



Identifying Water Stress in Container-Grown Plants

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Container nursery operations can be daunting to manage because they often span many acres and encompass hundreds of plant species and cultivars. A single nursery can produce a variety of annual bedding plants in one corner and cultivate woody perennials in another.

Producing a wide range of plants certainly extends marketing diversification and reaches a broader horticultural audience. However, the standard practice of grouping different plants in the same irrigation zone, or using the same soilless substrate for most plants, can lead to water-related stress during production due to varying nursery-plant water requirements (fig. 1). Therefore, it's important to understand the visual symptoms of water stress and which plant characteristics can exacerbate water-related stress.

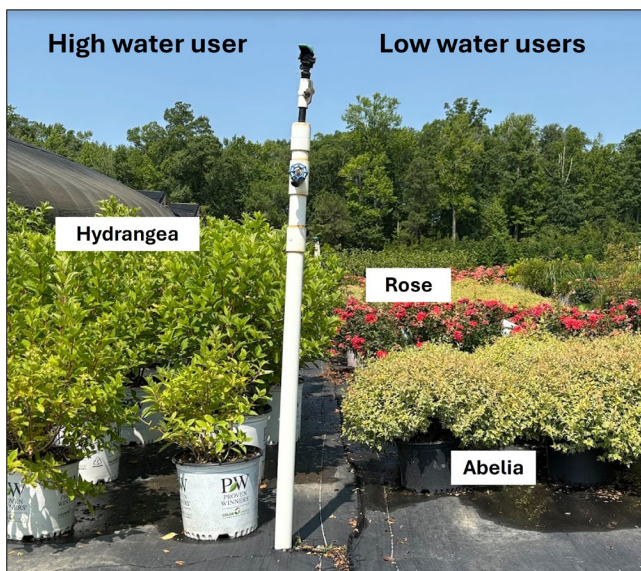


Figure 1. Different plants can have varying water needs yet are often grouped under the same irrigation zone.

This Virginia Cooperative Extension publication is designed to briefly walk growers through identifying water-related stress by evaluating shoot and root visual symptoms, and to improve growers' understanding of water requirements for popular nursery stock and the different plant characteristics that may influence water use.

Signs of drought and overwatering

Plants exhibit multiple physical indicators when they are water-stressed. Sometimes these indicators can look similar, making it more challenging to identify the source of the stress.

Shoots

As plants experience drought, roots are the first to detect when water in the rootzone becomes less available. A stress hormone called abscisic acid (ABA) begins to accumulate. Since plants communicate through hormones, roots will send ABA signals to the leaves and convey that there is low water availability. Plants can be sensitive to ABA, and when they detect ABA in the leaves, the stomata will typically close. Thus, the first symptom of drought is wilting or flagging (fig. 2a).

Similarly, when plants are overwatered, ABA will also accumulate. Roots respire and need oxygen to grow. When there is too much water or little oxygen is available, the roots will send ABA stress signals to the leaves. Therefore, overwatering can also lead to wilting or flagging.

Open stomata — the tiny openings on the surface of plant leaves and stems that allow for the exchange of gases — play a key role in driving water up through the plant and out into the atmosphere. When the stomata are closed, water can't move upward through the

transpiration stream. This is why, in either drought or overwatering, water cannot get to the leaves.

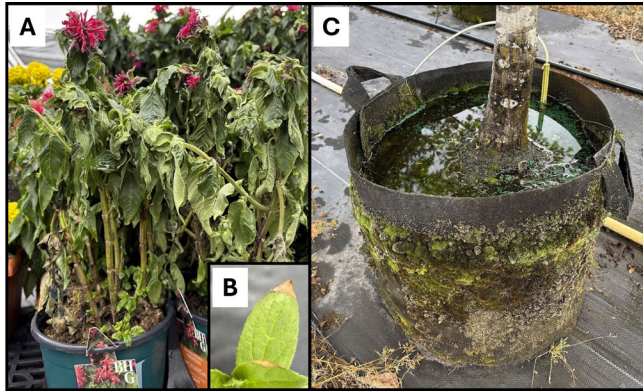


Figure 2. (A) A drought-stressed plant and (B) the beginning signs of leaf scorch. (C) Heavily overwatered rootzone conditions.

Although the initial responses to drought and overwatering are similar, there are key indicators that differentiate the two.

In drought conditions, the edges of leaves are typically the first to show symptoms, particularly the newest growth or the leaves furthest from the roots. Leaf margins start to die back due to cell dehydration and as a result, leaves become brittle and brown (leaf scorch; fig. 2b). These margins can also be sharp like a straight line. Another visual symptom of drought is curling leaves, which can occur as leaves try to minimize water loss. Leaves can turn yellow and quickly drop their older leaves, though this can vary by species. Newer leaves will typically grow smaller than normal.

