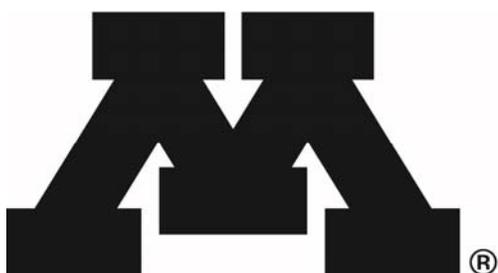


Urban Forestry Outreach, Research & Extension Nursery and Lab

2016 Interim Green Report

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



Department of
FOREST RESOURCES

UNIVERSITY OF MINNESOTA

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6 Steps to Landscape Diversity

Monica Randazzo - Undergraduate Research Assistant, Nursery Manager

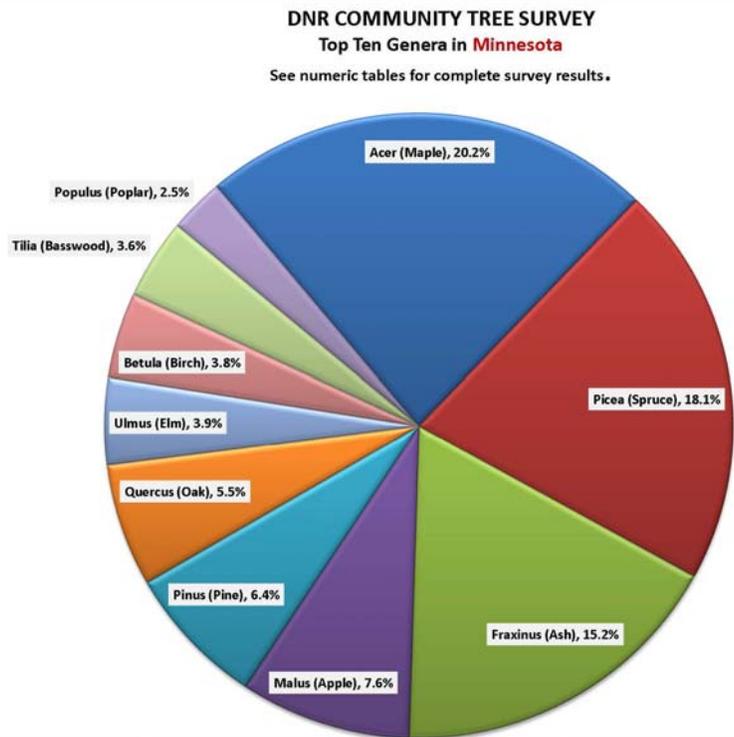
1. Taking Inventory

Before determining any steps to take, what is your community dealing with? Taking an inventory of the species, age class/trunk size, and conditions of street and park trees allows for a plan to include the issues that are most prevalent within your community.

2. What Are You Willing to Lose?

The standard for genetic diversity within an urban environment has been proposed by the 30-20-10 rule: no greater than 30 per cent of trees from a single botanical family, no greater than 20 per cent from the same genus, and no greater than 10 per cent of the same species (*Diversity in Planting Trees*, Morton Arboretum). For example, *Fraxinus pennsylvanica* is a species, green ash. *Fraxinus* (ash) is the genera, and it is in the *Oleaceae* (olive) family. To explore the many families, genera and species of plants, check out The Plant List at <http://www.theplantlist.org/>.

The 30-20-10 rule still leaves a lot of potential for massive losses given the right (or wrong) circumstances, and may be an outdated approach for creating diverse urban forests. Is any community willing to lose 30 per cent of your tree population to a disease such as Dutch elm disease or an invasive pest such as the Emerald Ash Borer? What if the ratio of the genetic make-up a tree population was changed to something like 5-2-1, or even 5-5-5? Would 5 per cent of a tree population be an acceptable loss? Once the percentage of trees a community is comfortable losing at once is determined, planting different families and genera to increase the genetic diversity of trees throughout community to match the desired ratio can begin.



Data from 2010 survey, Minnesota DNR



Trees in nursery setting

3. Diversify Age-classes

When tree populations are aging past maturity the chances of failure of trees during weather loading events such as wind, rain, or snow are much higher. A fairly simple and inclusive method of addressing issues associated with a largely aging tree population is holding an annual community wide tree sale, introducing a new

age-class of young trees to the community every year. A number of cities in Minnesota already hold annual tree and plant sales, such as Blaine, Hendricks Saint Paul, and Minnetonka. The sale not only allows for community members to be involved in the selection process, but also can be an opportunity for providing information on best planting and maintenance practices.

A tree sale can also offer cities and organizations a controlled way of increasing the genetic diversity of trees within the community. Given an inclusive inventory of what trees are already present, organizers can select species from different genera and families than are present within the community, excluding species that may already be overabundant.



Trees in a street setting

4. Considering Space, Above and Below

Still before selecting a tree for a site, the amount of space needed by the species of the tree and the amount of space available at the site need to be paired up. Naturally, looking up and observing the potential obstacles to a tree canopy is important. Being aware of the height and distance requirements for utility lines, or the proximity of a building or landmark should help you decide what size and shape tree you want for that site.

The space available below ground is also critical, a tree's root spread influences how well a tree can obtain water and nutrients as well as the anchoring stability of a tree. James Urban, author of *Up by Roots – Healthy Soils and Trees in the Built Environment* recommends an ideal minimum of 20 feet in diameter in soil space around the tree, however in most urban environments this is near impossible (158). A quick and easy tool for determining how much underground space a tree will need is a simple math equation: **the square feet of desired canopy spread multiplied by two is equal to the number of cubic feet required for root space/volume**. Using this formula, you can determine whether or not a site even has enough space for the root system of the size tree you want.

5. Knowing the Site Limitations

Limitations above and below ground have been noted, but what other site limitations need to be considered?

- **Compaction:** In urban areas, compaction is one of the greatest and most common limitations to tree growth. Compacted soils not only make it difficult for roots to penetrate and grow outward, but they also limit the availability of oxygen and water. Testing the compaction of a soil can be as simple as using a shovel to break the surface, or it can be measured more objectively using a tool like a penetrometer, which measures the amount of resistance as you penetrate the soil with its sensor.
- **Alkalinity:** Another factor in urban areas is the soil pH, which is likely to be alkaline. Species such as red maple or white ash do not tolerate alkaline soils well, whereas black maple or bur oak are more tolerant to a high pH. To test pH, you can bring soil samples



Trees in a park setting

to the University of Minnesota Soils Lab (<http://soiltest.cfans.umn.edu/>), or buy your own soil pH test kit from most garden stores.

