How to Speak Christmas Tree

# Understanding Heat and Drought Injury

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Christmas tree producers face numerous challenges in getting trees from planting to harvest. Many of these issues involve various insect pests and diseases, commonly labeled as **biotic disorders**, which we've discussed in recent issues of the Great Lakes Christmas Tree Journal. However, Christmas trees are also impacted by an array of **abiotic disorders** that are associated with environmental stresses.

In the next few installments of '*How to Speak Christmas Tree*', we'll discuss the basics of some of the environmental factors that can cause damage – or even death – of trees in Christmas tree plantations. We'll begin by turning our attention to heat and drought – two common and interrelated problems for Christmas tree producers.

## The Soil-Plant-Atmosphere Continuum

To begin to understand the impacts of heat and drought on Christmas trees we need to review some of the basics of how water moves through trees. This gets back to the age-old question of how water gets to the top of a 300' redwood. At one point people thought root pressure 'pushed' water up trees. While water can move through plants via root pressure under specific conditions, it rarely provides enough force to move water more than a few feet upwards. Instead, water is essentially pulled through trees via **transpiration**, which is the loss of water from leaves (or needles in the case of conifers) (Fig. 1). As each water molecule moves out of the pores on the needles (**stomates**), another molecule is pulled upward like a link in a chain. This creates a tension (negative pressure) that is transferred along a continuous column of water in the conducting elements (**xylem**) of the stem. Ultimately this gradient of tension reaches the roots and results in water uptake from the soil. The continuous flow of water from the soil, through the tree, and finally into the atmosphere is often referred to as the **Soil-Plant-Atmosphere Continuum**. This concept is central to understanding how trees respond to drought stressbecause if the tension of water in the plant (**water potential**) becomes too great, cells within the plant will lose the internal pressure needed to expand and grow. In addition, pores on the needles will begin to close. This helps the tree to reduce transpiration and conserve water but also reduces photosynthesis and ability of the tree to produce sugars for growth and defense. If the stress is especially severe, the water column inside the conducting elements can **cavitate** and possibly lead to tree death. The key takeaway

