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Effect of Container Color on Substrate Temperatures and Growth of Red Maple and Redbud

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Abstract. **Heat stress is problematic to root growth in the production of containerized nursery plants. Container color may moderate effects of solar radiation on substrate temperatures. Studies were conducted near Manhattan, KS, to evaluate effects of container color on growth of roots and shoots in bush beans (*Phaseolus vulgaris* L.), red maple (*Acer rubrum* L.), and eastern redbud (*Cercis canadensis* L.). Four treatments among studies included containers colored flat and gloss white, silver, and black; a green container color treatment was added to the tree studies. Plants were grown in bark-based soil-less substrate and temperatures were measured at 5-cm depths in the south sides and centers. After 4 months, plant variables were measured. Roots were separated into three sections: core, north, and south. In the bean study, substrate temperatures at the south side of the container averaged lowest in flat and gloss white (≈36 °C) and greatest in black containers (50.3 °C). Root density at the south side was reduced in beans by 63% to 71% in black compared with flat and gloss white. In heat-sensitive maples, substrate temperatures at the south side of containers averaged up to 7.7 °C greater in black and green than in other treatments. Substrate temperatures in the center averaged 3.5 to 3.8 °C greater in black than in flat and gloss white, resulting in up to 2.5 times greater root density in flat and gloss white than in black containers. In heat-tolerant redbuds, the effects of container color on whole-plant growth were less evident. Data suggest that heat-sensitive plants benefit from being grown in white containers or painting outer surfaces of green and black containers white.**

Heat stress imposed on roots of container-grown plants is an important problem in the nursery industry. In a number of nursery-grown species, substrate temperatures over 30 °C may cause root growth to slow considerably (Johnson and Ingram, 1984). Furthermore, in a number of woody species, root growth stops completely at temperatures above 39 °C (Mathers, 2003). Substrate temperatures inside nursery containers can rise higher than 54 °C (Ingram et al., 1989; Martin et al., 1989; Mathers, 2000), resulting in crop loss or reduced crop quality. This is especially problematic to some woody species [e.g., Japanese holly (*Ilex crenata* Thunb. 'Helleri')] because their roots die when exposed to temperatures of 51 °C for merely 30 min (Martin et al., 1989).

The detrimental effects of heat stress on root growth affect the whole plant and thus also impacts aboveground production. For example, high root-zone temperatures in container-grown nursery plants may cause leaf wilting, chlorosis, and drop; reduce flower numbers and quality; cause abnormal branching; and interfere with normal physiological and biochemical processes (e.g., photosynthesis and respiration, water and nutrient uptake, hormone synthesis, and translocation processes) (Ingram et al., 1989). High root-zone temperatures may also increase the incidence of disease and cause plant injury or death (Ranney and Peet, 1994; Webber and Ross, 1995). Therefore, investigations into the effects of heat stress on root growth in container-grown plants would benefit by including evaluations of whole-plant responses.

It is possible that growing plants in containers made of colors lighter than standard black may improve root growth. Lighter colored containers have greater albedo than dark containers and thus reflect more solar radiation away from the container (i.e., less solar energy absorbed by the container) (Ham et al., 1993). Consequently, lighter colored containers may be a means to mitigate heat stress in nursery production.

Fretz (1971) reported that substrate temperatures were reduced by 5.6 °C in light- than in dark-colored containers. Whitcomb (1980, 1999, 2003) also found that substrate temperatures were reduced by 3 to 6 °C when standard black containers were covered with white laminated fabric sleeves (RootSkirts®; Rootmaker Products Co., Huntsville, AL). Similarly, substrate temperatures were decreased by 1 to 7 °C in containers made of an insulating black fabric that was coated on the outside with white polyethylene (Whitcomb and Whitcomb, 2006).

Ingram (1981) evaluated the effects of substrate temperature on root growth of flowering dogwood (*Cornus florida* L.), rhododendron (*Rhododendron simsii* Planch. 'Formosa'), and japanese pittosporum (*Pittosporum tobira* Banks) grown in polyethylene bags with a white outer surface and conventional, rigid black containers. In their study, maximum daily temperatures were 6 °C higher in black containers than in white polyethylene bags. Root growth of plants in white polyethylene bags, with cooler substrate compared with black conventional containers, was three times greater in rhododendron and four times greater in flowering dogwood but unaffected in japanese pittosporum, indicating substantial differences in heat tolerance among species.

Although container-grown species in the nursery industry may vary in their susceptibility to heat stress, all species benefit from developing an extensive root system in propagation and early production (Davidson et al., 2000). If root growth is compromised during production, transplant survival and growth may later be negatively affected in the landscape (Richardson-Calfee et al., 2010). Therefore, investigations into potentially heat-mitigating practices such as the use of lighter colored containers on root growth and distribution may prove beneficial for a number of important nursery crops.

Red maple and eastern redbud are examples of important species in the nursery industry because they are native to the United States, tolerant of a wide range of environmental conditions, and have desirable ornamental characteristics (Dirr, 2009). Wilkins et al. (1995) evaluated several genotypes of red maple for tolerance to high root-zone temperatures and showed that some were relatively sensitive, whereas others demonstrated resistance to heat stress in the root zone. A study by Griffin et al. (2004) revealed that redbud is tolerant of high temperatures and drought.

In this study, we evaluated effects of container color on substrate temperatures, including spatial variability in substrate temperatures. Subsequent effects of container color and substrate temperature on root distribution and shoot development were also evaluated in container-grown maples and redbuds.

Materials and Methods

Bean study. Several container colors were evaluated first in an experiment with bush beans late in the summer of 2004 to quickly determine appropriate color selections for the woody plant experiments, which were conducted the next summer. Bean plants were grown in soil-less potting substrate (Metro-Mix

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