- **Drainage:** The percolation rate (drainage) of a soil is another important limiting factor to be aware of in terms of oxygen availability, and it is fairly easy to test. Detailed directions on how to test soil percolation rate can be found on the following website <http://www.extension.umn.edu/environment/housing-technology/moisture-management/how-to-run-a-percolation-test/>

Different species are better suited to deal with different limitations and conditions, so understanding the preferences of a specific species is very important. The University of Minnesota Extension site has a chart (<http://www.extension.umn.edu/garden/yard-garden/trees-shrubs/tough-trees-and-shrubs-for-tough-sites>) showing which species are tolerant of common site limitations in Minnesota. The list includes both native and non-native species, with numbers indicating which species are native (bur oak, ironwood, honey locust, etc.).

6. Giving Trees a Head Start

After having gone through all of the necessary steps of to determine goals for landscape diversity and narrowing down which species is best suited for the site, a tree must be planted correctly. That is, it cannot be buried, as many street and landscape trees often are. To correctly plant a tree the first major root should be at the soil surface, which means any excess soil from the pot or soil ball needs to be removed at planting time. This is also the best time to inspect the root system, and remove any encircling roots, those against the stem of the tree, or in any odd direction that may become problematic later. After planting, trees must be watered for the first year. The soil should be checked once a week, and watered only as needed. Correctly planting a tree and correcting any problem roots early can prevent failure of the tree in the future, as well as reduce future maintenance costs by giving the tree the best growing conditions from the very beginning.



Volunteer planting in Rochester, MN

More information on best planting practices can be found on the following website: <http://trees.umn.edu/files/2013/07/Best-Planting-Practices.pdf>

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Nursery Research Projects



Flowering crabapple

2016 in the UFore Nursery

Monica Randazzo -
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In-ground gravel bed after installation of trees

Gravel Beds:

The large, permanent gravel beds of various mixtures (pea-stone, pea-stone and 10% sand, b-stone and 30% sand) are nearly filled with large and small caliper bare root trees. The gravel-in-pot (G.I.P.) mixtures are filled with small caliper bare root trees, and the most recently constructed temporary gravel bed is filled with a variety of trees as well. For the species with enough replicates, we will be inspecting the root systems of the individual bare root trees and how they differ from the root systems of trees of the same species held in different gravel mixtures.

In the first few weeks after installing bare root trees in gravel beds, we discovered severe rodent damage on the stems of the trees. Smaller caliper trees were completely browsed off either at the ground line or a few inches above. River birch were the hardest hit by rodent damage, nearly all of the sixty, three-foot tall trees were browsed to four or five inches off the ground within just a few days of installation. Chicken wire fencing was quickly put up around the gravel beds holding trees at the time, and small cages were made for potted trees. Small rodents such as the thirteen-lined ground squirrel are still able to crawl through this type of fencing, so for extra reinforcement we regularly spray the trees around the nursery with Liquid Fence™, a repellent with a very strong scent that drives deer and rodents away from browsing on plant material. Where there is heavy irrigation, Liquid Fence™ has to be applied more frequently.



Gravel bed trees after wind loading event in July, 2016

Species	Pea-stone	Pea-stone & Sand	B-stone & Sand	G.I.P.
Redbud			Yes	
Hackberry	Yes	Yes		
Bur Oak	Yes	Yes		Yes
White Oak	Yes	Yes		Yes
Pagoda Dogwood	Yes	Yes	Yes	
River Birch	Yes	Yes		
Musclewood	Yes	Yes		
Ironwood	Yes	Yes		
Kentucky Coffeetree	Yes	Yes		
Smooth Sumac			Yes	
Northern Catalpa	Yes	Yes		
American Plum	Yes			
Paper Birch	Yes	Yes		
White Pine				Yes
Kerria	Yes	Yes		
Majestic Skies N. Pin Oak	Yes	Yes		
Male Cottonwood	Yes			
Manchurian Ash	Yes	Yes		
Ginkgo	Yes	Yes		
Prairie Stature Oak			Yes	



Jersey barrier gravel bed

The gravel bed trees also are susceptible to wind-throw during weather loading events, particularly the larger caliper trees. Many of the large bare root trees have fairly minimal root systems when they are installed, and their location exposes them to strong winds. Some of the less anchored trees have been staked for extra support, others are buried deeper into the gravel. For a few individuals, they must be moved to a location better suited for wind protection.

This season a new gravel bed made of J-barriers and cement bricks was installed beneath a large hackberry and an Amur maakia. The J-barriers are against a row of metal stakes for some support, and filled with water (with room for antifreeze for winter weather) to weigh them down, and mesh is lining the edges to contain the gravel. Gravel and trees were installed on the same day, gravel being dumped in by a skid loader over the roots of trees being held upright by nursery staff. Once enough gravel had been dumped to fill the

area as well as cover the roots, the open end of the bed was lined with cement bricks.

Installation of the bed itself requires minimal labor and can be easily removed. The location provides the trees greater protection from weather loading events, the larger trees above and surrounding offer a wind break as well as enough shade to reduce the need for irrigation.

Gravel-in-Pot:

The most recently installed research project at the nursery is using a space that had been dedicated to similar projects in the past. 72 pots in the ground with various mixtures of gravel or soil control.

The research question is how will different mixtures of gravel affect the growth of roots of three different species over a single growing season?



The G.I.P. rows in the UFORE Nursery

White pine, bur oak, and white oak are the three species being tested. There are also three different gravel mixtures, modeled after those most used in communities throughout Minnesota. Eighteen pots are filled with 100% pea stone gravel, 18 are filled with 90% pea stone gravel and 10% sand, 18 are filled with 70% pea stone gravel and 30% Turface™ (a clay-based soil conditioner), and the last 18 pots are filled with soil as the control. Each pot is stocked with either two or three trees, and each tree is assigned a 3-digit ID number corresponding to its

location in regards to the row, column, and placement in the pot.



The roots of a white pine against grid before installing in pot

Before planting, the root system of each tree was photographed against a grid with a note of its species and ID number, as is pictured to the right. After this growing season, the trees will be removed from their pots and photographed against the same grid, so that after one season in their given gravel mixture the difference in area covered by the root system of each tree can be quantified.

