Urban Forestry Outreach, Research & Extension Nursery and Lab

2015 Green Report

University of Minnesota Department of Forest Resources
www.trees.umn.edu

Department of FOREST RESOURCES

UNIVERSITY OF MINNESOTA

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Urban Forestry Outreach Research and Extension team, 2014-2015

Forestry Resources Academic Research Staff:

Gary R. Johnson, Professor/Extension Professor, Urban and Community Forestry

Chad P. Giblin, Research Fellow, Urban and Community Forestry

Dustin J. Ellis, Research Assistant, Urban and Community Forestry

Eric A. North, Research Fellow, Urban and Community Forestry

Sean A. Peterson, Research Technician and Tree Inspector Certification and Education

Valerie K. Price, Volunteer Programs Coordinator, Urban and Community Forestry

Ryan L. Murphy, Researcher Two, Urban and Community Forestry

Undergraduate Research Assistants:

Dane Bacher

Mike Bahe

Rebecca Bies

Brianna Egge

Andrea Fick

Melissa Lenius

Cassandra List

Mary Pederson

Nick Perry

Monica Randazzo

Teng Vang

Report Prepared By:

Monica Randazzo

Undergraduate Research Assistant, Nursery Manager

randa318@umn.edu

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Nursery Research Projects

Autumn 2015 In the UFore Nursery

Monica Randazzo

University of Minnesota, Department of Forest Resources

Harvesting Manchurian Ash

Seven Manchurian ash (*Fraxinus mandschurica*), a northern Asia species of ash that were selected from a Minnesota nursery and root-developed in our gravel beds before planting out were harvested from the nursery this fall. All trees were root-pruned in autumn of 2014 in anticipation of their transplanting. Manchurian ash has exhibited resistance to emerald ash borer (EAB) in studies conducted by Ohio State University; it is speculated this resistance may be due to their evolutionary development in the same part of the world where emerald ash borer is native, northern Asia.

Each tree was dug with a 44" tree spade after leaf fall and moved to various sites in the metropolitan area where EAB infestations and pressure for infestation are high. The intent is to monitor their health and progress over an extended period of time. Although EAB is considered a non-contributory insect, that is it has little to no preference for weakened versus healthy ash trees, we are also interested if there will be a higher infestation rate on a tolerant species that is weakened due to transplant shock.

Harvest of Gravel Bed Trees

Gravel beds are most beneficial for finishing tree root systems before planting out. When managed correctly, a single season in a gravel bed can greatly improve the root systems for most trees by encouraging growth of smaller, fibrous roots. This season in the gravel beds, we explored the potential of larger calipered species that we haven't used much in the past to determine whether they experienced the same benefits as other species and smaller trees.

Ostrya viginiana and *Carpinus caroliniana* were installed as 1.75 inch caliper trees in earlier summer. The goal was to develop better root systems before these trees were to be planted out in sidewalk planting sites in the metropolitan area in mid-autumn (October), and if so, would that impact the survival and performance of the trees long-term? What was soon learned was that the trees had produced noticeably improved root systems compared to the bare-root nursery stock we received in the spring.

In addition to the Ostrya and Carpinus, several ‘Valley Forge’ American elms (Ulmus americana) were installed in the beds in early June. These bare-rooted trees were donated by Davey Tree Experts. As with most elms, their root systems improved noticeably after a few weeks. The elms lifted from the gravel bed in the autumn were either stored in our coolers for overwintering, planted in the demonstration nursery or near the hoop house in a pleaching demonstration.

Pleaching Valley Forge American Elm

Fourteen of the Valley Forge American elms from the gravel bed were planted as an example of pleaching, an arboricultural practice in which trees or shrubs are grown and trained on an existing structure to create a green, verdant, arched pathway. The trees were all approximately .75” calipered, seven feet tall, bare rooted with light branching. Because elms grow quickly and are supple when younger, they are ideal for pleaching.

The elms were planted one to each of the poles ends of the larger of our two hoop houses, with their trunks and zip-tied to the curved poles. As the elms grow, they can be further tied to the poles until their growth forms the identical arch of the arched poles, creating a natural, green shade house that is perfect for out outdoor summer classes.

By the way, don’t attempt a project like this unless you have lots of time to prune on a very frequent basis, two-three times a year until it’s developed.

Long-term Nursery Management Tasks:

Root-Pruning Trees for Upcoming Harvests

In preparation for harvesting in the spring, the following trees were root-pruned: cockspur hawthorne, red pine, and 'Heritage' oaks. Root pruning is a common practice for developing a more compact, fibrous root system that results in a transplanted soil ball containing a higher percentage of fine roots and a shorter transplant shock period.

Using a tiling spade, roots are severed in a radius from the stem that is determined by the plant's size. The American Standard for Nursery Stock (ANSI Z60.1) is used to calculate this radius and is a function of whether the plant is deciduous or evergreen, a tree or a shrub, its height or its stem caliper. The ANSI Z60.1 is available on-line.

Because the soil in the autumn is moist and warm, especially if there's a layer of mulch over the root system, the roots have ample time to develop a more compact, fibrous root system before they are transplanted the following spring.

Stem Protection

All of our nursery trees require stem protection due to rabbit and vole damage in the winter, so each tree received a cylinder of either ½" or ¼" hardware cloth around the trunk. Some of the smaller trees received a complete wire enclosure. The trunk protection cylinders ranged between 24-36 inches high. Wire protection provides the best protection against animal damage while not blocking sunlight from reaching the photosynthetic bark. For this reason, the wire cylinders may be left on year 'round.

Tree Identification and Tagging

To better organize and record all relevant information about the nursery trees, a spreadsheet and map was created that included the detailed data for each individual tree. This data includes species, caliper, year it was planted, the root type (e.g., containerized or bare root), its location and any other relevant information that we believe would be useful to visitors and users of the nursery.

Each tree is linked via an ID number and once the specific information is organized it is uploaded to a WhizTag. The WhizTag, attached to each tree via a zip tie, may be scanned by a smart phone or a tablet that contains the appropriate app and allows the visitor to view all information relevant to the tree.

Nursery String Decomposition Study

Gary Johnson, Principle Investigator

Monica Randazzo, Undergraduate Research Assistant and Outreach Nursery Manager

University of Minnesota, Department of Forest Resources

Research Question: How long does it take for various ropes and twines that are commonly used by tree nurseries to decompose?

Background

There is a notable discrepancy in the time required for the complete decomposition of strings and ropes commonly used to tie up branches or secure wire baskets to tree trunks in production nurseries. At one extreme, tree installation professionals maintain the strings and ropes decompose "rapidly," easily before the end of the growing season. At the other extreme, manufacturers claim useful lives ranging from two to seven years.

Study area

A search of the research literature yielded no experimental study that simulated the use of twines and ropes in nurseries and their subsequent rates of decomposition upon installation in landscapes. The use of the common twines and ropes and in particular the retention of them on the installed landscape trees and shrubs has been a point of controversy between those that grow and install the trees and those that maintain the trees after installation. Claims that nursery strings and twines are indispensable for the stability of the trees have been anecdotal with only limited evidence to support those claims. Premature tree losses due to retained strings have likewise only been supported by anecdotal reports and limited observations.

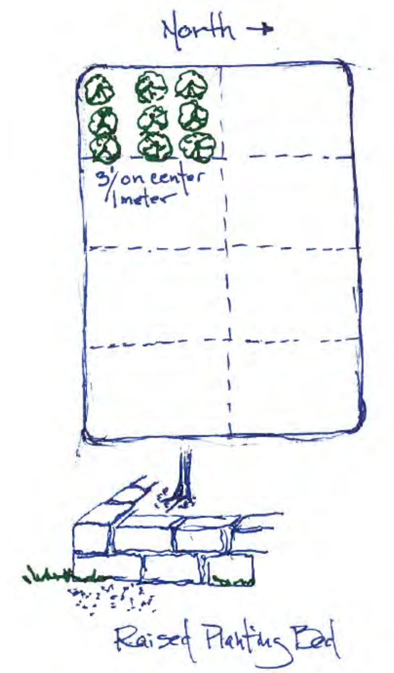
To determine the range of time required to reasonably decompose the commonly used strings and ropes used by the tree nursery industry, a study was designed and installed at the Urban Forestry Outreach Research and Extension (UFore) nursery at the University of Minnesota Twin Cities campus in Saint Paul. The design and installation of the study was performed by the principle investigator with assistance provided by undergraduate research assistants and other UFore employees. The experiment was designed to eliminate as much of the bias as possible, yet still emulate a typical landscape situation.

METHODOLOGY

The Design

The experimental design was a randomized block design. Ninety "tree trunks" were used for this study, provided by five different tree species – "clump" river birch (Betula nigra), white pine (Pinus strobus), quaking aspen (Populus tremuloides), "clump" 'Royal Frost' birch (Betula, cross between 'Crimson Frost' and 'Whitespire') and 'Windover Gold' ginkgo (Ginkgo biloba 'Windover Gold'). All trees were installed in a raised planting bed with a 76 cm depth of sand-amended clay loam soil at the UFore nursery. No tree crops had been grown in the bed for more than 12 months prior to the installation of the trees in this study. The trees were randomly assigned planting positions in eight blocks, each consisting of three rows with three trees in each row and planted at (approximate) 1.0 meter, on center spacing.

All trees were purchased from a Minnesota retail nursery, containerized (no. 3 containers) at time of purchase. All trees were severely pot-bound, therefore, the root systems were "boxed" to remove all encircling roots and excess soil over the first main order roots was removed. The trees were planted in late autumn of 2014 and the root zones were mulched with composted wood chips as typical for a landscape installation. Trees were individually watered as needed during the growing season until October 19, when irrigation was terminated.