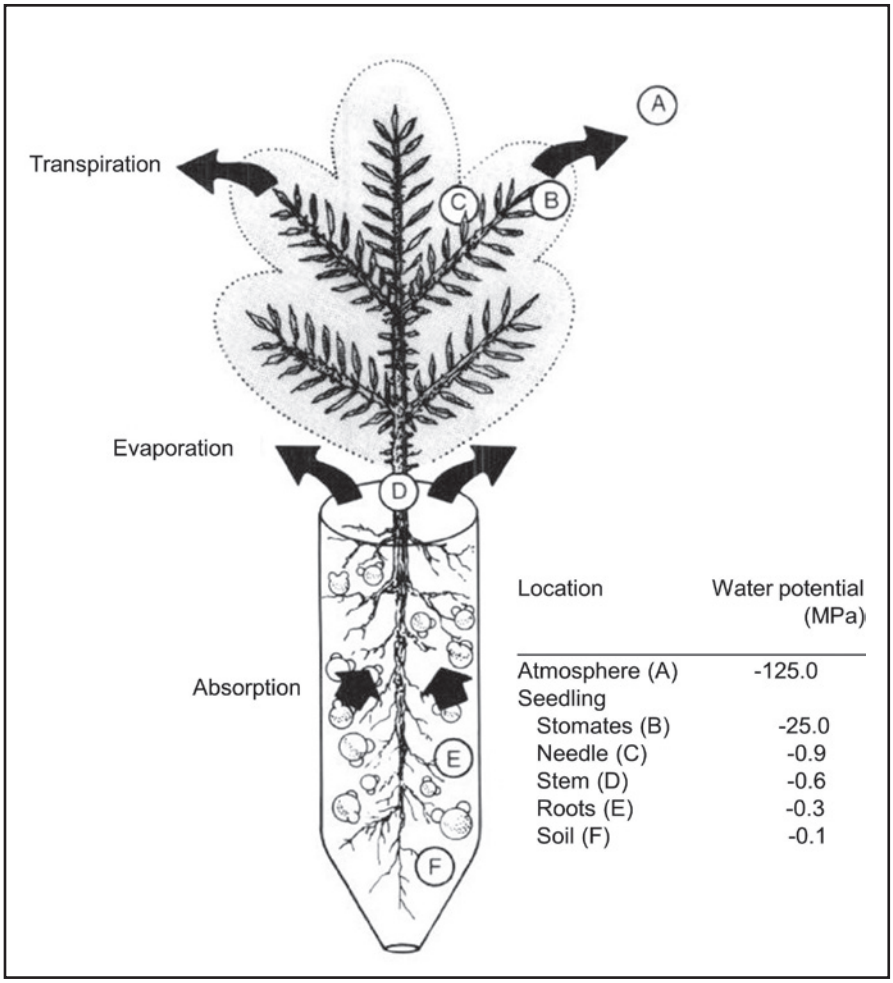


***Figure 1 –*** *Water movement through trees follows a continuous path from the soil through the plant and into the atmosphere.*

from this is that the level of stress a tree is facing (i.e., the tension in the water column in the xylem) is determined by the atmospheric demand for water vapor (more on that below) and the ability of the soil to provide water to meet that demand.

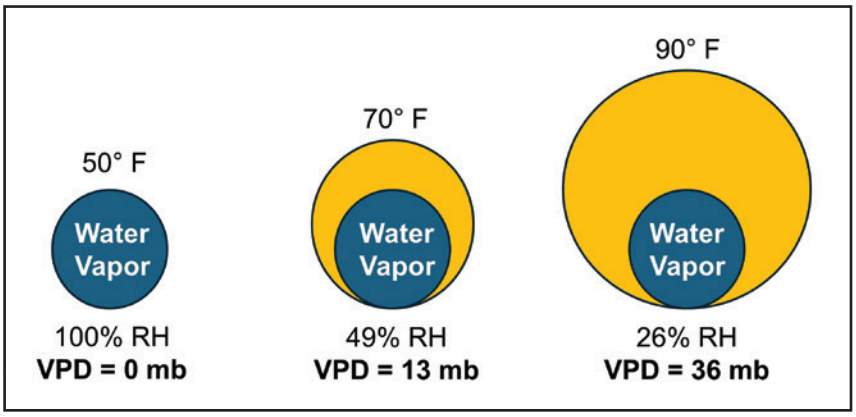


***Figure 2 –*** *Vapor Pressure Deficit (VPD) is the difference between the amount of water vapor air can hold at a given temperature (saturation vapor pressure – illustrated by the yellow ball) and the actual vapor pressure – represented by the blue ball.*

## Atmospheric Water – Vapor Pressure Deficit

The main determinant of water loss from the needles on a tree is the **Vapor Pressure Deficit (VPD)**. VPD is the difference between the amount of water vapor air can hold at a given temperature (**Saturation Vapor Pressure**) and how much water is currently present in the air (**Actual Vapor Pressure**). A key feature to note about VPD is that it increases dramatically with temperature. This is because warm air expands and can hold more water. As a result, Saturation Vapor Pressure increases exponentially with temperature. For example, at a dew point of 50° F (i.e., air is saturated at 50° F), VPD will nearly triple as the air temperature rises from 70° F to 90° F (Fig. 2).

