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Energy-Efficient Annuals: Rudbeckia & Viola

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**

SCHEDULING bedding plants in flower for exact market dates is challenging considering the diversity of crops produced. Rising energy costs and shrinking profit margins have made it important to improve scheduling and efficiency of crop production. 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 eighth article of this series, we present crop timing data on annuals rudbeckia (*Rudbeckia hirta*) and viola (*Viola cornuta*) and then use that information to estimate greenhouse heating costs at different locations, growing temperatures and finish dates.

Materials & Methods

Seeds of rudbeckia 'Becky Cinnamon Bicolor' and viola 'Sorbet Plum Velvet' 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 (31 to 38 days after seed sow), 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 58, 63, 68 and 73°F (14, 17, 20 and 23°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. Rudbeckia is an obligate long-day crop and must be grown under long days for flowering. Violas do not require long days for flowering, but flower faster if grown under long days.

Our experiments were performed once with viola and twice with rudbeckia to obtain average DLIs that ranged from 3.5 to 20 mol·m^{-2}·d^{-1}. To give perspective, a DLI of 3.5 mol·m^{-2}·d^{-1} is representative of light conditions received by a northern greenhouse on a cloudy day in the winter. A

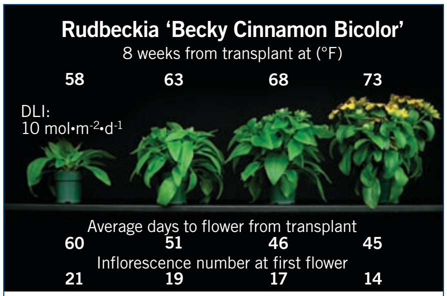

Figure 1. The effects of average daily temperature on time to flower and number of inflorescences (at first flowering) in rudbeckia 'Becky Cinnamon Bicolor.' Plants were grown under a 16-hour photoperiod and an average daily light integral (DLI) of 10 mol·m^{-2}·d^{-1}. Photograph was taken eight weeks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

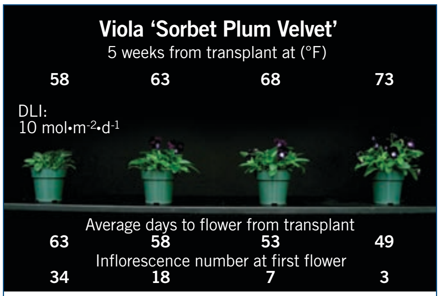

Figure 2. The effects of average daily temperature on time to flower and number of flower buds (at first flowering) in viola 'Sorbet Plum Velvet.' Plants were grown under a 16-hour photoperiod and an average daily light integral (DLI) of 10 mol·m^{-2}·d^{-1}. Photograph was taken five weeks after transplant 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	
		Rudbeckia	Viola
April 1	58°F	January 9	February 26
	63°F	January 27	March 5
	68°F	February 7	March 10
	73°F	February 15	March 13
May 15	58°F	February 22	April 11
	68°F	March 12	April 18
	73°F	March 23	April 23
	79°F	March 31	April 26

Table 1. Date of transplant of 288-cell plug trays of rudbeckia 'Becky Cinnamon Bicolor' and viola 'Sorbet Plum Velvet' 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.

DLI of 20 $mol \cdot m^{-2} \cdot d^{-1}$ is typical for inside a greenhouse on a mid- to late spring day.

The flowering date was recorded for each plant when rudbeckia had one whorl of petals fully reflexed and when viola had one open flower. 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 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 of rudbeckia and viola decreased as average daily temperature increased. In rudbeckia grown under a DLI of 10 $mol \cdot m^{-2} \cdot d^{-1}$, time to flower from a 288-cell plug decreased from 82 days at 58°F to 45 days at 73°F (Figure 1). This data illustrates

Location	Estimated Heating Cost (U.S. Dollars Per Square Foot Per Crop)							
	April 1				May 15			
	58°F	63°F	68°F	73°F	58°F	63°F	68°F	73°F
Rudbeckia								
San Francisco, Calif.	0.20	0.22	0.25	0.28	0.15	0.18	0.20	0.23
Tallahassee, Fla.	0.20	0.21	0.23	0.24	0.08	0.08	0.07	0.11
Grand Rapids, Mich.	0.78	0.69	0.64	0.59	0.42	0.36	0.31	0.32
New York, N.Y.	0.58	0.50	0.48	0.47	0.27	0.23	0.21	0.23
Charlotte, N.C.	0.35	0.34	0.31	0.30	0.14	0.14	0.14	0.17
Cleveland, Ohio	0.69	0.63	0.60	0.56	0.37	0.31	0.31	0.28
Fort Worth, Texas	0.23	0.24	0.23	0.25	0.07	0.06	0.08	0.10
Viola								
San Francisco, Calif.	0.07	0.09	0.11	0.12	0.05	0.07	0.08	0.09
Tallahassee, Fla.	0.05	0.06	0.07	0.08	0.01	0.01	0.01	0.02
Grand Rapids, Mich.	0.24	0.22	0.23	0.23	0.10	0.09	0.09	0.10
New York, N.Y.	0.18	0.17	0.17	0.17	0.04	0.06	0.06	0.06
Charlotte, N.C.	0.09	0.10	0.11	0.11	0.03	0.03	0.03	0.03
Cleveland, Ohio	0.22	0.22	0.20	0.21	0.08	0.09	0.10	0.10
Fort Worth, Texas	0.05	0.06	0.06	0.08	0.01	0.01	0.02	0.03