Pleached Elms & Precision Organics C20™ Application:

About 10 months ago, fourteen ‘Valley Forge’ American elms were planted at the base of each of the 14 poles that support the large shade house in the northern area of the UFORE nursery. The elms were all approximately .75” caliper at the time of planting, with light branching and seven feet tall. They were all harvested as bare root trees from the UFORE gravel beds. Each tree was zip-locked to the pole from the ground up, following the curved form of the poles. They are being used for the arboricultural practice called pleaching, which has been popularly used throughout history and is documented to have been used in medieval times. Pleaching creates a natural arc out of trees or shrubs and in the case of the nursery provides a living shade house.

Half of these elms have also been included in the testing of a soil amendment, which has greatly increased their growth over this last growing season. They have been treated with C20™ from Precision Organics, which increases the soil microbial activity, root growth and proliferation, photosynthesis, and a number of other benefits to plant growth. It is a carbon food source for soil microbial populations, which promotes tree canopy and root health through creating a more productive living soil. The product is applied to the soil surface, and the application rate corresponds to the size of the root zone. For a root zone with a radius of 6", 3lbs of C20™ is applied in a 6" band around the tree stem (<http://www.precisionorganics.com/c20-application.html>).

Less than a year later, the elms have grown a great deal, and many already have branches reaching those of their neighbors. To encourage lateral branching, wires were installed perpendicular to the poles for the branches to be attached to as they grow. The zip-locks have to frequently be checked and loosened to avoid girdling the stems and branches of the trees. For any branches that need to grow more perpendicularly, massaging those limbs helps them bend to the wire as needed. Branches that are not conducive to flexibility may need to be pruned, such as codominant leaders. Pleaching is a very time intensive project, particularly with a fast growing species.



Pleached elms in UFORE Nursery



Dachplataner example in UFORE Nursery

Dachplataner:

Another example of alternative tree form/pruning in the UFORE Nursery is on a honey locust in a corner of the pruning area. Dachplataner is a German pruning practice which creates a single plane within a tree, forming a roof-like structure out of a woody tree or shrub. This summer, the structure being used to support the level branches of the tree was expanded to support the lengthening limbs outward.

Another fairly time intensive technique, the structure used to support the young limbs needs to be sturdy enough to also withstand weather and maintenance loading events. In addition, trouble branches must be pruned and small branches must be bent into shape early on.

Low Maintenance Turf Pollinator Plots:

In the northeastern section of the UFore Nursery area there are multiple squares of low-maintenance turf pollinator plants mixed in with the usual turf grass mixture. By increasing the number of flowering plants and biodiversity within a landscape, the quality of habitat for wildlife is increased. The three plants growing within the turf in the UFORE nursery are lanceleaf self-heal (*Prunella vulgaris ssp. Lanceolate*), Dutch white clover (*trifolium repens*), and creeping thyme (*Thymus serpyllum*). Both the lanceleaf self-heal and creeping thyme bloom best



Three squares of flowering turf mixtures

when the mowing heights are at or above 3.5 inches above the ground. The University of Minnesota Bee Lab has conducted a great deal of research on flowering bee lawns, and more information can be found at <http://www.beelab.umn.edu/bees/beelawn>.

Nursery String Decomposition Rate Study – www.trees.umn.edu

Gary Johnson – Primary Investigator
MN-UFore

Urban Forestry Outreach Research and Extension Nursery
July 6, 2015 to August 5, 2016

How long does it take for nursery strings that are using to secure wire baskets to tree trunks, tie up branches or provide any type of support for newly planted trees to decompose to the point where there is no danger of damage to the host trees? A simple question that had not been specifically addressed in an experimentally design study, one with multiple treatments and built-in controls.

In late autumn of 2014, 72 trees, many with multiple stems (aka, clump forms) were planted at the UFore nursery. These 72 trees provided 97 individual tree trunks and represented four different tree genera: Populus (fast growing), Betula (fast but not as fast as Populus), Ginkgo (slow growing) and Pinus (moderate growth rate and a conifer). All trees were grown in #2 smooth plastic containers and were severely pot-bound. All tree root systems were “boxed” to remove any bias from dysfunctional root systems.

The nursery ropes or twines used were selected based on the frequency of their use in wholesale and retail nurseries. Six nursery strings were selected for this study:

1. Baling Twine – orange, photodegradable resistant
2. 3-ply Jute – natural
3. 3-ply Green Jute – dyed for aesthetics
4. 2-ply Sisal - Copper Naphthenate Treated
5. 1-ply Sisal – natural
6. 3-ply Sisal – natural

On July 6, 2015, the various ropes or twines were installed on the surviving trees from the autumn planting. The research design was a randomized block design with 14 replicates per treatment (type of rope or twine). All trees were caliper measured at 15 cm. above ground and at points 2.5 cm above and below the caliper measurement. Each tree then received the rope/twine treatment. The installation was at the caliper measurement point, three wraps of the rope or twine around the stem and secured with a knot.



2-ply Treated Sisal, 5 months after installation

Observations were made at monthly intervals through November, 2015 and then starting again in April, 2016. “Pull-tests” were made on the ropes/twines to determine if any decomposition had occurred. All pull-tests were conducted by the same researcher. Also noted was whether the rope or twine had become imbedded in the tree trunks (aka, girdling) and whether the trees had died or snapped off in wind-loading events.

Preliminary Results – August 10, 2016

Decomposed Ropes or Twines: 17 treatments: 6 - 3-ply untreated jute, 7 – 3-ply green jute, 1 – 2-ply treated sisal, 3 – 1-ply natural sisal.

Number of Trees with imbedded ropes or twines that are showing some degree of girdling: 72 treatments.

Number of Trees that snapped off at points of rope or twine girdling compression points during wind-loading events: 31

This study will conclude when all ropes and twines have completely decomposed or are completely imbedded with no obvious negative effect on the trees.



Failure during wind-loading event at point of rope imbedded in trunk. 3-ply untreated sisal, 10 months after installation.

Community Outreach and Research Projects

Tree Care Advocate Program – www.mntca.org Volunteers Helping Trees Help Communities

Gary Johnson
MN-UFore

Urban Forestry Outreach Research and Extension Nursery
January 1 to August 5, 2016

The Tree Care Advisor (TCA) program began in January of 1993 with two years of start-up funding provided by the U.S. Forest Service. Since then, almost 500 volunteers in urban forestry have completed the 36 hour core course and have contributed tens of thousands of hours to helping their community's and their state's urban forests.

The TCA program has evolved into the Tree Care Advocate program, with several community-based programs as “branches,” to wit: Tree Care Advisors (150+ active), Citizen Pruners and Tree Stewards. Newest of the programs are the Citizen Pruners and the Tree Stewards. Both are community-based with their curriculum community-generated. The intent of each program is to involve community members in the management of their urban resources, and increase the capacity of the community to sustainably develop and care for that resource.

