e-GRO Research Update

October 2015, #2015-08

PURDUE UNIVERSITY

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Reduce Air Temperatures during Bedding Plant Production with the use of Root-zone Heating

by Roberto Lopez and Joshua Gerovac

Plants integrate temperature in their environment over time and any change to the temperature set point in your greenhouse influences developmental rates. Plants develop leaves and progress toward flowering in response to the average daily temperature (ADT).

In an effort to save on energy costs, greenhouse growers often lower their air temperature set points. As a result, plant temperature is reduced and plants develop progressively slower and this varies from species to species. At some species-specific temperature, development stops and this is referred to as the base temperature (T_b). As temperature increases above the T_b, the rate of development increases until an optimum temperature (T_o) is reached. Annual bedding plants can be categorized into three response types based on their T_b: cold-tolerant (T_b < 39 °F), cold-intermediate (39 °F < T_b < 45 °F), and cold-sensitive (T_b > 45 °F).

Bedding plant production begins in mid- to late-winter and early spring in temperate Northern latitudes where average daily outdoor air temperatures can range from 27 to 48 °F (Figure 1). During this time, greenhouses use a variety of heating systems such as forced air, perimeter, radiation, infrared, unit, etc. to maintain desirable production air temperatures. The energy used for heating accounts for 10 to 30 % of the total operating cost of commercial greenhouses in Northern climates. Therefore, due to volatile energy costs and lower profit margins, producers are seeking alternative heating strategies for bedding plant production that further reduce overall fuel consumption. In response to these rising energy costs, greenhouse growers have implemented a variety of strategies,

Figure 1. Bedding plant production begins in mid- to late-winter and early spring in temperate Northern latitudes.

Summary of Findings

- As root-zone heating temperature set-points increased, time to flower (TTF) of all cold-tolerant and cold-intermediate species decreased; however, there was a delay in TTF compared to plants grown under an average daily temperature of 68/65 °F day/night (commercial control).
- Our results indicate that the delay in TTF of marigold, pansy, and petunia is less than one week with RZH temperature set-points of 75 or 80 °F in combination with an air temperature of 60 °F, compared to the commercial control.
- The production of cold-tolerant bedding plants under cool air temperatures with root-zone heating could reduce energy costs, when compared to conventionally heated greenhouses.

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including lowering their air temperature set points, increasing insulation, starting production later in the season, consolidating production, installing thermal energy curtains, contracting fuel, purchasing energy-efficient heaters, or switching to alternative fuel sources.

Of the energy cost reduction strategies implemented, only ≈7 % of greenhouse growers have taken advantage of energy-efficient root-zone heating due to the lack of crop-specific production information available to them. While air and root-zone temperature set points for potted plants such as poinsettia and chrysanthemum and cut flowers are available, there is little or no published research identifying air and root-zone temperature combinations for commercially available cold-tolerant, -temperate and -sensitive bedding plants species. Therefore, we wanted to quantify the growth and development of nine commercially important bedding plant species with different cold tolerance classifications when grown in a greenhouse with a reduced air temperature set point and on benches with root-zone heating.

The Experiment

Bedding plants were selected on the basis of their cold tolerance and included 'Durango Bee' French marigold, 'Oh Snap Pink' snapdragon, 'Matrix Yellow' pansy, 'Serenity Bronze' osteospermum, and 'Dreams Midnight' petunia (cold-tolerant species), 'Aztec Blue Velvet' verbena and 'Super Elfin Lipstick' seed impatiens (cold-intermediate species), and 'Celebration Red' New Guinea impatiens and 'Pacifica XP Rose Halo' vinca (cold-sensitive species). Plugs or liners were received from a commercial greenhouse propagator and were transplanted into 4.5-inch round containers filled with substrate comprised of Canadian sphagnum peat moss, perlite, and vermiculite. Plants were fertilized weekly with clear water supplemented with a water-soluble fertilizer providing 400 ppm N. Between each fertigation, plants were irrigated as necessary with acidified clear water and leaching was kept to a minimum. The weekly application of 400 ppm N was used to reduce any confounding variables that could have been associated with treatments receiving different fertigation rates as a result of substrates drying out faster under higher root-zone temperatures.