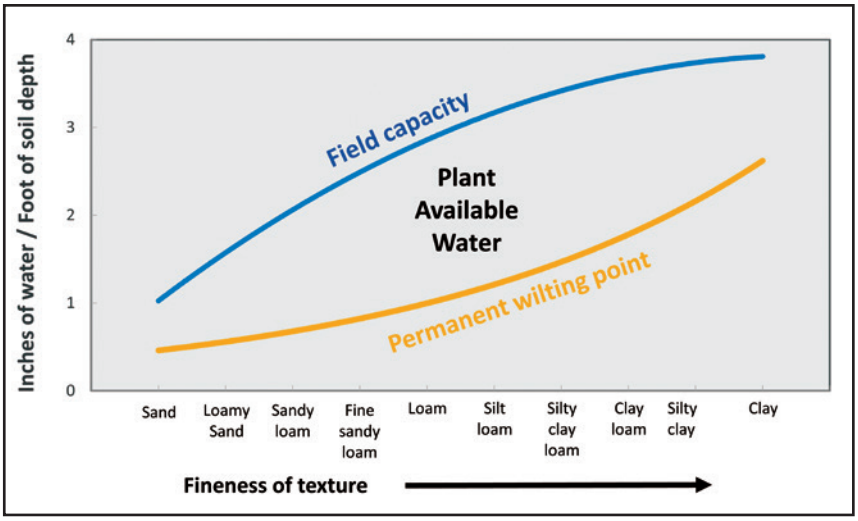


***Figure 3 –*** *Plant available water of soils varies with soil texture. Soils with a variety of particle sizes (Loams) have higher available water than sands or clays.*

## Soil Moisture

While VPD reflects atmospheric demand for water vapor, the ability of the soil to supply water is equally critical to understanding and managing tree water stress. Moisture in the soil can be quantified based on the volume of water present in a given volume of soil (**volumetric soil water content**) or **soil moisture tension**. Soil moisture tension (also referred to as **soil matric potential**) indicates how tightly water is bound to soil particles. As soils dry, water is bound more tightly to the soil particles making it progressively more difficult for roots to absorb water. Soil scientists quantify **plant available water** as water that is held between 1/3rd bar of tension (**field capacity**) and 15 bars of tension (**permanent wilting point**, i.e., water that is held too tightly for plants to access). Soil texture plays a key role in determining how much water is available for plants from a given soils (Fig. 3). In sandy soils, available water is limited because large pore spaces result in relatively low water contents at field capacity. In contrast, available water can be limited in clays because water is held very tightly, beyond the wilting point. Therefore, loamy soils typically have the highest overall levels of plant available moisture.



***Figure 4 –*** *Newly planted trees are at the greatest risk of drought stress due to their limited root systems.*

## Managing Tree Moisture Stress

Under typical summer conditions in the Great Lakes region, young trees within the first few years of transplanting are under the greatest risk of drought impacts due to their shallow and limited root systems (Fig. 4). Trees

