practicing green industry professionals. When planting, at least 2 structural roots should be within 1 to 3 inches of the soil surface, measured 3-4 inches from the trunk. For recently planted trees, the greatest long-term benefit will be achieved by replanting the tree at the proper depth. For larger, established trees, a practice being used regularly by arborists is to perform a root collar excavation to remove the excess soil in contact with the trunk.

An industry-wide working group was formed in 2003 to develop consensus regarding a complex national issue: tree decline and death in the landscape due to excessive amounts of soil over the root system.

This effort was coordinated by the Morton Arboretum in Chicago, with Dr. Gary Watson as Chairman. The working group currently includes representatives of ANLA, ISA, ASLA, PLANET, TCIA, and ASCA.

The working group has developed a Best Management Practice (BMP) to aid in the interpretation and implementation of current knowledge in the industry as a guide for practicing green industry professionals. This is a summary of the BMP published in the April 2005 issue of *Arborist News*, and in the December 2005 and January 2006 issues of *Ornamental Outlook*. The BMP can be summarized with this single statement and accompanying illustration (Figure 1).

What Are The Structural Roots?

The large woody roots giving characteristic form and shape to the root system. These woody roots serve as a conduit between the fine roots and the above-ground parts of the tree and must be in an environment that will keep them healthy.

Why at Least 2 Roots?

Because, single roots are sometimes found above the main root system.

Why 3-4 Inches From The Trunk?

Because, the trunk swelling below the graft union can be mistaken for the root flare. Probing approximately 3-4 inches away from the trunk will determine the true depth of the roots.

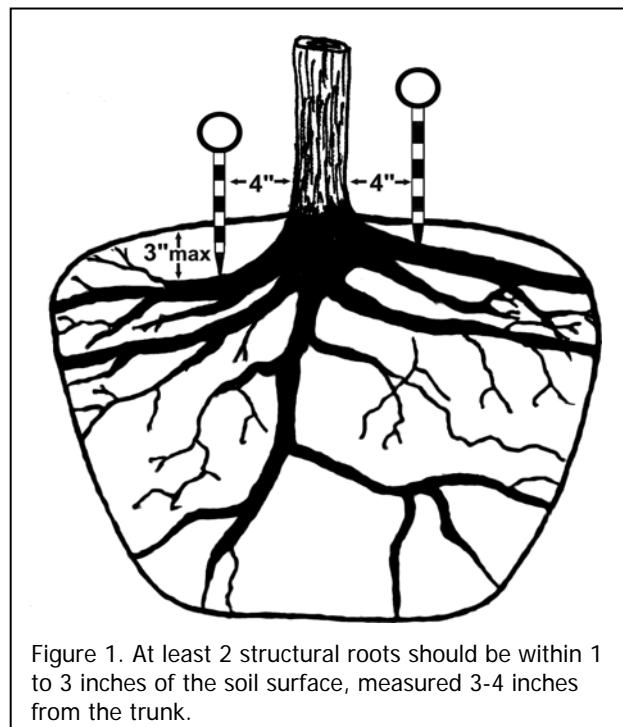
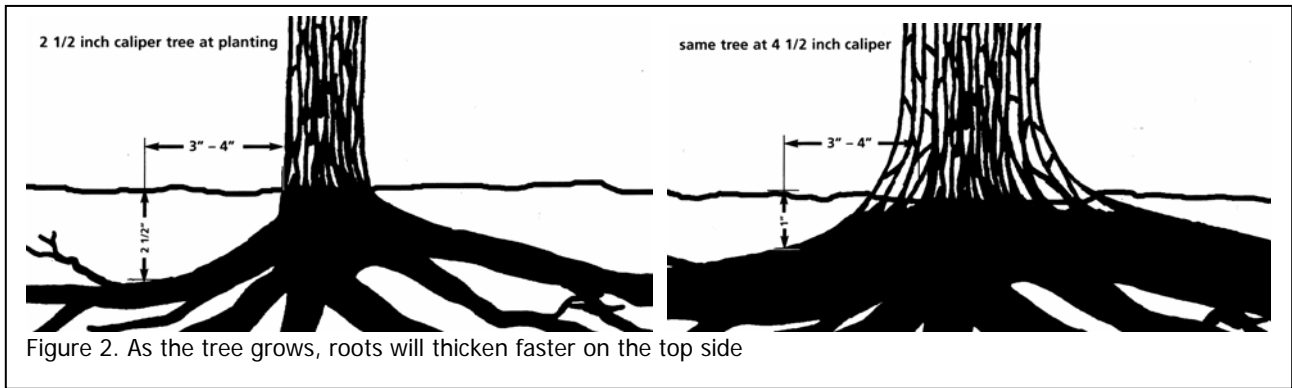


Figure 1. At least 2 structural roots should be within 1 to 3 inches of the soil surface, measured 3-4 inches from the trunk.



