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How Container Color and Root Zone Temperature Affect Plant Growth and Fertilizer

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Summary

Black plastic pots, the nursery industry standard for over 50 years, are poor at managing root-zone heat. They readily absorb solar radiation, which raises substrate temperatures to harmful levels. On hot days, root-zone temperatures (RZT) in black containers can exceed 133°F in the southern U.S., resulting in plant stress and fertilizer inefficiency. In contrast, white containers reflect solar radiation, reducing RZTs and improving plant growth. Recent studies in Tennessee and Ohio show that using white containers, especially with cyclic afternoon irrigation, significantly lowers RZTs and improves plant growth, nutrient retention, and fertilizer efficiency. Plants grown in white containers exhibited less nutrient leaching and, in some cases, doubled in size compared to those in black containers. Although white containers cost 10-20% more, they offer better protection from heat stress, making them a cost-effective solution, especially in hot climates. For nurseries, investing in white containers may improve plant quality and yield long-term benefits.

INTRODUCTION

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 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 ambient air temperature, with peaks as high as 133°F in the southern U.S. Lighter-colored (optimally, white) containers reflect more and absorb less solar radiation, resulting in lower maximum daily root-zone temperatures (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 gal 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 roots.

Excessive heat in the container substrate can also impact the life of 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 the nursery retention reservoir.

Over the past three growing seasons, USDA-ARS researchers, Jake Shreckhise and Jim Owen, have been conducting experiments concurrently replicated in McMinnville, TN and Wooster, OH to explore how container color (black vs. white plastic) and irrigation schedule (once daily at 7:00 am vs. three times daily at 12:00, 3:00, and 6:00 pm; matched total daily irrigation) affect RZT and 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 min in the west-facing quadrant of fully exposed shrub rose (*Rosa* x 'ChewPatout' Oso Easy® Urban Legend®) root balls for 14 weeks, the cumulative time RZTs exceeded the lower threshold for indirect injury (i.e., stunted growth, impaired nutrient uptake, increased susceptibility to diseases) was 332, 234, 152, and 22 hrs, respectively, for the once-daily irrigated black containers, cyclic irrigated black containers, once-daily irrigated white containers, and cyclic irrigated white containers, respectively (**Fig. 1**). As such, in TN, 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.

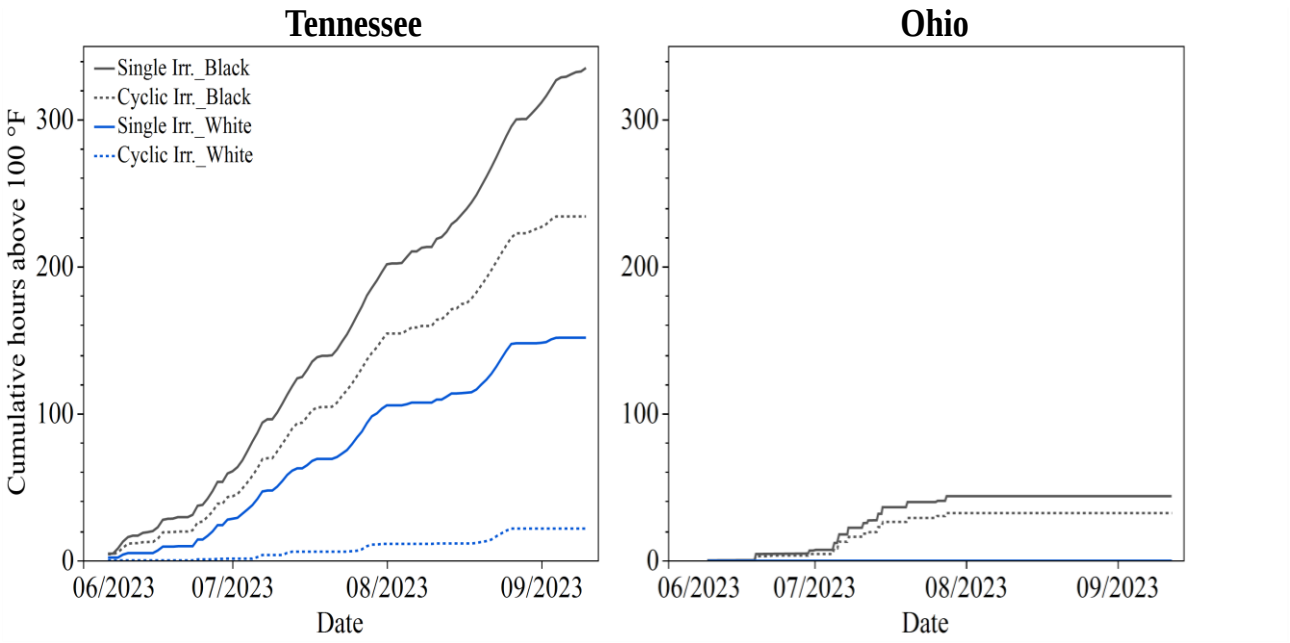

Figure 1. Cumulative time the root-zone temperature of shrub rose grown in McMinnville, TN (left) or Wooster, OH (right) exceeded the lower threshold for indirect injury (100°F) in 2 gal. black or white containers irrigated once-daily at 7 am (single irrigation) or three times daily at 12, 3, and 6 pm (Cyclic irrigation.). Temperature was recorded every 10 min in the western quadrant, 2 in. from the container wall, of three plants per treatment.

