Monitoring tree health using water-uptake rate

By Reza Ehsani, Azadeh Alizadeh and Davie Kadyampakeni

Many scientists in Florida and other parts of the world are working hard to find a treatment for citrus greening and frequently conducting field trials to evaluate the effectiveness of their treatments. Monitoring plant physiological factors, yield and fruit quality are usually among the factors that they need to assess tree health. One of the factors that has been very promising in evaluating overall plant health improvement has been the tree's water uptake rate.

There are different ways to monitor a plant's water-uptake rate. Most of them are very time-consuming or prone to human error. Using a sap-flow sensor is one way of monitoring water uptake. Sap-flow sensors are commercially available and can be used for continuous monitoring of a large number of trees. This article reviews the existing sap-flow sensors and discusses their advantages and disadvantages.

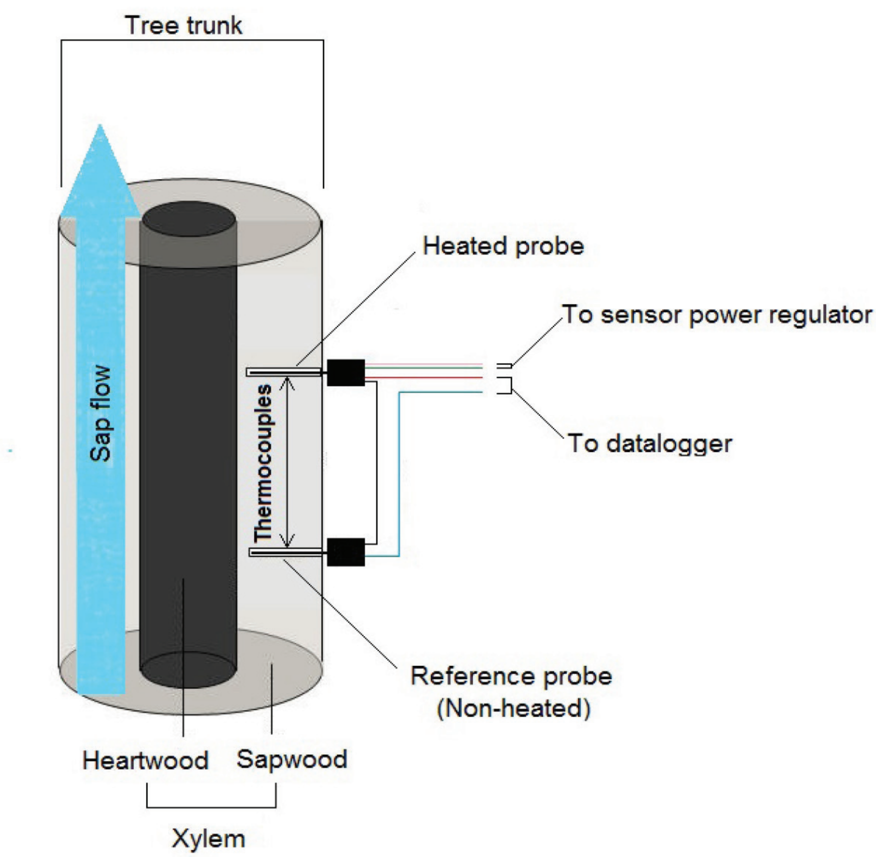

Figure 1. Thermal dissipation probes method.

UNDERSTANDING SAP FLOW

Sap flow is the movement of minerals, nutrients and water in xylem caused by the potential gradient from the soil (a region of high-water potential) to the air (a region of low-water potential). Sap flow looks different depending on the species, time of day and time of year. The sap flow is increased when the highest amount of solar radiation (midday) occurs. Thus, during the night (below freezing temperature), very little sap flow typically occurs. Also, cool and cloudy days will lessen the sap flow due to less sunlight or solar radiation effect on tree canopies.

During periods of water restriction, sap-flow depletion is expected as a result of stomatal closure. After irrigation, sap flow will return to the normal stage. During the budbreak, sap flow is approximately zero. After that, sap flow will increase. At the end of the year during senescence and when the trees drop their leaves, the sap flow declines. Sap flow is influenced by environmental factors such as solar radiation, vapor-pressure deficit, rainfall, air temperature, wind speed, soil-water content and disease.

MEASURING SAP FLOW

Sap flow is measured in plants via thermometric (heat-based) methods. These methods have advantages and disadvantages, depending on the application. These techniques can be classified into three general approaches,

Table 1. Advantages and disadvantages of sap-flow measurement methods

Methods	Advantages	Disadvantages
Heat Pulse Velocity	• Measures flow volume and orientation (low flow, zero flow and reverse flow) • Suitable for any size stem >10 millimeters • Suitable for roots • Low power usage • Ease of use and configuration	• Invasive (insertion of a probe can damage the vascular tissue) • Not suitable for herbaceous stems
Trunk Segment Heat Balance	• Measures sap flow in stems and roots of diameters from 2 to 125 millimeters • Useful in identifying optimal times for irrigation, depending on soil type and crop variety	• Large errors occur when sap flow is low • Can kill a limb or trunk when not properly installed, due to the heating effect
Thermal Dissipation Probes	Provides continuous measurements of sap flow	• Calibration is difficult • Lack of measurement accuracy (tissue damage by prolonged heating effect, toxic effect of silicon compounds used to improve thermal contact between heater and stem, wound responses) • High electricity consumption

as shown in Table 1.

While there are differences in the way these techniques have been developed, the basic concept is based on Andre Granier's work in the 1980s in which a technique was developed called thermal dissipation probes. Figure 1 shows the principle of this technique. The method consists of two probes inserted one above the other about 2 to 4 inches apart into the sapwood of the trees.

The upper needle is continuously heated while the lower needle (non-heated) serves as a reference. Both probes contain a copper-constantan thermocouple. As sap-flow rates increase, heat is more rapidly dissipated away from the heated probe. Consequently, the temperature difference between the probes will decrease. The sensor basically measures heat flux. With some assumptions and through some conversions, it is possible to measure sap flow.

Although sap-flow sensors are commercially available, they are relatively very expensive. It costs about $10,000 to monitor up to four trees. The high cost and high energy demand of the existing sap-flow sensors limit their use for large-scale plant health monitoring. Also, the sensors require users to have knowledge of programming language, which makes it difficult for someone to easily use and adapt. One key advantage of using this technique is that it is nondestructive, nonintrusive and is very accurate in estimating water use.

NEW AND IMPROVED TECHNIQUE

At the University of Florida's Citrus Research and Education Center, we have developed a new technique for monitoring a tree's water-uptake rate that is very cost effective. This newly developed sensor technology is currently being tested and compared with the existing commercially available sensors.

So far, the results have shown the newly developed sensor technology for water-uptake monitoring is able to create better results at a fraction of the cost of existing sap-flow sensors. This technique not only is able to monitor tree health, but can also be used in an automated irrigation system.

Reza Ehsani (ehsani@ufl.edu) is a professor of agricultural and biological engineering, Azadeh Alizadeh is a graduate student, and Davie Kadyampakeni is an assistant professor — all at the University of Florida/Institute of Food and Agricultural Sciences Citrus Research and Education Center in Lake Alfred.