Assessing Foliar Water Uptake in the Northern Deciduous Temperate Forest Tree Species

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Abstract
Trees possess the ability to absorb water through their leaves in order to regulate its hydric status (Breshears et al. 2008). Leaves use trichomes within the adaxial side to uptake water while the abaxial side repels it to protect the gas exchange rate (Fernandez et al 2014). Water will transport throughout the tree to satisfy requirements for a prolonged life (Cassena et al 2015). This experiment differentiates foliar water uptake between groups (gymnosperms and angiosperms) and between each species (*Thuja occidentalis, Tsuga canadensis, Pinus resinosa, Pinus strobus, Betula alleghaniensis, Betula papyrifera, Acer rubrum, Acer saccharum*). We found that the results were statistically significant between angiosperms and gymnosperms as well as between each species of the dehydrated treatment. Results between hydrated and dehydrated treatments were also statistically significant.

Key Words: foliar water uptake, leaf absorption, angiosperms, gymnosperms, deciduous

Introduction

Trees have adapted and lived within many different ecosystems throughout history. These adaptations include water absorption through different parts of the tree. This is especially needed now with global warming creating drier environments (Eller et al 2013). Drought stress can occur within any environment, even the ones that are considered wet forests (Choat et al 2012). Mortality rates increase as the temperature rises within periods of drought (Allen et al 2015). These three factors are critical influences for vegetation change (Allen et al 2015). Production of photosynthesis directly correlates to the raising temperatures which can create hydraulic failures and unbalanced carbon levels if stress intensity is too high (Allen et al 2015). This suspended production is due to stomatal closure which would eventually kill the tree (Allen et al 2010). However, these mortality rates are decreased due to foliar water intake of fog condensation and rainfall (Goldsmith et al 2013).

Overall, most people who contemplate about trees absorbing water, would typically think about the root systems. However, recent studies have shown that water can be absorbed through the leaves (Burgess & Dawson 2004, Cassena et al 2015, Eller et al 2013, Fernandez et al 2014). Leaves can uptake water from rainfall, snowmelt, and even fog condensation (Breshears et al. 2008). Soils may appear to be dry, however, water balance is still able to be achieved using these sources (Limm et al 2009). Foliar water uptake occurs by means of the leaf cuticle and through the trichomes (Eller et al 2016). Trees can reverse water flow in order to get water to different parts of its appendages (Cassena et al 2015). Although root systems are dominant in rainfall events, leaf wetting through fog residue takes control during drought conditions (Limm et al 2009). Fog condensation can help maintain stomatal openings, decrease temperature, and increase carbon values just by contributing to water balances (Berry & Smith 2013). Since these new perspectives on leaf wetting has come to light, many new projects are needed to be studied with different locations along with different species (Goldsmith 2013, Li et al 2014).

Project

The objective of this project is to differentiate foliar water uptake between groups (gymnosperms and angiosperms) and between each species. Finding differences between taxonomic groups is compelling considering how different species can be more vulnerable than others in a water-stressed environment. Choosing trees from the same genus can show subtle differences between the two along with amidst each family. Other variances can be shown through orders and classifications, having further relations compared to the others. This leads us to hypothesize that all species have the capability of uptaking water through leaves and this difference will be distinct depending on taxonomic groups and tree species.

Materials and Methods

Site and Tree Selection

This study was conducted at the University of Notre Dame Environmental Research Center in the Upper Peninsula of Michigan. Eight sites were chosen based on a map of the property, which depicted the location of each primary tree species. Eight tree species were chosen, four being gymnosperms and the other four being angiosperms. The gymnosperms are:

Name		**Scientific Name**		**Family**		**Order**		**Class**
White Cedar	-	*Thuja occidentalis*	-	Cupressaceae	-	Pinales	-	Coniferopsida
Hemlock	-	*Tsuga canadensis*	-	Pinaceae	-	Pinales	-	Coniferopsida
Red Pine	-	*Pinus resinosa*	-	Pinaceae	-	Pinales	-	Coniferopsida
White Pine	-	*Pinus strobus*	-	Pinaceae	-	Pinales	-	Coniferopsida

