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Urban Tree Selection in a Changing Climate

By Bert Cregg and Dana Ellison
Michigan State University, Department of Horticulture and Department of Forestry

Current climate projections indicate that mean global temperatures will increase 1-2°C (2-4°F) by 2050 and increase an additional 1-3°C (2-5°F) by the end of the century (IPCC, 2007). In the Great Lakes region, summer temperatures are projected to increase by 4-8°C (7-14°F) by 2070-2099. If greenhouse gas emissions continue to increase during this period, summer rainfall in the region is projected to decrease by 20% (Hayhoe *et al.,* 2010). To put all of this into perspective, this means the climate in Lower Michigan could resemble that of present-day Oklahoma by the later part of this century (Fig. 1). In addition, severe heat waves and other extreme events are likely to increase in severity and intensity (Meehl and Tebaldi, 2004).

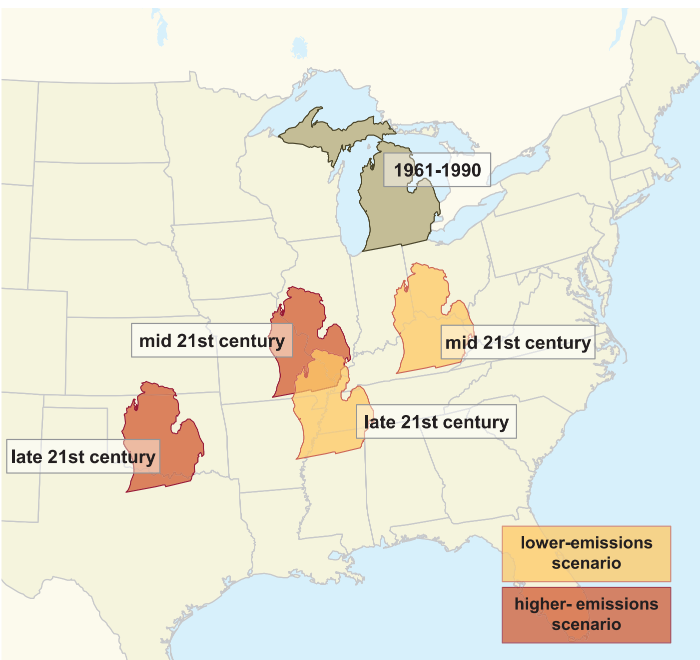

Figure 1. Projected changes in summer average temperature and rainfall for Michigan indicate that summers will feel progressively more like summers currently experienced by states to the southwest. Image by Marlene Cameron. Adapted from Hayhoe *et al.,* 2010.

Trees in urban ecosystems are especially vulnerable to climate change since general warming will be exacerbated by urban heat island effects. Urban heat island effects generally add 4°C (7°F) to air temperatures of cities compared to surrounding rural areas, but may range as high as +9°C (16°F) for summer daytime temperatures in cities in the central U.S. (Imhoff et al., 2010). This magnitude of temperature increase can result in doubling of atmospheric humidity deficit, dramatically increasing tree water demand (Fig. 2).

Landscapers and urban foresters need to incorporate climate predictions into tree selection decisions since trees are long-lived organisms and will experience changes in climate during their projected lifespan (Aitkin *et al.,* 2008; Millar *et al.,* 2007). Selecting trees that are adapted to changing environmental conditions is essential to the future of urban and community forestry in Michigan and the Midwest. Since trees are sessile organisms and are unable to move when environments become unfavorable, their ability to acclimate to changing conditions (referred to a 'phenotypic plasticity') is an important mechanism to adapt to climatic change (Nicotra, *et al.,* 2010). Common examples of plastic response to increased temperatures are changes in physiological processes such as photosynthetic rate (Cordell *et al.,* 1998), changes in leaf and shoot morphology (Hovenden and Vander Schoor, 2003; Morin *et al.,* 2009; Royer *et al.,* 2009), and changes in growth patterns (Kramer, 1995).

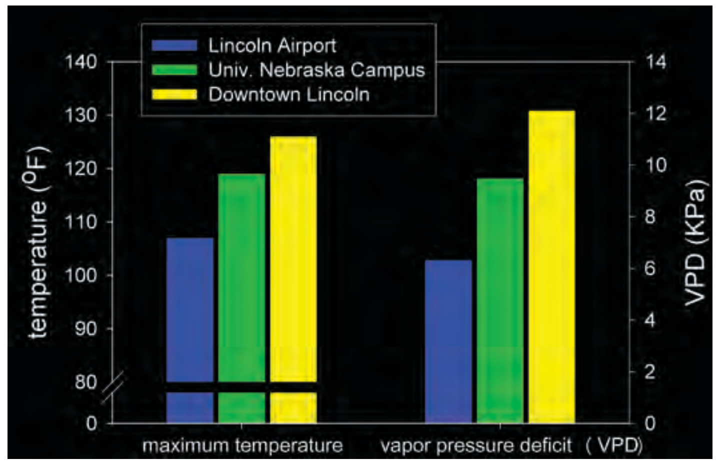

Figure 2. Urban heat effect of maximum temperature and vapor pressure deficit in Lincoln, NE, July 7, 1995. Lincoln Airport indicates conditions at National Service Office; conditions on Univ. Nebraska Campus and Downtown Lincoln were recorded using portable temperature and humidity loggers placed in tree crowns. Adapted from Cregg and Dix, 2001.