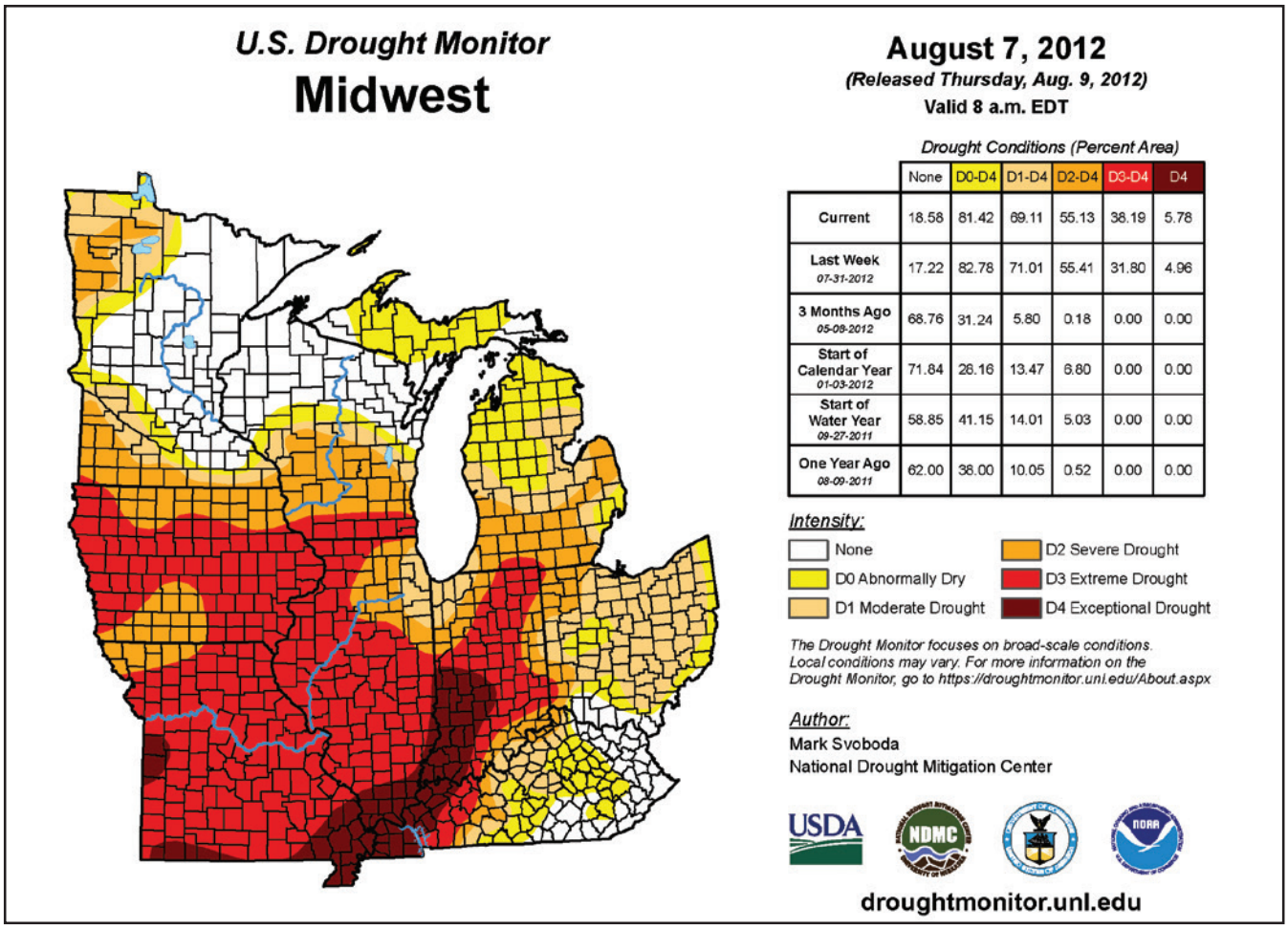


***Figure 5 –*** *The Midwest drought of 2012 was severe enough to cause mortality of established trees.*

that are well established (i.e., 3+ years past planting) are normally able to withstand periods of moderate drought. Rarely, mid-rotation trees may be at risk for mortality in severe droughts. For example, growers in southern parts of the Great Lakes region reported drought-related losses during the severe Midwest drought in 2012 (Fig. 5).



***Figure 6*** *– Overhead irrigation systems, such as this center pivot system, allow growers to easily irrigate large areas.*

**Irrigation** is the most direct way to address rainfall deficits. The most common approaches to irrigation are **overhead irrigation**, **drip irrigation**, **travelers**, and **hand watering**. Overhead and drip irrigation are often permanently installed and can be used throughout a given rotation of trees. Permanent irrigation systems have high up-front costs. However, once installed, overhead systems (Fig. 6) are relatively easy to operate and troubleshoot. The main disadvantages of center-pivot overhead are they need for large volumes of water to operate, some production area is lost to the wheel tracks, and considerable irrigation water can be lost to evaporation, especially on hot, windy days. Drip irrigation systems (Fig. 7) are highly efficient but require maintenance to address damage to lines from animals or farm equipment. Temporary irrigation systems (travelers and hand-watering)(Figs. 8 & 9) allow growers the flexibility of targeting their irrigation efforts (and expenses) on areas of their farm that are

most at-risk from drought, typically trees that have been planted within the previous two years.