Angiosperms that were selected:

Name		**Scientific Name**		**Family**		**Order**		**Class**
Yellow Birch	-	*Betula alleghaniensis*	-	Betulaceae	-	Fagales	-	Magnoliopsida
Paper Birch	-	*Betula papyrifera*	-	Betulaceae	-	Fagales	-	Magnoliopsida
Red Maple	-	*Acer rubrum*	-	Sapindaceae	-	Sapindales	-	Magnoliopsida
Sugar Maple	-	*Acer saccharum*	-	Sapindaceae	-	Sapindales	-	Magnoliopsida

Leaf Collection

Within the appointed sites, we chose five reachable trees from each of eight species. From each tree, a branch with at least ten fully expanded leaves was plucked and labeled so as to be brought back for hydration. When at the lab, the branches were immediately immersed in water and were then left overnight. Treatments will consist of fully hydrated leaves and partially dehydrated leaves.

Dehydrated Experiment

After leaving the branches in water overnight, five leaves were extracted and weighed before being left out to dry. When the initial mass was recorded, glue was used to seal up the end of the petiole where it was snapped off the branch to prevent water loss. Then the leaves were laid out in a dark area for 90 minutes before being weighed again. As soon as the second mass (dry) was recorded, the leaves were then submerged in separate beakers of distilled water. When submerged, the petiole of the leaf was not allowed to be in the water to observe leaf blade absorption. After 90 minutes, the leaves were taken out and gently dried off before being weighed a third time. While making sure all water residue was off of the leaf, we had to be consistent that only slight pressure was applied and at a reasonable pace. Finally, after the third weight measurement, the leaves were put in labeled paper bags and placed inside an oven that was set at 50°C. Two days later, the leaves were taken out to provide a fourth weight (oven).

Hydrated Experiment

Five leaves off of the branches were measured for their initial mass. They were then placed into water, excluding the petiole, for 90 minutes following the procedure explained above. After being dried, they were again measured for the second mass (wet) and put into paper bags to be placed inside the oven. Two days later, the leaves were taken out to provide a third weight (oven).

Statistical Analysis Tests

To assess the differences between hydrated and dehydrated leaves a t-test was performed. To evaluate if the species are statically different we use a one-way ANOVA on ranks (Kruskal-Wallis H test). This test was also used to assesses the difference between angiosperms and gymnosperms. To observe this difference we ran a Dunn test (Bonferroni method) as Post-hoc analysis. We used a non-parametric test because data does not have normal distribution. These statistics were done using RStudio.

Results

The leaves of every species absorbed water in both treatments. Although, there was differences in the quantity of water that they uptake as well as in the percentage that this water represent of total water content. There was a significant difference of dehydrated foliar water uptake between angiosperms and gymnosperms (ANOVA; Mean +- SE; angiosperms, 0.034946 +- 0.0093138259; gymnosperms, 0.021555 +- 0.01288782; f-value = 6.4603; df = 1; p-value = 0.003485; Figure 1).

There was a significant difference of dehydrated foliar water uptake among species (ANOVA; Mean +- SE; white pine, 0.00352 +- 0.000526194; white cedar, 0.04656 +- 0.01564124; hemlock, 0.030856 +- 0.01478315; red pine, 0.005284 +- 0.000218028; yellow birch, 0.03104 +- 0.003395238; red maple, 0.026052 +- 0.002416631; sugar maple, 0.016988 +- 0.003279004; paper birch, 0.065704 +- 0.00657299; f-value = 6.4603; df = 7; p-value = 0.0001119; Figure 2).

There was a significant difference of biomass percentage between each species (ANOVA; df = 7; p-value = 3.617e-05; Figure 3).

