



Photo 1. SPAD chlorophyll index was measured on State Street maple and Harvest Gold linden trees grown in #25 containers in the MSU Pot-in-Pot nursery.

MSU Research Update: Water and Nutrient Management for Container Tree Production

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Landscape tree nurseries in Michigan are faced with numerous challenges. These include adapting to a shift in the nursery industry from traditional field production to container production and meeting rising consumer demands for sustainably-produced landscape materials (Dennis et al., 2010). Managing water and nutrient inputs are two of the most critical elements in any tree production system. Effectively and efficiently managing water and nutrients can have a direct impact on the economics and environmental impacts of production, two of the three oft-cited “triple bottom lines” of sustainability. For example, if growers under-irrigate, trees may undergo water deficits resulting in reduced caliper growth, which is one of the first processes affected by water stress. This is especially critical in shade tree production since economic return is based largely on trunk caliper. If growers over-irrigate, economic efficiency is reduced since they’ve paid to apply water that has simply passed through the container. In addition, over-irrigation can leach fertilizer from container substrates, potentially reducing growth and increasing loss of nitrates and phosphorus from the site. Failing to apply adequate fertilizer can also result in sub-optimal growth and poor crop quality, especially leaf color. On the other hand, applying more nutrients than trees can utilize is an inefficient use of an expensive resource (fertilizer) and can lead to adverse environmental impacts, such as eutrophication of surface water or groundwater contamination.

For the past six years, we have conducted research trials on improving nutrient and water management of landscape conifers and shade trees in Pot-in-Pot container production (Klooster et al., 2010; Taylor et al., 2009). The overall goal of the program is to improve our understanding of the growth and physiological response of landscape shade trees and conifers to varying water and nutrient inputs. Support for these projects has been provided by Michigan State University Project GREEN, Michigan Department of Agriculture Horticulture Fund, USDA Specialty Crop Block grant program and nursery industry partners (see Sidebar 2). Below we present two recent highlights from this research program.

Use of SPAD Chlorophyll index as an indicator of foliar nutrition

Why it matters

Foliar nutrient sampling is one of the best ways to determine the nutrient status of trees and determine the need for fertilization. However, target foliar nutrient concentrations can vary among species and even between cultivars within species. Adequately sampling for a large nursery may require dozens of samples, each costing \$15-\$20. A possible alternative for monitoring foliar nutrition is to use a SPAD meter (SPAD-502, Minolta, Inc.) to measure leaf chlorophyll

index (Chung and Robison, 2003). A SPAD meter is a portable unit that provides an index of leaf chlorophyll content based on transmittance of different light wavelengths through a leaf. SPAD meters are easy to use and provide fast and non-destructive measurements of chlorophyll index. Meters can be purchased for about \$2,000. The goal of the study was to determine the seasonal variation in chlorophyll index and determine how well SPAD readings related to foliar nutrient concentrations for landscape trees.

What we did

In the spring of 2008, we planted twenty four 1½" bare-root liners each of State Street® Maple (*Acer miyabei* ‘Morton’) and Harvest Gold Linden (*Tilia cordata* × *mongolica* ‘Harvest Gold’) in #25 containers in a mix of composted pine bark and peat moss (80%:20% v:v). The trees were placed in socket pots in the MSU Pot-in-Pot research nursery and watered daily during the growing season via individual spray stakes (Photo 1). Four trees from each species were randomly assigned to receive one of six levels of controlled release fertilizer (Osmocote Plus 15-9-

12 (N-K2O-P2O5), 8-9 mo. northern release): 200, 275, 350, 425, 500, or 575 g of product per container. Trees were grown for two years and were fertilized at the start of each season. During the second growing season, we measured SPAD index on five leaves on each tree periodically through the growing season (Photos 2 and 3). Fully expanded leaves were selected at random from the mid-canopy for measurement. In mid-July, we collected leaves from the same crown position on each tree and sent them to a commercial laboratory (Harris Labs, Inc. Lincoln, NE) for foliar nutrient analysis.

What we found

SPAD index of leaves of State Street Maple and Harvest Gold Linden followed a pronounced seasonal pattern (Fig. 1); SPAD index increased until mid-July and then leveled off. This indicates that there is a broad plateau for SPAD readings and that measurements taken any time during mid- to late-summer should provide a representative sample. SPAD index increased with foliar nitrogen and phosphorus concentration (Fig. 2) for both species. However, the relation between SPAD and foliar nutrient concentration differed between species. This species effect likely reflects differences in leaf morphology between species since SPAD meters provide an index of total chlorophyll content, which is dependent on nutrient concentrations as well as leaf thickness (Marenco et al. 2009).

