GROWING KNOWLEDGE

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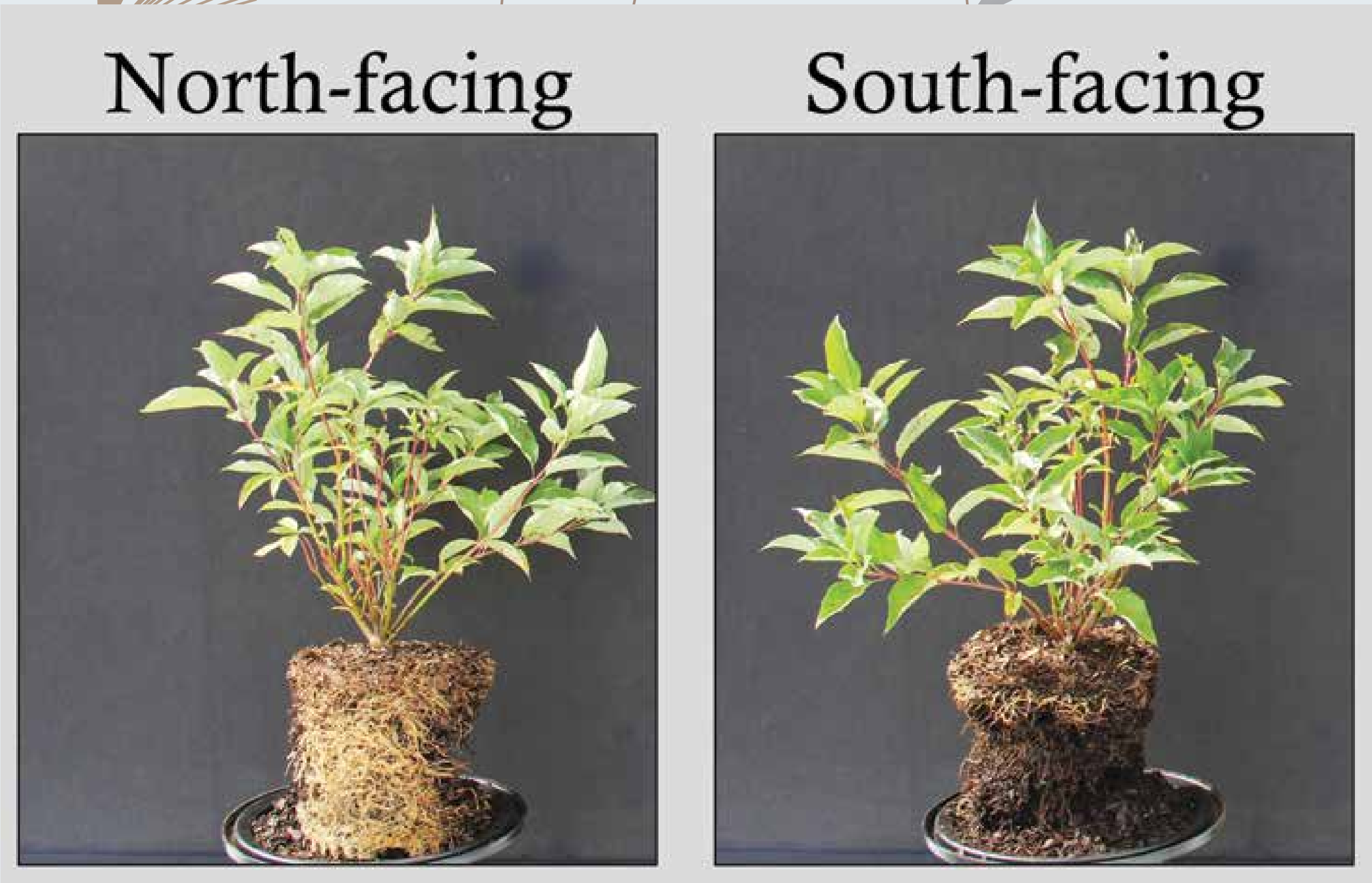

Figure 1. The north- and south-facing sides of a red osier dogwood (*Cornus sericea* 'SMNCSBD' Arctic Fire® Yellow) grown in a black, plastic container for 10 weeks in full sun in McMinnville, Tennessee. PHOTO COURTESY OF OREGON STATE UNIVERSITY

Benefits beyond branding

USDA research shows plant container color can prevent root damage from high temperatures

BY JAKE SHRECKHISE AND JIM OWEN

Roots of temperate woody plants are adapted to the cushy, below-ground climate, where temperature extremes are buffered by soil. In conventional above-ground, container-based nursery production, the limited volume of a poorly insulated and highly porous substrate does little for root-zone climate control.