Plants were grown in glass-glazed greenhouses located in West Lafayette, IN. The photoperiod was a constant 16 hours consisting of natural day lengths with day-extension lighting provided by high-pressure sodium lamps (HPS) that also delivered supplemental lighting to achieve a daily light integral (DLI) of 10 to 12 $mol \cdot m^{-2} \cdot d^{-1}$.

For plants that were grown on benches with root-zone heating, the average daily air temperature in the greenhouse was relatively cool and maintained at ≈60 °F throughout the study. Root-zone temperature treatments of 65, 70, 75, and 80 °F were created using independently programmable sections of bench-top tubing that circulated hot water from a high efficiency boiler. Additionally, we had a treatment receiving no root-zone heating serving as a control (ambient at ≈60 °F). A separate greenhouse served as our commercial control and we maintained an average daily air temperature of ≈67 °F [day/night set point of (12 h/12 h) 68/65 °F] and no root-zone heating. Ten plants of each species were randomly selected, spaced equally in trays, and placed on benches with or without root-zone heating.

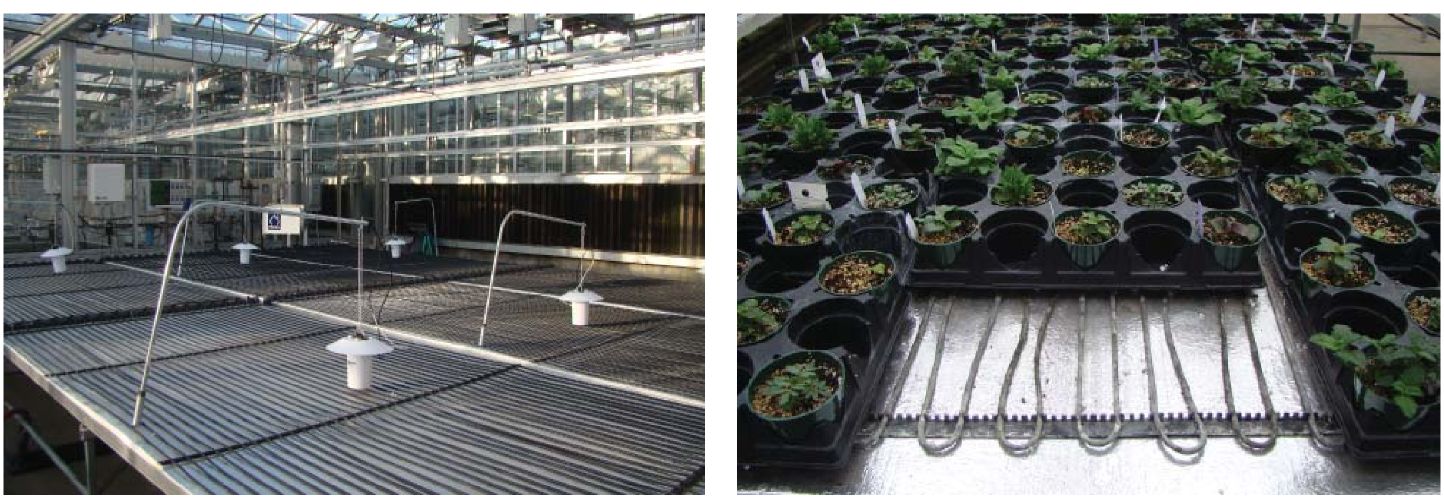


Figure 2. Six independently controlled bench-top root-zone heating sections used at Purdue University for finishing bedding plants.