Why 1-3 Inches Deep?

Because, the roots will thicken faster on the top side and become closer to the surface over time (Figure 2). *Because*, the root system will be undersized if the roots are more than 3 inches deep in the root ball (Figure 3). *Because*, current nursery production methods often result in no roots in the first few inches. *Because*, roots (not the root flare) need to be deep enough to avoid exposing them. *Because*, trees should be able to survive with the structural roots up to 3 inches deep if the site is adequate. Don't blame the tree for site problems!

Presence of a visible root flare is a good indicator that the structural roots are just below the soil surface. A gap around the trunk at the soil line is a sure sign that the first roots are at least several inches below the soil surface. If neither of these signs is visible, more investigation is required. A surveyor's chaining pin, or similar tool, can be used to quickly and non-destructively probe for the roots.

Will There Be Exceptions?

Yes. For example, on trees with steeply angled roots, the roots may be deeper at 3-4 inches from the trunk.

If The Roots Are Too Deep In The Root Ball, You Can Reject The Tree!

The ANSI Z60.1 American Standard for Nursery Stock (2004) states that "Soil above the root flare shall not be included in the root ball depth measurement" If the resulting depth measurement of the root ball does not meet the minimum, the tree can be rejected.

If you accept the tree, plant it with the structural roots 1-3 inches below the soil surface. If soil is removed from the base of the trunk, the newly

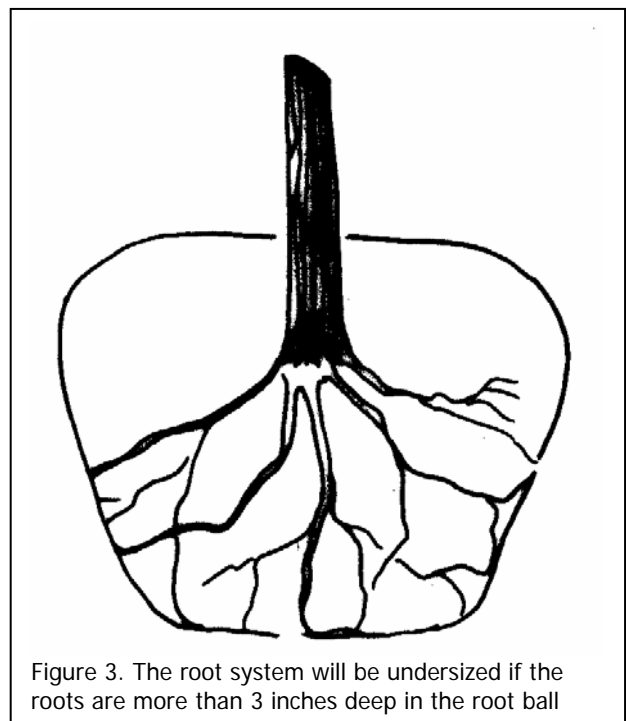
exposed tissue may be more susceptible to cold and sunscald damage. Exercise caution until more is known.

What About Trees That Are Already Planted?

There are many trees already planted in the landscape with the structural roots too deep. These trees are likely to have reduced vigor and shorter life spans if no remedial action is taken.

For recently planted trees (less than 2-3 months of warm soil for root growth), the greatest long-term benefit will be achieved by replanting the tree at the proper depth.

For larger, established trees, a practice being used regularly by arborists is to perform a root collar excavation to remove the excess soil in contact with the trunk. Removal of this soil will reduce



the possibility of basal and collar rot diseases, and improve aeration to the structural roots at lower depths. The excavated soil is sometimes replaced with well-aerated mulch or gravel.

What Next?

A much deeper understanding of the causes and effects of deep root systems is needed. Studies have been initiated by researchers around the country. As more information becomes available through both research and practical experience, the BMP will be updated.