In overwatered plants, the second post-wilting symptom is yellowing, soft, or sometimes mushy leaves (the latter is more common in herbaceous or houseplants). Overwatered plants tend to drop their leaves, old or young. Some of these effects are more noticeable on broadleaf plants, though a common overwater response in conifers is leaf drop.

If the plant wilts during the day, becomes turgid at night, and recovers the following morning, this usually indicates that moisture is available in the substrate, but the roots cannot take up water fast enough to maintain transpiration rates. This can be either due to large leaf canopies, substrate properties, or high rootzone temperatures. In this case, irrigating while the plant is wilted during the day may not help or stop the wilting. Consider pruning the foliage, if possible, to lower the canopy coverage area.

If the substrate is very wet, the container is heavy, and the shoot shows drought symptoms, the plant may have

been initially overwatered, and root dieback may have occurred. Thus, the leaves were unable to receive a steady water supply due to smaller root systems. This can happen during summer, when growers cool down plants in high temperatures through irrigation. However, doing so can overwater the plant; if root dieback has occurred, recovery is difficult.

Other characteristics of excessive moisture conditions can include algae growth or moss growing on the substrate surface (fig. 2c).

Roots

Roots are highly sensitive to water stress and are the first to detect water-supply-related issues. Typically, but not always, healthy nursery stock roots will appear white and turgid to indicate a strong and vigorous root system (fig. 3a). However, not all nursery plants will have traditionally “white” roots. Take, for instance, the roots of arborvitae (brown; fig. 3b) or loropetalum (red; fig. 3c). Both the color and turgidity of the roots can be used to evaluate root health. In drought-stressed plants, roots will appear thin or frail. In overwatered plants, roots will appear mushy, brown/black, or may not even be visible at all (i.e., root dieback or root rot).

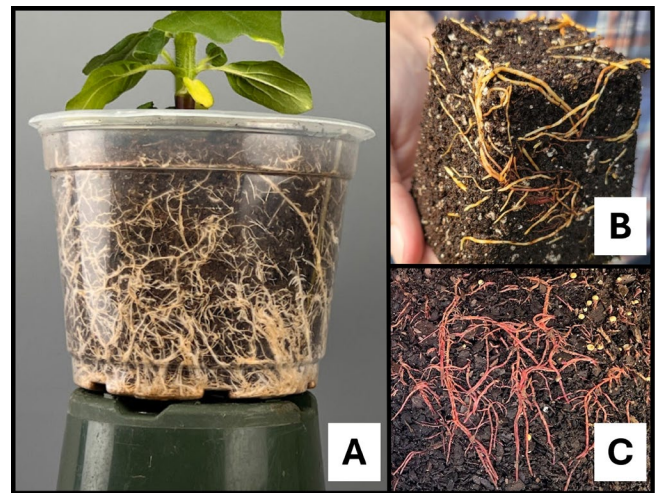


Figure 3. (A) Standard white healthy rooting. (B) Healthy brown roots of arborvitae. (C) Normal red roots of loropetalum.

In either excessively dry or wet conditions, remove the root ball from the container and evaluate — does the structure remain intact or do the substrate particles collapse from the root ball? While this might depend on the level of rooting, in a healthy, established root system, the root ball structure should remain intact.

After visually assessing the plant, the next step is monitoring the substrate. While this depends on the time of year and stage of growth, check if the substrate is dry by lifting the container (gauging its weight), and monitor a few inches down from the surface. These first few inches from the surface are a critical zone to maintain moisture, as newly transplanted liner roots are mostly concentrated in this upper layer. Another way to gauge if the root zone is waterlogged is to check the bottom drain holes. If there is sufficient moisture in the bottom layers but the upper substrate layers are dry, consider shallower, more frequent irrigations.

“Thirsty” vs. “drought-tolerant” crops

Cultivars in the same species can have completely different water requirements. Boxwoods are a classic example of this, where boxwood ‘Green Mountain’ requires water more frequently and has faster-drying

root zones, while boxwood ‘Green Gem’ does not require as frequent irrigations and transpiration rates are slower. Thus, identifying which species and cultivars are large water users is important in making more informed substrate or irrigation decisions. Some popular ornamental nursery stock and their water requirements and tolerances are listed in table 1.