To date, these communities have been part of either the Citizen Pruner and/or the Tree Steward programs in 2016 with a total of 100 community residents participating in the programs:

1. Ada
2. Arlington
3. Fridley
4. Mankato
5. Maple Grove
6. North Saint Paul
7. Rochester
8. Shakopee
9. Saint James
10. Saint Paul



Tree Essential Classes

Throughout the summer, update training classes are held at the UFore nursery on the Saint Paul campus. Two hour classes are offered most Friday mornings in tree and shrub identification and selection, tree health issues, best planting practices, best pruning practices, and predicting/preventing storm damage to urban trees.



A good example of the need for Citizen Foresters. These volunteers focus on making the urban forests safer and healthier by removing branches and foliage that block sight lines, among other tasks.

CEP – www.mntreesource.com The Community Engagement and Preparedness Program

Gary Johnson
MN-UFore
Urban Forestry Outreach Research and Extension Nursery
January 1, 2016 to August 5, 2016

Minnesota's Community Engagement and Preparedness (CEP) program began in 2009 as a cooperative venture between the University of Minnesota's Department of Forest Resources and the Minnesota Department of Natural Resources-Division of Forestry. The goal of the project was to work with communities, providing necessary technical assistance that would help

them develop more sustainable urban forest management programs. Since its inception, we have partnered with other organizations – e.g. County Soil and Water Conservation Districts, the University of Minnesota’s capstone course in Environmental Sciences Policy and Management, the University of Minnesota Extension, and the Minnesota Pollution Control Agency’s GreenCorps program to most effectively engage communities and their citizens in the management of their urban forests.

More than 40 communities have received technical assistance through the CEP program and the partnerships. This assistance consisted of training volunteers to conduct tree inventories or surveys, construction of community gravel beds, best planting and pruning practices and getting out the best information on managing exotic invasive pests such as emerald ash borer. For those communities that have completed inventories or surveys (25+), the CEP team has provided an assessment of data collected and prepared individual Community Tree Reports based on that data.



The Minnesota Tree Trek project is one of the more unique examples of technical assistance that the CEP program provides. This is another community-based program that engages citizens and city personnel in developing walking-tours of mini-arboreta. The CEP program assists by identifying existing trees, suggesting new species, locating trees in the best sites and creating signage and web site references for the selected trees.

Ongoing and new research considered by the CEP program includes:

1. Volunteer motivation and retention.
2. Cost:benefit analysis of various nursery tree root types.
3. Impact of volunteer contributions to community capacity.
4. Accuracy assessment of volunteer-collected data.
5. Impact of community gravel beds on diversifying community tree populations.



Community Gravel Beds

<http://trees.umn.edu/products/>

An Option for Communities to Reforest and Diversify

MN-UFore
Urban Forestry Outreach Research and Extension Nursery
January 1, 2016 to August 5, 2016

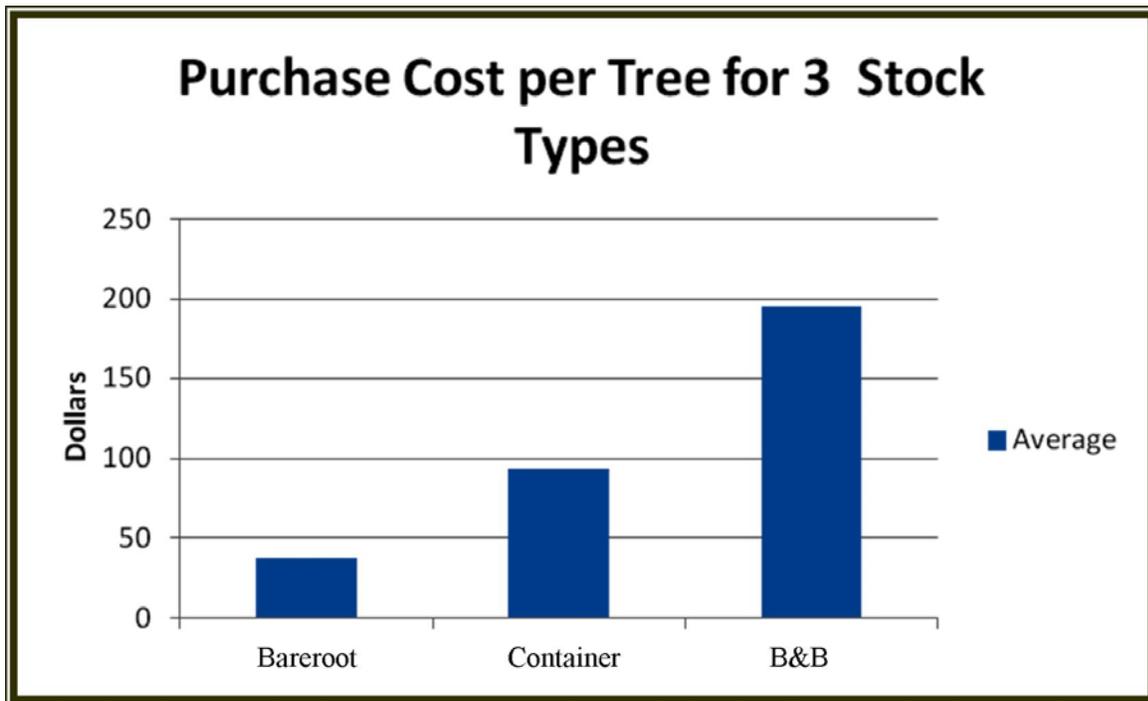
Several new gravel beds have been installed in communities around Minnesota, bringing the total number of (known) community gravel beds to over 50. These options for reforesting communities (and in some cases, counties) range from the simplest of the simple (the Bond Dumpster Method) to the large and elaborate (City of Maple Grove and Hennepin County Environment and Energy). This is good news because it means more communities are planting more affordable trees, introducing more genetic and age-class diversity to their urban forests as well as patronizing their home state's bare-root tree nurseries. Win, win, win.



The "Bond Dumpster Method" – City of North Saint Paul

Community gravel beds are intended as holding areas, aka heeling-in nurseries for spring-dug, bare-root trees and shrubs. The plants are normally installed in the gravel beds during the early spring months (April-May), and within 5-12 weeks (depending on the species), they can be pulled from the beds and planted in the landscapes when there are fewer seasonal labor demands, milder temperatures and less of a demand for water. They are also more suitable for volunteer plantings since they do not have the weight that accompanies containerized or balled-and-burlapped trees.

