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Energy-Efficient Annuals: Pentas & Verbena

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

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

EFFICIENT production of bedding plants requires information on how temperature, photoperiod, and daily light integral (DLI) influence crop timing and flowering characteristics. During the past several years at Michigan State University (MSU), we have performed experiments with seed-propagated annuals to quantify how temperature and DLI influence flowering time and plant quality.

In the 12th and final article of this series, we present crop timing and scheduling information on pentas (*Pentas lanceolata*) and verbena (*Verbena ×hybrida*). Based on that information, we used Virtual Grower to estimate greenhouse heating costs for two market dates at different locations and growing temperatures.

Materials & Methods

Seeds of pentas 'Graffiti Lavender' and verbena 'Obsession Lilac' and 'Quartz Waterfall Mix' were sown in 288-cell plug trays by C. Raker & Sons, then grown in controlled environmental growth chambers at MSU at a constant 68°F (20°C). Inside the chambers, the photoperiod was 16 hours and the DLI was 9 to 11 mol·m^{-2}·d^{-1}. This DLI is typical of that

Market Date	Average Temp.	Date of Transplant of 288-Cell Plugs for Desired Market Dates		
		Pentas 'Graffiti Lavender'	Verbena 'Obsession Lilac'	Verbena 'Quartz Waterfall Mix'
April 1	63 °F	January 9	February 22	January 31
	68 °F	January 30	March 1	February 11
	73 °F	February 12	March 7	February 19
	79 °F	February 21	March 11	February 25
May 15	63 °F	February 22	April 7	March 16
	68 °F	March 15	April 14	March 27
	73 °F	March 28	April 20	April 4
	79 °F	April 6	April 24	April 10

Table 1. Date of transplant of 288-cell plug trays of pentas 'Graffiti Lavender' and verbena 'Obsession Lilac' and 'Quartz Waterfall Mix' to achieve first flowering when grown at different temperatures for two market dates. Time to flower for two of these crops is presented in Figure 1. Plugs were grown at 68 °F for six weeks (pentas) or four weeks (verbena) under a daily light integral (DLI) of about 10 mol·m^{-2}·d^{-1}. Transplant dates assume an average DLI of 10 mol·m^{-2}·d^{-1} during the finish stage.

Location	Estimated Heating Cost (U.S. Dollars Per Square Foot Per Crop)							
	April 1				May 15			
	63°F	68°F	73°F	79°F	63°F	68°F	73°F	79°F
Pentas								
San Francisco, Calif.	0.31	0.29	0.29	0.31	0.24	0.24	0.24	0.25
Tallahassee, Fla.	0.28	0.26	0.26	0.25	0.13	0.10	0.11	0.13
Grand Rapids, Mich.	0.93	0.77	0.63	0.58	0.53	0.41	0.34	0.33
New York, N.Y.	0.72	0.58	0.52	0.47	0.37	0.28	0.25	0.25
Charlotte, N.C.	0.46	0.40	0.33	0.32	0.21	0.18	0.18	0.19
Cleveland, Ohio	0.83	0.68	0.61	0.55	0.48	0.37	0.32	0.31
Fort Worth, Texas	0.32	0.29	0.27	0.26	0.12	0.10	0.11	0.13
Verbena 'Quartz Waterfall Mix'								
San Francisco, Calif.	0.20	0.23	0.26	0.28	0.16	0.18	0.20	0.23
Tallahassee, Fla.	0.19	0.20	0.21	0.22	0.05	0.07	0.09	0.11
Grand Rapids, Mich.	0.65	0.56	0.53	0.51	0.32	0.29	0.28	0.28
New York, N.Y.	0.46	0.44	0.42	0.42	0.20	0.19	0.20	0.21
Charlotte, N.C.	0.31	0.27	0.26	0.29	0.12	0.13	0.14	0.17
Cleveland, Ohio	0.56	0.54	0.49	0.47	0.28	0.27	0.26	0.27
Fort Worth, Texas	0.20	0.21	0.21	0.23	0.06	0.07	0.08	0.11

Table 2. Estimated heating costs to produce flowering pentas 'Graffiti Lavender' and verbena 'Quartz Waterfall Mix' from a 288-cell plug (see Table 1) at different temperatures and locations for first flowering on April 1 or May 15. Calculations performed with Virtual Grower software with constant temperatures. Greenhouse characteristics include: 8 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.

received in greenhouses in early March in the northern United States.

When plugs were ready for transplant (six weeks for pentas; four weeks for verbena), they were transplanted into 4-inch (10-centimeter) pots and grown in greenhouses with constant temperature set points of 58, 63, 68, 73 and 79°F (14, 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. These pentas and verbena varieties do not require long days for flowering, but plants flower faster if long days are provided.

The average DLI during the finish stage ranged from 3 to 20 $mol{\cdot}m^{-2}{\cdot}d^{-1}$. No growth regulators were applied during the plug or finish stage. Plant and flowering characteristics were measured when each plant first flowered. 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 2.51 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 market dates and in seven locations in the U.S.

