Optimizing the Water Relations of Cuttings

Managing the water relations of cuttings can increase rooting success during propagation and lead to faster liner production. It is important to remember that water is the universal solvent; it brings minerals from the roots for biosynthesis within the leaf. Approximately 1 to 2 percent of the water utilized also is needed for photosynthesis and plant growth, while the remaining 98 percent is lost to transpiration and the subsequent cooling of leaves. Evaporative cooling occurs during transpiration as water passes from a liquid to a gaseous phase (vapor).

Transpiration is the “engine” that pulls water up from the roots. A plant, unlike a person who can move and find a more comfortable location, lacks mobility, so it needs to do its best to reduce the heat load by transpiration.

There is tremendous pressure that occurs at the top of a 300-foot-tall California redwood (Sequoia) while water moves up the tree from the roots. The pressure in the xylem can exceed 250 pounds per square inch (psi), which is approximately 18 times greater than atmospheric pressure. The lifting of water occurs through transpiration and the process of the hydrogen bonding with water molecules. This gives a column of water tremendous tensile strength — as strong as metal.

Environmental factors. There are three environmental factors that affect transpiration: light, temperature and humidity. Light causes plants to transpire more rapidly. It also stimulates the opening of the stomata and warms the leaf. Temperature increases transpiration because of how quickly water evaporates. An increase of 20° will cause a threefold increase in transpiration.

Humidity affects the diffusion of water as a vapor from the leaf through the stomata into the surrounding, drier air. Water travels from a high-potential element (saturated internal leaf cavities) to a low-potential element (unsaturated, drier air) outside the leaf.

Vapor pressure deficit. Vapor pressure is determined by temperature and relative humidity (RH). The vapor pressure deficit (VPD) is the gradient measured as the difference between the water vapor pressure in leaves (Vleaf) and in the surrounding air (Vair).

A professor of nursery crop physiology explains how transpiration, vapor pressure deficit, environmental factors and propagation media can play a key role in rooting success.

Text and photos by Dr. Fred T. Davies Jr.
Intermittent mist forms water droplets with an average size of more than 50 micrometers and a range of 50 to 100 micrometers. Water from mist condenses and forms a film of water on the leaf surface. Water evaporates from the leaf surface rather than from internal water in the tissue.

At 85", the air inside the leaf is saturated at 100 percent RH and has a vapor pressure of 0.60 psi. If the drier air surrounding the leaf has 75 percent RH, then its vapor pressure is 0.45 psi. Hence, the VPD is 0.15 psi, which is the result of subtracting 0.45 psi from 0.60 psi. Reducing the VPD is the goal of controlling the water relations of cuttings.

Finding the right balance. The water relations of cuttings are a balance between transpirational losses and the uptake of water. Water travels from the soil through the roots into the stems and leaves where photosynthesis and transpiration occurs. Cells must maintain adequate turgor for growth and for initiation and development of adventitious roots.

Root meristematic areas also produce a phytohormone, abscisic acid (ABA), which is a chemical signal for drought. As the surrounding soil dries, ABA travels through the xylem from the roots to the leaves and causes the guard cells to collapse, which closes the stomata and helps to regulate the loss of water.

The problem. Because cuttings initially do not have roots, they can’t produce ABA to control water loss, and they lack effective organs to replace the lost, transpired water. Cuttings take up water poorly through the base of the stem until adventitious roots are formed. The cutting base and any foliage immersed in the propagation medium are the main entry points for water.

Water absorption through leaves is not a major source or contributor of water balance. Water uptake in cuttings and the relative water content (RWC), which helps to determine the actual water in tissue, declines after the cuttings initially are inserted into the propagation medium. There also can be a decline in hydraulic conductivity of cuttings caused by blockage of the xylem vessels and a collapse of tracheids.

It is important to maintain hydraulic contact between the cutting base and the propagation medium. Wounding increases the contact area between the cutting base and the propagation medium for a more optimum water uptake of cuttings.

Control of water loss in cuttings. Intermittent mist is the most common system for propagating cuttings (photo, top left). Mist comprises water droplets that average more than 50 micrometers and have a size that ranges from 50 to 100 micrometers (100 micrometers is the diameter of human hair). The mist condenses and forms a film of water on the leaf surface. Water evaporates from the leaf surface rather than from internal water in the leaf tissue.

Mist decreases the Vleaf by reducing leaf temperature and causes a modest increase in the Vair by increasing the RH. Mist lowers the leaf-to-air VPD and slows down transpiration of the cutting leaf surface.

