Growing Your Crops **Above Their Base Temperature**

Is lowering temperature set points in the greenhouse the best option for you to combat rising heating costs?

by **ROBERTO G. LOPEZ** and **ERIK S. RUNKLE**

ASK any grower about the winter of 2013 to 2014 and they will tell you they spent a lot of money on energy to heat their greenhouses. Today, energy for heating is typically the second largest overhead cost (about 10 to 30 percent) in Northern latitudes, and this cost is expected to increase. As growers, you have some options to lower those costs by making investments, such as installing energy curtains or efficient heaters. However, many growers find that the easiest option in a time of rising energy costs is to lower the temperature set point in the greenhouse. In fact, a *Greenhouse Grower* survey reported that nearly one-third of growers did this, or delayed the start of their production, when energy costs skyrocketed in the early 2000s.

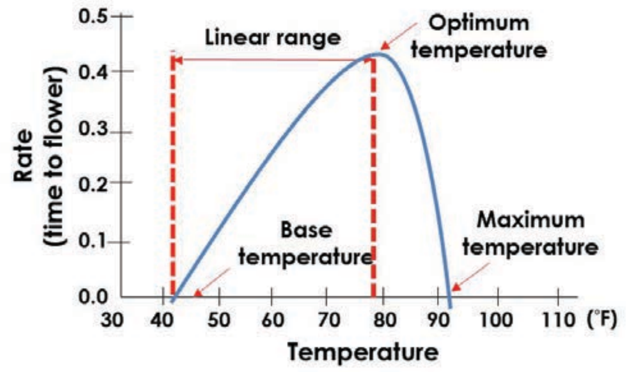

Figure 1. **An example of the effect of temperature on developmental rate such as time to flower. The base temperature is the species-specific temperature at which plant development stops. The optimum temperature is where plant development is most rapid, and the maximum temperature is where development stops.**

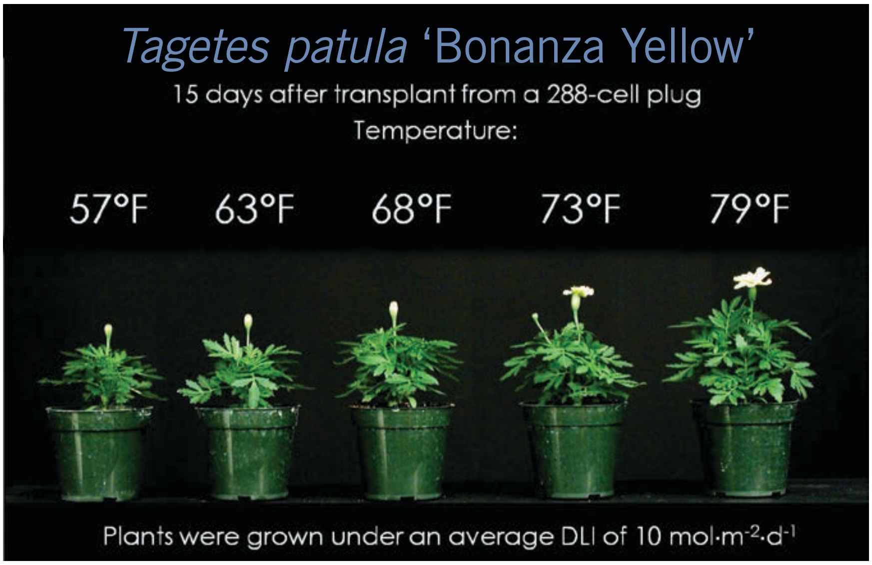

Figure 2. **The effect of average daily temperature on flowering of cold-tolerant marigolds. Photo courtesy of Lee Ann Moccaldi.**

Lowering Temperatures Affects Plant Development

Unfortunately, this strategy is not always the cheapest option, since plants integrate temperature over time and lowering the temperature slows down developmental rates. Plants develop leaves and progress toward flowering in response to the average daily temperature (ADT) within the greenhouse. Each species has a specific minimum, optimum and maximum temperature that influences its development (Figure 1). Therefore, a crop grown at a day/night (12 h/12 h) temperature of 70°F /60°F (21°C/16°C) would flower at the same time as a crop grown at a constant 65°F (18°C) because the ADT is the same.