Design of raised planting bed

Ropes and Twines

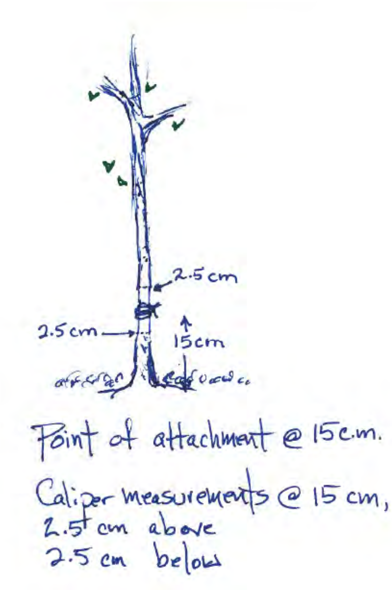
Six different twines or ropes were used as treatment variables in this experiment:

- Bright orange thermoplastic polymer "baling" twine
- Jute rope, untreated, 3-ply
- Jute rope, green treated with copper napthalate, 3-ply
- Sisal rope, untreated, 3-ply
- Sisal twine, untreated, 1-ply
- Sisal rope, green treated with copper napthalate, 2-ply

Jute twines and ropes are made from the fibers of the plant genus Corchorus.
Sisal twines and ropes are made from the fibers of the plant Agave sisalana.
Both plant fibers are valued for their strength, flexibility and breaking strength.
Twines were defined as any one of the materials, no larger than 1-ply.
Ropes were defined as any one of the materials, larger than 1-ply.

The six versions of twine or rope were selected based on several random visits to twin cities tree nurseries and garden centers, assessing the types and strengths (number of plys) most commonly used. Each twine or rope was applied to the trunk of 15 (aka, replications) randomly selected trees.

To eliminate the potential effects of excessive moisture and restricted light as well as to comply with best



Placement of material on stem

planting practices that advocate not burying tree trunks at planting time, the various twines or ropes were attached to the stems at a point 15 cm above the first main order root which was located at ground surface level. Each material was wrapped tightly by hand around the stem and double-knotted. All installation was performed by the principle investigator.

Prior to material attachment, the diameter of the stem at 15 cm above ground (aka, trunk caliper) was measured, recorded and entered in a spread sheet. Additionally, in an effort to determine if any stem physiological changes might occur, two other stem diameter measurements were taken: one at a point 2.5 cm above the top wrap of twine or rope and one at a point 2.5 cm below the lowest wrap of twine or rope. All measurements were determined with an electronic digital calipers, recorded to the nearest one-hundredth of a centimeter and entered in a spread sheet. All material installation and measurements began on June 29 and was completed by July 2, 2015.

Data Collection Protocol

An arbitrary inspection interval of four weeks (+/- 2-4 days) as long as weather permitted was established. Data collection was halted during the winter months when snow buried the materials.

Data collected at each inspection interval was limited to an assessment of the extent of decomposition of the materials by performing a "pull-test," literally pulling on a tail of the twine or rope to determine if it had reached the point of strength loss due to decomposition. Second, if any materials had been imbedded by the tree trunks, this was noted and photographed.

Imbedded material in stem

RESULTS

Results to Date

As of the December data collection date, no materials had decomposed enough to fail the "pull test."

By the September inspection date, twenty-six (26) stems has some degree of compression due to the attached twine or ropes. Several had the materials almost completely imbedded in the stems. The baling twine and the 3-ply green sisal were the materials most commonly causing stem compression or had been imbedded. No assessment of the impacts on tree health or condition were made in 2015.

University of Minnesota Elm Selection Program

Elm Collection Activities - 2015 Report

Dane Bacher, Melissa Lenius, Ryan Murphy and Chad Giblin

University of Minnesota, Department of Forest Resources

Introduction

Grafted Elm material

The UMN Elm Selection Program is dedicated to collecting, cloning and screening Minnesota native elm trees for resistance to Dutch elm disease (DED), a vascular wilt disease caused by the fungus *Ophiostoma ulmi* and *Ophiostoma novo-ulmi*. The program also works to find more efficient methods for both propagating and screening elms with potential resistance to DED. This is a joint effort between Professors Robert Blanchette in the Department of Plant Pathology and Gary Johnson in the Department of Forest Resources at University of Minnesota. The UMN Elm Selection Program has been making great steps toward finding a native Minnesota elm cultivar with tolerance to DED. Native cultivars are expected to show increased fitness across the northern United States. Since the arrival of the Dutch elm disease fungus *O. ulmi* in Minnesota, and the more aggressive strain *O. novo-ulmi*, millions of American elms (*Ulmus americana*), red elms (*U. rubra*), and rock elms (*U. thomasii*) have been lost to the disease.

American elm is a particularly hardy and resilient tree. It has the ability to tolerate the stresses of an urban environment making it an excellent choice for planting along boulevards and in parks. Elm also plays an important ecological role in Minnesota's forests as a dominant species in many cover types. Trees that survived in areas where the disease had a significant impact are of particular interest. With the help of State Park managers and staff as well as arborists, urban foresters and private residents from throughout the state, we have been able to locate and identify large trees that may have inherent tolerance to the disease. However, these trees need to be propagated and rigorously tested by means of inoculation to determine if this is the case. Identification, propagation, and screening takes a significant amount of time, and for this program to be successful, long term research is essential. Continued support from important stakeholders in the state, such as Minnesota State Parks, city foresters, and private land owners will help make the UMN Elm Selection Program a success.

Greenhouse grown Elm trees

Elm scions were cleft grafted on wild-type American (*U. americana*) elm or Siberian elm (*U. pumila*) rootstocks or used for making rooted cuttings. Cleft grafting is an easy form of grafting and involves first preparing the rootstock by pruning 15 cm above the roots and making a deep cleft in the top center of the cut stem. Next, a scion is trimmed to create a wedge at the basal end of the scion. When inserting the scion material into the cleft, the cambium of the scion is aligned with the cambium of the root stock. The graft is secured with a rubber band strap and sealed with laboratory film, to be removed once callus material is formed at the union. Grafting allows for the production of new growth quickly that can be used either for cuttings production or the creation of additional grafted clonal selections in the future.

Propagation during the winter and spring of 2015 occurred at the Plant Growth Facilities greenhouses located at the University of Minnesota. Successfully grafted elms and rooted cuttings were categorized and moved to the University of Minnesota's Urban Forestry Outreach, Research & Extension Nursery.

Research to date has yet to produce results on the level of resistance, because the trees are not yet large enough to perform field inoculations with the pathogen *O. novo-ulmi.* One red elm selection obtained from Lake Shetek (MNT 0410) will be used in a 2016 greenhouse inoculation trial. Greenhouse inoculations are a tool for preliminarily assessing if a genotype of interest has some tolerance to DED. Trees destined for field inoculation trials will need at least two growing seasons before they are of size to reliably test. For proper statistical analysis of each genotype a minimum of six clones are needed. Additional replicates will need to be made from the initial clones obtained in 2015. This means that the majority of the genotypes collected in 2015 will be field inoculated no sooner than 2018. However, a select number of genotypes may have enough clones for a greenhouse inoculation in 2017.

The goal of the UMN Selection Program is to obtain a diverse selection of native elms from Minnesota that are genetically different but all show resistance to DED and have optimal growth and hardiness characteristics to fit for commercial production and to reintroduce the beautiful native elms to the Minnesota landscapes. Identification of elms with superior tolerance to *O. novo-ulmi* will also give Minnesota foresters the opportunity to reintroduce elms to our native forests.

Potted Elm grafts in green house

Tree Number	Address	City	Variety	DBH (in)
MNT 0400	Lower Campground in Camden	Camden State Park	U. rubra	10.5
MNT 0401	Lower Campground in Camden	Camden State Park	U. rubra	25.5
MNT 0318	Lower Campground in Camden	Camden State Park	U. americana	30.5
MNT 0319	Lower Campground in Camden	Camden State Park	U. americana	24
MNT 0402	Lower Campground in Camden	Camden State Park	U. rubra	21.5
MNT 0320	Lower Campground in Camden	Camden State Park	U. americana	27.5
MNT 0321	Camden Park South	Camden State Park	U. americana	14.75
MNT 0338	Camden Park South	Camden State Park	U. americana	17
MNT 0339	Camden Park South	Camden State Park	U. americana	15
MNT 0340	Camden Park South	Camden State Park	U. americana	N/A
MNT 0341	Camden Park South	Camden State Park	U. americana	25
MNT 0372	ND (hill by tracks)	Camden State Park	U. americana	26
MNT 0392	Across TH 61 from 1015 N. Lakeshore Dr.	Lake City	U. americana	36.1
MNT 0393	620 S. Lakeshore Dr.	Lake City	U. americana	44.9
MNT 0394	418 S. Prairie St.	Lake City	U. americana	39.4
MNT 0405	Loon Island in Lake Shetek State Park	Lake Shetek State Park	U. rubra	12.5
MNT 0406	Loon Island in Lake Shetek State Park	Lake Shetek State Park	U. rubra	19.1
MNT 0365	Loon Island in Lake Shetek State Park	Lake Shetek State Park	U. americana	19.5
MNT 0407	Loon Island in Lake Shetek State Park	Lake Shetek State Park	U. rubra	23.8
MNT 0366	Loon Island in Lake Shetek State Park	Lake Shetek State Park	U. americana	21
MNT 0367	Loon Island in Lake Shetek State Park	Lake Shetek State Park	U. americana	24
MNT 0369	Causeway to Loon Island	Lake Shetek State Park	U. americana	15
MNT 0373	Boat Landing Near Loon Island in Shetek	Lake Shetek State Park	U. americana	15
MNT 0374	Boat Landing Near Loon Island in Shetek	Lake Shetek State Park	U. americana	27
MNT 0410	Group Camp in Lake Shetek State Park	Lake Shetek State Park	U. rubra	12
MNT 0403	808 Willow St.	Mankato	U. rubra	39
MNT 0350	201 N Broad St.	Mankato	U. americana	33
MNT 0351	119 S 4th St.	Mankato	U. americana	30
MNT 0353	1223 Highland Ave.	Mankato	U. americana	42
MNT 0354	120 Ellis Ave.	Mankato	U. americana	30
MNT 0404	526 Carney Ave.	Mankato	U. rubra	30
MNT 0355	410 Hubbell Ave.	Mankato	U. americana	36
MNT 0362	110 Fulton St.	Mankato	U. americana	39
MNT 0375	Legion Field	Marshall	U. americana	36.5
MNT 0376	Legion Field	Marshall	U. americana	37.5
MNT 0377	Legion Field	Marshall	U. americana	26
MNT 0378	Legion Field	Marshall	U. americana	24
MNT 0379	Legion Field	Marshall	U. americana	23.5
MNT 0386	Legion Field	Marshall	U. americana	26
MNT 0387	Legion Field	Marshall	U. americana	28
MNT 0388	Legion Field	Marshall	U. americana	33
MNT 0390	Legion Field	Marshall	U. americana	N/A
MNT 0399	Plymouth, near Carlson Pkwy	Plymouth	U. americana	N/A
MNT 0347	1080 Dayton Ave.	Saint Paul	U. americana	56
MNT 0349	2273 Edgecumbe Rd	Saint Paul	U. americana	38
MNT 0364	1863 Lincoln Ave.	Saint Paul	U. americana	37
MNT 0391	1731 Princeton Ave.	Saint Paul	U. americana	N/A
MNT 0396	1811 Summit Ave.	Saint Paul	U. americana	N/A
MNT 0398	370 Woodlawn Ave.	Saint Paul	U. americana	41