Discussion

The experimental results support the hypothesis that all species have the capability of uptaking water through leaves, as well as the differences being distinct between taxonomic groups and species. Results show that Hemlock and Yellow Birch are the most relatable species out of the eight (Figure 2). Paper Birch would seem to be the most unaffiliated species as it only relates to White Cedar, Hemlock, and Yellow Birch (Figure 2). However, when it comes to the percentage of foliar water uptake, there are an equal amount of related species between each group (Figure 3). Although, it is interesting to note that Paper Birch does not relate to Red Pine or White Pine, and White Pine does not relate to White Cedar (Figure 3). Paper Birch, Yellow Birch, and Red Maple are statistically significant, which means they are different from each other even though they are angiosperms (Figure 6). Paper Birch also seems to be the species that has the most intake up water when dehydrated, while White Pine had the least amount (Figure 4).

Dehydrated leaves, for the most part, have the most foliar water uptake compared to hydrated leaves between species (Figure 4). This is most likely due to the leaves being stressed for not obtaining enough water. Of course, this trend is also the same when comparing angiosperms and gymnosperms (Figure 1,5). The uptake of water is greater within dehydrated leaves. In addition, angiosperms have higher dehydrated intake rates than gymnosperms, however, the average hydrated intake values are slightly higher in gymnosperms (Figure 5).

Other studies have found similar results with the fact that foliar water uptake is indeed possible within different species of trees (Eller et al 2013, Li et al 2014, etc.). Although, many experiments need to be done with direct leaf wetting rather than fog submersion. Another recent study has proven that angiosperms are more likely to recover from drought (Anderegg et al 2016), which seems to be the case in this completed experiment.

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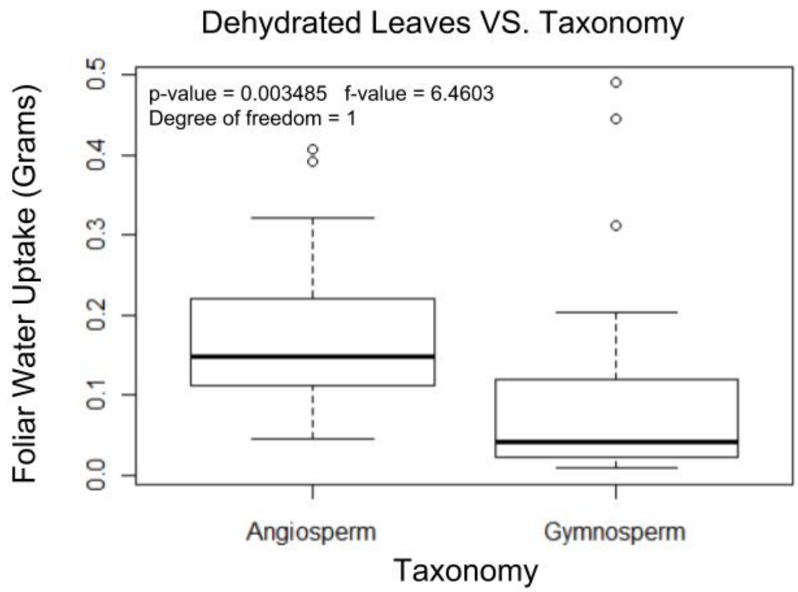

Figure 1. Dehydrated foliar water uptake measured (in grams) between taxonomic groups. Analyzed with Kruskal-Wallis test.