Most trees start their lives as bare-rooted transplants. Sometimes they end their production lives in field nurseries where they are harvested as balled-and-burlapped trees or larger bare-rooted trees. More often than not, they are harvested bare-rooted and potted up in containers, "finished off" for a growing season and planted in landscapes. Every extra step in the production process, every extra pound they gain (soil and water weight), justifiably increases their final costs to the public.



Andrea Dierich - CEP lab, MN Tree Prices, 2013.

2016 Trends

The less hand/back labor involved with stocking and harvesting community gravel beds, the better. Trends in more recent community gravel beds have been for more flexibility including more repurposed materials and designs that facilitate rapid stocking and harvesting with tractor equipment.

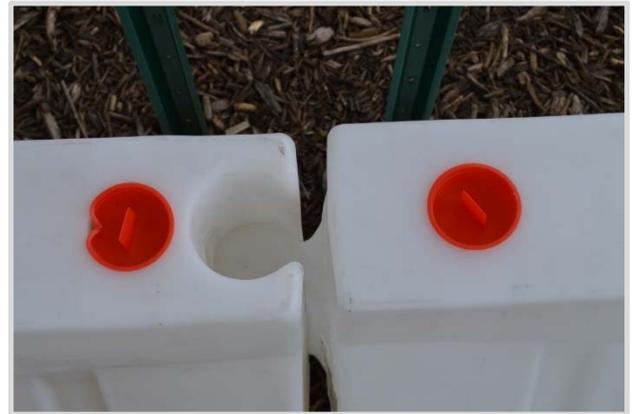


Repurposed Garden Waste Bins near community gardens



*Repurposed Garden Waste Bins near community Gardens.
Tree capacity is 85 1.75-2.0" caliper trees.*

Portable and flexible systems such as this new style of gravel bed at the University of Minnesota UFore Nursery are becoming even more popular as communities integrate this technology into their palette of planting options. The j-barriers are smaller than their concrete highway brethren and much lighter – 33 pounds empty. When filled with water, they weight 300+ pounds, 400+ pounds when filled with sand. This system is perfect for a quick set-up (1.5 labor hours), is size/design flexible and quite affordable. Also note that the wide opening accommodates a front end loader that makes for quick tree installation and harvesting.



For more information on construction types, siting, and tree performance, access the primer found on the web site address in the title of this report.

Urban Tree Growth and Resilience

Eric North

Research Fellow

University of Minnesota Department of Forest Resources

January 5, 2016

Planting trees is simply not enough to gain the long-term benefits ascribed to trees. In order to realize their greatest benefits, we need to maintain long-lived trees in urban areas. Despite many peoples' love and enjoyment of trees in their communities, large, old urban trees appear to be the expectation rather than the rule. Even as tree-care experts, there are gaps in our understanding of how the growth and longevity of urban trees, particularly publicly managed street and park trees, are influenced by the urban environment. There is a lot we still do not fully understand. The long-term impacts of infrastructure construction activities, site quality, and climate on the growth and morphology of urban trees is the focus of ongoing research at the University of Minnesota, Department of Forest Resources.



Data collection at Farview Park in North Minneapolis.

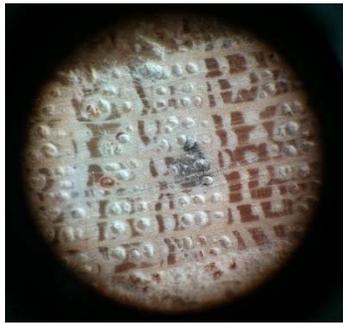
August 2015 marked the end of data collection on 480 street and park trees in the Twin Cities of Minneapolis and Saint Paul. As part of the research, a core sample was taken from each tree, along with height, diameter, and canopy measurements. While gathering data, I was asked by more than one resident if I was cutting the tree down and if coring the tree caused damage. Each conversation was an opportunity to inform a curious public.

Core samples were mounted and sanded. Tree rings from each sample were counted and aged. Each ring width was measured to 0.001 millimeter to better quantify how trees grow through time. In total, over 17,000 individual tree rings were measured. The individual tree data combined with site characteristics (e.g., sidewalk damage, planting-space area, etc.) is currently being analyzed to help better understand how urban trees grow and interact with the urban environment. The goal of the research is ultimately to provide communities with the tools needed to improve the health and longevity of their urban forests.



Eric North coring a Norway maple at 0.5 meters from the ground.

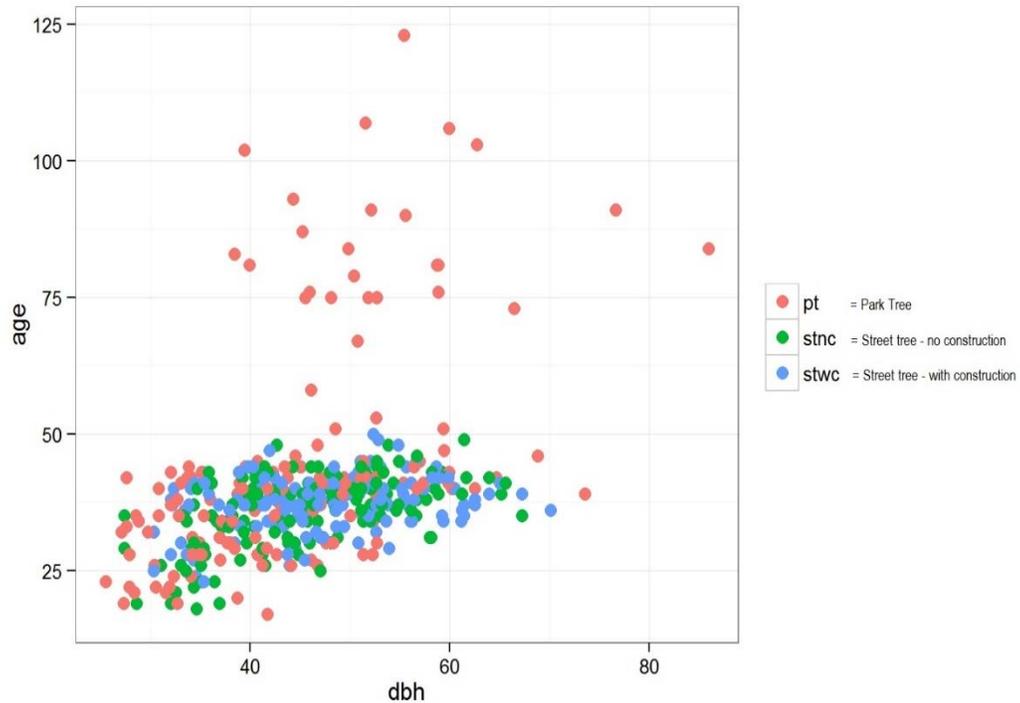
Data was collected from living Norway maple (*Acer platanoides*), hackberry (*Celtis occidentalis*), honey locust (*Gleditsia triacanthos* var. *inermis*), and basswood (*Tilia spp.*) street and park trees. These species were chosen as they occur across a wide range of sites, allowing for evaluation of the influence of different levels of site quality and construction activity on growth and survival. Site data included: soil compaction, the boulevard width, sidewalk construction date, length of construction segments, distance to the nearest trees, and surface area of the planting location.