Table 1. UMN Elm Selection Program – City and State Park Collections 2015

MNT 0394 – Ulmus americana (American elm), located on 418 S. Prairie St. Lake City, MN

MNT 0393 – Ulmus americana (American elm) located on 620 S. Lakeshore Dr. Lake City, MN

MNT 0362 – Ulmus americana (American elm), located on 110 Fulton Street, Mankato, MN

MNT 0354 – Ulmus americana (American elm), located on 120 Ellis Ave. Mankato, MN

Ulmus americana (American elm), located in Legion Field, Marshall, MN

MNT 0321 - Ulmus americana (American elm), located in the Lower Campground at Camden State Park

MNT 0400 - Ulmus americana (American elm), located in the Lower Campground at Camden State Park

MNT 0369 - Ulmus americana (American elm) found along the causeway to Loon Island, Lake Shetek State Park

MNT 0410 - Ulmus rubra (red elm) located at the group camp in Lake Shetek State Park

MNT 0407 - Ulmus rubra (red elm) located on Loon Island in Lake Shetek State Park

Cloned Ulmus americana (American elm) selection collected at Lake Shetek State Park

Cloned Ulmus rubra (red elm) selection collected at Lake Shetek State Park

Cloned Ulmus americana (American elm) selection collected on 620 S. Prairie St., MN

Cloned Ulmus Rubra (Red elm) selection collected on 808 Willow St. Mankato, MN

Preliminary Data for Tree Tube and POTP Organic Matter Amendment Research Project

Trout Brook Nature Preserve Grow Tube Amendment Study

Melissa Lenius and Chad Giblin

Department of Forest Resources - University of Minnesota

Executive Summary

The City of Saint Paul, MN is interested in increasing urban hardwood canopy cover using planting stock alternative to traditional containerized or balled and burlapped. Seedlings are an available option. Unfortunately, hardwood tree seedlings are especially susceptible to animal browse (Sharrow, 2001).Tree shelters, or tree tubes effectively protect seedlings from all types of browse (Shea 1998). Tree shelters also provide a microclimate that produce higher height and diameter growth (Sharrow 2001).

An open hillside at the new Trout Brook Nature Preserve presents itself as an excellent opportunity to monitor the effects of different tube types, tube colors, and tube heights on bur oak growth, establishment and survivability. Preliminary work using small seedlings and tree tubes or shelters dates back to the early 1990s with very successful bur oak (*Quercus macrocarpa)* plantings at Central High School and more recently with bur oak regeneration in tree tubes at Newell Park in 2013.

In this study a Test Product from Precision Organics (POTP) will be incorporated into the plantings at two different rates in a factorial design with each tube type.

Image 1. (Google Earth) Tube study being conducted within the outlined area between the car lot and the Trout Brook Nature Preserve parking area.

Image 2. Hillside in Trout Brook Nature Preserve where study is being conducted.

to the study. Using SPSS statistical analysis software, Chi-Square tests were performed to determine the relationship between tube treatment and mortality and amendment treatment and mortality for the first and second year of the study.

Tube Treatment and Mortality

A 7.9% mortality rate was experienced after the first year. No significant relationship was found between tube treatment type and mortality rate. Chi-Square (χ^2) for tree mortality related to tube treatment was χ^2 (5, n = 139) = 4.825, p = 0.438. Although no significance was found, trees treated with the 6ft Tubex Tubes experienced the highest rate of mortality, at 36.4% of total mortality. The 5ft Tubex Tube experienced zero mortality, while the 6ft Plantra SunFlex Tube experienced the second lowest mortality rate at 9.1%. The 4ft Plantra SunFlex Tube, 4ft Tubex Tube, and 5ft Plantra SunFlex Tube all accounted for 18.2% of total mortality (Figure 1).

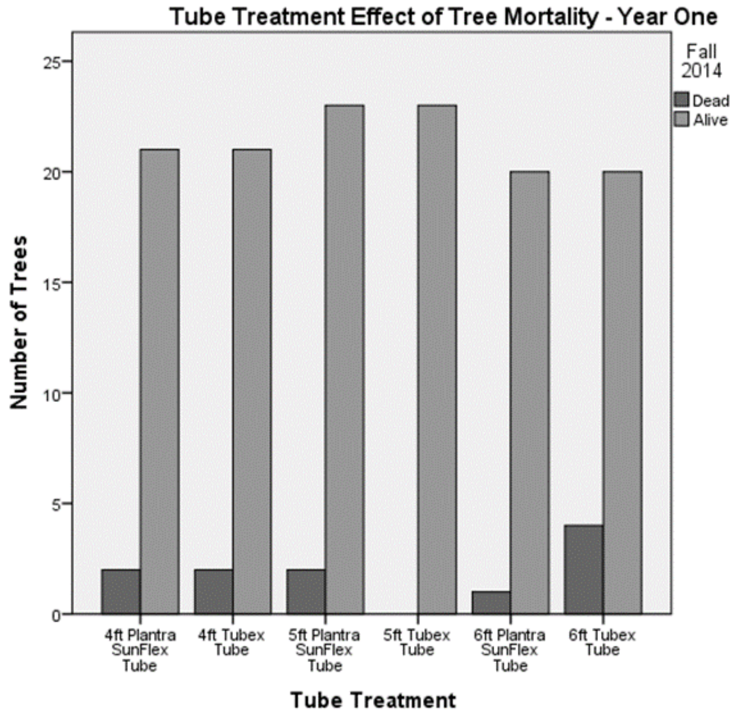


Figure 1. Number of trees that faced mortality compared to tube treatment during the first year of the study.

The same test was applied the following year comparing tube treatment and mortality. A 4.7% mortality rate was experienced. No significant relationship was found. χ^2(5, n = 128) = 2.313, p = 0.804. Again, the 6ft Tubex Tube experienced the highest amount of mortality at 33.3% of the total. The 4ft Plantra SunFlex Tube, 5ft Plantra SunFlex Tube, 5ft Tubex Tube, and the 6ft Plantra SunFlex Tube experienced the same rate of mortality at 16.7% of the total. The 4ft Tubex Tube experienced zero percent of total mortality the second year of the study (Figure 2).

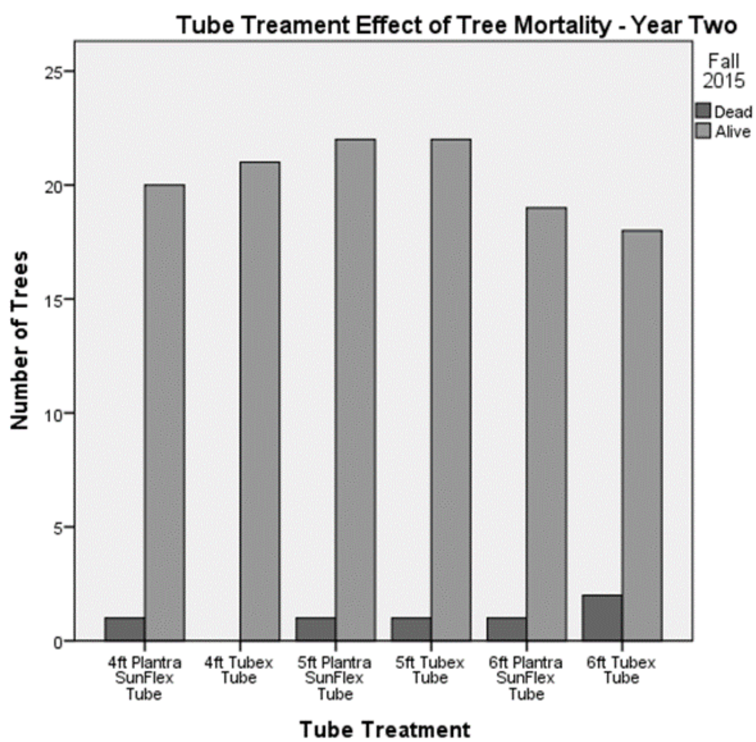


Figure 2. Number of trees that faced mortality compared with tube treatment during the second year of the study.

Materials and Methods

In May, 2014, one hundred and forty-four bur oak seedlings were planted into a completely randomized, two-way factorial design. Six different types of grow tubes are being used in this study; 6 ft Plantra Sunflex Tube, 5 ft Plantra SunFlex Tube, 4 ft Plantra SunFlex Tube, 6ft Tubex (vented) Tube, 5ft Tubex (vented) Tube, and 4ft Tubex (vented) Tube. Three different amendment rates were used; 'Full Rate' (3 cups), 'Half Rate' (1.5 cups), and 'No Amendment'.

