Research Update:

Analysis of Factors Contributing to Young Tree Survival

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The benefits that trees provide, especially benefits encountered in urban areas, are wide ranging and well documented. Trees can act as air filters and carbon sequestration machines, they can intercept rainwater and reduce summer air temperatures, they can cool our homes and increase our property values, and even play a part in reducing crime and speeding up healing processes. So it is no small wonder that humans have a great interest in both preserving existing tree canopy (tree benefits increase as tree size increases) and growing additional tree canopy. However, many of these trees are vulnerable to impacts from pests and pathogens, as well as a changing climate, resulting in an even greater need to engage in more effective tree planting and maintenance, in order to foster a new, diverse urban forest of trees that will provide important benefits for generations to come.

Volunteer boulevard tree planting near Shepard Road in St. Paul.

The Study

Ensuring that young trees advance through their establishment period is critical to the goals of urban forestry in building a healthy, sustainable urban forest and reaping the ecosystem benefits that come with having mature trees as a large component of the canopy. Understanding what factors play a role in young tree mortality during this time (the first 1-5 years of a tree's life) is critical to making targeted management decisions to minimize young tree loss.

The focus of this study was to examine the potential relationships of several variables to young tree mortality one year after planting. While there are many factors that contribute to mortality during the establishment period, only four were examined during this study for their possible connection to rates of one-

year post-planting mortality: site type, taxa, root stock type, and planting entity. This was done by assessing historical records of plantings of publicly owned trees in Minnesota and Wisconsin communities. To maximize the number of trees that could be used to make a robust sample size, pre-existing tree plantings from 13 communities and organizations were selected for inclusion in this study. The communities that were selected for inclusion represented a range of urban, suburban, and rural areas that agreed to participate and share their tree planting data.

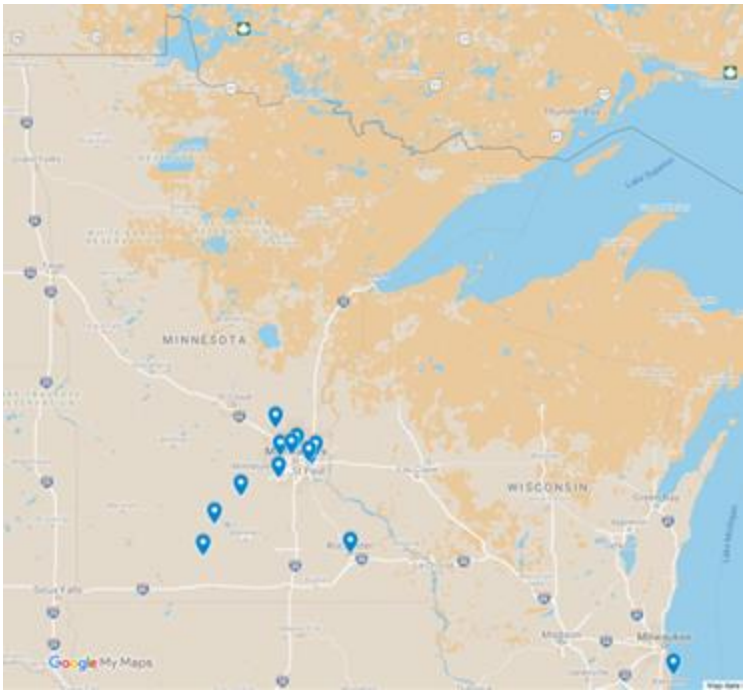

Figure 1. Map of study communities.

Data was selected from studies that had been conducted between 2015 and 2018. Initially, data was collected on 6,312 trees representing 115 unique tree taxa, though this was later refined to 4,428 trees in 25 unique taxa, as trees without a statistically significant number of replications (less than 75), and invasive species were omitted. The results of this research indicate that several of the study variables had statistically significant contributions to tree mortality, and are worth considering in planning for tree plantings.