Encapsulate this soilless system in a black container exposed to 12 or more hours of direct sunlight and you get root-zone temperatures (RZTs) exceeding 120 F, even in the Willamette Valley. For roots, this can be a recipe for disaster!

In regions where winter temperatures periodically dip below freezing, nurseries have a standard operating procedure for protecting container plants, specifically the roots, from cold injury (e.g., moving plants into overwintering houses, jamming containers, wrapping blocks with insulating fabric, etc.).

In contrast, strategies for protecting plant roots from the summer heat have been less unanimously adopted. This is likely because root-zone heat stress, especially in milder climates (like Oregon), is often a slow bleed, manifesting in container plants as stunted growth, increased susceptibility to diseases, impaired

Figure 2. Root-zone heat stress symptoms exhibited by flowering dogwood (*Cornus florida* 'Appalachian Snow'; left) and panicle hydrangea (*Hydrangea paniculata* 'SMHPLQF' Little Quick Fire®; right) when grown in spaced, black, 2-gallon containers in McMinnville, Tennessee.
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nutrient uptake, and other indirect consequences that can go unnoticed without a non-stressed "standard" plant for comparison.

Even when the RZT is high enough to kill roots directly, the brown, mushy roots are hidden by the container and the downstream effects on the shoots are not always immediately obvious. Nonetheless, as will be demonstrated later, the season-long cumulative effects of implementing strategies that reduce summer RZT may dramatically affect crop finishing times, plant quality, and even fertilizer longevity.

Critical temperature thresholds

The negative effects of high RZTs take on two different forms: direct injury and indirect injury.

Direct injury occurs when roots are exposed to a critically high temperature for just 20–35 minutes, and results in dead roots. The temperature threshold for direct injury of woody plant roots can range from 113–130 F, depending on the plant species, cultivar, and whether the roots were previously subjected to an acclimation period of relatively high, yet sublethal, temperatures.

Roots that are the most susceptible to direct injury are in the south- and west-facing sides of above-ground containers, where peak temperatures are highest. Plants can develop a one-sided root system (Figure 1, Page 41) when they are grown in dark-colored containers that aren't protected from direct solar radiation in the summer.

Indirect injury occurs when the RZT remains above a lower threshold (≈104 F) than that required for direct injury but for a longer duration (≈5–6 hours). Compared to direct injury, indirect injury is more subtle; root and shoot growth ceases, hormone signaling may be impaired, nutrient uptake is inhibited, and susceptibility to root rot and canker diseases increases.

In addition to stunted growth, woody plants with heat-stressed roots may have smaller-than-usual leaves that appear cupped or curled despite having sufficient water (Figure 2, above). If the heat-stress continues, common symptoms are brown leaf tips, general leaf chlorosis (yellowing), and ultimately, early leaf-drop.

Excessive heat in the container substrate can also impact the life of your controlled-release fertilizer (CRF).

All leading polymer- and resin-coated CRFs used for container-based nursery production in the U.S. are highly influenced by temperature, with the nutrient release rate increasing with increasing temperature. As such, CRF manufacturers include on each label an estimated effective longevity based on the average substrate temperature (e.g., 7 months at 70 F, 6 months at 80 F, 5 months at 90 F).

When substrate temperatures exceed ≈104 F — a common occurrence in nurseries throughout the U.S. — CRFs "dump" nutrients into the substrate. This surplus of available mineral nutrients comes at a time when plant nutrient uptake is impaired due to heat stress. Thus, most of these nutrients will be leached from the container and enjoyed by the algae in your retention reservoir.