Consequently, those growers who decided to lower their greenhouse temperature set points found that their crop developmental

Figure 3. **Compartmentalization of cold-sensitive greenhouse crops such as vinca and lantana can reduce energy costs.**

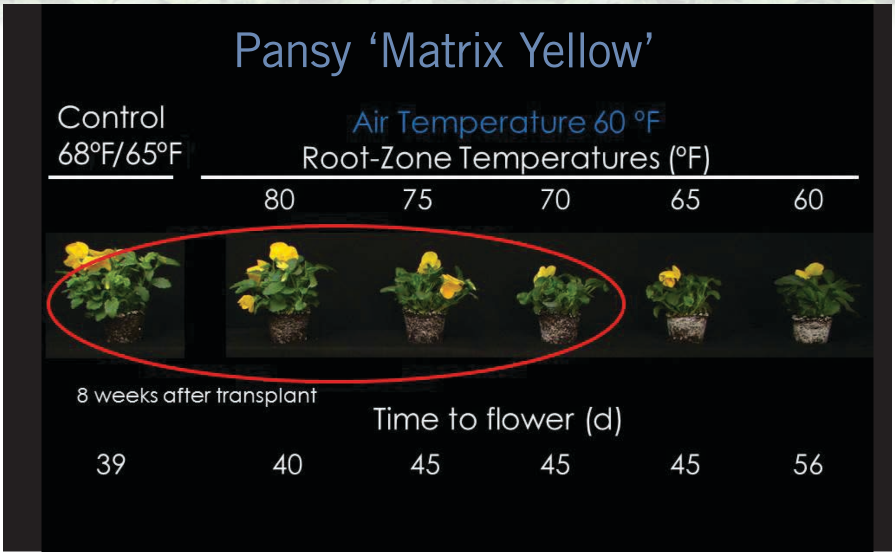

Figure 4. **Inhibition of root growth and development of pansy (cold-tolerant species) when grown on root-zone heating temperatures above 65°F or day/night air temperatures of 68°F/65°F.**

rates (such as the rate of flowering) decreased, and they did not meet their market dates. As temperatures in the greenhouse are lowered, plants develop progressively slower, and this varies from species to species. At some species-specific temperature, development stops. This is referred to as the base temperature (T_b; Figure 1).

The T_b can vary among species and even cultivars, and is estimated to range from roughly 30°F to 54°F (–1°C to 12°C) for the floriculture crops that have been investigated so far. For example, the T_b of marigold is about 34°F (1°C), which means that at or below this temperature, a marigold crop will stop growing (Figure 2).

Now, let's focus on another crop, vinca (catharanthus), which has a T_b of about 53°F (12°C). Not surprisingly, many growers find that vinca will develop slowly when grown in the same greenhouse as a marigold crop if the temperature set point is cool, such as 60°F (16°C). Growers who set their thermostats too low can end up spending more on heating because the crop is in the greenhouse longer. Some growers compartmentalize their crops based on their T_b, where they grow cold-sensitive crops such as angelonia, celosia, lantana and vinca, etc., in warm houses (Figure 3).

As temperatures are raised above the species-specific base temperature, crop developmental rates increase linearly until they reach their optimum temperature (Figure 1).

Light-Limiting Conditions May Call For Optimum Temperatures

Now, you might be thinking that you should grow all your crops at their optimum temperature. Not so fast!

Under light-limiting conditions, such as during the winter and early spring in Northern latitudes, crops can be of moderate-to-low quality if grown at their optimum temperature. Additionally, if temperatures exceed the optimum temperature, developmental rates again begin to decrease. Once the maximum temperature is reached (Figure 1), development stops due to plant stress. When possible, plants should not be exposed to temperatures above their optimum.

Cold-Tolerant Crops Show Better Quality When Grown At Cooler Temperatures

Extensive research has been conducted at Michigan State University (MSU) to estimate the T_b of a wide variety of floriculture crops. This information was then used to categorize crops into different temperature response categories (Table 1.