What it means

SPAD meters can provide growers with a rapid and inexpensive means to assess foliar nutrition and to supplement foliar sampling. Our research suggests there is a relatively broad ‘window’ during the growing season when SPAD index may be assessed. Due to differences in leaf morphology, target SPAD readings will vary by species.



Photos 2 & 3. SPAD index can provide a rapid means to assess trees with high (Photo 2) and low (Photo 3) nutrient status.

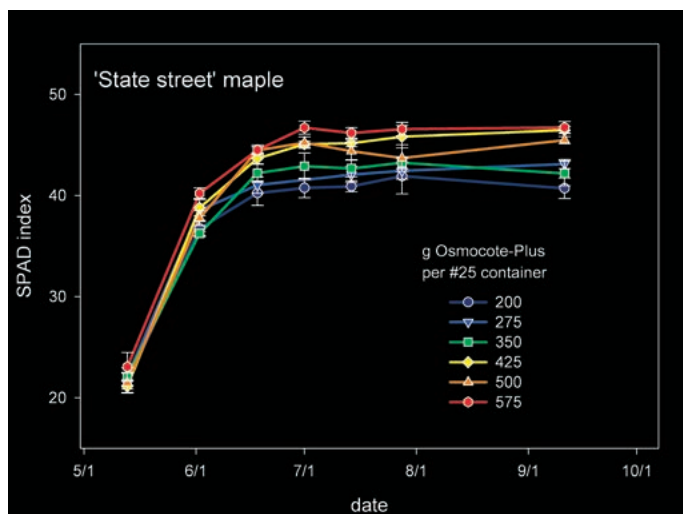


Figure 1. Seasonal trend of SPAD chlorophyll index of State Street maple trees grown in #25 containers fertilized with 6 rates of controlled release fertilizer (Osmocote Plus 15-9-12; 8-9 mo. release).

Estimating water use of container-grown conifers using crop coefficients

Why it matters

Irrigation is critical for container-grown trees since containers have limited water holding capacity. Michigan currently requires producers with the capacity to withdraw more than 100,000 gallon per day (70 gal per min.) in a

30-day period to report water use. Several states including Florida, California, and North Carolina currently regulate water consumption by container nurseries (Beeson et al., 2004). In order to efficiently irrigate trees in container production it is important to know how much water trees use. Researchers have used a variety of methods to estimate water use of container-grown trees including periodic weighing, stem sap flow, and calculating the difference between irrigation and leaching. In this study, we developed crop coefficients to predict water use of conifers based on measurements of tree evapotranspiration (total water loss due to plant transpiration and evaporation from substrate surface).

What we did

We monitored daily water use of conifers (*Picea pungens* and *Abies fraseri*) grown in #7 containers during the 2010 and 2011 growing seasons. Trees were up-potted from #3 containers in April 2010 and averaged 23" (blue spruce) and 31" (Fraser fir) in height at transplanting (Photo 4). All trees were grown in a mix of pine bark and peat moss (80:20 v:v) and top-dressed with either controlled release fertilizer (Osmocote Plus 15-9-12 N-K2O-P2O5) or an organic fertilizer source (NatureSafe fertilizer, Griffin Industries) at a rate of 25 g of N per container. (Note: comparisons of fertilizer source will be part of future research updates.) Trees were irrigated daily at 9:00 am by individual spray stakes in each container. Volumetric soil moisture content (MC) was monitored continuously using 20 cm long Time Domain Reflectometry (TDR) sensors and recorded every 15 minutes by an automated datalogger