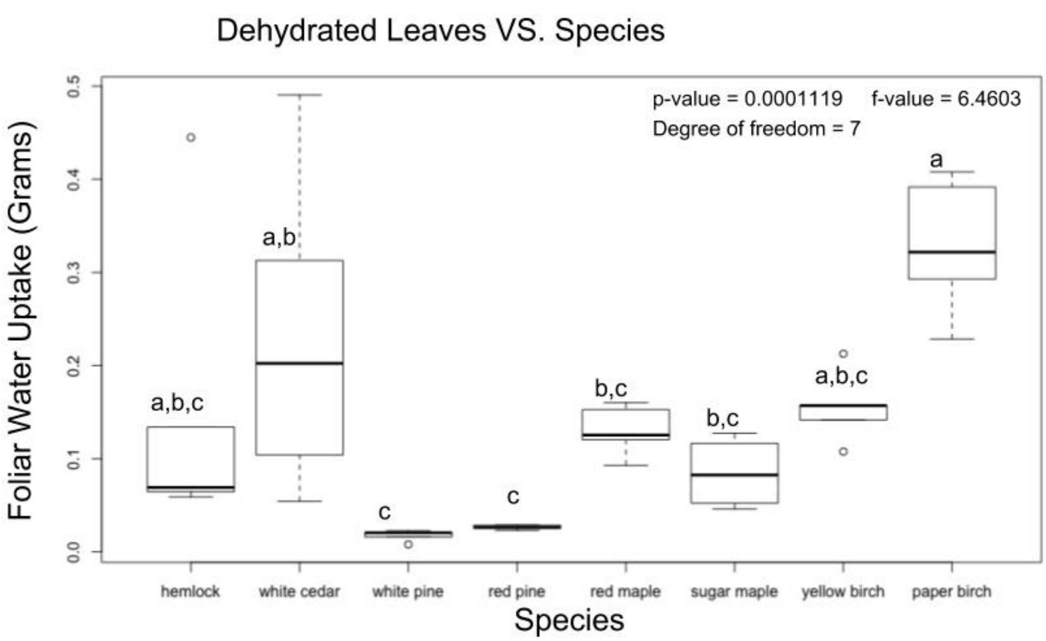

Figure 2. Dehydrated foliar water uptake measured (in grams) between each tree species. Analyzed in a one-way ANOVA, Tukey test, and a Kruskal-Wallis test.

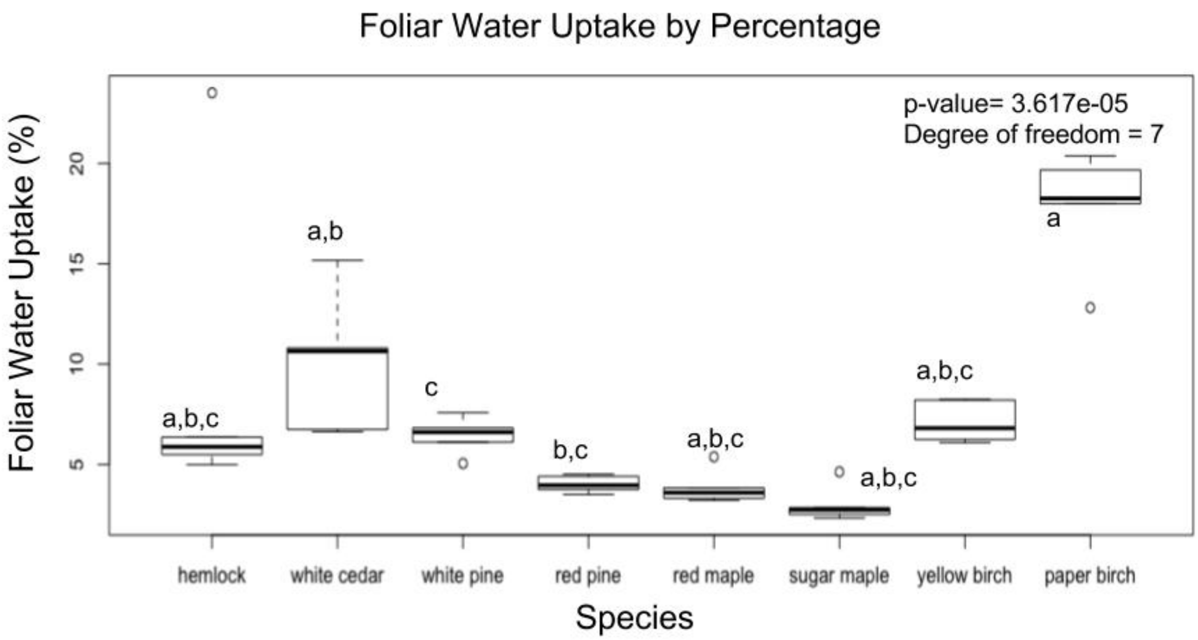

Figure 3. Dehydrated foliar water uptake measured (by percentage) between each tree species. Analyzed in a one-way ANOVA, Dunn test, and a Kruskal-Wallis test.