Each factorial combination was been replicated eight times and was randomly assigned in the research plot at Trout Brook in one of 144 available planting locations. At planting, trees were two-year old (2-0) seedlings grown in air pruning propagation trays at the University of Minnesota. Seed was collected from a mature stand of bur oak at Newell Park in Saint Paul, MN. Seedlings were graded by basal diameter, height, and number of leaves to ensure equal distribution of all sizes and grades across all treatments.

All trees were planted into 8 in. wide by 4-6 in. deep hand-dug holes and assigned an individual identification number to be tracked throughout the study. Organic matter treatments were uniformly incorporated into existing backfill at planting. All tube treatments were installed according to instructions and materials supplied by the manufacturer at the time of planting. All trees were well-watered at planting and received a uniform application of wood mulch around the tube. After-care of trees will follow standard operating procedures as specified by the Forestry Unit with the City of Saint Paul.

Subsequent data collection will be performed annually by University of Minnesota staff for the first five years of the study, beginning fall 2014, and will consist of the following variables: mortality - years 1, 3 and 5, tree height - years 1, 3 and 5, stem taper - year 5, stem caliper year 5. After the initial five year period, data will be collected at five year intervals and will consist of the same variables collected during the first five years.

Image 3. University of MN undergraduate research assistants collecting tube study data, spring 2015

Preliminary Results

In total 139 trees were available for data collection. Due to unforeseen circumstances, six replicates were left out of the study. One 4ft Plantra Sunflex Tube with 'No Amendment', One 4ft Tubex Tube with 'No Amendment', One 5ft Tubex Tube with 'Full Rate, Two 6ft Plantra Sunflex Tubes with 'Full Rate' and one 6ft Plantra Sunflex Tube at 'Half Rate'. One extra 5ft Plantra Sunflex Tube with full rate amendment was added

Amendment Rates and Mortality

The same test was used to compare the relationship between mortality rates and rates of amendment. The first year, no significant relationships were found between mortality and amendment rate. $\chi^2(2, n = 139) = 0.228$, $p = 0.892$. Of the 7.9% trees that faced mortality, oaks treated with no amendment and those treated with a full rate both faced a 36.4% mortality, while oaks treated with half rates experienced a 27.3% mortality rate (Figure 3).

The second year, no significant relationships were found between mortality and amendment rate, $\chi^2(2, n = 128) = 0.003$, $p = 0.998$. Of the 4.7% of trees that faced mortality, one third consisted of each amendment rate (Figure 4).

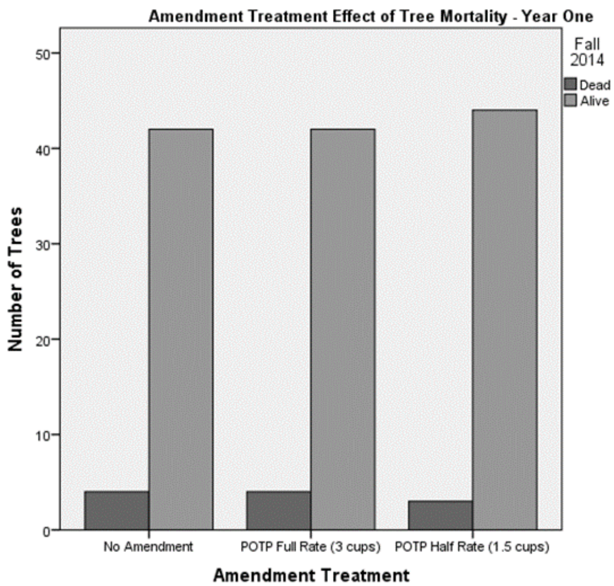


Figure 3. Number of trees that faced mortality compared to amendment treatment during the first year of the study

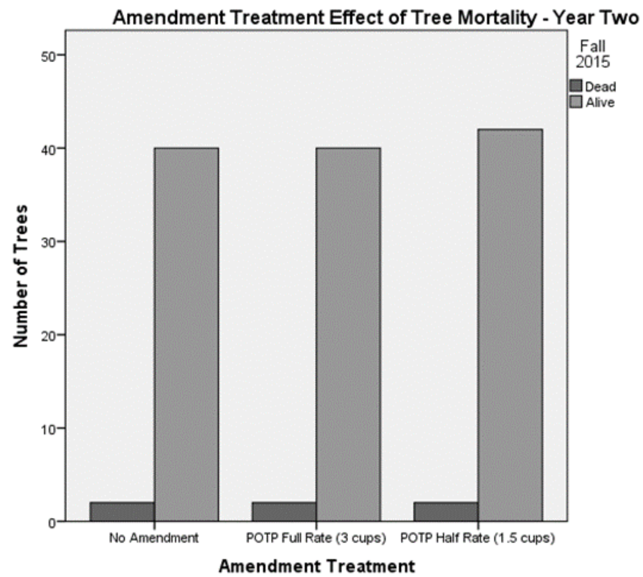


Figure 4. Number of trees that faced mortality compared to amendment treatment during the second year of the study