View of 2 full honey locust tree rings as seen through a microscope.

Trees were sampled from three site types: (1) city parks, (2) non-arterial city streets with no sidewalk replacement in the previous 10 years, and (3) non-arterial city streets with a sidewalk replacement having occurred between 5 and 10 years in the past. All trees had a diameter at breast height (DBH) that was equal to or greater than 25 centimeters (~10 inches) at the time of observation. Sampled trees were located using tree inventories provided by the forestry departments of Minneapolis and Saint Paul. Sidewalk construction data was obtained from the Department of Public Works in Minneapolis and Saint Paul. Each city was segmented according to its forestry management districts, and trees were randomly selected from each defined site type within the districts.

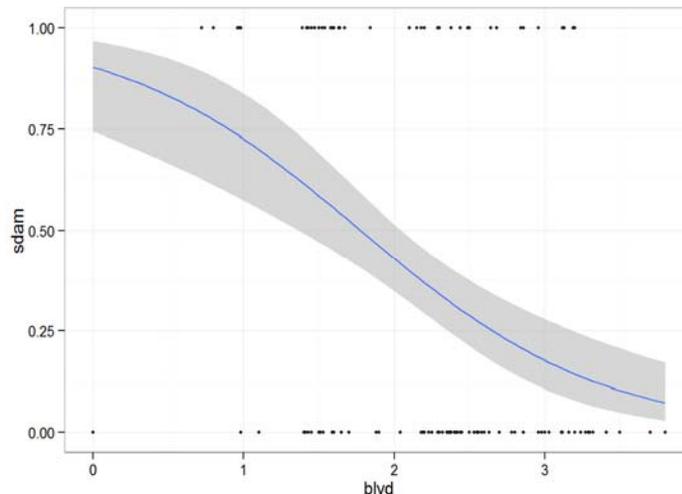
The following graph shows the age and size distribution of trees, based on the site type. The graph indicates that there are no street trees older than approximately 50 years (of those sampled), whereas park trees 120+ years of age were observed. The reasons for the age differences in street and



Age and size distribution of urban trees by site type.

park trees is currently unknown. While it is tempting to speculate (I have some ideas) about the differences in age between street and park trees, it is too soon to tell the underlying cause of the differences. As the research continues, we hope to be able to provide answers to the patterns seen in the data.

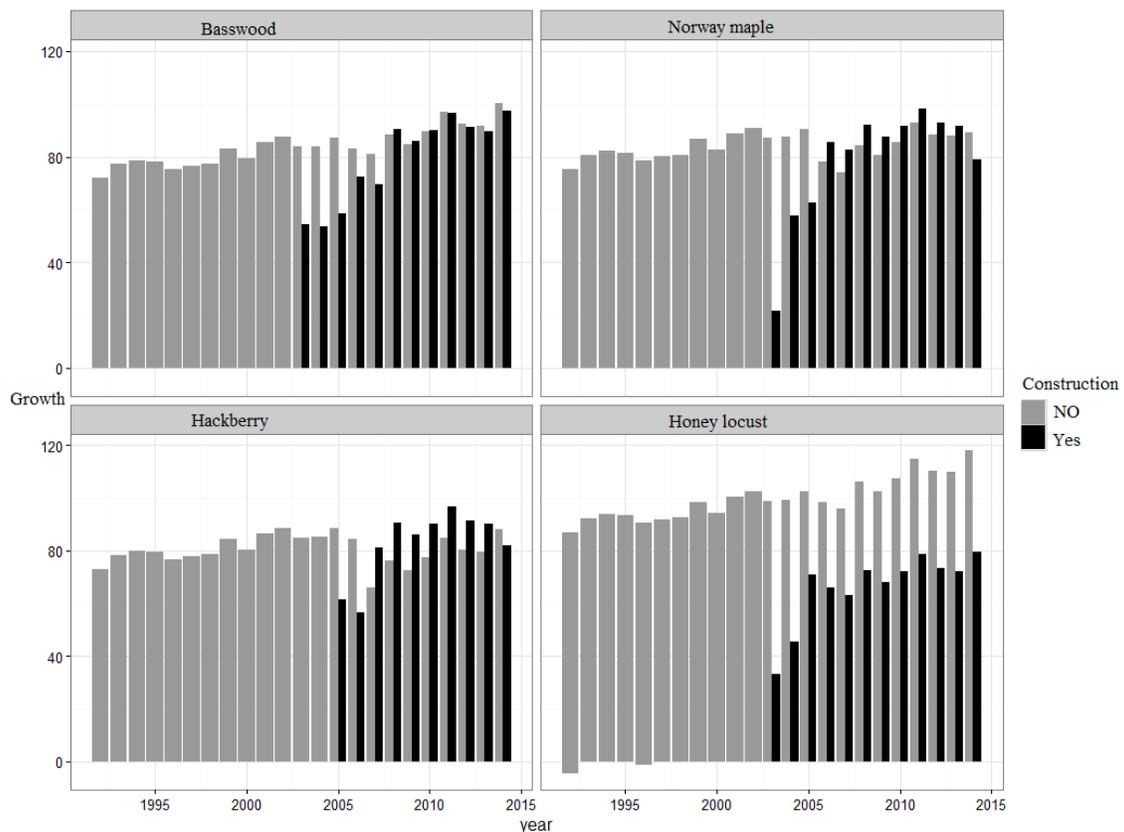
Statistical models of probability are very useful for the investigation of events that have either occurred or not occurred (like sidewalk damage, it's either damaged or it's not damaged). In terms of sidewalk damage, the following graph can be used to investigate the probability (likelihood) of damage given boulevard width and tree presence.