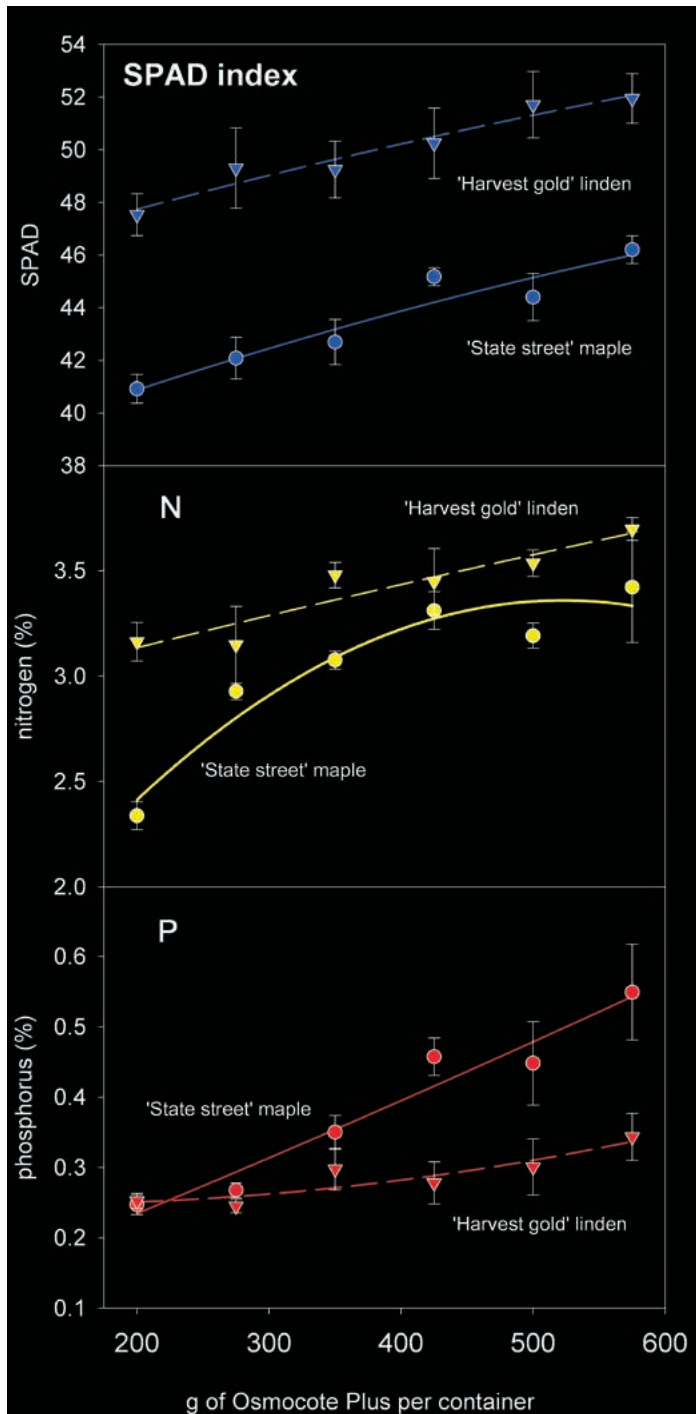


Figure 2. SPAD chlorophyll index, foliar nitrogen concentration, and foliar phosphorus concentration of State Street maple and Harvest Gold linden trees grown in #25 containers fertilized with 6 rates of controlled release fertilizer (Osmocote Plus 15-9-12; 8-9 mo. release).



Photo 4. Colorado blue spruce and Fraser firs in #7 containers after up-potting at the start of the 2010 growing season.



Photo 5. This blue spruce container includes a 20 cm long moisture probe that is continually recorded by an automated datalogger.

(Photo 5). Daily water use was estimated from the difference between soil MC 15 minutes after each irrigation and MC before the next day's irrigation. We calculated crop coefficients (Kc) as the ratio of actual tree evapotranspiration (ET_{act}) to reference potential evapotranspiration (ET_{ref}) to provide a broad indicator of irrigation need (Sidebar 1). ET_{ref} is calculated from temperature, humidity and radiation and estimates are readily available on the Internet for over 60 locations around Michigan at <http://www.enviro-weather.msu.edu/>

What we found

Our data illustrate the potential utility, as well as the limitations, of estimating crop water use via crop coefficients.