- Cold-tolerant crops have a base temperature of 39°F (4°C) or lower and generally should be grown at an ADT of 60°F to 65°F (16°C to 18°C)
- Cold-temperate crops have a base

temperature between 40°F and 45°F (4°C to 7°C), and generally should be grown at an ADT of 65°F to 70°F (18°C to 21°C)

• Cold-sensitive crops have a base temperature of 46°F (8°C) or higher and should generally be grown at an ADT of 70°F to 75°F (21°C to 24°C)

Cold-tolerant crops are those crops for which development is less influenced by lowering the temperature set point. The quality of these crops is typically much higher when they are grown cooler (<65°F), especially when the daily light integral (DLI) is low (< 10 mol·m^{-2}·d^{-1}). Although the T_b of cold-tolerant crops is below 39°F, growers find they can save on energy, achieve their market dates without delays and produce high-quality crops when they are grown at temperatures of 60°F to 65°F.

You might also consider growing cold-tolerant crops in a minimally heated high tunnel or with root-zone heating when the air temperature set point is reduced to save on energy costs. If you utilize root-zone heating, be careful not to set the temperature too high to compensate for reduced air temperatures. Research at Purdue University is highlighting how root development of some cold-tolerant crops is actually inhibited by root-zone temperatures of 65°F or higher (Figure 4).

Table 1. Estimated base temperature (T_b) of floriculture crops from research conducted at Michigan State University. Crops were categorized into the following three temperature response categories based on their T_b: cold-tolerant, intermediate and sensitive.

Cold Tolerant[1] (Low T_b) <39°F	Cold-Temperate (Moderate T_b) 40°F to 45°F	Cold-Sensitive (High T_b) >46°F
Alyssum	Calibrachoa	Ageratum
Dianthus	Calendula	Angelonia
Diascia	Cosmos	Blue salvia
American marigold	Cupflower	Browallia
French marigold	Dahlia	Celosia
Nemesia	Gazania	Gerbera
Osteospermum	Geranium	Globe amaranth
Petunia (Bravo, Dreams and Easy Wave)	Flowering tobacco	Hibiscus
Snapdragon (Liberty Classic and Montego)	Impatiens (seed)	Pentas
Stock	Lobelia	Poinsettia
Viola	Petunia (Shock and Wave Purple Classic)	Portulaca
	Rudbeckia	Torenia
	Verbena	Vinca
	Wax begonia	Zinnia

[1]For more specific information, visit **http://www.flor.hrt.msu.edu/annuals.**

Flowering Delayed For Cold-Intermediate And Cold-Sensitive Crops Grown At Reduced Temperatures

Now we will discuss cold-intermediate (or cold-temperate) crops, which are those with a T_b of 40°F to 45°F. Crops in this category include those you might consider cold-tolerant such as verbena and some petunia cultivars. Generally, to reduce time to flower while still producing high-quality crops, we advise growing cold-intermediate crops at an ADT of 65°F to 70°F. Crop quality may be higher when grown at lower temperatures, but flowering is delayed and thus may not be economical.

Finally, cold-sensitive crops have a T_b ≥46°F and flowering is delayed substantially when greenhouse temperatures are lowered. Thus, plants should generally be grown at warm temperatures of 70°F to 75°F to avoid excessively long production times. By growing cold-sensitive crops at warm temperatures, you can actually reduce the amount of energy used for heating — on a per-crop basis — than if they were grown at cooler temperatures. Additional benefits of growing these crops warm could include reduced pathogen occurrence and chlorosis that can develop from low temperatures.

Avoid Growing Cold-Tolerant And Cold-Sensitive Crops Together

The temperature response categories outlined in Table 1 can be used to compartmentalize greenhouse crops depending on their T_b and the suggested production temperatures. We realize that not all growers have the option to compartmentalize their crops. Our goal is to help you avoid growing cold-tolerant and cold-sensitive crops together for the reasons stated above. Other factors to consider before making any changes include your particular heating costs, outdoor environmental conditions in your area, market date, plant size (plug or liners) and desired finish quality.

You may wish to download Virtual Grower (VirtualGrower.net) to build your own virtual greenhouse and then estimate energy costs for your specific crops, growing dates and temperature set points. **GG**

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