Root Stock Type

The first variable included in this study was root stock type (nursery production method). There are essentially three different types of root stock available to purchasers: ball and burlap (B&B), container, and bare root, all with their own unique benefits and challenges. B&B trees can be found in many tree nurseries and are the most expensive and labor intensive option available as heavy machinery is needed for harvesting, transportation, and planting. Additionally, B&B trees have hidden root systems that often obscure potential problems and require corrections before planting. Benefits of B&B trees include larger available sizes, longer season of availability, and dramatically reduced risk of drying out during transportation and planting.

The second stock type we examined were container trees. Container trees are the most commonly sold root stock type in the US. Container trees share some of the same drawbacks as B&B trees in that they are relatively heavy and expensive, though to a notably lesser degree. Containerized trees also have obscured root systems that often need to be excavated and corrected prior to planting. Like B&B trees, container trees also

have a long season of availability, a good selection of species, lesser likelihood of drying out, and they cost less than B&B trees.

We also examined bare root root stock. Bare root trees are generally the lowest cost root stock type available, come in the widest variety of species, and because they have no soil ball to contend with, visual assessment of stock quality and determination of proper planting depth is generally easy. It is because of these advantages that bare root trees are the preferred root stock type for use in volunteer plantings. Bare root trees also have their drawbacks, which include availability limited to the spring season and generally in smaller sizes relative to B&B trees. Perhaps one of the biggest drawbacks to bare root trees is that their exposed root system is vulnerable to desiccation if not kept moist during storage, transportation, or just before planting.

Finally, we examined gravel bed bare root trees. Gravel bed bare root trees are simply bare root trees that have been installed in a gravel bed "nursery" in an effort to improve their root system. A gravel bed "nursery" is in essence an irrigated pile of gravel where bare root trees are "heeled in" in spring (when bare root trees are most available) and held over the summer (growing fibrous root tissue) until it can be harvested and planted in the fall, which is the best time to plant most tree species. While their benefits and drawbacks are the same as bare root trees, gravel bed bare root trees have the advantage of having a vastly superior fibrous root system.

Japanese tree lilac after a season in a gravel bed nursery.

Planting Entity

The "Planting Entity" category essentially describes who planted the tree. There are three types of entities that are most commonly responsible for planting public trees: city/ organization staff, contractors, and volunteers. Contractors are classified in this study as an entity hired and paid to plant trees. Eighty eight percent

Contractors planting boulevard trees in Hennepin County.

(88%) of communities reported utilizing paid contractors for tree care activities, and of those communities, 58% reported using contractors for tree planting. This included any paid tree planting organization that wasn't the "host organization". Organization staff consists of paid employees of the sponsoring municipality, county or organization. Finally, volunteers were non-paid participants in tree plantings. Sixty five percent (65%) of communities reported using volunteers for tree activities and tree planting was by far the most common task. All volunteers used in this study were subject to a brief tree planting best practices presentation and received limited supervision during the actual tree planting.

Volunteers planting trees in Racine.

Site Type

A young tree's final planting location can have a large impact on its survival. Generally speaking public trees are planted in one of two locations: in street adjacent areas or parks and other public spaces. In addition to the stressors that all young trees face, each of these site types are subject to their own site related pressures. Street trees face many pressures relating to conditions on adjacent roads. These trees are subject to heavy salt spray and soil salt, increased air contaminants from vehicle exhaust, desiccation, and pressure from surrounding impervious surfaces. Parks and public spaces also have their own pressures including higher exposure to mower or weed whip strikes, competition from grasses and other plants, as well as a higher likelihood of damage caused by animal browse (deer, rabbits, porcupine, etc.). Trees were considered boulevard trees if they were less than 10 feet (US) from a roadway or street. For the purpose of this study, trees in Right of Way (ROW) areas less than 10 feet from a roadway or street were included under the label "boulevard" even if no sidewalk was present. Conversely, trees were considered to be park/ public space trees if they were greater than or equal to 10 feet from a roadway or street.