Table 2. Estimated heating costs to produce flowering rudbeckia 'Becky Cinnamon Bicolor' and viola 'Sorbet Plum Velvet' (from a 288-cell plug; see Table 1) at different temperatures and locations for first flowering on April 1 or May 15. Cities were chosen from each of the seven leading garden plant-producing states. Calculations performed with Virtual Grower 2.5 software with constant temperatures. Greenhouse characteristics include: eight spans each 112 × 24 feet, arched 12-foot roof, 9-foot gutter, polyethylene double-layer roof, polycarbonate bi-wall ends and sides, forced air-unit heaters burning natural gas at $1 per therm ($10.24 MCF), 50 percent heater efficiency, no energy curtain and an hourly air infiltration rate of 1.0.

that flowering of rudbeckia is considerably delayed when grown at cool temperatures.

For example, rudbeckia grown at 58°F would flower almost three weeks later than if the crop was grown at 63°F under the same light conditions. Viola had a comparatively faster crop time: Time to flower from a 288-cell plug decreased from 34 days at 58°F to 19 days at 73°F when the DLI was 10 mol·m^{-2}·d^{-1} (Figure 2).

An increase in DLI also accelerated flowering of rudbeckia and viola. For example, when DLI increased from 4 to 10 mol·m^{-2}·d^{-1}, time to flower decreased by 12 days in rudbeckia and 17 days in viola when grown at 63°F. The estimated saturation DLI for the shortest time to flower was 10.5 mol·m^{-2}·d^{-1} for rudbeckia. In other words, increasing the DLI above this value did not shorten crop time. Viola was only grown under a DLI of 3.5 to 12 mol·m^{-2}·d^{-1} and the saturation DLI is greater than 12 mol·m^{-2}·d^{-1}.

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). The crops grown at the same temperatures but under lower light levels or under a short photoperiod (less than 14 hours) would take longer to flower.

The number of inflorescences or flower buds at first flowering increased as average daily temperature decreased and as DLI increased. For example, at 63°F, as DLI increased from 4 to 12 mol·m^{-2}·d^{-1}, the number of flower buds increased by 66 percent in rudbeckia and by 38 percent in viola. Plants grown at 73°F and under 4 mol·m^{-2}·d^{-1} had the fewest flowers and were the poorest quality. Therefore, there is a tradeoff with quick crop timing and high plant quality, especially when the DLI is low.

Rudbeckia were shortest at flower when grown cool and under high light. In viola, temperature and DLI did not influence plant height.

Heating Costs

The production temperature that had the lowest estimated heating costs to produce a flowering crop of rudbeckia and viola varied among locations and market dates. We estimated that to produce a flowering crop of rudbeckia for April 1, a greenhouse located in Grand Rapids, Mich., New York, N.Y., Charlotte, N.C., or Cleveland, Ohio, would consume 14 to 24 percent less heating per square foot if the crop was transplanted on February 15 and grown at 73°F compared to the same crop transplanted earlier and grown at 58°F (Table 2).

In other words, a shorter crop time at a warm temperature required less energy for heating on a per-crop basis than a longer crop time at a cool temperature. However, for a greenhouse located in San Francisco, Calif., Tallahassee, Fla., or Fort Worth, Texas, heating costs would increase 9 to 40 percent if rudbeckia were grown for April 1 at 73°F, instead of 58°F.

At a temperature of 58 to 73°F and under a DLI of 10 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, viola had a four- to seven-week shorter crop time than rudbeckia. Thus, for all locations and finish dates, a finish crop of viola was predicted to consume 56 to 88 percent less energy for heating than to produce rudbeckia. At some locations, the most energy-efficient production temperature varied between market dates.

For example, rudbeckia grown for April 1 in Grand Rapids, Mich., New York, N.Y., or Charlotte, N.C. is projected to require less heating when grown at 73°F, while a crop grown for May 15 would consume the least amount of energy for heating if grown at 68°F.

We encourage growers to use this crop scheduling information with Virtual Grower to determine the most energy-efficient production temperature for your location and market date. The cost of energy for heating is just one of the many production expenses for greenhouse crops.

Other factors, such as the number of crop turns and overhead costs, should also be considered when choosing the most economical growing temperature for each floriculture crop producer. The impact of temperature and DLI on plant quality, and response variability among cultivars, should also be considered. **GG**

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