Probability of sidewalks damage (sdam) given boulevard width (blvd) in meters and tree presence using a subsample of Norway maple, hackberry,

Interpreting the probability graph takes a little practice. Essentially, the X-axis (bottom of the graph) is the boulevard width in meters (1 meter equals approximately 3 feet) and the Y-axis (the left vertical side) is the probability of sidewalk damage (1.00 = 100%, 0.50 = 50%, etc.). The blue line is the average probability of sidewalk damage occurring where a tree has been planted at a given boulevard width. The grey shading represents how confident we are about the average prediction of sidewalk damage (the upper and lower predictions). For example, trees planted in boulevard space with a width of less than 1 meter (under 3 feet) are represented by a dot near the 0 on the X-axis. Beginning at 0 on the X-axis, follow the vertical line until it meets the blue line, notice the probability of sidewalk damage (“damage” is any sidewalk lift or crack) where a tree has been planted is approximately 90% (with a range of ~75% to 98%). That’s a fairly high probability of sidewalk damage in small boulevards. Graphs such as these allow us to better understand trends. The overall trend appears to be that as boulevard widths increase, the probability of sidewalk damage decreases (regardless of tree size or species). This initial finding isn’t surprising; however, this is only the beginning, and we hope to be able to provide much more information once the data have been fully analyzed.

The bar graph below shows the growth before and after construction damage. Across all of the species there appears a drop in growth following the construction. There is also a species response. Basswood appears to recover over time, but honey locust appear to continue growing at a reduced rate compared the construction damaged trees.



As a point of interest, people always ask what was the largest or oldest tree measured. (*Remember*, only Norway maple, hackberry, honey locust, basswood trees were sampled.)

Oldest - 123 years – hackberry, Como Park, Saint Paul

Tallest - 29.7 meters (approximately 97 feet) – hackberry, Como Park, Saint Paul

Largest DBH - 89.3 centimeters (approximately 35 inches) – basswood, Farview Park, Minneapolis

A note of caution: preliminary research data **should not** be used to inform management decisions, as interpretations or conclusions may change substantially as the data are further analyzed and interpreted. However, the data collected show promise in providing important answers for how trees grow and interact with the urban environment.

There is still a lot of work ahead, and over the next year we hope to be able to provide scientifically solid results for new management strategies to grow and maintain large, old urban trees capable of providing many benefits for years to come.

Cooperative Projects:

Pruning Cycles and Storm Damage: Are Young Elms Failing Prematurely?

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With the increasing popularity of trees like Princeton American elm and others that have seen widespread planting over the last decade or so, there have been increasing reports of premature failure, usually resulting from storms. Are these failures simply a result of increasing planting frequency? We see similar trends emerging in Dutch elm disease, or are they truly the result of exceptional rates of failure in a species that is being planted more and more every year?

To test the hypothesis of exacerbated failure in young elms, I examined the rate of failure in two storms in the City of Saint Paul over the last two years. In both cases I determined the rate of young elm failure and compared it to the rate of other species in these two storms. To simplify interpretation, at least for this report, failures were pooled at the genus level.

On July 5th, 2016 a severe storm brought very heavy winds and toppled trees throughout the region. Weather data collected near the University of Minnesota reports that about one inch of rain fell with maximum wind speeds of 38 MPH and maximum gusts of 67 MPH. Tree failure data provided by the City of Saint Paul shows that 543 trees required removal as a result of this storm. This includes trees that failed due to windthrow, stem failure, or catastrophic failure of the crown. Over one third of these failures were in the *Ulmus* (elm) genus and were mostly Princeton and Valley Forge American elm.

Genus		Count	DBH (in)
Celtis	Hackberry	25	13.6
Fraxinus	Ash	33	20.8
Tilia	Linden	105	21.0
Acer	Maple	145	16.9
Ulmus	Elm	194	5.5

Another, similar storm event hit Saint Paul just one year prior on July 28th, 2015. This event was not as severe as the storm this year, with weather reports showing about one-half inch of rain falling. Wind speeds were much slower, maxing out at 25 MPH with maximum gusts of 33 MPH. This storm required only 181 removals

Genus		Count	DBH (in)
Celtis	Hackberry	9	13.1
Fraxinus	Ash	11	19.1
Ulmus	Elm	44	5.5
Acer	Maple	45	15.1
Tilia	Linden	55	18.2

Interestingly, five genera consistently exhibited storm failure at rates higher than all others in both storm events. Ash, elm, hackberry, linden, and maple represented about 90% of all failures in both storms. These same five genera comprise just under 70% of the overall tree population, citywide.

Genus		Count	%
Celtis	Hackberry	6517	5.5%
Ulmus	Elm	8483	7.1%
Tilia	Linden	13711	11.5%
Fraxinus	Ash	19784	16.6%
Acer	Maple	32591	27.4%

There are two disturbing trends that present themselves when elm failures are examined alongside others. First, elms are failing at a rate that is two or three times greater than other species when compared to their overall population, citywide. It's no surprise that ash and maple top out the composition of the forest at 16.6% and 27.4%, respectively. Elms, by comparison, comprise just 7.1%. In the 2016 storm, elms lost 2.287% of their population while maples lost just 0.004%.

A second trend observed in elm failure is their size at the time of failure. In both the 2015 and 2016 storms, the average DBH at the time of failure for all elms was about 5.5", this even includes the handful of larger, mature elms that also failed. In contrast, all other species were much larger at the time of failure, ranging from 13" in hackberry to nearly 20" in ash and linden. This cursory examination of failure from just two storms seems to indicate that elms are failing more frequently and much earlier in their lives than any other species. I find this trend particularly troubling when communities like Saint Paul are devoting so much effort on pruning young elms and other small trees.

Because of the trends just described and the increasing concern regarding young tree failure, the UFORE Lab will continue to collect data and examine causal relationships leading to premature failures, especially in young elms. Additionally, 2016 marks the launch of exciting new research conducted in cooperation with the City of Saint Paul, Minneapolis Park & Recreation Board, and Rainbow Treecare Scientific Advancements.

This research is designed to examine the effects of various pruning cycles in combination with plant growth regulator (PGR) treatments on the growth and overall structural quality of five tree species planted in Saint Paul and four species in Minneapolis. This research will also include a cost-benefit analysis of work performed.

The primary goal of this project is to determine the most cost-effective pruning cycle and/or PGR treatment that will result in the greatest maintenance cost reduction while reducing structural defects and young tree failure in the first 10 years after planting. Results from this study will be useful when examining work practices that will reduce both maintenance costs and structural defects by optimizing pruning cycles and/or PGR applications to achieve the ideal combination of establishment, growth rate, and form.