Community Outreach and Research Projects

Community Outreach and Citizen Education and Engagement

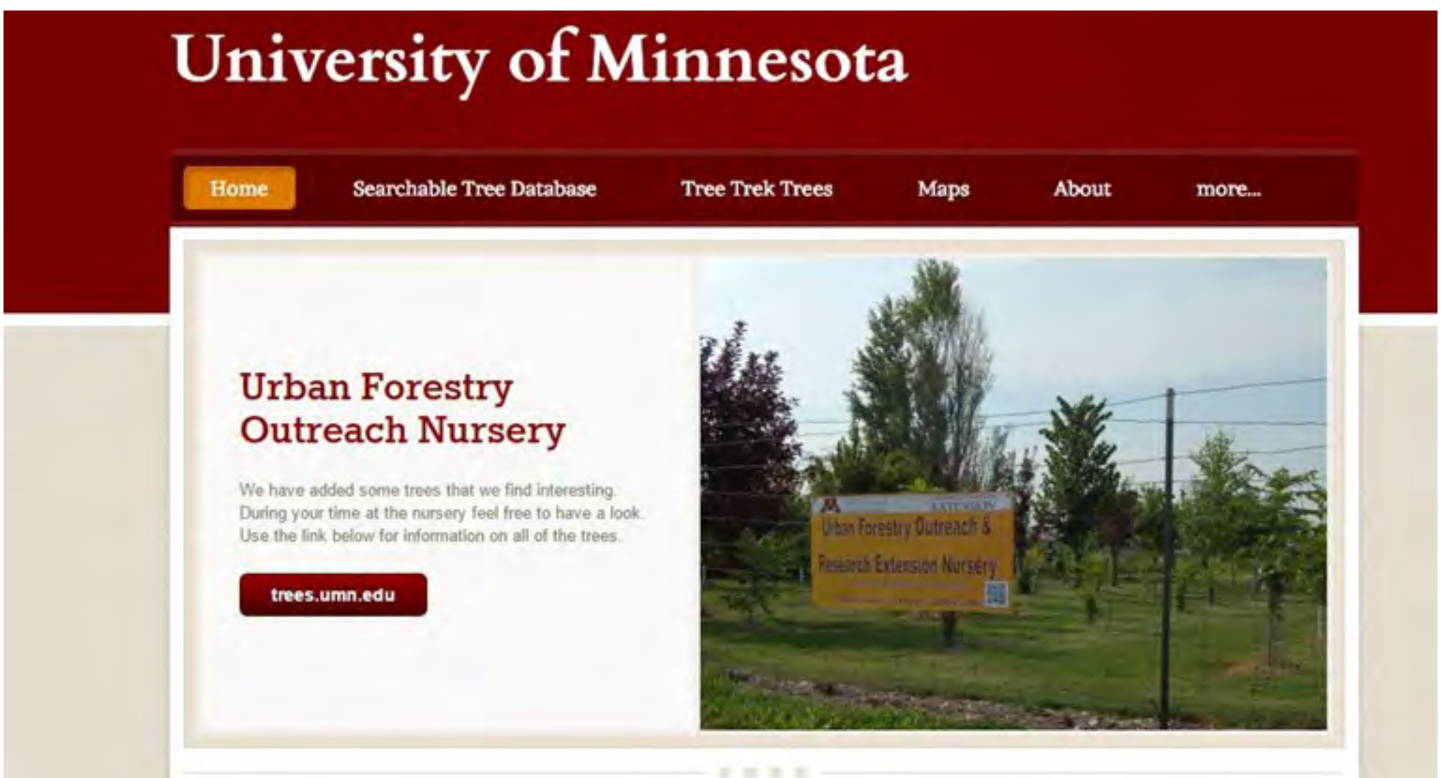
Dustin Ellis

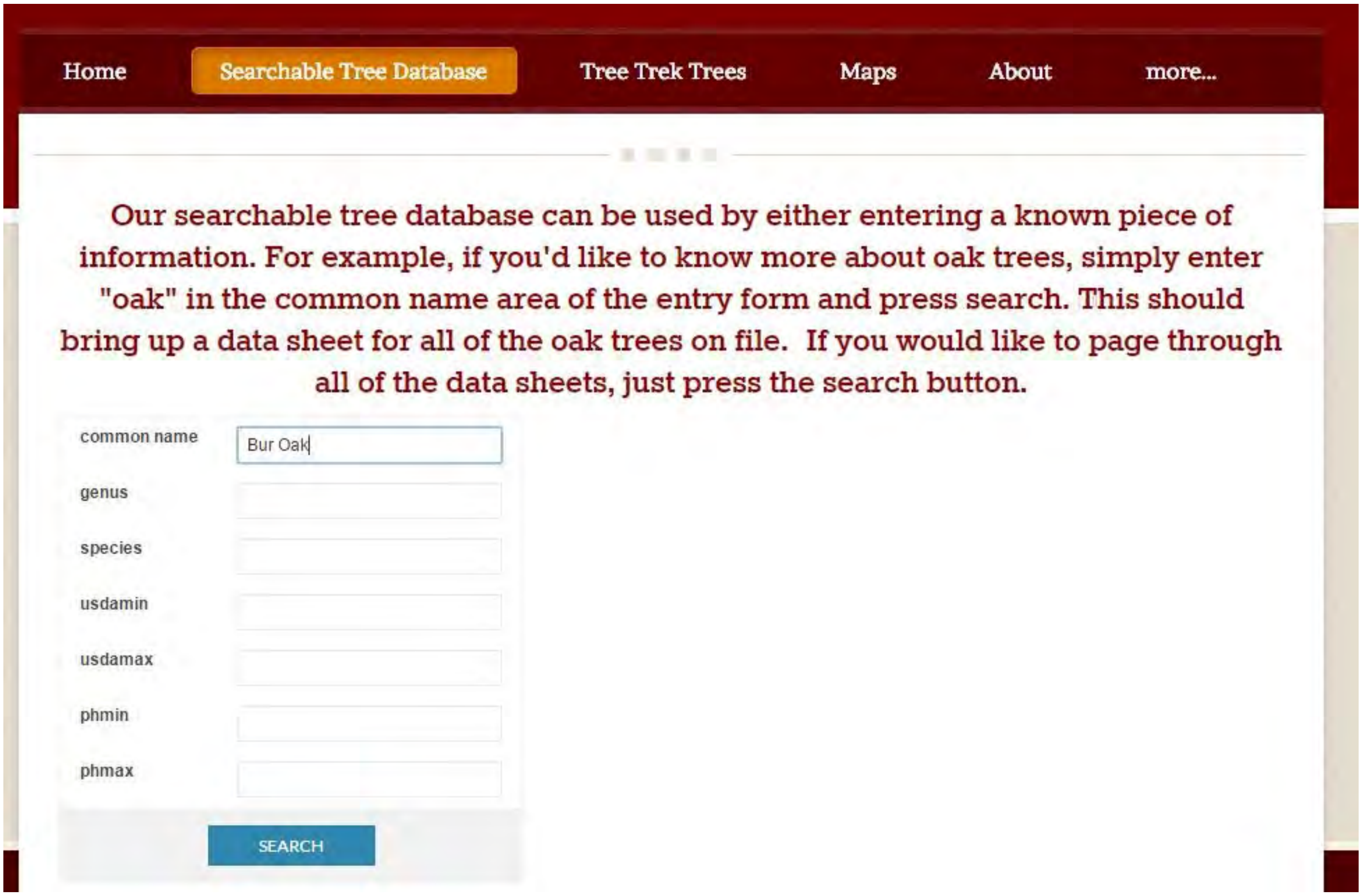
Department of Forest Resources - University of Minnesota

The year of 2015 was as productive of year as one can hope for. Many projects were started, expanded and improved, or came to completion.

The projects that I continue to promote and provide either assistance or instruction on are the Minnesota DNR Tree Inspector Program, Tree Treks, the Shade Tree Short Course (STSC) House of Horrors, and the Minnesota LCCMR Grant. In working with the LCCMR grant, I have been involved with the production of the RFP and application for communities, and am currently working with communities to identify applicable programming that is suitable for their grant application. We continue to act as the instructors for the Tree Inspector program. This includes traveling and producing workshops in communities throughout greater Minnesota. The Tree Trek program is ever expanding, this year we added 3 new communities and added trees to 2 existing Tree Treks. The STSC House of Horrors production involves creating new interactive displays that convey urban forestry practices or techniques in a way that is accessible to all who attend. The most impressive project in my opinion was the roll out of the Searchable Tree Database. The database is Minnesota centric and allows for any user to access information regarding a wide range of trees commonly found in Minnesota. The database can be found at ufoutreach.weebly.com. Once the user arrives at the home page, they can click on the link provided for the database.

This will then bring the user to the page as shown here.





Once the user has typed the tree's common name, genera, or species and clicked on the "search" tab, the browser will then direct to the tree data page (as shown below). This will project continue to be perfected as new trees are added.

Minnesota Tree Care Advocate

Valerie McClannahan

Department of Forest Resources - University of Minnesota

Minnesota Tree Care Advocate is an organization of University of Minnesota-trained volunteers throughout the state all dedicated to community forestry. It is currently comprised of three community forestry programs including Minnesota Tree Care Advisor, Minnesota Tree Steward, and Minnesota Citizen Pruner. Minnesota Tree Care Advocate works to educate members about the benefits and best management practices of their community's urban forest so that they in turn can volunteer in their neighborhoods and community.

The Minnesota Tree Care Advisor program, founded in 1993, aids in the development of environmental stewards through education and the promotion of volunteerism. TCA Volunteers provide communities throughout the state with a valuable pool of educated stewards to support and enhance our urban and community forests.

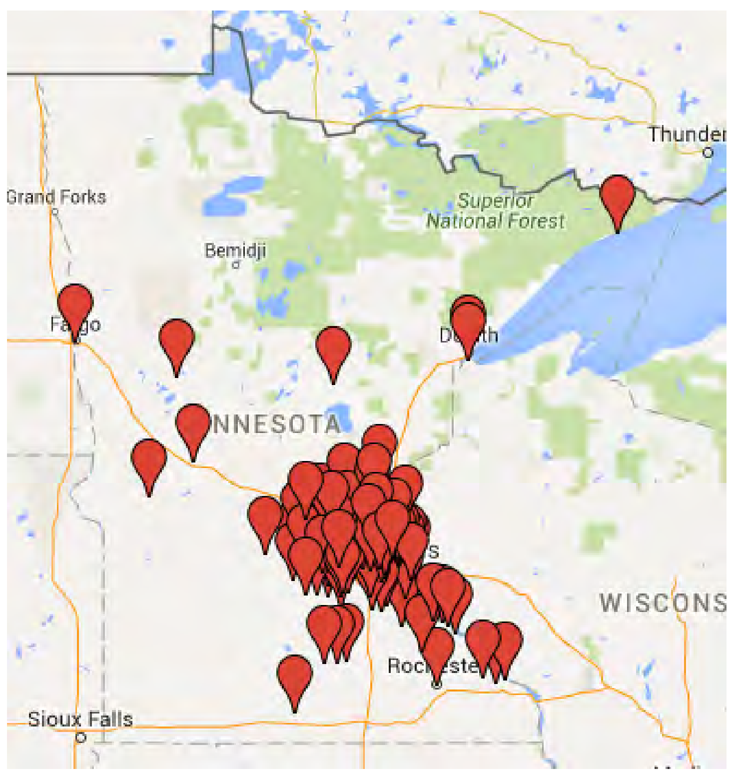
Minnesota Tree Care Advisor

Minnesota Tree Care Advisor Accomplishments in 2015

- The average active TCA volunteered 69.7 hours a year and gained 19.79 hours of continuing education.
- In 2015, TCAs submitted 5,342 volunteer hours.
- TCAs serve on tree boards, educate other citizens and children by teaching classes, volunteer at plant clinics, and volunteer in several other capacities all to better urban and community forestry as a whole for the state of Minnesota.

Minnesota Tree Care Advisors complete over 30 hours of education and are trained in:

- Communicating urban forestry to the public
- Tree identification
- Plant selection
- Best planting practices
- Small tree structural pruning
- Predicting and preventing storm damage
- Small group volunteer management



Where Minnesota Tree Care Advisors volunteered in 2015

MONEY TALKS: Measuring Volunteers in Dollars
The organization, Independent Sector, has calculated an hourly dollar rate for volunteer contributions. Based on 2014 figures, the hourly rate is $24.83, resulting in $132,641.86 for the volunteer work done by Tree Care Advisors in 2015. This is money the state, counties, cities and non-profits are saving.
This savings reduces unnecessary expenses by not needing to hire professionals for simple tasks, transferring the use of skilled labor (arborists) to more technical duties that require said skills, improving a community's urban forest as a whole. As a matter-of-fact, TCA activities generate more demand for professional arborists as TCAs educate citizens on the importance of timely and professional tree care.

Minnesota Tree Steward

Minnesota Tree Steward is an advanced stewardship volunteer and outreach program that works to meet the direct needs of communities. Program staff will work directly with cities, counties, or non-profits to develop an advanced stewardship volunteer program based on the unique needs of the community.

Programs can include helping you create a volunteer team to:

- plant trees into gravel beds and/or into the landscape
- help lead planting teams for Arbor Day events
- structurally prune small trees
- aid in the monitoring of newly planted tree health
- help in other ways your community wants to utilize volunteers

The Minnesota Tree Steward will help you decide on how your community wants to utilize volunteers within urban and community forestry. The program staff will then develop an education unique to your community and offer courses to your volunteers. Minnesota Tree Steward will also create a webpage specific to your community needs, offer resources, track volunteer data and hours, and develop reports for you to share successes with others in your community.

Minnesota Citizen Pruner

Citizen Pruners are needed now more than ever. As municipal budgets continue to be cut, the aid from citizens becomes increasingly more important to communities. Citizen Pruners are able to manage small branches near the ground while tree care professionals can focus on larger branches higher in the tree canopies. Completing this ground work is vital for clearing sight lines and blocked sidewalks.

The Minnesota Citizen Pruner program can be tailored to meet the unique needs of your community. For example, some communities have volunteers only clear sight lines by pruning sprouts and suckers, while other communities have volunteers structurally prune their small trees. Volunteers always maintain both feet on the ground and utilize tools that include bypass pruner, handsaw, and pole pruner. Minnesota Citizen Pruner is currently in Becker, Big Lake, Elk River, Mankato, Princeton, Robbinsdale, Rochester, Saint. Paul, and Zimmerman.

