Part 7 of 12
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Energy-Efficient Annuals: Geraniums & Zinnias

Researchers from Michigan State University present research-based information for scheduling annuals in a more energy-efficient and predictive manner.

by **MATTHEW BLANCHARD** and **ERIK RUNKLE**

MOST bedding plants are produced in heated greenhouses from January through May, when high energy inputs can be required to maintain a desirable temperature. With shrinking profit margins and volatile energy prices, scheduling crops in an energy-efficient manner is increasingly desirable. At Michigan State University (MSU), we have performed experiments with many seed-propagated annuals to quantify how temperature and daily light integral (DLI) influence flowering time and plant quality.

In the seventh article of this series, we present crop timing data on seed geranium and zinnia and then use the information to estimate greenhouse heating costs at different locations, growing temperatures and finish dates. We also highlight the effect of DLI on flowering of these two crops.

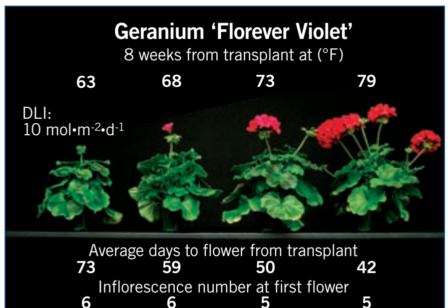

Figure 1. The effects of average daily temperature on time to flower and number of inflorescences (at first flowering) in seed geranium 'Florever Violet.' Plants were grown under a 16-hour photoperiod and an average daily light integral of 10 mol·m^{-2}·d^{-1}. Photograph was taken eight weeks after transplant from a 288-cell plug tray that was grown under long days.

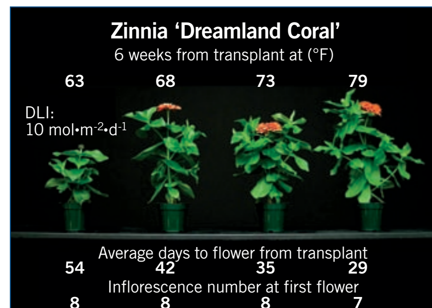

Figure 2. The effects of average daily temperature on time to flower and number of inflorescences (at first flowering) in zinnia 'Dreamland Coral.' Plants were grown under a 16-hour photoperiod and an average daily light integral of 10 mol·m^{-2}·d^{-1}. Photograph was taken six weeks after transplant from a 288-cell plug tray that was grown under long days.

Market Date	Average Temp.	Date Of Transplant Of 288-Cell Plugs For Desired Market Dates	
		Seed Geranium	Zinnia
April 1	63°F	January 18	February 6
	68°F	February 1	February 18
	73°F	February 10	February 25
	79°F	February 18	March 3
May 15	63°F	March 3	March 22
	68°F	March 17	April 3
	73°F	March 26	April 10
	79°F	April 3	April 16

Table 1. Date of transplant of 288-cell plug trays of seed geranium 'Florever Violet' and zinnia 'Dreamland Coral' to achieve first flowering when grown at different temperatures for two market dates. Time to flower is presented in Figures 1 and 2. Plugs were grown at 68°F and under a 16-hour long day. Transplant dates assume a 16-hour long day and an average daily light integral of 10 mol·m^{-2}·d^{-1} during the finish stage.

Materials & Methods

Geranium and zinnia seeds were sown in 288-cell plug trays by C. Raker & Sons, then grown in controlled environmental growth chambers at MSU at 68°F (20°C). Inside the chambers, the photoperiod was 16 hours and the DLI was 9 to 11 mol·m^{-2}·d^{-1}.

When plugs were ready for transplant (29 days after seed sow for geraniums and 16 days after seed sow for zinnias), they were thinned to one seedling per plug and transplanted into 4-inch (10-centimeter) pots and grown in greenhouses with constant temperature set points of 63, 68, 73 and 79°F (17, 20, 23 and 26°C).

At each temperature, plants were grown under a 16-hour photoperiod with two different DLIs provided by sunlight, a combination of shade curtains and different supplemental lighting intensities from high-pressure sodium lamps.

Seed geranium is a day-neutral crop and

thus, day length has no effect on flowering time. Many zinnias are facultative short-day plants. Although they flower under long days, flowering can be accelerated under short days.

Our experiments were performed twice to obtain average DLIs that ranged from 3 to 19.5 $mol \cdot m^{-2} \cdot d^{-1}$. To give perspective, a DLI of 3 $mol \cdot m^{-2} \cdot d^{-1}$ is representative of light conditions received by a Northern greenhouse on a cloudy day in the winter. A DLI of 19.5 $mol \cdot m^{-2} \cdot d^{-1}$ is typical for inside a greenhouse on a mid- to late spring day. The flowering date was recorded for each plant when geraniums had an inflorescence with five open flowers and zinnias had one whorl of petals fully reflexed. When each plant flowered, plant height, number of leaves and number of flowers and flower buds were recorded.

Crop timing data were used to develop mathematical models to predict flowering time and plant quality under different temperature and DLI conditions. The scheduling models were validated by growing a crop of geranium 'Pinto Red' at 71°F to compare predicted flowering times with actual times. Crop models for zinnias were validated by growing plants at three different constant temperatures. The Virtual Grower software (available free at **VirtualGrower.net**) was used to estimate the cost to heat a 21,504-square-foot greenhouse (about half an acre) to produce each crop for different finish dates and at different locations in the United States.