Results

The delay in development or time to flower for most of the cold-tolerant species was minimal when they were grown on benches with root-zone heating temperature set points of 75 or 80 °F and a reduced air temperature of 60 °F. For example, compared to the commercial control (air temperature of 67 °F and no-root zone heating), time to flower for French 'Durango Bee' marigold was delayed by 6 and 5 days (Figure 3), 'Dreams Midnight' petunia by 6 and 4 days (Figure 4), and 'Matrix Yellow' pansy by 6 and 1 days. For cold-intermediate 'Super Elfin Lipstick' impatiens, time to flower compared to the commercial control increased by 8 and 4 days were grown on benches with root-zone heating temperature set points of 75 or 80 °F and a reduced air temperature of 60 °F (Figure 5).

Surprisingly, we found that the cold-tolerance classification of a crop was not necessarily a good indicator of how the crop would develop when grown under reduced air temperatures and root-zone heating. For example, there was a 9 and 14 day delay in time to flower for cold-tolerant 'Oh Snap Pink' snapdragon and 'Serenity Bronze' osteospermum (Figure 6), respectively, even when grown on root-zone heating temperatures of 75 and 80 °F.

If we consider how root-zone heating works, the containers in contact with the root-zone heating tubing are heated through conduction, while the air surrounding the tubing

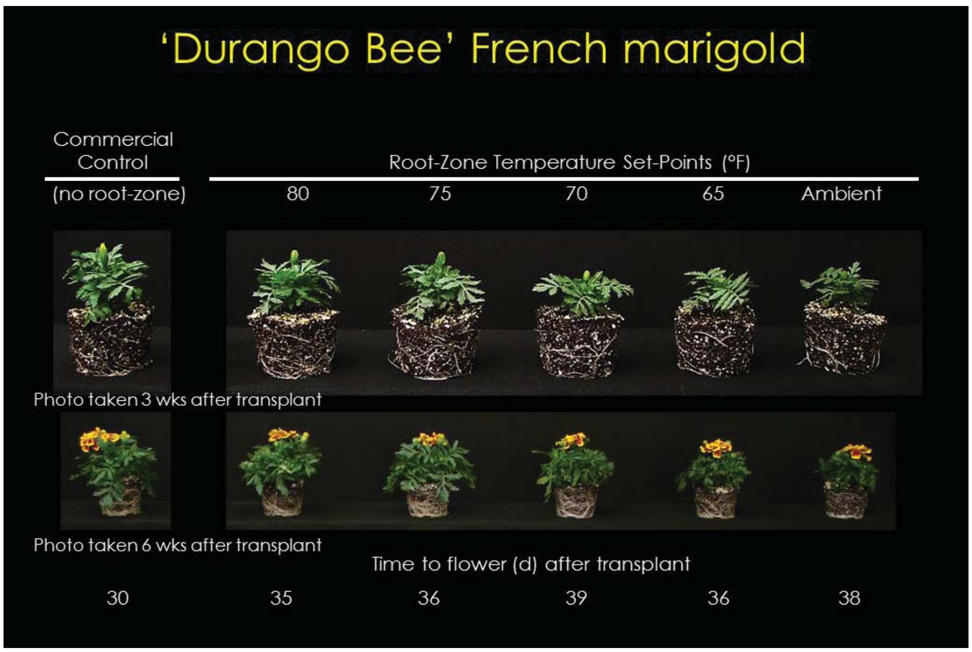


Figure 3 (left). Days to flower from transplant of cold-tolerant 'Durango Bee' French marigold as influenced by root-zone temperature (ambient, 65, 70, 75, or 80 °F) compared to a commercial control (68/65 °F). Photos were taken 3 and 6 weeks after transplant.