Minnesota Citizen Pruner Accomplishments in 2015

Total trees pruned	**798**
Suckers removed	3756
Sprouts removed	7795
Deadwood removed	1272
Included branches removed	4
Co-dominant leaders removed or suppressed	49
Crossing branches removed	879
Branches removed for crown raising	1228
Other branches removed	160
Total branches removed	**15143**
Mulch volcanos corrected	16
Tree stem protection removed	15
Total volunteer hours submitted	**231.75**

MONEY TALKS: Measuring Volunteers in Dollars

The organization, Independent Sector, has calculated an hourly dollar rate for volunteer contributions. Based on 2014 figures, the hourly rate is $24.83, resulting in $5754.35 for the volunteer work done by Citizen Pruners in 2015. This is money that can be used as in in-kind match on a grant proposal.

Minnesota Citizen Pruners are trained in:

- how to work with the public
- how to be safe in the work zone
- how to manage brush
- tree identification of pruning restricted species
- how to identify and prioritize removals
- best mulching practices
- the three-cut method
- compartmentalization of decay in trees

Minnesota Tree Care Advocate

115 Green Hall,

1530 Cleveland Avenue North,

St. Paul, MN 55108

www.mntca.org

Report developed by:

Valerie McClannahan

Volunteer and Program Coordinator

612-625-2361

vmcc@umn.edu

The Rapid Urban Site Index (RUSI) as an Indicator of Tree Performance on Urbanized Planting Sites

Gary Johnson and Chad Giblin, principal investigators.

Cassandra List, Undergraduate Student Research Scholarship recipient

Aaron Rendahl, Statistical Consulting Manager

Department of Forest Resources - University of Minnesota

Background

The Rapid Urban Site Index (RUSI) was developed by Brian Scharenbroch, formerly of the Morton Arboretum in Lisle, Illinois and presently as a University of Wisconsin, Stevens Point faculty member. The intent of the protocol is – as the title implies – to use an evaluative system that assesses the qualities of a planting site and relate it to tree performance… rapidly. This has the potential of being a valuable tool for those selecting and planting trees in urbanized sites. Currently, the most common criteria for selecting trees is dominated by cold hardiness zone, the tree's status as a Minnesota native and availability. Three components in a recipe for unpredictable consequences.

The University of Minnesota sponsored the undergraduate research assistant – Cassandra List – that directed the majority of the data collection in the field. This student was funded by the Undergraduate Student Research Scholarship program that selected student interns based on a very competitive selection protocol and matched them with faculty mentors engaged in higher level research projects that could assimilate the student into the research process. This scholarship provided funding for the student for two full semesters.

METHODOLOGY

The RUSI involves two assessment techniques. First, an assessment of the health and condition of the trees under observation. Second, an extensive assessment of the site characteristics. Conversations and an agreement with the author of RUSI allowed this lab to modify the site index criteria to accommodate the limited time frame that this study had to work within, yet still contribute to the body of RUSI knowledge and stay consistent with its protocol.

The trees randomly selected were part of a two-year planting program on public property in the City of Minneapolis, with the cooperation of the Minneapolis Park and Recreation Board (MPRB), division of Forestry. This study is a complimentary extension of an earlier research study of said planting which focused on survival and subsequent condition of the planted trees. The RUSI study was designed to correlate any performance indices (survival, growth rate, condition, health) with the site indices.

RUSI Sample Storage in Lab

Two hundred twenty-two (222) trees from the nine genera were randomly selected as part of this study. Said trees were located, assessed on site for their condition and health using a modified, numerical assessment system designed by the University of Minnesota Urban Forestry Outreach Research and Extension (UFore) lab and approved by the author of the RUSI system.

Site criteria included: soil penetrometer readings at 15 cm depths and then correlated to the soil compaction protocol used in the RUSI system; soil pH; soil organic matter %; texture. With the exception of the soil penetrometer readings, all soil assessments were field collected and completed in the UFore lab at the University of Minnesota, Department of Forest Resources.

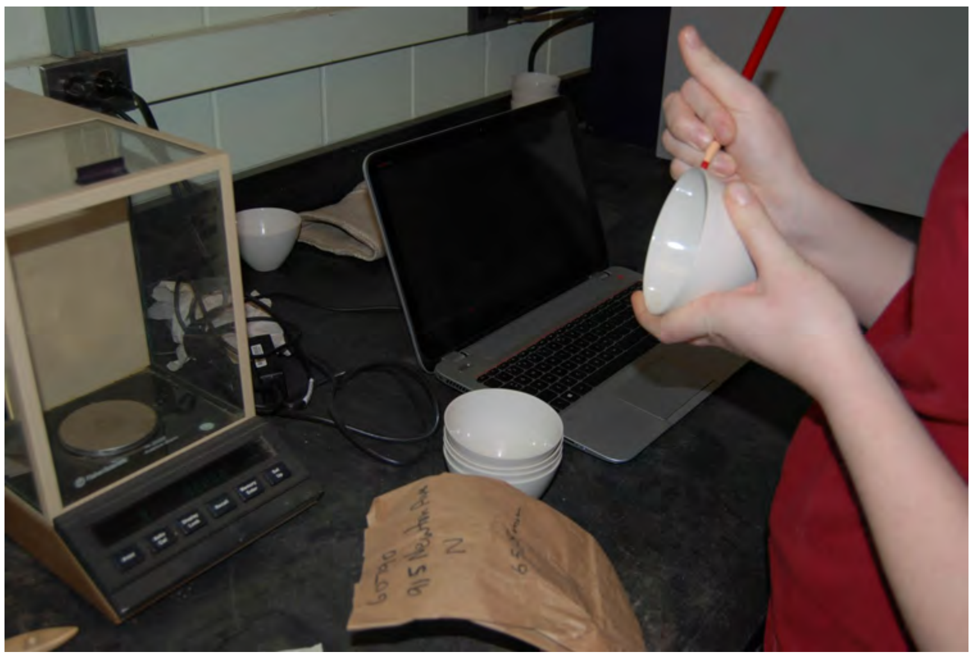
The research design and selection of the trees was provided by the Statistical Consulting Center, University of Minnesota Department of Statistics. Analysis of the data will be completed by the Center.

Timeline

The study will be completed by the end of May, 2016.

RESULTS

Field data collection has been completed. Soil samples have been gathered and stored in the UFore lab in preparation for pH, organic matter and texture analyses.



Cooperative Projects

MPRB-City of Minneapolis Biochar Amendment Research Project

Minneapolis, MN (2014-2019) - Year One Progress Report

Mary Pederson, Melissa Lenius, Teng Vang, Danielle Ringle and Chad Giblin

University of Minnesota, Department of Forest Resources

Jim Doten

City of Minneapolis, Department of Health

INTRODUCTION

Trees planted in urban boulevards are faced with a number of conditions that may limit their growth and long-term success. Transplant shock, soil compaction, low soil moisture and barriers to root growth are just a few of many factors that can negatively impact young tree establishment (Struve 2009). These factors may lead to high mortality within the first few years of planting young street trees. Soil amendments are organic substances added to planting locations which are designed to increase the quality of the existing soil and improve tree survival and growth.

Urban soils experience compaction due to construction (Grabosky and Bassuk 1995) and typically do not have the organic matter and microbial life found in natural topsoil. This may result in poorer quality soils (Sæbø and Ferrini 2006, Jim 1998, Craul 1999). A study performed to examine the quantity of soil microbes along an urban-rural gradient determined the number soil microbes vary across urban, suburban and rural forest soil types (Zhao and Guo 2010). The function of these soil microbes changes between urban and rural soils as well. There is less microbial biomass, but increased microbial respiration and physiology in urban soils likely due to pollution and other anthropogenic stressors (Yang et al. 2001).

Two studies found reduced nitrogen mineralization rates in urban soils compared to suburban and rural soils (Zhu and Carreiro 1999 and White and McDonnell 1988). White and McDonnell 1988 also found that urban soils were extremely hydrophobic compared to rural forest soils. Another study found increased rates of nitrification in urban soils compared to rural soils (Zhu and Carreiro 1999). Within the urban landscape, soil properties can vary based on time since last site disturbance. Older urban soils have lower bulk densities, greater extractable phosphorous, more nitrogen availability and increased soil organic matter (Scharenbroch et al. 2005). Soil amendments can improve the physical and nutrient properties of soils (Cogger et al. 2008, Beyer et al. 1996 and Rawls et al. 2003).

There have been several studies looking into the effects of soil amendments. Some research suggests that soil amendments have no impact on tree growth. A study performed to examine the benefits of soil amendment on tree growth of silver maple (*Acer saccharinum*) showed that soil amendment had no apparent benefits on tree growth regardless of preexisting soil quality (Scheutle and Whitcomb 1975). Other studies testing tree survival, establishment and growth have similar results (Gilman 2004, MacDonald et al. 2004). These projects were conducted in agricultural fields, however, and may not be reflective of typical, urban environments.

Other studies indicate mixed results when soil amendments were added to tree plantings. One study found a delayed beneficial response to soil amendment added at planting (Oldfield et al. 2015). Soil amendment was found to increase growth after three years. This was potentially due to trees overcoming transplant shock and/or slower mineralization of soil amendment components. This study also found increased mortality in sample plots containing soil amendment.

Other studies found positive benefits associated with using soil amendments. In one study, water and fertilizer were most important when analyzing the success of tree plantings, but they found soil amendments positively influenced tree structure (Ferrini et al. 2005). Studies have also shown that soil amendments can increase tree root growth which enhances growth and survival (Donn et al. 2014, Vidal-Beaudet et al. 2010). One study found the addition of compost doubled survival and increased tree growth of *Pinus taeda* (Stuckey and Hudak 2001). Another study involving several tree species showed that soil amendment can improve plant growth within the first season after planting (Layman et al. 2010). A meta-analysis of 33 studies indicated that soil amendments generally have positive impacts on soil quality and tree health (Scharenbroch 2009).