In a project funded by the Michigan Nursery and Landscape Association and other research partners (see sidebar), we are investigating the potential impacts of warming temperatures on growth and physiology of urban trees. We are conducting the project in two phases. In Phase 1, we are conducting intensive greenhouse trials to determine the relative ability of street tree cultivars to acclimate their physiological responses to changing temperature regimes. In Phase 2, we are working with a community forestry partner (Greening of Detroit) to compare the ability of cultivars to acclimate under contrasting urban conditions. The long-term goal of this project is to determine whether street tree genotypes differ in their ability to acclimate to increasing temperatures. In addition, we aim to identify key physiological factors that can guide further selection for projected future urban stress conditions.

Phase 1: Greenhouse evaluation of physiological acclimation to varying temperatures

In 2012 and 2013, we received bare-root liners (5' whips or lightly-branched liners) of street tree cultivars from J. Frank Schmidt and Sons Nursery, Inc., Boring, OR (Table 1). The trees were planted in 10-gallon containers in a mixture of pine bark and peat moss (80:20 v:v) at the MSU Horticulture Teaching and Research Center (HTRC). Trees were placed in three sections of a glass greenhouse at the MSU Research Greenhouses (Fig. 3). Trees of each cultivar were assigned to one of three temperature acclimation treatments: High, Medium, or Low. The ‘Low’ temperature regime was designed to track average air temperatures for the area. Average temperatures were calculated from 1996-2011 daily temperatures for East Lansing, MI from the MSU Enviro-Weather website. Medium and High temperatures tracked the average daily temperature +5°C or +10°C, respectively.

Figure 3. Shade trees acclimating to increased temperatures in MSU research greenhouses.

After eight weeks of acclimation we evaluated the response of light saturated photosynthesis and leaf respiration to temperature (Fig. 4). Temperature and respiration response curves were developed for each tree using a portable photosynthesis system (LI-6400, Li-Cor, Inc., Lincoln, NE) in a growth chamber at temperatures of 25, 30, 35, 40, and 45°C.

Figure 4. MSU research aide Aiman Shahpurwala measures photosynthesis of shade trees in response to temperature.

Results to date: Photosynthetic response to temperature varied by cultivar. Moreover, the interaction effects of cultivar and acclimation temperature were also significant indicating photosynthetic acclimation differed among cultivars. For example, in 2012 tulip poplar showed increased photosynthesis in response to increased temperature following acclimation at the Medium and High temperature regimens, whereas swamp white oak showed a high degree of acclimation, but only under High temperatures. Similarly, species differed in leaf respiration response to temperature and degree of acclimation. These results are consistent with our working hypothesis that species vary in their ability to acclimate to increasing temperatures.

Figure 5. Planting day. Over 80 Greening of Detroit volunteers planted 200 shade trees as part of the MSU tree selection study.

Phase 2: Field planting study with Greening of Detroit

Twenty large (1½" caliper) liners of each of the nine cultivars used in 2012 Phase 1 were received from J. Frank Schmidt and Sons Nursery, Inc. in April 2012. The trees were planted in 20-gallon containers in a mix of pine bark and peat moss (80:20 v:v) and grown for an additional year in the Pot-in-Pot research nursery at the MSU HTRC in order to increase size before planting in Detroit. During the nursery year, trees were irrigated daily with spray stakes and received 400 g of controlled release fertilizer (Osmocote Plus 15-9-12 8-9 month Northern release). In May 2013, Greening of Detroit volunteers and staff planted ten trees of each cultivar on two adjacent but contrasting sites near downtown Detroit (Fig. 5). Half of the trees were planted in the median of a major thoroughfare (St. Aubin Avenue) and half were planted in an adjacent park (Lafayette Park). We installed portable data-loggers and sensors to record temperature and relative humidity at each site. We are tracking growth of trees at each location and in 2014 will initiate a program of physiology measurements to compare the physiological responses of the cultivars to contrasting urban conditions (Fig. 6).

Figure 6. MSU Researchers Aiman Shahpurwala (left) and Dana Ellison (right) assess initial heights of trees along St. Aubin Avenue in Detroit.

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Table 1. Shade trees used in MSU Urban Climate Change Study

Acer rubrum 'Frank Jr.'	Redpointe® Maple
Acer saccharum 'JFS-Caddo2'	Flashfire® Maple
Acer saccharum 'Green Mountain'	Green Mountain® Maple
Acer truncatum x *platanoides* 'Warrenred'	Pacific Sunset® Maple
Carpinus betulus 'Fastigiata'	Pyramidal Hornbeam
Gleditsia triacanthos 'Skycole'	Skyline® Honeylocust
Liriodendron tulipifera 'JFS-Oz'	Emerald City® Tulip Tree
Pyrus calleryana 'Glen's Form'	Chanticleer® Pear
Quercus bicolor	Swamp White Oak
Ulmus propinqua 'JFS-Bieberich'	Emerald Sunshine® Elm

Looking ahead

Increasing levels of CO_2 and other atmospheric greenhouse gases are predicted to lead to increased temperatures and more frequent severe drought events. Trees are key components of green infrastructure needed to mitigate changes in climate by sequestering carbon and reducing energy use to cool buildings. However, projected increases in temperatures will increase stresses on trees; especially in urban areas where moisture deficits are amplified by urban heat island effects and limited root volumes (Cregg, 1995; Krizek and Dubik, 1987; Lindsey and Bassuk, 1991). Selecting trees that are able to acclimate their physiology and morphology to future climatic conditions will be critical in order to realize the benefits and ecosystem services of trees in urban and community forests.

Dr. Bert Cregg is an Associate Professor in the Departments of Horticulture and Forestry at MSU. He conducts research and extension programs on management and physiology of trees in landscape, nursery, and Christmas tree systems.

Dana Ellison is a Research Associate in the Department of Horticulture at Michigan State University. She conducts research projects in Dr. Bert Cregg's lab focusing on the management and physiology of trees in landscape, nursery, and Christmas tree systems.

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