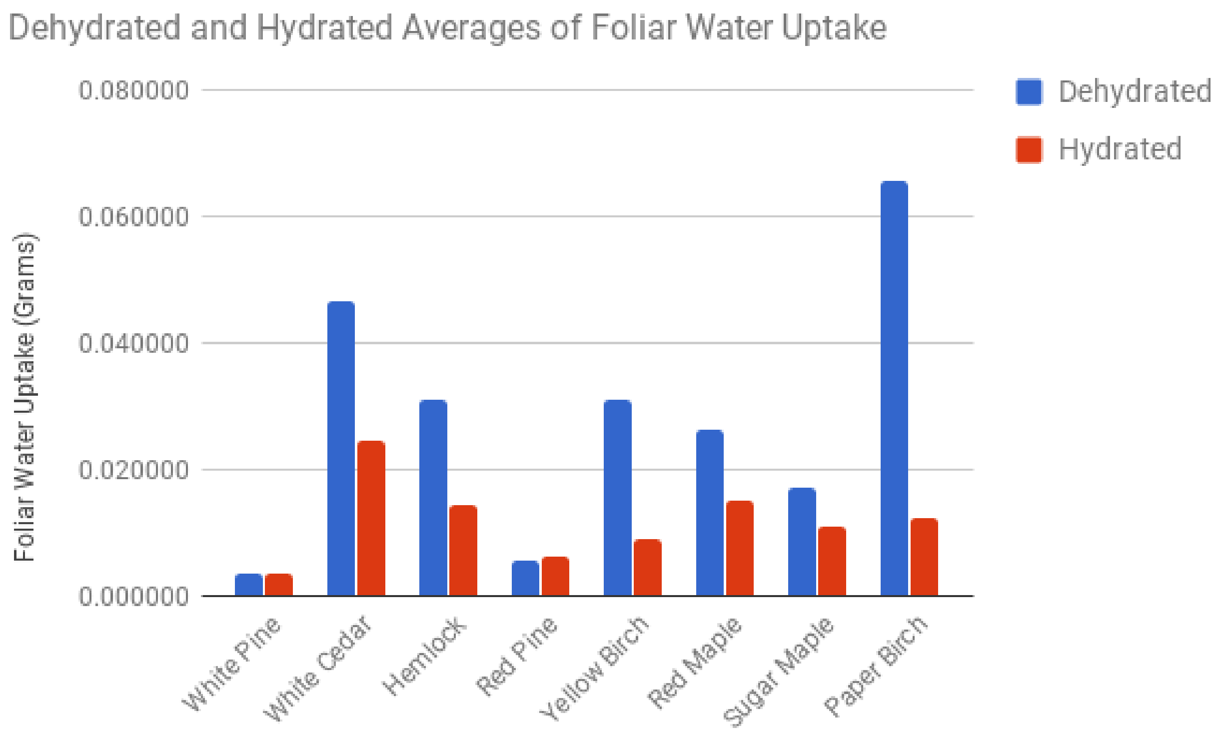

Figure 4. Average foliar water uptake (fwu) per leaf (in grams) between hydrated and dehydrated treatments within each species. Analyzed using a bar chart.