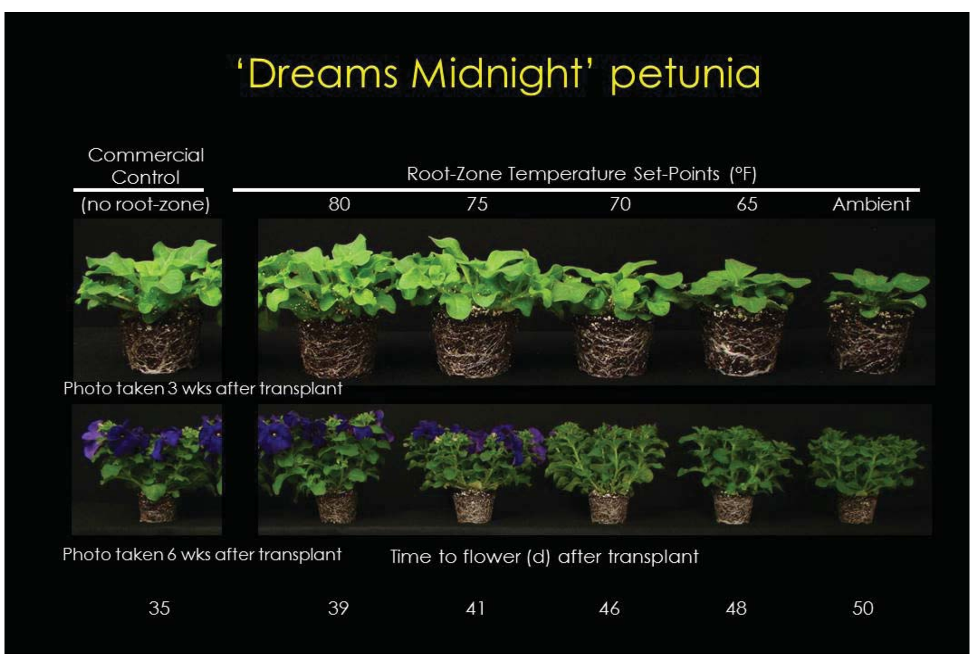


Figure 4 (right). Days to flower from transplant of cold-tolerant 'Dreams Midnight' petunia as influenced by root-zone temperature (ambient, 65, 70, 75, or 80 °F) compared to a commercial control (68/65 °F). Photos were taken 3 and 6 weeks after transplant.

and crop canopy are heated through convection. Unlike petunia, pansy, and marigold which have a more prostrate and compact growth habit, snapdragon and osteospermum are taller and more upright crops and therefore plant temperature did not significantly increase from convection.

The development of 'Celebration Red' New Guinea impatiens (cold-sensitive crop) was significantly delayed compared to the commercial control even with root-zone heating. Additionally, plants were deemed unmarketable due to symptoms of chilling injury and reduced growth. However, cold-sensitive 'Pacifica XP Rose Halo' vinca was only delayed by 2 days when grown on benches with root-zone heating temperature set points of 80 °F and a reduced air temperature of 60 °F (Figure 7).

Virtual Grower 3 (www.virtualgrower.net) was used to estimate potential energy savings a grower may achieve by producing a petunia crop in a double-poly greenhouse located in Grand Rapids, MI and Denver, CO with a projected market date of March 10th, April 10th, and May 10th. It is estimated that a growers in Grand Rapids could reduce their heating costs by 26, 24, and 13%, and 2, 13, and 16% in Denver, by reducing the air temperature from 68/65 °F to a constant 60 °F with an added 4