Volunteer tree planting at Crosby Park in St. Paul.

Tree Taxa

Urban forests species composition has changed a great deal over the years. In

Minneapolis, MN during the early 1900's, the public urban forest was made up of 95% elm trees, and this was not abnormal for the time. Since then, after the cataclysmic events of Dutch elm disease and emerald ash borer, urban forest managers have sought to increase the diversity of urban forests to promote resilient and healthy forests. Fostering tree species diversity was the most commonly cited goal for community urban forest resources programs. The commonly accepted tree taxa stocking rate is that in any urban forest, no species should exceed 5-10% representation, no genus should exceed 10-20% representation, and no family should exceed 15- 30% representation. Species that were examined in this study include trees in the following table.

Table 1. Final tree taxa for analysis

American Basswood	Black Tupelo	Ginkgo	Kentucky Coffeetree	Osage Orange
American Elm	Bur Oak	Hackberry	London Planetree	Autumn Brilliance Serviceberry
American Hophornbeam	Crabapple	Honey Locust	Northern Catalpa	Smooth Serviceberry
Asiatic Elms	European Hornbeam	Japanese Tree Lilac	Northern Red Oak	Swamp White Oak
Bald Cypress	Freeman Maple	Japanese Zelkova	Ohio Buckeye	Yellowwood

Results

Planting entity (i.e. who planted the tree) was not found to have a statistically significant impact on mortality, indicating that less expensive tree planting options, i.e. volunteers, can be effectively utilized in tree plantings, thus augmenting staff capacity at negligible risk to tree survival. Planting location had a statistically significant impact on tree survival, with street adjacent trees surviving at higher rates than trees in parks/ public areas. The implications of this finding may be of particular interest to those who plant in natural areas, who may want to either utilize more tolerant tree species in these difficult sites, or reduce planting numbers while increasing post planting maintenance efforts to ensure survival in otherwise difficult conditions. Tree root stock type was shown to have a statistically significant impact on the

Volunteer tree planting near Shepard Rd in St. Paul.

young tree mortality. Container trees had the lowest rates of mortality, followed by B&B, gravel bed bare root, and spring bare root trees. Species selection also plays a role in tree mortality, as indicated by the wide variety of survival rates based on the various species included in this study. This information should be utilized by practitioners to help inform their species selection decisions, but not as a dictation of which species should and shouldn't be planted, as species diversity is critical to the future of urban forestry. Combining variables also produced consistent outcomes in terms of percent probability of mortality when organized by species. The percent probability of mortality performance relative to the combined variables of root stock type and site type were lowest for container trees planted on boulevards, followed by container trees in park/ public areas, B&B trees in Boulevards, B&B trees in park/ public areas, gravel bed bare root trees in boulevards, gravel bed bare root trees in park/ public areas, and bare root trees in boulevards. Bare root trees in park/ public areas consistently produced the highest mortality rates regardless of species.