Biochar is one type of soil amendment and is a carbon-rich byproduct of organic materials, such as wood, burned at a high temperature in a closed container without the presence of oxygen (Lehmann and Joseph 2009). Biochar is viewed as a potential means of improving soil quality while sequestering carbon (Lehmann et al. 2006). A study testing the effects of biochar on soil fertility found that the biochar amendment increased overall soil fertility by increasing soil pH, soil organic carbon, Ca, K, Mn and P while decreasing exchangeable acidity, S and Zn (Novak et al. 2009). Biochar has been shown to improve physical and chemical characteristics of soil such as nutrient availability and retention as well as moisture-holding capacity. Scharenbroch et al. (2013), found that biochar treated trees showed a significant increase in total biomass compared to controls.

The objective of this study is to study the effects of biochar and organic compost matter amendments on tree survival, establishment and growth when combined with existing Minneapolis boulevard soils at the time of planting.

MATERIALS AND METHODS

Experimental Design:

Eleven tree species were included in the biochar and compost organic matter amendment study: *Gymnocladus dioicus* 'Espresso' (Espresso Kentucky coffeetree), *Malus* ‘Prairifire’ (Prairifire crabapple), *Platanus* x *acerifolia* ‘Bloodgood’ (Bloodgood London planetree), *Quercus bicolor* (swamp white oak), *Syringa reticulata* ‘Ivory Silk’ (Ivory Silk Japanese tree lilac), *Tilia cordata* ‘Glenleven’ (Glenleven littleleaf linden), *Ulmus americana* ‘Princeton’ (Princeton American elm), *Ulmus americana* ‘Valley Forge’ (Valley Forge American elm), *Ulmus* ‘Morton’(AccoladeTM hybrid elm), *Ulmus* ‘Morton Glossy’ (TriumphTM hybrid elm) and *Ulmus* ‘Patriot’ (Patriot hybrid elm).

Trees were graded as bareroot and having a 4.4cm stem caliper by the production nursery. Planting sites were randomly selected from available locations in public boulevards throughout Minneapolis. Each tree received one of five, randomly assigned, amendment treatments: biochar + compost (full rate), biochar + compost (half rate), compost only (full rate), compost only (half rate) or control (no amendment, native backfill only). Full rates were 41.6L of amendment treatment and half rates were 20.8L of amendment treatment.

The biochar used for this project was produced in Missouri by Terra Char Technology Company from hardwood sawmill waste. The biochar was blended with composted manure at a rate of 1:5 at the Shakopee Mdewakantonwakanton Sioux Community’s Organics Recycling Facility in Prior Lake, MN. The biochar and compost were mixed three weeks prior to use. This allows the biochar to absorb nutrients from the compost in a process known as charging. This prevents the raw biochar from initially robbing nutrients from the surrounding soil.

Each treatment was replicated eight times for each listed species at a randomly assigned boulevard planting site in Minneapolis. All trees were planted into 76.2 to 85.3 cm wide by 20.3 to 25.4 cm deep holes. Amendment treatments were uniformly incorporated into existing backfill at planting. All trees were well-watered at planting and received a uniform application of wood mulch to the soil surface following standard Minneapolis Park & Recreation Board (MPRB) Forestry planting protocols. After-care of trees will follow standard operating procedures as specified by MPRB Forestry.

Data Collection:

Geographic location (including house number and street name or number, street orientation (N-S or E-W), street use classification (arterial or residential), boulevard width, stem caliper of tree (measured at 15cm and 30cm) and soil compaction (measured at 15cm and 30cm) will be collected at each planting location.

Tree condition data was collected one year after initial planting. Information on mortality, stem caliper increase and stem and crown condition ratings were taken. Possible conditions ratings included: ‘Planted Tree Removed’, ‘No Tree Planted’, ‘Poor Appearance’, ‘Top Dead’, ‘Damage’, ‘Possibly Dead’, ‘Dead’ and ‘Alive - Good Condition.’

Statistical Analysis:

Several tree condition ratings were pooled. Trees rated as ‘Planted Tree Removed’ and ‘Dead’ were pooled and classified as ‘Dead.’ Trees rated as ‘Poor Appearance’ and ‘Top Dead’ were pooled and classified as ‘'Alive, Fair'.’ Trees rated as ‘Damaged’ and ‘Alive - Good Condition’ were pooled and classified as ‘'Alive, Good'.’ Trees rated as ‘No tree planted’ were excluded from the analysis. Chi-square tests were performed to examine the relationship between tree species, amendment and year one condition using the crosstab function in SPSS Statistics 22.0 (IBM Corp. 2013).

RESULTS

Overall, 431 trees were included in the study. Due to unforeseen circumstances, three replicates at half rate biochar, three replicates at full rate compost and three replicates at half rate compost were left out of the study.

After the first year 20.0% of the trees were classified as dead, 11.1% were classified as 'Alive, Fair' and 68.9% were classified as 'Alive, Good'. There was a significant relationship between tree species and year one condition χ^2 (20, n = 431) = 110.12, $p < 0.001$. *Gymnocladus dioicus* 'Espresso', *Malus* 'Prairifire', *Platanus* x *acerifolia* 'Bloodgood', *Syringa reticulata* 'Ivory Silk', *Tilia cordata* 'Glenleven', *Ulmus* 'Morton Glossy', *Ulmus* 'Morton', *Ulmus* 'Patriot', *Ulmus americana* 'Princeton' and *Ulmus americana* 'Valley Forge' had a higher percentage of survival (condition ''Alive, Good'') than mortality. Quercus bicolor had a higher percentage of mortality than survival (condition ''Alive, Good'').

There was no significant relationship between amendment treatment and year one condition χ^2 (8, n = 431) = 5.02, $p =$ 0.756. 'Alive, Good' was the highest classified condition for all amendment treatments. The relationship between amendment treatment and year one condition was also assessed for each tree species. There was no significant relationship between amendment treatment and year one condition for any of the tree species used in the study (Table 1). Several non-significant trends were observed, however, showing both a positive treatment effect in *Gymnocladus dioicus* 'Espresso' (Fig. 1) and a negative treatment effect in *Ulmus americana* 'Valley Forge' (Fig. 2).

Species	**Alive-Good (%)**	**Alive-Fair (%)**	**Dead-Removed (%)**	**Chi-Squared test ($\chi 2$)**
Gymnocladus dioicus 'Espresso'	55.3	26.3	18.4	(8, n = 38) = 9.75, $p = 0.283$
Malus 'Prairie Fire'	81.6	15.8	2.6	(8, n = 38) = 13.65, $p = 0.091$
Platanus x acerifolia 'Bloodgood'	59.0	30.8	10.3	(8, n = 39) = 5.02, $p = 0.756$
Quercus bicolor	37.5	5.0	57.5	(8, n = 40) = 5.88, $p = 0.660$
Syringa reticulata 'Ivory Silk'	76.3	13.2	10.5	(8, n = 38) = 8.08, $p = 0.426$
Tilia cordata 'Glenleven'	47.5	7.5	45	(8, n = 40) = 4.708, $p = 0.788$
Ulmus americana 'Princeton'	78.6	4.8	16.7	(8, n = 42) = 7.54, $p = 0.480$
Ulmus americana 'Valley Forge'	76.9	2.6	20.5	(8, n = 39) = 10.09, $p = 0.259$
Ulmus 'Morton'	92.3	5.1	2.6	(8, n = 39) = 12.05, $p = 0.149$
Ulmus 'Morton Glossy'	87.2	7.7	5.1	(8, n = 39) = 8.27, $p = 0.408$
Ulmus 'Patriot'	66.7	5.1	28.2	(8, n = 39) = 7.64, $p = 0.471$

Table 1. Percent of individual tree species in each condition class rating and the pooled relationship between amendment treatment and year one condition using Chi-squared test for each species.

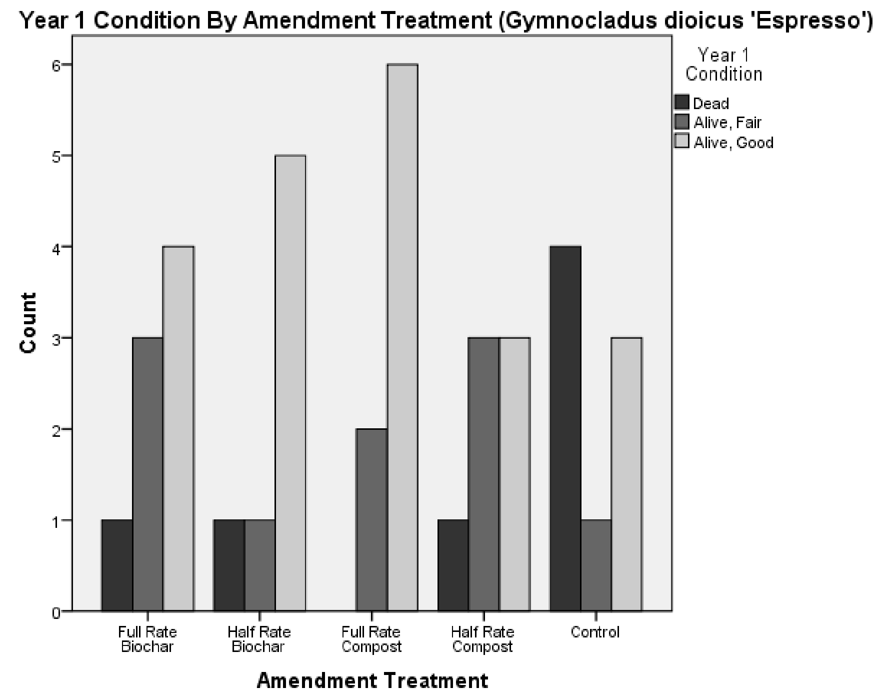


Figure 1. Year one condition observed in Gymnocladus dioicus 'Espresso' as affected by four different soil amendment treatments and a control.