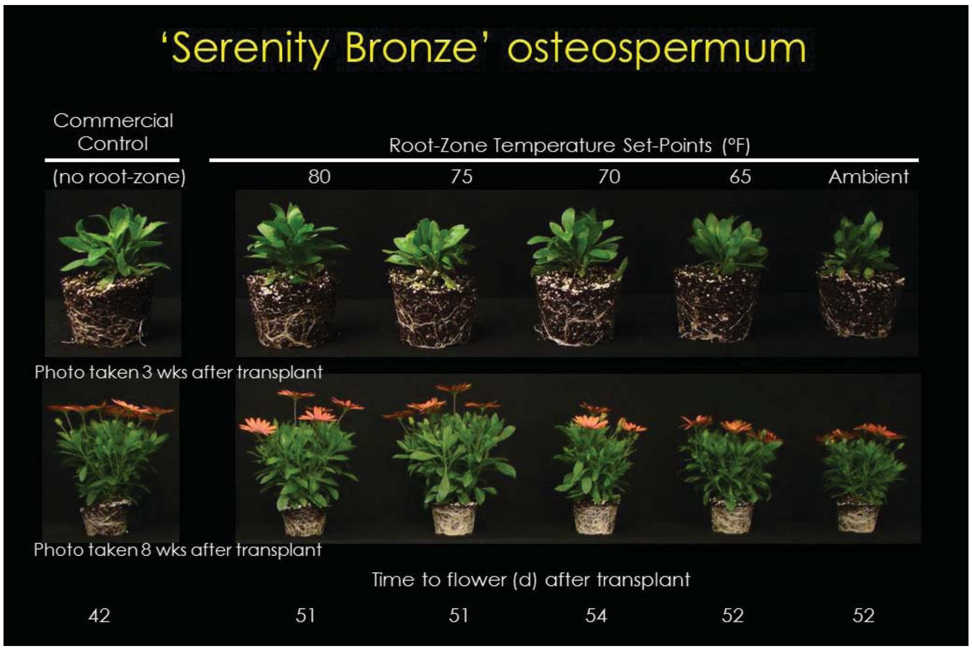
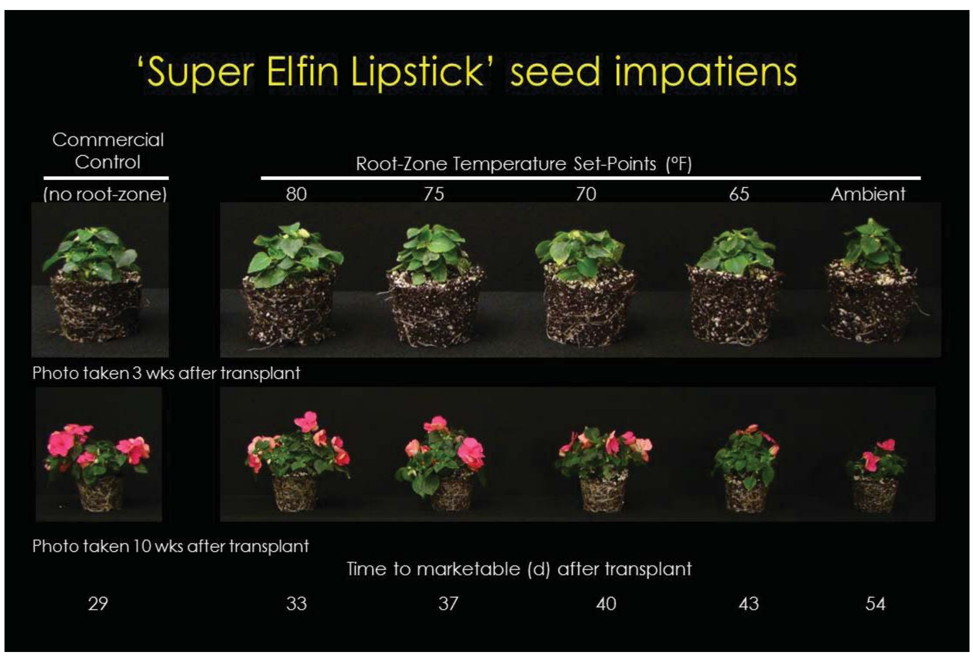


Figure 5 (left). Days to flower from transplant of cold-tolerant 'Serenity Bronze' osteospermum as influenced by root-zone temperature (ambient, 65, 70, 75, or 80 °F) compared to a commercial control (68/65 °F). Photos were taken 3 and 8 weeks after transplant.