Managing root-zone heat

Despite being the industry standard nursery container for over 50 years, black plastic pots are terrible for root-zone heat management. Dark colors absorb solar

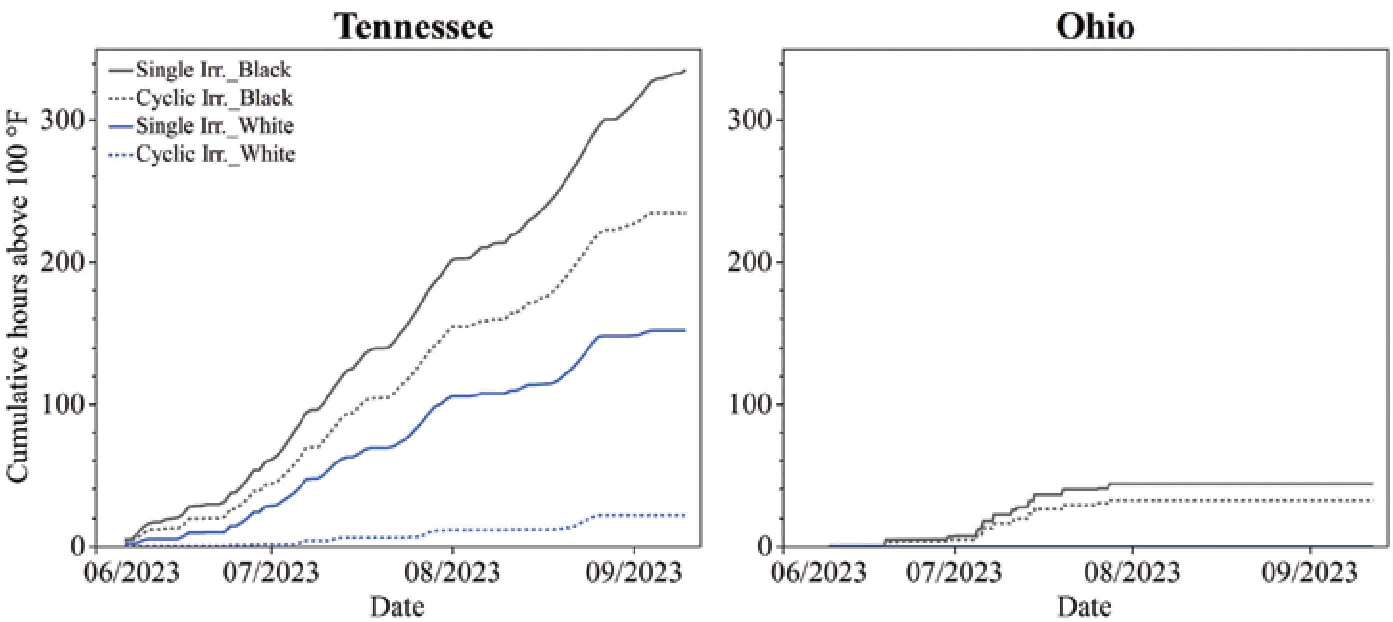

Figure 3. Cumulative time the root-zone temperature of shrub rose grown in McMinnville, Tennessee (left) or Wooster, Ohio (right) exceeded the lower threshold for indirect injury (100 F) in 2 gallon black or white containers irrigated once-daily at 7 a.m. (Single Irr.) or three times daily at 12, 3, and 6 p.m. (Cyclic Irr.). Temperature was recorded every 10 min in the western quadrant, 2" from the container wall, of three plants per treatment.
PHOTO COURTESY OF OREGON STATE UNIVERSITY

radiation, effectively converting it to heat. Therefore, on a hot, sunny day, the substrate temperature in a black plastic container can be 30 F higher than the ambient air temperature, with peaks as high as 133 F in McMinnville, Tennessee.

Lighter-colored (optimally, white) containers reflect more and absorb less solar radiation, resulting in lower maximum daily RZTs compared to black containers.