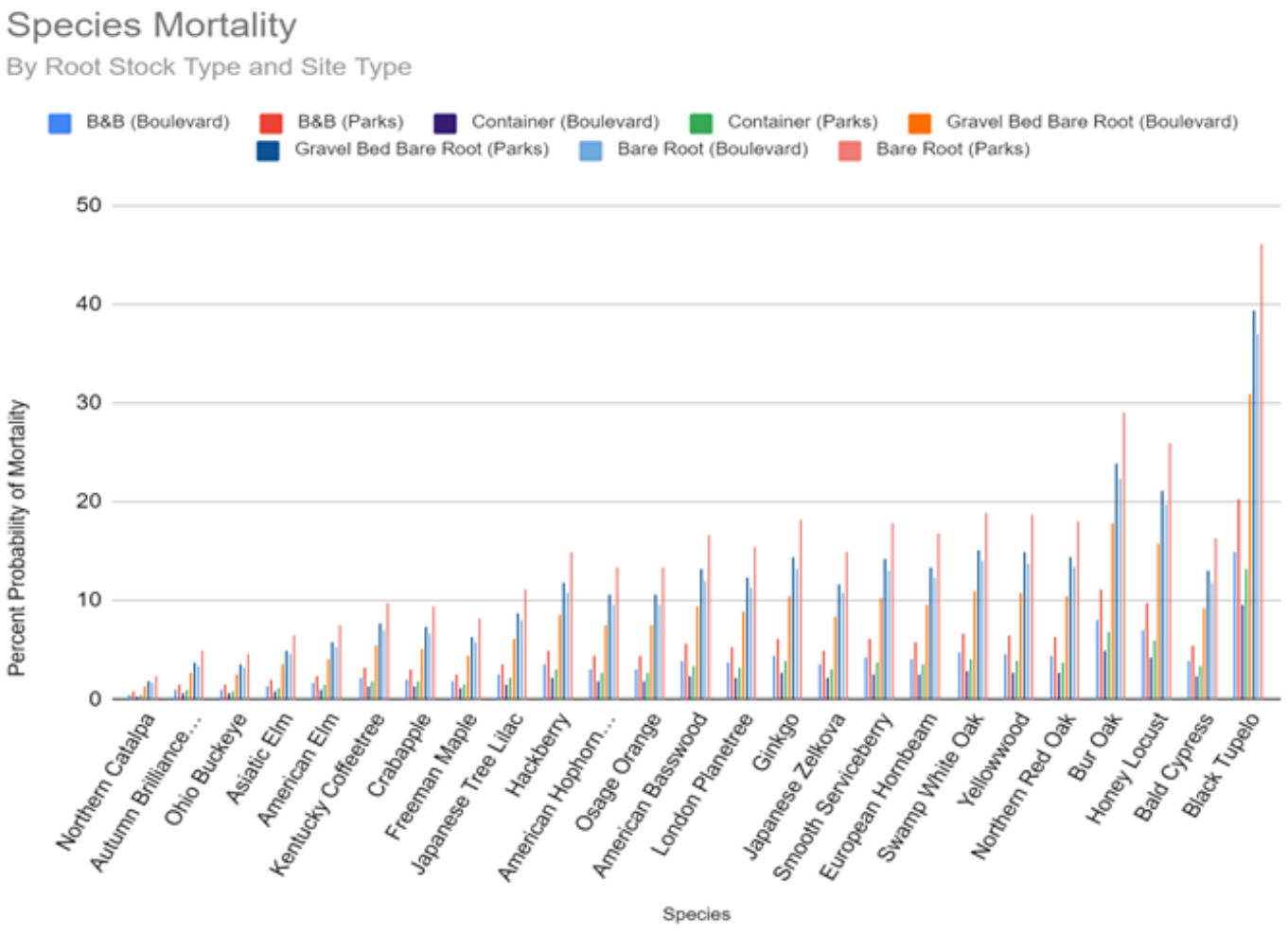

Figure 2. Species mortality by root stock type and site type

By being better informed on factors that influence young tree mortality, practitioners can better utilize their resources in replanting their urban forest. Minimizing establishment mortality rates reduces the costs associated with planting, and then removing, young dead urban trees. It is the intention of this study to aid tree planting organizations in picking the right tree in the right root stock type, planted by the right people, in the right location according to their needs, resources and capacity. The outcomes of this research project will help to fill gaps and build upon the existing body of literature that practitioners may draw from to make educated management decisions. Understanding that certain species in certain combinations of stock type and location perform better than others, urban forest professionals can be more strategic in their tree orders and operations based upon their known planting locations, and post planting maintenance ability.

Gravel bed nursery at the Science Museum of Minnesota.

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Daniel Wattenhofer is a graduate research assistant at the University of Minnesota. He received his undergraduate degree from St. John's University and graduate degree in natural resource science and management from the University of Minnesota. His research has focused on urban and community forestry, ecological restoration, and young tree health. His favorite tree is either a northern catalpa, bur oak, or black tupelo, but he really can't decide.