MEASURING WATER STRESS OF URBAN TREES

Because water is becoming scarce, landscape personnel must be aware of plant moisture needs and of appropriate methods for measuring plant water stress.

by Bruce R. Roberts, USDA

Because city trees are often planted with little regard for their adaptability to the urban environment, they are often exposed to extremely stressful conditions. One important problem is moisture stress, which often occurs in aboveground containers and in other restricted-space planting sites in the metropolitan environment.

A problem with measuring the water status of individual trees is the often poor correlation between soil moisture and plant growth. Because water absorption by tree roots is largely controlled by the rate at which water is lost in transpiration, moisture deficits can develop in trees—even in moist soils. In addition, trees planted in wet sites (a condition not uncommon in many urban areas) may still have water deficits. This is because saturated soil conditions result in poor aeration and subsequent reductions in water absorption.

Trees in the urban environment are often exposed to moisture stress, a situation which frequently occurs in aboveground containers and in other restricted-space planting sites that are characteristic of metropolitan environments.

Consequently, soil moisture status is not always a good indicator of plant water status. The most reliable measurement of plant moisture involves estimates made on plant tissue itself.

Relative water content

Water content, the amount of water contained in plant tissue, is probably the most common method used to determine plant water status. However, expressing the amount of water in plant tissue by itself is impractical; it cannot be compared with measurements made from other plants or from other tissue on the same plant. So a common frame of reference is needed. Turgid weight (the maximum amount of water the tissue will hold) is frequently used as this reference point.

Relative water content (RWC) is determined by obtaining the fresh weight of leaf tissue (either leaf discs or entire leaves) and measuring its turgid weight after an appropriate equilibration period.

Turgid weight is obtained by floating the tissue on water or by placing it on water-saturated polyurethane foam in a moist chamber for a prescribed period of time. The same tissue is then oven-dried to a constant weight and RWC calculated from the following equation:

RWC equals fresh weight minus oven dry weight divided by turgid weight minus oven dry weight times 100.

From this equation we can see that RWC provides a measure of water content relative to the maximum water-holding capacity of the tissue (i.e. 100% RWC = 0 plant water deficit).

Thermocouple psychrometry

Thermocouple psychrometry is used to measure the water potential or physiochemical activity of water in a plant system against a base measure of water. As such, it is probably the single best measure of plant water stress available.

In recent years, psychrometers

Measuring the water status of woody plant tissue using the thermocouple psychrometer technique.

have come into general use and commercial units are available for measuring water potential in the field. Briefly, measurements are obtained by recording the relative humidity in a small, sealed chamber containing the plant sample and a reference thermocouple. The newer psychrometer units use thermocouple transducers which eliminate the need for precise temperature control and make the instrument more practical for field use.

Although some possible sources of error are associated with the psychrometric technique, they can be largely overcome by modifying current technology. Modifications of existing equipment have been made to permit water potential measurements to be made on tree trunks as well as on intact leaves and roots.

Pressure equilibration

An excellent method for measuring water stress of woody plants, particularly in the field, is the pressure equilibration or pressure bomb technique. This procedure, first introduced in 1965, has been widely used in recent years.

In actual operation, a single leaf or leafy shoot is sealed in a pressure chamber with the cut end of the sample protruding outside the chamber. It is exposed to atmospheric pressure. Then pressure is applied to the chamber from a tank of compressed gas until xylem sap appears at the cut end of the sample. The amount of pressure needed to force water out of the leaf cells into the xylem and up to the cut surface is approximately equal to the original water potential of the cells. If consistent sampling and measuring procedures are followed, this method should give very reliable information on the water status of urban trees.

The three techniques previously described have enjoyed wide acceptance and use over the years. This does not mean that other methods are not available for measuring water stress, but most have disadvantages which limit their usefulness for urban trees in the field.

In addition to the aforementioned direct procedures, other indirect methods for estimating water stress may have applicability for use with urban trees.

Stem diameter changes

This procedure uses an instrument developed by scientists at Battelle Memorial Institute referred to as the Ceres device. It is based on the physiological principle that as water moves out of living cells into the transpiration stream, it causes the cells to shrink. This shrinkage in cell size causes a small but detectable decrease in stem diameter.

The Ceres device measures these changes by means of strain gauges and a pressure transducer. As stress increases within the strain gauges, electrical resistance also increases, yielding data on sensitive alterations in stem diameter.

The Battelle instrument is similar in principle to earlier measuring devices referred to as dendrographs or dendrometers, but technology has improved the sensitivity of these newer instruments.

The concept behind the Ceres device and similar measuring systems is based on the cohesion theory. Water confined in small capillaries can withstand very low negative pressure potentials because of the strong attractive forces that exist between water molecules. Thus, microcontraction of water conducting elements occurs when moisture in the plant is subjected to a water potential gradient. The amount of contraction is proportional to the degree of stress.

Leaf temperature changes

Relative differences in moisture stress between plants can be estimated by measuring leaf temperature. This concept can be particularly useful in establishing irrigation regimes for landscape plants in urban and suburban environments.

If transpiration decreases (assuming that other factors such as solar radiation and wind velocity remain relatively constant), the decrease in heat exchange between the plant and the atmosphere will result in an increase in leaf temperature. Thus, a sensitive measure of temperature differences between plants (preferably between plants known to be well watered and others) may indicate transpirational and water status differences. This principle has already been used to measure relative water stress of plants in the field.

One of the problems with using leaf temperature to estimate plant water status is obtaining uniform samples.

It stands to reason that a leaf perpendicular to the sun will be warmer than one at an angle or one completely shaded. Because of this sampling difficulty, in the past the difference between leaf and air temperature has been used to predict relative water stress. However, studies have shown that leaf and air temperatures are not always correlated. Leaves are often warmer than the surrounding air during the day and cooler at night.

Recent developments in infrared thermometry have largely overcome many of these sampling problems so leaf temperature measurements may become a very useful technique for estimating the relative water status of urban trees.

Transpirational modeling

In this age of computer technology, it seems only fitting that one of the possible techniques for estimating plant water stress involves computer modeling of moisture loss from individual

Measuring the water status of woody plant tissue using the pressure equilibration technique.

tree crowns. A recent study using two species of maple suggests that this technique may have practical application for problems associated with tree maintenance, especially in determining irrigation strategies.

Transpiration water loss is computed by taking the net flux density of incident radiation minus convectional net energy loss minus conductional energy loss divided by latent heat of vaporization of water.

The authors of this research suggest that their model functions best when the modeled trees are under relatively low levels of soil moisture stress.

Summary

The growth and development of urban trees is probably influenced more by plant moisture than by any other single factor. In a time when water resources are becoming scarce, prudent use of existing water supplies becomes an important management decision. Part of this decision process involves understanding the moisture needs of urban trees and learning the methods for accurately estimating the water status of woody plant tissue.

Relative water content, thermocouple psychrometry, and pressure equilibration are recommended as readily-adaptable field techniques for measuring plant water relationships in urban trees. Monitoring sensitive changes in stem diameter, leaf temperature, and transpirational water loss are also potentially useful methods for indirectly estimating plant water status in the field. **LM**

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