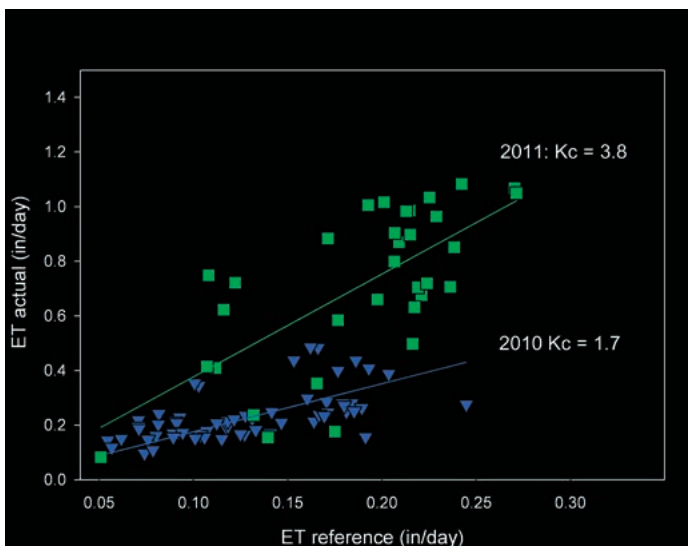


Figure 3. Actual evapotranspiration (ET_{act}) and reference evapotranspiration (ET_{ref}) of conifers grown in #7 containers in 2010 and 2011. Crop coefficients (Kc) represent overall ratio of ET_{act} to ET_{ref}.

Crop coefficients for the conifers increased from 1.7 in the first year after planting to 3.8 in the second season (Figure 3). Based on these Kc values and average daily ET_{ref} data compiled from the MSU Enviro-weather site, predicted daily water use for these conifers ranged between 0.12 and 0.19 gallon per day in the first year after up-potting and between 0.27 and 0.43 in the second year (Table 1). In both years, however, the Kc method occasionally resulted in large over- or under-estimates of irrigation need on individual days.

What it means

The utility of crop coefficients in container production is often debated in the nursery research literature (Bauerle et al., 2002). Crop coefficients may not completely reflect water use due to crown development, container size, or other environmental factors (Niu et al., 2006; Schuch and Burger 1997). In addition, it is not always necessary to replace 100% of water loss to maintain maximum plant growth (Warsaw et al., 2010). Nevertheless, in the absence of other information, crop coefficients can provide useful baseline information as an initial estimate of actual tree water use to guide irrigation decisions. Using an ET_{ref}-based system also helps growers to understand the importance of ET_{ref} in driving plant water use and the need for irrigation.

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Table 1. Estimated daily water use of Fraser fir and Colorado blue spruce in #7 containers based on ETref and crop coefficients (Kc)

Month	Average ¹ ETreference (in. per day)	Estimated daily water use (gallons per container)	
		2010 Kc = 1.7	2011 Kc = 3.8
April	0.12	0.13	0.30
May	0.13	0.15	0.32
June	0.17	0.19	0.42
July	0.17	0.19	0.42
August	0.15	0.17	0.37
September	0.11	0.12	0.27

¹ Ten-year average based on Enviro-Weather station at MSU Horticulture Teaching and Research Center, East Lansing, MI from 2001-2010

Sidebar 1. Estimating Tree water use from reference evapotranspiration (ETref) and crop coefficients (Kc).

Daily reference evapotranspiration (ETref) estimates are available for over 60 locations across Michigan on the MSU Enviro-weather network. In order to use a crop coefficient (Kc) to determine water use for trees in containers that are irrigated via spray stakes or drip emitters, estimated ETact must be converted to a volume.

Example: Conifer in #7 container during August of second year after transplanting
 Container inside diameter = 13.8" (radius = 6.9")
 Substrate surface area = $3.1416 \times 6.92 = 150$ sq. in.
 1 cu. in. water = 0.0043 gallons

Calculate ETactual from Kc and ETref
 $ET_{actual} = Kc \times ET_{ref}$
 $0.57 \text{ in.} = 3.8 \times 0.15 \text{ in.}$

Convert depth of water to volume
 $Volume \text{ (cu. in.)} = ET_{actual} \times \text{container surface area}$
 $85.5 \text{ cu. in.} = 0.57 \text{ in.} \times 150 \text{ sq. in.}$

Convert cu. in. of water to gallons
 $Volume \text{ (gal.)} = Vol \text{ (cu. in.)} \times 0.00433$
 $0.37 \text{ gal.} = 85.5 \text{ cu. in.} \times 0.00433$

Sidebar 2. Industry partners support MSU Pot-in-Pot Research Nursery

We gratefully acknowledge direct and in-kind support of the MSU Pot-in-Pot Research Nursery

- J. Frank Schmidt and Sons Nursery
- J. Frank Schmidt Family Charitable Foundation
- Nursery Supplies, Inc.
- Renewed Earth, Inc.
- Petersons Riverview Nursery
- Scotts, Inc.
- Griffin Industries, Inc.
- Michigan Nursery and Landscape Association
- Michigan Christmas Tree Association
- Spartan Irrigation