Results

In pentas and verbena, time to flower decreased as average daily temperature increased from 58 to 79°F. For example, under an average DLI of 10 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, time to flower of pentas from a 288-cell plug decreased from 81 days at 63°F to 38 days at 79°F (Figure 1). At the same DLI, verbena 'Quartz Waterfall Mix' flowered 25 days later at 63°F versus 79°F. Verbena 'Obsession Lilac' grown under 10 $mol{\cdot}m^{-2}{\cdot}d^{-1}$ of light and at 58, 63, 68, 73 or 79°F flowered in 51, 38, 30, 25 and 21 days, respectively.

Therefore, verbena 'Obsession Lilac' flowered 34 to 40 percent faster than 'Quartz Waterfall Mix.' The low temperature at which plant development was predicted to stop (sometimes referred to as the base temperature) was estimated to be 49°F for pentas and 41 to 44°F for the two verbena cultivars studied.

An increase in DLI also accelerated flowering. For example, time to flower at 68°F decreased by 13 days in pentas, 10 days in verbena 'Obsession Lilac' and 24 days in verbena 'Quartz Waterfall Mix' when DLI increased from 4 to 10 $mol \cdot m^{-2} \cdot d^{-1}$. The estimated saturation DLI for the shortest time to flower was 11 $mol \cdot m^{-2} \cdot d^{-1}$ for pentas and 17 $mol \cdot m^{-2} \cdot d^{-1}$ for verbena 'Obsession Lilac.' In other words, increasing the DLI above these values did not shorten crop time. Flowering time continued to decrease as DLI increased for verbena 'Quartz Waterfall Mix' and thus, the saturation DLI is greater than 20 $mol \cdot m^{-2} \cdot d^{-1}$. Using this research data, we identified dates that 288-cell plugs need to be transplanted for two market dates when finished under long days and an average DLI of 10 $mol \cdot m^{-2} \cdot d^{-1}$ (Table 1).

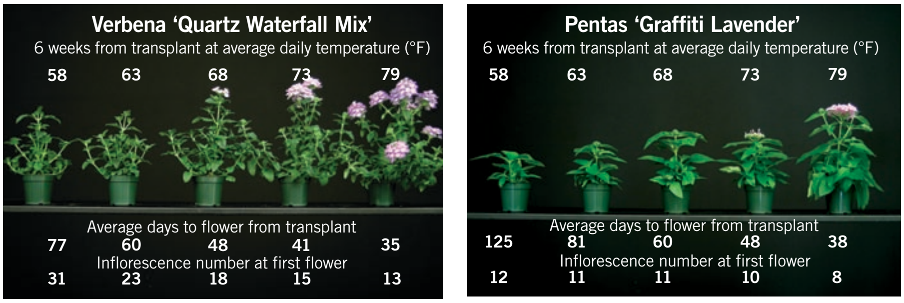

Figure 1. The effects of average daily temperature on time to flower and number of inflorescences (at first flowering) in pentas 'Graffiti Lavender' and verbena 'Quartz Waterfall Mix.' Plants were grown under a 16-hour photoperiod and an average daily light integral (DLI) of 10 $mol \cdot m^{-2} \cdot d^{-1}$. Photographs were taken six weeks after transplant from a 288-cell plug tray that was grown under a DLI of 9 to 11 $mol \cdot m^{-2} \cdot d^{-1}$.

The number of inflorescences at first flowering increased as average daily temperature decreased and as DLI increased (Figure 1). For example, at 68°F, the number of inflorescences increased by 31 percent in pentas and by 69 percent in verbena 'Quartz Waterfall Mix' as DLI increased from 5 to 15 $mol \cdot m^{-2} \cdot d^{-1}$. In both species, plant height at flower increased as DLI decreased.

Heating Costs

Heating costs for a crop of pentas grown for first flowering on April 1 in Tallahassee, Fla., Grand Rapids, Mich., New York, N.Y., Charlotte, N.C., Cleveland, Ohio, or Fort Worth, Texas, were predicted to be 11 to 38 percent lower at a constant 79°F versus 63°F (Table 2). Therefore, at these locations, it is more energy efficient to start spring production later and grow at a warmer temperature. To produce the same crop in San Francisco, Calif., heating costs per square foot would be 11 percent higher at 63 or 79°F versus 68 or 73°F.

We predicted verbena finished for April 1 would require the least amount of energy for heating if grown at 63°F in San

Francisco, Tallahassee and Fort Worth and at 73 or 79°F in Grand Rapids, New York, Charlotte and Cleveland. For a market date of May 15, the most energy-efficient temperature varied among locations and market dates. For example, in New York, pentas would consume the least amount of energy per crop at 73 or 79°F and verbena at 68°F.

The identification of energy-efficient production temperatures for all of the crops reported in this article series can make it possible to group species with similar environmental responses. For example, dahlia, French marigold, osteospermum, petunia Dreams series, snapdragon and viola grown for a market date of May 15 in a greenhouse located in Grand Rapids would consume the least amount of energy per square foot per crop at 58°F to 63°F. For the same location and market date, ageratum, angelonia, browallia, cosmos, seed geranium, pentas, verbena, vinca, wax begonia and zinnia would consume less energy for heating at 73 to 79°F versus cooler temperatures.

We encourage growers to use the crop scheduling data from this series along with Virtual Grower to determine the most energy-efficient production temperature for your location and market date. The cost of energy for heating is 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 as observed here with verbena, should also be considered. **GG**

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