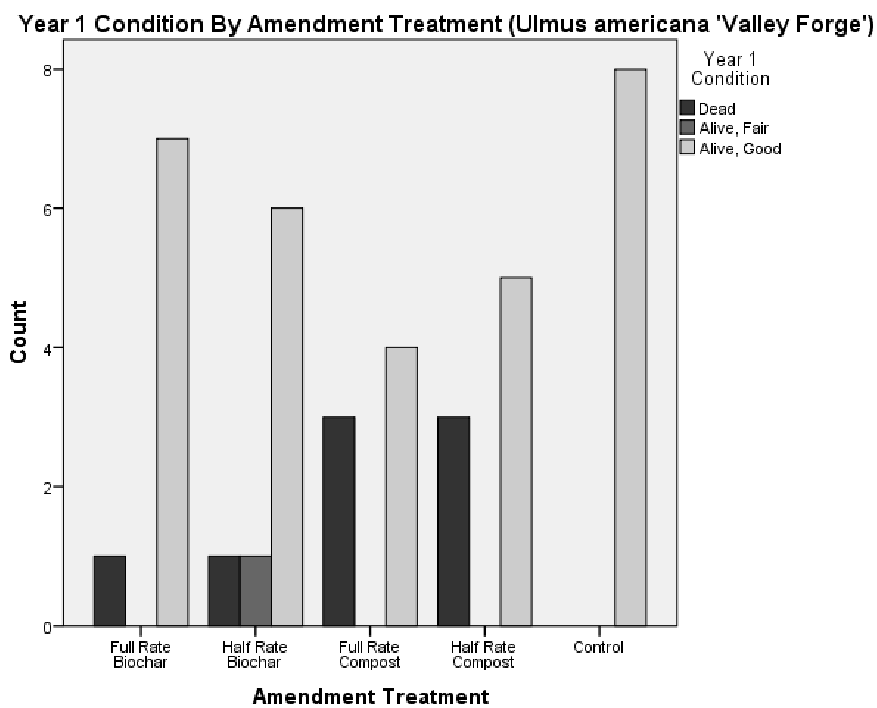


Figure 2. Year one condition observed in Ulmus americana 'Valley Forge' as affected by four different soil amendment treatments and a control

DISCUSSION

Preliminary data suggests that there may be differences in the way species react to amendment treatments as success and mortality rates varied greatly among species. High individual establishment success rates may be related to the addition of biochar and compost amendment to existing soils. Among those with a high percent of individuals classified in the 'Alive-Good' condition are *Ulmus* 'Morton' (92.3%), *Ulmus* 'Morton Glossy' (87.2%), and *Malus* 'Prairie Fire' (81.6%). For example, *Gymnocladus dioicus* 'Espresso' experienced 57.1% mortality in the control group while experiencing no mortality with a full rate compost amendment and a 14.3% mortality rate when treated with full and half rate biochar amendments (Fig. 1). Not all species appeared to benefit from the addition of soil amendment. *Ulmus americana* 'Valley Forge' showed strong performance in control, with 100% classified as 'Alive-Good'. However, half and full rate compost showed 37.5% mortality and half and full rate biochar produced 12.5% mortality (Fig. 2).

High first year mortality rates for specific species may be associated with quality of planting stock *Quercus bicolor* and *Tilia cordata* 'Glenleven' experienced consistent mortality citywide, even for trees of these two species not included in the study. When treatments were pooled, *Quercus bicolor* experienced 57.5% mortality and *Tilia cordata* 'Glenleven' experienced 45.0% mortality.

LITERATURE CITED

1. Beyer, L., E. Cordsen, H.P. Blume, U. Schleuss, B. Vogt, and Q. Wu 1996. Soil organic matter composition in urbic anthrosols in the city of Kiel, NW-Germany, as revealed by wet chemistry and CPMAS ^{13}C- NMR spectroscopy of whole soil samples. Soil Technology. 9:121–132.
2. Cogger, C., R. Hummel, J. Hart, and A. Bary 2008. Soil and redosier dogwood response to incorporated and surface-applied compost. HortScience. *43*: 2143-2150.
3. Craul, P.J. 1999. Urban soils: Applications and practices. John Wiley & Sons, New York.
4. Donn, S., R.E. Wheatley, B.M. McKenzie, K.W. Loades, and P.D. Hallett 2014. Improved soil fertility from compost amendment increases root growth and reinforcement of surface soil on slopes. Ecological Engineering. 71:458-465.
5. Ferrini, F., A. Giuntoli, F.P. Nicese, S. Pellegrini, and N. Vignozzi 2005. Effect of fertilization and backfill amendments on soil characteristics, growth, and leaf gas exchange of English oak (*Quercus robur* L.). Journal of Arboriculture. 31:182-190.

6. Gilman, E.F. 2004. Effects of amendments, soil additives, and irrigation on tree survival and growth. Jour nal of Arboriculture. 30:301-310.

7. Grabosky, J. and N. Bassuk 1995. A new urban tree soil to safely increase rooting volumes under sidewalks. Journal of Arboriculture. 21:187-201.

8. IBM Corporation (2013) IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

9. Jim, C.Y. 1998. Physical and chemical properties of a Hong Kong roadside soil in relation to urban tree growth. Urban Ecosystem. 2:171–181.

10. Layman, R.M., S.D. Day, J.R. Harris, W.L. Daniels and P.E. Wiseman 2010. Rehabilitation of severely compacted urban soil to optimize tree establishment and growth. Acta Hort. 8811:505-510.

11. Grabosky, J. and N. Bassuk 1995. A new urban tree soil to safely increase rooting volumes under side walks. Journal of Arboriculture. 21:187-201.

12. IBM Corporation (2013) IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

13. Jim, C.Y. 1998. Physical and chemical properties of a Hong Kong roadside soil in relation to urban tree growth. Urban Ecosystem. 2:171–181.

14. Layman, R.M., S.D. Day, J.R. Harris, W.L. Daniels and P.E. Wiseman 2010. Rehabilitation of severely compacted urban soil to optimize tree establishment and growth. Acta Hort. 8811:505-510.

15. Lehmann, J., J. Gaunt, and M. Rondon 2006. Bio-char sequestration in terrestrial ecosystems - a review. Mitigation and adaptation strategies for global change. 11:403-427.

16. Lehmann J., S. Joseph 2009. Biochar for environmental management: an introduction. Earthscan. London, UK.

17. MacDonald, J.D., L.R. Costello, J.M Lichter and D. Quickert 2004. Fill soil effects on soil aeration and tree growth. Journal of Arboriculture. 301:19-27.

18. Novak, K.M., W.J. Busscher, D.L. Laid, M. Ahmedna, D.W. Watts and M.A.S Niandou 2009. Impact of biochar amendment on fertility of a southeastern coastal plain soil. Soil Science. 174:105-112.

19.Oldfield, E.E., A.J Felson, D.S.N. Auyeung, T.W. Crowther, N.F. Sonti, Y. Harada, D.S. Maynard, N.W. Sokol, M.S. Ashton, R.J. Warren, R.A. Hallett, and M.A. Bradford 2015. Growing the urban forest: tree performance in response to biotic and abiotic land management. Restoration Ecology. 23:707–718.

20. Rawls, W.J., Y.A. Pachepsky, J.C. Ritchie, T.M. Sobecki and H. Bloodworth 2003. Effect of soil organic carbon on soil water retention. Geoderma. 116:61-76.

21. Sæbø, A. and F. Ferrini 2006. The use of compost in urban green areas - a review for practical application. Urban forestry & Urban Greening. *4*:159-169.

22. Scharenbroch, B.C. 2009. A meta-analysis of studies published in Arboriculture & Urban Forestry relating to organic materials and impacts on soil, tree, and environmental properties. Arboriculture & Urban Forestry. 35:221–231.

23. Scharenbroch, B.C., J.E. Lloyd and J.L Johnson-Maynard 2005. Distinguishing urban soils with physical, chemical, and biological properties. Pedobiologia. 49:283–296.

24. Scharenbroch, B.C., E.N. Meza, [M]. Catania and K. Fite 2013. Biochar and biosolids increase tree growth and improve soil quality for urban landscapes. Journal of environmental quality. 42: 1372-1385.

25. Scharenbroch, B.C., J.E. Lloyd and J.L Johnson-Maynard 2005. Distinguishing urban soils with physical, chemical, and biological properties. Pedobiologia. 49:283–296.

26. Scharenbroch, B.C., E.N. Meza, [M]. Catania and K. Fite 2013. Biochar and biosolids increase tree growth and improve soil quality for urban landscapes. Journal of environmental quality. 42: 1372-1385.

27. Struve, D.K. 2009. Tree establishment: a review of some of the factors affecting transplant survival and establishment. Arboriculture & Urban Forestry, 35:10–13.

28. Stuckey, H.T. and P.F. Hudak 2001. Effects of compost on Loblolly Pine tree growth in Northeast Texas. Compost Science & Utilization. *9:65-72.*

29. Vidal-Beaudet, L., V. Caubel and R. Olivier 2010. Street tree root development in topsoil amended with high levels of compost. Acta Hortic. 881:511-516.

30. White, C.S. and M.J. McDonnell 1988. Nitrogen cycling processes and soil characteristics in an urban ver sus rural forest. Biogeochemistry. 5:243-262.

31. Yang, Y., E. Paterson and C.D. Campbell 2001. Urban soil microbial features and their environmental sig nificance as exemplified by Aberdeen City, UK. Chinese Journal of Geochemistry. 20:34-44.

32. Zhao, Z. and H. Guo 2010. Effects of urbanization on the quantity changes of microbes in urban-to-rural gradient forest soil. Agricultural Science and Technology. 11:118-122.

33. Zhu, W.X. and M.M. Carreiro 1999. Chemoautotrophic nitrification in acidic forest soils along an urban-to -rural transect. Soil Biology and Biochemistry. 31:1091-1100.