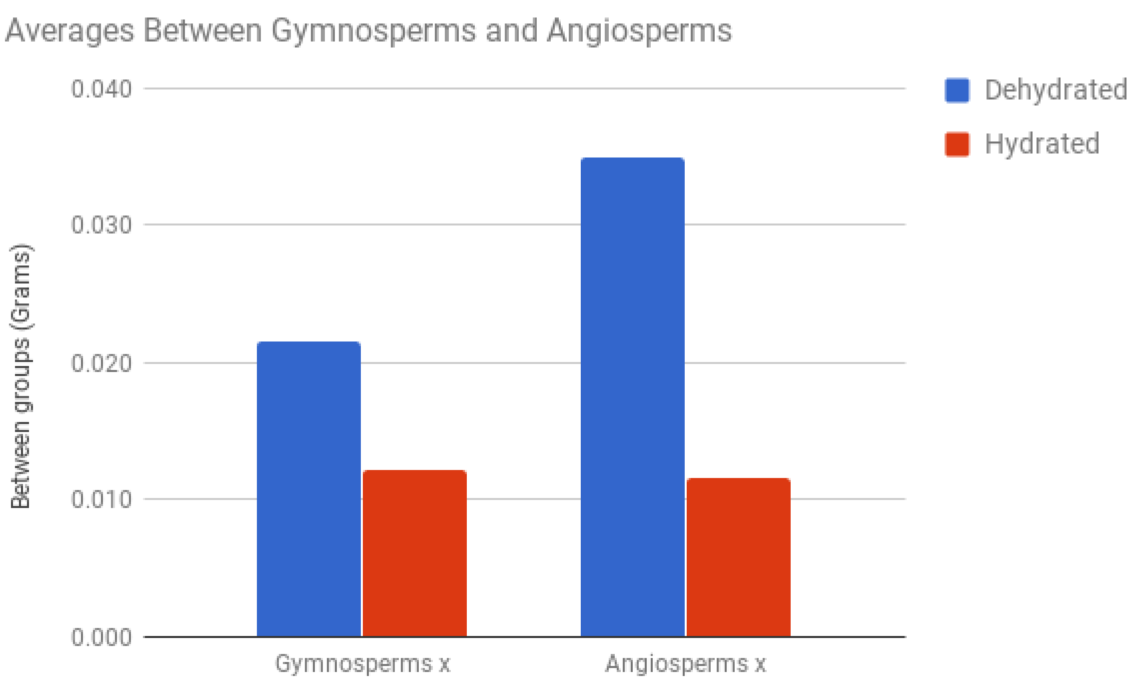

Figure 5. Average foliar water uptake (in grams) between hydrated and dehydrated treatments amidst taxonomic groups. Analyzed using a bar chart.

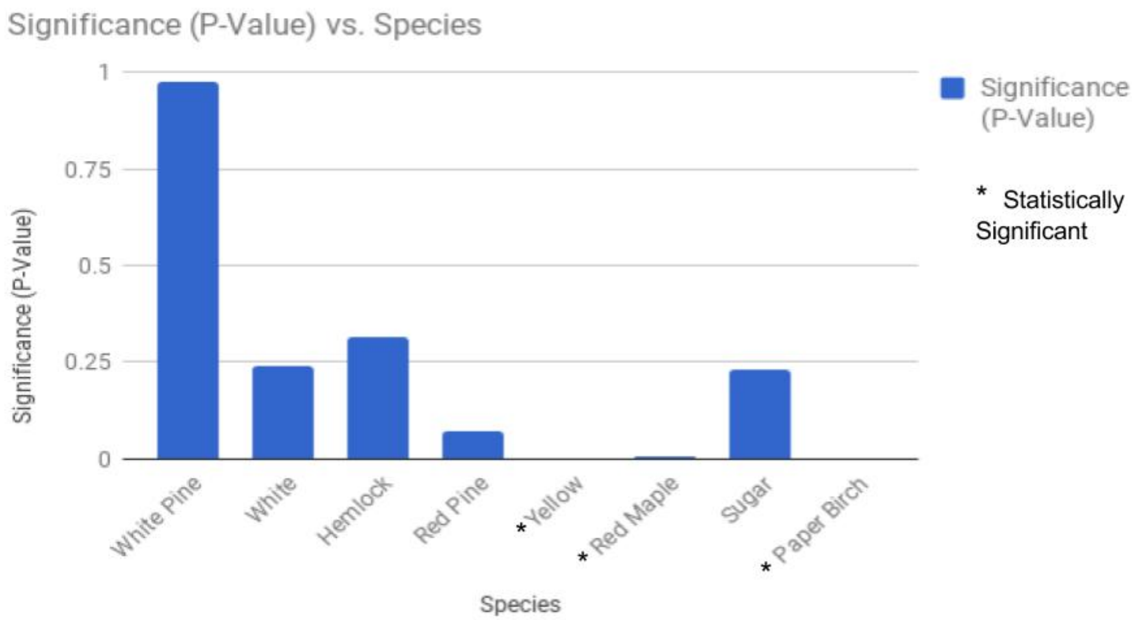

Figure 6. P-Values between species. Analyzed using a T-test.