The terms “wet feet” and “dry feet” are often used to describe a plant’s root conditions regarding substrate moisture. “Wet feet” is used when the root zone is regularly waterlogged; “dry feet” means the root zone is regularly dry. Using these terms can be an effective method to characterize plants and their water requirements. For instance, river birch (*Betula nigra*) and willows (*Salix* sp.) can tolerate wet feet, while American hollies (*Ilex opaca*) are generally intolerable of wet feet. Some plants, like Eastern Red Cedars (*Juniperus virginiana*), are dry footed, which means they can tolerate low water applications.

Table 1. Popular nursery stock grown in Virginia and their water requirements.

Common name	Botanical name	Water requirements
Juniper	<i>Juniper horizontalis</i> / <i>chinensis</i>	Low-Medium
Dogwood	<i>Cornus</i> / <i>florida</i> / <i>kousa</i>	Low-Medium
Camellia	<i>Camellia</i> spp.	Low-Medium
Japanese Holly	<i>Ilex crenata</i> / ‘Compacta’ / <i>attenuata</i>	Low-Medium
Korean Boxwood	<i>Buxus microphylla</i> var. <i>koreana</i>	Low-Medium
Glossy Abelia	<i>Abelia</i> x <i>grandiflora</i>	Medium
Fringe Bush	<i>Loropetalum chinense</i>	Medium
Spirea	<i>Spiraea</i> spp.	Medium
Arborvitae	<i>Thuja</i> x ‘Green Giant’	Medium
Japanese Boxwood	<i>Buxus microphylla</i> / var. <i>japonica</i>	Medium
Nandina	<i>Nandina domestica</i>	Medium
Chinese Privet	<i>Ligustrum sinense</i>	Medium
Rose	<i>Rosa</i> spp.	Medium
Japanese Maple	<i>Acer palmatum</i>	Medium
Oak	<i>Quercus</i> spp.	Medium
Virginia Sweetspire	<i>Itea virginica</i>	Medium
Clethra	<i>Clethra alnifolia</i>	Medium
Red Maple	<i>Acer rubrum</i>	High
Eastern Red Bud	<i>Cercis canadensis</i>	High
Hibiscus	<i>Hibiscus rosa-sinensis</i>	High
Birch	<i>Betula</i> spp.	High
Crape Myrtle	<i>Lagerstroemia indica</i>	High
Indica Azalea	<i>Rhododendron</i> spp.	High
Hydrangea	<i>Hydrangea macrophylla</i> / <i>paniculata</i> / <i>quercifolia</i>	High

Adapted from the Southern Nursery Association Best Management Practice Manual (2013).

Plant characteristics that contribute to water stress

What can exacerbate water stress? The stage of growth, the plant canopy architecture, and the cultural practices being used are three characteristics that can influence water use (table 2).

For instance, a young plant liner will not draw large amounts of water; however, growers may need to irrigate these new transplants more frequently, with less volume, than they would a larger, established plant. This is because the liner rootzone can quickly dry before

the roots have proliferated outward and explore the substrate.

Generally, plants with a large canopy or leaf area will use more water at faster rates; however, this is species- and cultivar-specific and is not always the case. For example, a fully grown azalea and spirea nursery stock can have similar leaf size and canopy area, but the spirea is going to deplete water reserves much faster. Understanding these intrinsic plant characteristics will be valuable in making more informed substrate management decisions.

Table 2. Plant traits that influence water needs.

Water requirements	Shoot traits affecting water use	Root traits affecting uptake	Cultural practice	Recommended substrate characteristics
High	Large leaf area; thin cuticle; high stomatal conductance; umbrella-shaped canopy	Fine, fibrous, and dense root systems; rapid rooting towards container base	Recent transplant or root-bound container; wide container-spacing (overhead irrigation)	High water-holding, moderate air space, finer bark material
Low	Small leaf area, waxy or thick leaves; low evapotranspiration; vase-shaped canopy	Coarse roots; slow-growth root systems	Shaded plants; tightly spaced containers	High porosity, fast draining bark material

Practical nursery recommendations

Appropriate management strategies can reduce substrate-related water stress in container-grown nursery stock.

Selecting substrate

Aside from irrigation scheduling decisions, proper selection of soilless substrates is critical for reducing water-related stress. When choosing a substrate, consider the plant's water requirements and the substrate's water and air storage capacity, since these properties will be very influential in water-related stress. Remember, a robust property in outdoor nursery substrates is their ability to drain and withstand long periods of precipitation. In outdoor production, err on the lower-water storage side (greater than 45% but less than 60% volumetric water content) rather than choosing a substrate with excessive water storage (greater than 60% volumetric water content). Oxygen availability is more important for roots than water availability.

Additionally, instead of using a single standard uniform substrate blend to produce most container crops,

consider selecting substrates tailored to plants with different water requirements. This may enable plants with varying water requirements to be grouped within the same irrigation zone. For example, some nurseries may contain multiple substrate piles, say different grades of pine bark or different substrates like pine bark and peat moss, and strategically blend them to better tailor to plant water requirements.