Trees will be randomly allocated to any available planting location, citywide. The project will utilize the following pruning cycle and PGR treatments:

- 0, 5, 10 years
- 0, 3, 10 years
- 0, 7, 10 years
- 0, 3, 7, 10 years
- 0, 5, 10 years + PGR Treatment at low rate
- 0, 5, 10 years + PGR Treatment at high rate

These treatments will be randomly applied to nearly 600 trees across both cities comprised of the following species:

- Common Hackberry (*Celtis occidentalis*)
- River Birch (*Betula nigra*)
- Kentucky Coffeetree (*Gymnocladus dioicus*)
- Accolade Elm (*Ulmus* ‘Morton’)
- Valley Forge Elm (*Ulmus americana* ‘Valley Forge’)
- Red Oak (*Quercus rubra*)

Below is an excerpt from an upcoming article to be printed in *Arborescence*, published by the Minnesota Society of Arboriculture. Both topics are critical to the storm failures and research projects just described.

Young Tree Pruning Cycles, Cost-Benefit Analyses and the Cost of Deferred Maintenance

An emerging issue in arboriculture and urban forestry is the cost of deferred maintenance – in other words the cost of doing nothing when something must be done! Performing research to generate reasonable, statistical proof of the need for timely pruning is very time consuming and lengthy. To achieve results that have real-world applications, research may take 10 years or more. Fortunately, we have few references that provide scientific evidence in support of regular tree pruning.

Research Results

Robert Miller and William Sylvester examined this issue in an article published in 1981. Using Milwaukee, WI as their subject city, the authors found that delaying maintenance resulted in trees of lower quality and, as a result, lower value. Because more frequent pruning cycles incur greater cost, the authors compared this decrease in value with the increased cost of more frequent maintenance. After statistical analysis, they determined that a pruning cycle between four and five years results in the best return from maintenance investments. One interesting fact found in this article was mention of small trees examined as part of the research. They found a number of discrepancies in condition class during one year of their study and traced this back to a young tree population that needed “extensive corrective pruning...[resulting in] temporarily misshapen crowns, large pruning wounds, and a lower average condition class...” This is very interesting because it draws attention to the fact that these young trees needed major pruning, perhaps for the first time, implying that young trees in particular are more sensitive to longer pruning cycles.

Fast forward 32 years to 2013 and we find another research article on pruning cycles, with a specific focus on pruning young trees. Ryder and Moore examined both the economic and biological effects of performing pruning on five species of trees. Their work compared the time required to perform developmental pruning on young trees (three times in seven years) to that required when pruning older trees (one time after 20 years). In the case of eucalyptus this delay increased the per tree cost of pruning by 13-18 times. When inflation adjustments are made, the increase in time required may cost up to 25 times more than investing in developmental pruning of young trees. Another important point made was noting the decrease in tree defects when they received timely pruning as young trees. This creates an immediate savings in maintenance costs while reducing tree defects. This may, in turn, decrease the overall pruning requirements of maturing trees and create a cost savings structure that lasts the lifetime of the tree.



Premature, catastrophic failure in Valley Forge American elm. This tree split in two due to a branch inclusion located in the lower canopy.

How to Convey

These results are very straightforward. The benefits of performing regular, developmental pruning on young trees is almost without doubt. The challenge lies in creating an argument in favor of performing pruning during periods of divestment in both the public and private sectors. There is a need for wise species selection and realistic planting schedules that are matched with available resources. The actual cost of producing a mature American elm (*Ulmus americana*) may be very different from that what is needed for a swamp white oak (*Quercus bicolor*). An understanding of these differences helps to positively influence appropriate decisions made at both the backyard and city levels.

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Included Branches, Union Strength and Failure During Loading Events

Most practitioners know that branch inclusions are a recipe for disaster. Once formed they typically get worse over time and can result in increasing chances for failure during loading events. Identification and timely correction of these defects is necessary to avoid catastrophic failure.

Research Results

In a study performed in 2003 at the Bartlett Tree Labs in Charlotte, NC, E. Thomas Smiley examined the relative strength of codominant stems harvested from red maples. After harvest, the mechanical force required to separate branch unions (with and without inclusions) was measured using a dynamometer. Dr. Smiley found that the presence of a branch inclusion resulted in significantly weaker branch unions. Not a big surprise, most arborists are aware of this through practical experience and observation of branch failures. One interesting outcome of this research, however, is the discussion of union strength and its relationship to branch size. In this study, smaller diameter branches with included bark were found to be weaker than larger ones. In summary, Dr. Smiley suggests that all branch inclusions should be considered weak when compared to those without included bark and should be addressed quickly.



Multiple, severe inclusions in a young Princeton American elm. If left unchecked, these defects can contribute to failure during loadina events.

Later that same year, Ed Gilman published results from a similar study that examined the role of BAR in predicting branch union strength. His work found that the amount of force required to break branches increases with BAR, stressing that codominant stems are much more likely to fail than other branches that are

smaller in diameter. After nearly 12 years, Gilman, Miesbauer and Masters published research that examined how suppression pruning cuts affect trunk strain at the point of branch attachment. This is the first work focused on solving problems observed in the research published in 2003. The effect of branch suppression was examined using pairs of codominant branches in live oak that were exposed to artificial wind loading events. To test the effects of reducing strain by pruning, the smaller of the two branches received one of four possible pruning doses that removed 0%, 33%, 66%, and 100% of the leaves and branch tissue. They found that strain exerted on the branch attachment was reduced by increasing the pruning dose – more pruning caused a greater reduction in strain. Furthermore, the authors discuss the implications of using reduction pruning (i.e. suppression cuts) to reduce branch aspect ratio and thus increase the strength of the branch union. This allows for removal of multiple codominant branches staged over numerous pruning events, especially important when working with trees that have numerous defects or codominant branches.

How to Convey

This concept of a defective or included branch union is very easy to describe and demonstrate. Quickly assess the crown before you meet with a customer, make a plan for branches that will be removed immediately and those that will require staged suppression and removal. When branch inclusions are visible from the ground, their defective nature can be demonstrated by pulling on the branch to slightly separate the inclusion. Be certain to express the need for immediate action to remove and/or correct these defects. Reference the research if they are concerned about the amount of suppression needed and mention that the aesthetic impact of pruning can be lessened by decreasing the pruning cycle and pruning the tree more frequently.

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