Additional steps that growers can take to minimize the impact of drought on tree stress are to maintain good weed control and to apply organic mulch. In a trial of Fraser fir trees at the MSU Southwest Michigan Research and Extension Center, keeping plots weed-free significantly reduced tree moisture stress in late summer and increased tree shoot and caliper growth compared to trees in plots without weed control. Using ground wood chips or bark as mulch can also conserve soil moisture and increase tree survival and growth. Applying wood chip mulch at two Christmas tree farms in Michigan during an early season drought increased available soil moisture in the upper 6" of soil by 20 to 30% compared to trees that were not mulched (Fig. 10). During a severe summer drought in Oregon, survival of noble fir seedlings was only 3% without mulch but increased to 49% on plots that received mulch. In trials in the Pacific Northwest and Michigan we have found that shade blocks can be effective in reducing stress and improving early growth of newly planted trees. In contrast, we found that applying a film-forming anti-transpirant (WiltPruf®) reduced transpiration but also reduced photosynthetic carbon gain and growth of young Fraser fir trees.



***Figure 7 –*** *Drip irrigation can be highly efficient, placing water near the tree roots with minimal water losses to evaporation.*



***Figure 8 –*** *A traveler is a self-propelled overhead irrigation system that can be moved to fields where water is most needed.* (Image: Dave Ellis)




***Figure 9 –*** *For farms that do not have access to irrigation systems, hand-watering from water wagons or portable tanks may be necessary during drought periods.* (Image: Dave Ellis)

## What About Direct Heat Injury?

For most locations in the Great Lakes Region, direct injury to plant tissue from elevated temperatures is unlikely. Separating out heat damage and drought injury can be difficult because hot and dry conditions often go hand-in-hand. Though it should be noted that damage from heat alone usually requires temperatures in excess of 115° F, which is beyond record highs for most of the north-central U.S. Christmas tree growers in the Pacific Northwest, however, experienced a unique weather event in 2021 known as a '**heat dome**', which resulted in temperatures soaring as high as 119° F in western Washington and Oregon. In several instances, temperatures in the region exceeded previous all time-record highs by 8° F or more. The extreme heat caused widespread tree damage to several species including noble fir and Turkish fir (Fig. 11). Tree damage from the heat dome event was likely exacerbated by the fact that it occurred early in the summer before new shoot growth had fully hardened off. For growers in the Great Lakes region, however, the impacts of

elevated temperature are usually related to increases in tree water use due to excessive VPD's in combination with soil moisture deficits from low rainfall. When possible, irrigation can help to alleviate drought impacts. Growers can also improve the water status of their trees by controlling competing vegetation and applying mulch.

***Note:*** *images by Bert Cregg except as noted.*

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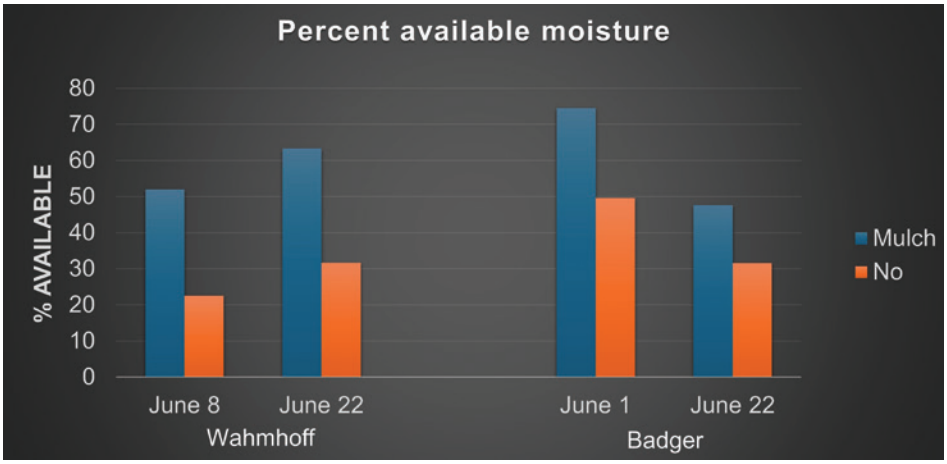


***Figure 10 –*** *Mulch increased available soil moisture at two Christmas tree farms in Michigan during an early-summer drought in 2023.*



***Figure 11*** *– The 2021 heat dome event in the Pacific Northwest resulted in direct heat injury to Turkish fir and other Christmas tree species.* (Image: Chal Landgren)