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* 'SMNCSBD' Arctic Fire®; Figure 2), shrub rose (**Fig. 2**), eastern redbud (*Cercis canadensis* 'Forest Pansy'), 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 am. However, when plants were grown using cyclic afternoon irrigation, growth differences between the white and black containers were less dramatic.

Figure 2. Shrub rose (*Rosa* x 'ChewPatout' Oso Easy® Urban Legend®) Red osier dogwood (*Cornus sericea* 'SMNCSBD' Arctic Fire® The south-facing side of the root balls were oriented toward the camera.

To shed light onto container color effects on controlled-release fertilizer longevity, granules of a 6-month (80 °F) CRF, which had been incorporated into a pine bark substrate at the time of planting 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.

Ohio site take-aways. Between June 6 and September 10 in Wooster, OH (AHS Heat Zone 4), the cumulative time that RZTs exceeded the lower threshold for indirect injury in the western-facing quadrant of shrub rose root balls was 44 hrs for once-daily irrigated black containers and 32 hrs for cyclic irrigated black containers (**Fig. 3**). 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, crapemyrtle, 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. That is, we pruned out infected stems and applied fungicide. We 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 (**Fig. 3**). 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 the prevention of canker with preemptive fungicide sprays, plant growth and quality was essentially the same across container color and irrigation treatments.

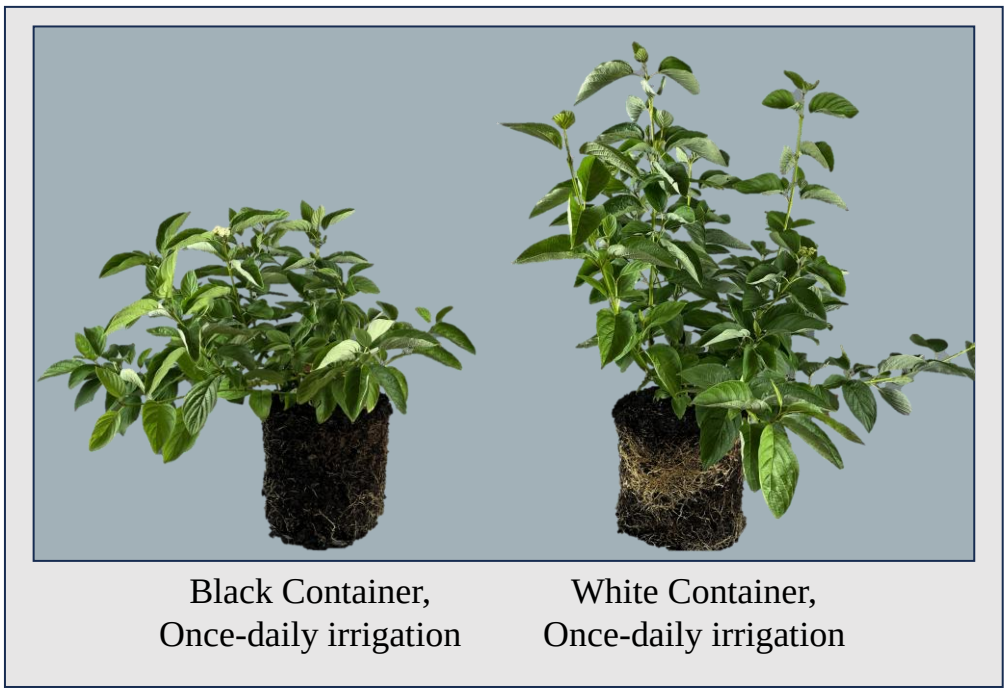

Figure 3. Red-osier dogwood (*Cornus sericea* 'SMNCSBD' Arctic Fire® Yellow) after being grown in Wooster, OH for 10 weeks in black or white plastic 2-gal containers under once-daily overhead irrigation. The south-facing side of the root balls were oriented toward the camera.

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 versus white containers, a consistent statistically significant difference was not detected.

A frequently asked question regarding container color choice, particularly in the northern US, is whether the warmer temperatures in black containers in the spring give plants a "head start." To investigate this, black and white 1-gal panicle hydrangeas and 2-gal red-osier dogwoods were removed from an 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 TN or OH, although early-spring root growth should be compared in future studies before making definitive conclusions.

Are white pots right for you? In the southern US 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 options 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. Consequently, relying on shade alone could be risky as plants get shuffled around the nursery.

At higher latitudes, like our Ohio trial site, 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-gal white containers and doing an on-site, side-by-side comparison with some of your "problem species". There is little to lose and, potentially, much to gain.