There are some inherent problems with intermittent mist. It rapidly leaches cuttings of nutrients, such as nitrogen, phosphorus, potassium and magnesium, with losses as high as 60 percent or more during the first week. Water condenses from mist, which can saturate the propagation medium, reducing aeration and creating anaerobic conditions that can lead to poor rooting and death of cuttings. The evaporative cooling of mist also can lead to suboptimal propagation medium temperatures, which is why bottom heat is used sometimes in indoor and outdoor mist propagation systems.

Fog systems. Fog systems produce fine water droplets that average approximately 15 micrometers (photos, above). Fog has a high surface-to-volume ratio that allows it to remain suspended in air as a vapor to maximize evaporation. Fog does not condense, and it avoids the oversaturation of media and foliar leaching that occurs with mist.

Fog maximizes the Vair by increasing the RH of the surrounding air. It also decreases the Vleaf by lowering leaf and air temperatures, and it decreases the leaf-to-air VPD and slows down transpiration.

Contact systems (left) and nonmisted enclosures reduce water loss from foliage. Condensation increases the relative humidity of the air. Minimal condensing occurs and the oversaturation of media and foliar leaching is avoided.
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Static mist-control systems rely on clocks and timers. They are unable to respond automatically to daily fluctuations in light irradiance, cloud cover, relative humidity, temperature or stage of root development.

Problems with fog systems include high costs and high maintenance requirements, including replacing clogged and worn-out nozzles. Filtration/deionizing systems are required to remove any salts from the water supply.

Contact systems/nonmisted enclosures. Contact systems and nonmisted enclosures reduce water loss from foliage, and the condensation increases the RH of the air (photos, page 31). These systems are simple, inexpensive and cost-effective. There is minimal condensing, and like fog, it avoids the oversaturation of media and foliar leaching that occurs with mist. This system works well with hardwood and semihardwood cuttings of difficult- to-root species that require longer propagation times.

Contact systems and nonmisted enclosures maximize the V<sub>air</sub> by preventing the escape of water vapor. The system predominately uses humidification because only the V<sub>air</sub> is affected. The V<sub>leaf</sub> is somewhat affected, particularly when the leaf temperature is cooler than the condensation that occurs in the contact system. It lowers the leaf-to-air VPD and slows down transpiration.

While inherently cheaper, there are some problems with contact systems and nonmisted enclosures. It is critical to control irradiance and subsequent heat load through shade and temperature control. The system easily traps heat via light irradiance, which adversely can increase the VPD by reducing the RH of air and increasing the air and leaf temperatures.

Static mist-control systems. Static mist-control systems are the most common way of controlling mist. They are relatively inexpensive and easy to install, and they rely on clocks and timers (photos, above). However, static mist-control systems are unable to respond automatically to the daily fluctuations in light irradiance, cloud cover, RH, temperature or stage of root development.

Under moderate conditions, static mist-control systems reduce evaporative demand by lowering the VPD. On cloudy days when solar radiation is low, too much mist is applied. Conversely, on very sunny, windy days when net radiation is high, too little mist is applied.

Dynamic mist-control systems. Dynamic mist-control systems respond to changes in the environment that affect the VPD (photo, page 33). These are evapotranspiration-based control systems of dynamic mist, which are based on air temperature and the time interval between misting and calculating the V<sub>air</sub>. Net solar radiation and RH also can regulate these systems. They are much more responsive to the changing environmental dynamics.

Ideal propagation medium. The ideal propagation medium has an air-filled porosity of between 15 and 40 percent; 20 to 25 percent is considered optimal. The ideal water holding capacity (WHC) has a range of between 20 and 60 percent after gravitational drainage.

There is not a best or universal propagation medium; however, it is important to have good water drainage for sufficient aeration and sufficient WHC to maintain adequate hydraulic contact between the cutting base and the propagation medium.

Stock plant maintenance. It is important to maintain stock plants that are nutritionally fit and are under optimal irrigation regimes. It also is important to maintain each plant's momentum by harvesting cuttings during the season of the year when maximum rooting occurs, to reduce the propagation time under mist.

Cuttings also should be collected early in the day when the plant-water status is optimum to minimize any stress to the cuttings, such as low VPD (photos, page 33). Storage under low light, high RH and cooler temperatures helps to control the VPD.

During the initial week or two of cutting propagation, it is not necessary to
It is important to maintain a plant's momentum during optimum seasonal rooting early in the day before plants become stressed. Storage under low light, high relative humidity and cooler temperatures helps to alleviate the vapor pressure deficit.

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References.