Figure 6 (right). Days to marketability from transplant of cold-intermediate 'Super Elfin LIpstick' seed impatiens as influenced by root-zone temperature (ambient, 65, 70, 75, or 80 °F) compared to a commercial control (68/65 °F). Photos were taken 3 and 10 weeks after transplant.



We gratefully acknowledge Ball Horticulture Co., Everris, Sun Gro Horticulture, and the Indiana State Department of Agriculture Specialty Crop Block Grant 205749 for supporting this research.

days of production. However, these estimated savings are reduced for every day the crop is delayed, and at a certain point, any savings that could be achieved by lowering the air temperate will be negated, and eventually will require more energy.

Now growers must consider the other costs associated with using root-zone heating systems in combination with reduced air temperatures, such as the expense of operating a boiler or hot water heater. Unfortunately, with our system we were unable to quantify the amount of energy that would be necessary to operate our boiler to heat the root-zone to 75 or 80 °F. The energy used to run a boiler or hot water heater to heat the root-zone would reduce the 13 to 26% savings for the Grand Rapids grower and 2 to 16% for the Denver grower, not to mention the additional cost to install the system and potential return on investment. For growers who have bench top or in ground root-zone heating systems installed, this study may give you a better idea of the substrate temperatures needed to grow bedding plants under reduced air temperatures. This study may also help growers who already have a system installed select crops that respond positively and avoid crops that we found to not benefit from root-zone heating.

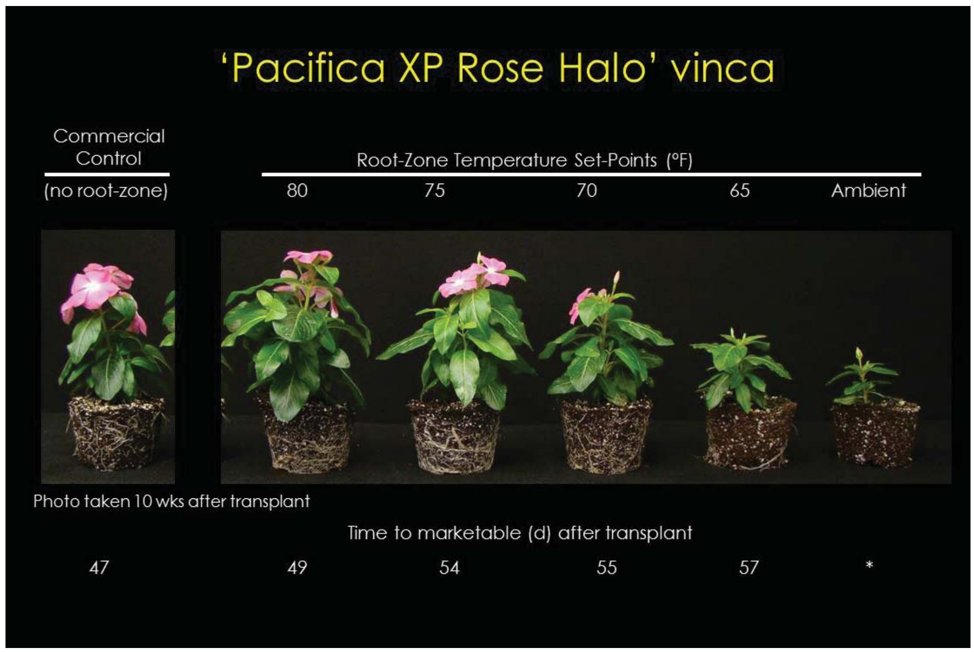


Figure 7 (right). Days to flower from transplant of cold-sensitive 'Pacifica XP Rose Halo' vina as influenced by root-zone temperature (ambient, 65, 70, 75, or 80 °F) compared to a commercial control (68/65 °F). Photo was taken 10 weeks after transplant.

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