Grouping nursery stock by water use needs

Short-term, it is certainly more efficient and simpler to group plants by species or by the most recent batch to come off the potting line; however, in the long term, water-related stress and irrigation challenges may occur. These challenges can be partly mitigated by grouping plants according to their associated water use. This can also be an effective way to conserve water. By grouping plants based on irrigation requirements, plants within the same irrigation zone can receive the proper volume of water.

The plant's size and age will have a strong influence on water use, but it's important to remember that the size of the container matters, too. Small containers may have less air space and more water-filled pores, but

they dry out faster than larger containers do. Meanwhile, larger containers store more water after an irrigation application, so transplanting too early can lead to overwatering the plant.

Conducting leaching fraction tests

The leaching fraction is calculated as the ratio of water volume that leaches from a container to the volume of water applied by irrigation (fig. 4). It can provide growers with insight into whether they are irrigating too much or not enough, and it can indicate how much water their soilless systems are storing. It is recommended that approximately 10-20% of the water applied leaches out to flush out fertilizer salts adequately.

Leaching fractions can be determined by placing plants in catchment containers designed so that only leached water can enter and not overhead water. Then, place empty catchment containers randomly spaced throughout the irrigation zone to measure the total amount of water applied during irrigation. It is recommended that this test be conducted in groups of four (12-16 total catchment containers are sufficient). Apply the irrigation for the standard application time. Afterward, let the containers drain for approximately one hour, then measure the volume of water that leached from the plants. Divide that number by the volume of water that filled the empty catchment containers to determine the leaching fraction. For example, if the empty catchment containers each capture 4 cups of irrigation water and a catchment container under a plant holds 1 cup of leached water, the leaching fraction would be 25%. Note: When possible, placing plastic bags in the empty catchment containers can make it easier to measure the volume of irrigation water.

Another simple test is to place containers filled with different substrate composites under the same irrigation zone and irrigate for the same duration. Measure how much water leaches from each substrate system (as described above when conducting a leaching fraction test) to determine if irrigation timings need to be modified. For example, if your standard substrate has a leaching fraction of 25%, while another substrate has a leaching fraction of 5% with the same irrigation application time, this might indicate that the new substrate will store more water.

For more information on leaching fractions, see the Virginia Cooperative Extension publication “Leaching

Fraction: A Tool to Schedule Irrigation for Container-Grown Nursery Crops” (SPES-128), available online at <https://www.pubs.ext.vt.edu/SPES/SPES-128/SPES-128.html>.

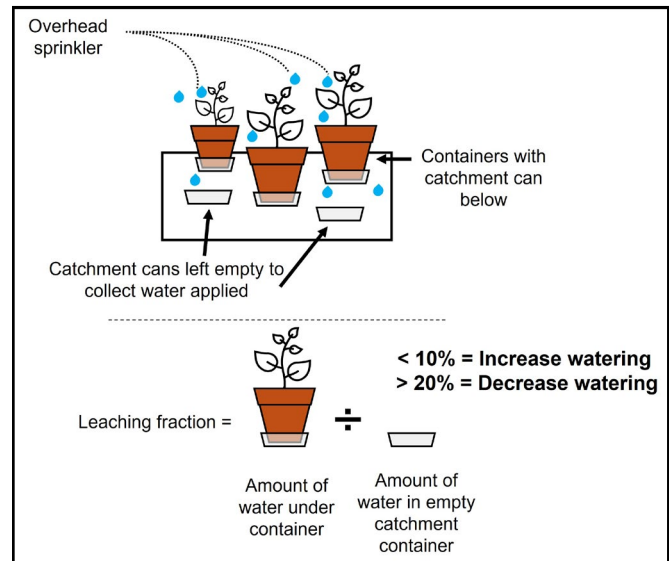


Figure 4. Leaching fraction test.

Additional Resources

Owen, J. S., Jr., A. LeBude, A. Fulcher, J. Stanley, and L. Oki. 2019. “Leaching Fraction: A Tool to Schedule Irrigation for Container-Grown Nursery Crops,” VCE Publication SPES-128P. Virginia Cooperative Extension, Blacksburg. <https://www.pubs.ext.vt.edu/SPES/SPES-128/SPES-128.html>.

Yeary, W., A. Fulcher, and B. Leib. 2023. “Nursery Irrigation: A Guide for Reducing Risk and Improving Production,” UT Extension Publication PB 1836. University of Tennessee Extension, Knoxville. Available to download at <https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/PB1836.pdf>.

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