Historically, the limited availability or high expense of light-colored containers was a serious barrier to their adoption by commercial nurseries. Nursery container manufactures have since streamlined the production of affordable, white, plastic containers (5 gallon or less in size) that have an opaque, black interior wall to block sunlight from reaching the roots. These non-branded, white pots typically cost about 10-20% more than the equivalent black pots, which is a relatively small price to pay for the heat-stress protection they can provide to roots.

Over the past three growing seasons, USDA-ARS researchers Jake Shreckhise and Jim Owen have been conducting experiments concurrently replicated in McMinnville, Tennessee and Wooster, Ohio to explore how container color (black vs. white plastic) and irrigation schedule (once daily at 7 a.m. vs. three times daily at 12, 3, and 6 p.m.; matched total daily irrigation) affect RZT and the resulting plant growth, CRF nutrient release rate, and nutrient leaching in two disparate climates. Below are some of the key takeaways from this research.

Tennessee site takeaways

After logging temperature every 10 minutes in the west-facing quadrant of fully exposed shrub rose (*Rosa* × 'ChewPatout' Oso Easy® Urban Legend®) root balls for 14 weeks, the cumulative time RZTs exceeded the lower threshold for indirect injury was 332 hours, 234 hours, 152 hours, and 22 hours for the once-daily irrigated black containers, cyclic irrigated black containers, once-daily irrigated white containers, and cyclic irrigated white containers, respectively (Figure 3).

Thus, in Tennessee, white containers had a stronger heat-mitigating effect than cyclic irrigation; however, the combination of these two practices, by far, provided the greatest protection from temperatures associated with root-zone heat stress.

The effect of container color on root and shoot growth varied depending on the species. Compared to black containers, white containers had little effect on crapemyrtle (*Lagerstroemia* × 'Natchez') but dramatically improved growth and quality of all other evaluated species, including flowering dogwood (*Cornus florida* 'Appalachian Snow'), red osier dogwood (*C. sericea* cultivars), eastern redbud (*Cercis canadensis* 'Forest Pansy'), shrub rose, panicle hydrangea (*Hydrangea paniculata* cultivars), and smooth hydrangea (*H. arborescens* 'NCHA3' Invincibelle® Ruby).

In many of these species, including the heat-tolerant shrub rose, plants in white containers were up to twice the size as those in black containers when plants received once-daily overhead irrigation at 7 a.m. However, when plants were grown using cyclic afternoon irrigation, growth differences between the white and black containers were less dramatic.

To shed light onto container color effects on controlled-release fertilizer longevity, granules of a 6-month (80 F) CRF that had been incorporated into a pine bark substrate at pot-up were picked from the substrate after 14 weeks of outdoor production.

Analyzing the partially released CRF for nutrients revealed that the prills from the white containers had 18–35% more nitrogen, 14–18% more phosphorus, and 18–25% more potassium than those from black containers. Cyclic irrigation also conserved fertilizer nutrients, with CRF granules containing 8–15% more nitrogen, phosphorus, and potassium than those collected from once-daily irrigated plants.

Periodically analyzing nutrients in the leachate draining from the containers showed consistently higher nitrogen and phosphorus concentrations from the black, once-daily irrigated containers compared to the other treatments.

To summarize, at the Tennessee site (AHS Heat Zone 7), using white containers alone and especially in combination with cyclic afternoon irrigation produced larger, higher-quality plants while conserving CRF and limiting the amount of wasted nitrogen and phosphorus leaving the container through the drainage holes.

Figure 4. Red osier dogwood (*Cornus sericea* 'SMNCSBD' Arctic Fire® Yellow) after being grown in Wooster, Ohio for 10 weeks in black or white plastic 2-gallon containers under once-daily overhead irrigation. The south-facing side of the root balls were oriented toward the camera. Photo courtesy of Oregon State University

Ohio site take-aways

Between June 6 and September 10 in Wooster, Ohio (AHS Heat Zone 4), the cumulative time RZTs in the western-facing quadrant of shrub rose root balls exceeded the lower threshold for indirect injury was 44 hours for once-daily irrigated black containers and 32 hours for cyclic irrigated black containers (Figure 3, Page 43).