Results

Time to flower for seed geraniums and zinnias decreased as average daily temperature increased. For example, in geraniums grown under a DLI of 10 $mol \cdot m^{-2} \cdot d^{-1}$, time to flower from a 288-cell plug decreased from 73 days at 63°F to 42 days at 79°F (Figure 1). Zinnias grown under the same DLI flowered 3.5 weeks earlier at 79°F versus 63°F (Figure 2). Our crop timing data for zinnias is for plants grown under long days, and flowering could have been accelerated if short days had been provided. Regardless of daylength, we anticipate similar temperature trends on crop development rates.

Time to flower also decreased as the DLI increased until some saturating value. For example, as the DLI increased from 4 to 12 $mol \cdot m^{-2} \cdot d^{-1}$, time to flower for geraniums grown at 68°F decreased by four weeks and zinnias decreased by 12 days. The estimated saturation DLI for the shortest time to flower was 18 $mol \cdot m^{-2} \cdot d^{-1}$ for geraniums and 12.5 $mol \cdot m^{-2} \cdot d^{-1}$ for zinnias (Figure 3).

In other words, increasing the DLI above these values did not shorten crop time. Figure 3 also illustrates that the value of supplemental lighting is greatest when the natural DLI is lowest. Plants grown under a high DLI developed fewer leaves on the primary stem before flowering and thus flowered earlier compared to a lower DLI.

The geranium and zinnia crop models predicted time to flower within five days for at least 94 percent of the validation data. To illustrate the effect of temperature on crop times, we identified dates that 288-cell plugs grown under long days would need to be transplanted for two market dates when grown long days and 10 mol·m^{-2}·d^{-1} of light (Table 1).

In geranium, inflorescence number increased slightly as temperature decreased and as DLI increased. Geraniums grown at 63°F and under 16 mol·m^{-2}·d^{-1} had two more inflorescences than plants grown at 79°F and under 4 mol·m^{-2}·d^{-1}.

In zinnias, the number of flower buds at first flowering was primarily influenced by DLI. For example, plants grown at 73°F and under a DLI of 15 mol·m^{-2}·d^{-1} had almost twice as many inflorescences than plants grown at the same temperature, but under 4 mol·m^{-2}·d^{-1}.

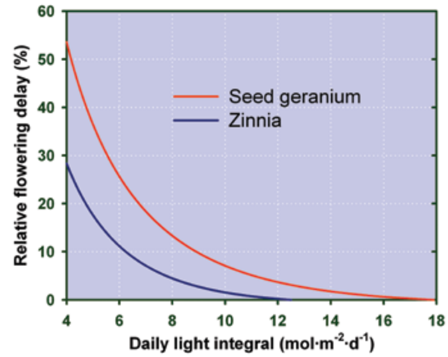

Figure 3. The relative delay in flowering as the daily light integral (DLI) decreases in seed geranium and zinnia grown under a 16-hour photoperiod. The estimated saturation DLI for the shortest time to flower was 18 mol·m^{-2}·d^{-1} for geranium and 12.5 mol·m^{-2}·d^{-1} for zinnia. For example, compared to flowering time under a DLI of 18 mol·m^{-2}·d^{-1}, flowering of geranium would be delayed by 4 percent if grown under a DLI of 12 mol·m^{-2}·d^{-1} and by 26 percent if grown under 6 mol·m^{-2}·d^{-1} of light.

Plant height at flower increased as DLI decreased. For example, geranium and zinnias grown at 73°F and under 4 mol·m^{-2}·d^{-1} were 4 to 7 inches (10 to 18 centimeters) taller than plants grown at the same temperature, but under 18 mol·m^{-2}·d^{-1}. The number of branches in zinnias increased as temperature decreased and as DLI increased.

More Online
For estimated heating costs for 'Florever Violet' and 'Dreamland Coral,' go to **www.GreenhouseGrower.com.**

Heating Costs

We used our crop timing data to determine if it is more energy-efficient to transplant a spring crop earlier and grow cool versus transplanting later and growing warm. We estimated that to produce a geranium crop for April 1 in Grand Rapids, Mich., New York, N.Y., Charlotte, N.C. or Cleveland, Ohio, heating costs per square foot would be 16 to 20 percent lower at 79°F versus 63°F.

In contrast, to produce the same crop in San Francisco, Calif., Tallahasee, Fla. or Fort Worth, Texas, heating costs would be 7 to 26 percent higher at 79°F versus 63°F. To produce zinnia for April 1, transplanting the crop early and growing at 63°F was the most energy-efficient scheduling strategy for only San Francisco, Calif. and Fort Worth, Texas.

At some locations, the most energy-efficient production temperature was different between market dates. For example, zinnia grown for April 1 in Charlotte, N.C. would consume the least heat at 68°F, while the same crop grown for May 15 would save the most heat if grown at 63°F. Heating costs are lower to produce a crop for later spring market dates because outside temperatures are warmer and energy inputs for heating are less. Among these seven cities, we predicted geraniums or zinnias grown at 63 to 79°F would require 18 to 67 percent less energy to produce a crop for May 15 versus April 1. **GG**

About the authors: Matthew Blanchard (**mgblanch msu.edu**) is a Ph.D. candidate and Erik Runkle (**runkleer@msu.edu**) is associate professor and floriculture extension specialist in the Department of Horticulture at Michigan State University.

Correction

In last month's article on petunias, the average days to flower from transplant and flower number at first flower for petunia 'Wave Purple' were listed incorrectly in a graphic. To view the correct graphic, visit **GreenhouseGrower.com**.

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