In white containers, regardless of irrigation schedule, RZTs never exceeded 100 F. Despite these differences, white containers did not notably improve shoot or root growth in shrub rose, crape myrtle, flowering dogwood, panicle hydrangea, or smooth hydrangea.

One noteworthy exception was when red osier dogwood liners were unintentionally exposed to Botryosphaeria canker a few days after transplanting into white or black containers; those in black containers were noticeably more severely infected than those in white containers. Instead of terminating the study, we managed the disease as a grower would — pruning out infected stems and applying fungicide — and then continued evaluating the plants.

At 10 weeks after transplanting, shoots of the red osier dogwoods in white containers were approximately 50% larger those in black containers, regardless of irrigation schedule (Figure 4, above). Cyclic afternoon irrigation, compared to once-daily morning irrigation, also improved shoot and root growth, but to a lesser degree than white containers. When the experiment was repeated a year later using a different red osier dogwood cultivar and preventing canker with preemptive fungicide sprays, plant growth and quality was essentially the same across container color and irrigation treatments.

Controlled-release fertilizer granules collected from the substrate in white containers 10–14 weeks after transplanting, depending on the year, had 7–12% more nitrogen, phosphorus, and potassium compared to those gathered from black containers, whereas irrigation treatment had no effect on CRF release. While leachate nutrient concentrations trended higher from black vs. white containers, a consistent statistically significant difference was not detected.

A frequently asked question regarding container color choice, particularly in the northern U.S., is whether the warmer temperatures in black containers in the spring give plants a "head start."

To investigate this, black and white 1-gallon panicle hydrangeas and 2-gallon red osier dogwoods were removed from the overwintering house in early April, placed on an outdoor gravel pad, and monitored weekly for flushing and stem elongation. No differences were detected between container colors in the aerial portions of the plants in either Tennessee or Ohio, although early-spring root growth should be compared in future studies before making definitive conclusions.

Are white pots right for you?

In the south and regions with high solar radiation during the summer months, using a root-zone heat mitigation strategy appears to be a *necessity* for maximizing quality and minimizing finishing time of most container-grown woody landscape plant species.

Cyclic afternoon irrigation and using white or light-colored containers are just two tools in the toolbox. Overhead shade cloth, jamming plants together until their canopies can provide shade, using porous-walled containers (e.g., air-pruning plastic, fabric, or fiber pots), or adopting a pot-in-pot systems are all improvements — with varying degrees of efficacy — over solid-walled, black plastic in full sun.

Keep in mind that a plant produced in black containers can lose the south-facing half of its root system after less than a day of exposure to full sun. In McMinnville, we found that when plants in white or black containers were faced with this scenario due to trimming or removing the shade-providing neighboring plants on a hot July day, those in white containers had substantially less root death than those in black containers. The same would likely be true when setting plants outside the shade house for a customer pickup. Thus, relying on shade, alone, could be risky as plants get shuffled around the nursery.

In higher latitudes, like our Ohio trial site or the Pacific Northwest, the use of white containers and other practices for managing root-zone heat are similar to an insurance policy. They may not provide noticeable benefits for every species every year, but when the next "heat dome" or disease outbreak comes around, you'll be glad you had them.

To determine whether using white containers would be beneficial under your current production system, consider purchasing a pallet of 1- or 2-gallon white containers and doing an on-site, side-by-side comparison in some of your "problem species." There is little to lose and, potentially, much to gain.

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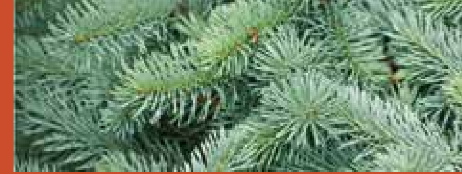
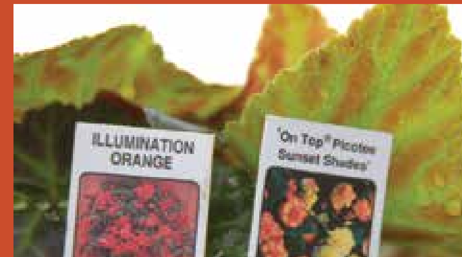

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