Energy-Efficient Annuals: Petunias

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**

ESCALATING fuel costs have made it important for greenhouse growers to improve production efficiency and schedule crops more efficiently. 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 sixth article of this series, we present crop timing data on petunias and then use this information to estimate greenhouse heating costs at different locations, growing temperatures and finish dates.

Petunias are among the top 10 bedding plants produced in the United States. In 2008, the 15 largest floriculture-producing states collectively sold 34.5 million flats, pots and hanging baskets at a total wholesale value of $120 million. Among the different species and hybrids of petunias available, our studies have included grandiflora petunia 'Dreams Neon Rose,' milliflora petunia 'Fantasy Blue,' and spreading petunias 'Easy Wave Coral Reef' and 'Wave Purple.'

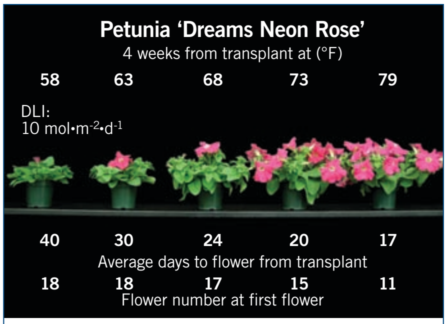

Figure 1. The effects of average daily temperature on time to flower and number of flower buds (at first flowering) in petunia 'Dreams Neon Rose.' Plants were grown under a 16-hour photoperiod and an average daily light integral (DLI) of 10 $mol \cdot m^{-2} \cdot d^{-1}$. Photograph was taken four weeks after transplant from a 288-cell plug tray that was grown under long days.

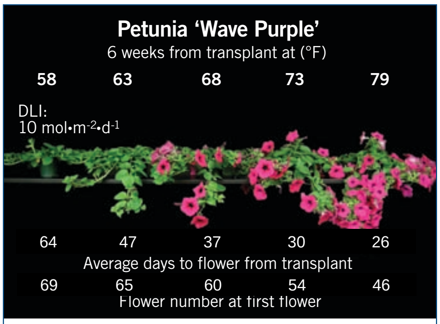

Figure 2. The effects of average daily temperature on time to flower and number of flower buds (at first flowering) in petunia 'Wave Purple.' Plants were grown under a 16-hour photoperiod and an average daily light integral (DLI) of 10 $mol \cdot m^{-2} \cdot d^{-1}$. Photograph was taken six weeks after 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	
		Dreams Neon Rose	Wave Purple
April 1	58°F	February 20	January 26
	63°F	March 2	February 13
	68°F	March 8	February 23
	73°F	March 12	March 1
May 15	58°F	April 5	March 11
	63°F	April 15	March 29
	68°F	April 21	April 8
	73°F	April 25	April 14

Table 1. Date of transplant of 288-cell plug trays of petunia 'Dreams Neon Rose' and 'Wave Purple' 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 $mol \cdot m^{-2} \cdot d^{-1}$ during the finish stage.

Materials and Methods

Seeds of each petunia variety 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 (an inductive long day) and the DLI was 9 to 11 $mol \cdot m^{-2} \cdot d^{-1}$.

When plugs were ready for transplant (27 to 35 days after seed sow), they were thinned to one seedling per plug and transplanted into 4-inch pots and grown in greenhouses with constant temperature set points of 57, 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 a combination of shade curtains and different supplemental lighting intensities from high-pressure sodium lamps.

Some petunia varieties such as 'Dreams Neon Rose' do not require long days for flowering, but flower faster if grown under long days. Other petunia varieties such as 'Wave Purple' are obligate long-day plants and must be grown under long days for flowering. Therefore, when producing petunias under naturally short day lengths (less than 13 to 14 hours), photoperiodic lighting will accelerate flowering and shorten cropping time.

Our experiments were performed twice to obtain average DLIs that ranged from 4 to 20 $mol \cdot m^{-2} \cdot d^{-1}$. To give perspective, a DLI of 4 $mol \cdot m^{-2} \cdot d^{-1}$ is representative of light conditions received by a northern greenhouse on a cloudy day in the winter; a DLI of 20 $mol \cdot m^{-2} \cdot d^{-1}$ is typical for a mid- to late spring day. The flowering date was recorded for each plant when the first flower opened, and at that time, 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 petunias at three different constant temperatures to compare predicted flowering times with actual times. 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

In all petunia varieties, time to flower decreased as average daily temperature increased. For example, in 'Dreams Neon Rose' grown under a DLI of 10 $mol \cdot m^{-2} \cdot d^{-1}$, time to flower from a 288-cell plug decreased from 40 days at 58°F to 20 days at 73°F (Figure 1). At the same DLI, 'Wave Purple' flowered almost five weeks later at 58°F versus 73°F (Figure 2). Petunia 'Fantasy Blue' grown under 10 $mol \cdot m^{-2} \cdot d^{-1}$ and at 58, 63, 68, 73 or 79°F flowered in 27, 22, 19, 17 and

15 days, respectively. Petunia 'Easy Wave Coral Reef' grown under 10 $mol \cdot m^{-2} \cdot d^{-1}$ and at 58, 63, 68 or 73°F flowered in 46, 35, 28, 23 and 19 days, respectively.

An increase in DLI also accelerated flowering of petunia. For example, for plants grown at 63°F, time to flower decreased by four days in 'Dreams Neon Rose,' 13 days in 'Fantasy Blue,' and 11 days in 'Easy Wave Coral Reef' and 'Wave Purple' 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 10.5 $mol \cdot m^{-2} \cdot d^{-1}$ for 'Dreams Neon Rose,' 16 $mol \cdot m^{-2} \cdot d^{-1}$ for 'Easy Wave Coral Reef,' and 14 $mol \cdot m^{-2} \cdot d^{-1}$ for 'Wave Purple.' In other words, increasing the DLI above these values did not shorten crop time. Flowering time continued to decrease as DLI increased for 'Fantasy Blue' 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 grown under long days need to be transplanted for two market dates when grown at different temperatures under long days (Table 1).

The number of flower buds at first flowering increased as average daily temperature decreased and as DLI increased. For example, in petunia 'Wave Purple', the number of flower buds increased by 75 percent as DLI increased from 5 to 15 $mol \cdot m^{-2} \cdot d^{-1}$. In all petunias, plants had the fewest flowers when grown at the warmest temperature (79°F) and under the lowest DLI (4 $mol \cdot m^{-2} \cdot d^{-1}$). Plant height at flower increased as DLI decreased.

As most growers already know, crop timing varies significantly among petunia varieties. In the four petunias we studied, crop timing at 68°F varied from 19 to 37 days even when light conditions were nearly identical during the plug and finish stages. Similarly, increasing the DLI had different promotive effects on the varieties studied. However, all crops flowered faster, and plants were of higher quality, when the DLI was increased to at least 10 $mol \cdot m^{-2} \cdot d^{-1}$.

Heating Costs

This crop timing information can be used with Virtual Grower to identify the most energy-efficient production temperature for different dates and locations. According to our predictions, heating costs for a crop

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
	Petunia 'Dreams Neon Rose'							
San Francisco, Calif.	0.08	0.10	0.12	0.13	0.06	0.08	0.09	0.10
Tallahassee, Fla.	0.07	0.07	0.07	0.09	0.01	0.01	0.02	0.03
Grand Rapids, Mich.	0.31	0.26	0.24	0.24	0.12	0.11	0.11	0.11
New York, N.Y.	0.22	0.19	0.18	0.18	0.06	0.06	0.07	0.07
Charlotte, N.C.	0.10	0.11	0.12	0.12	0.03	0.04	0.04	0.05
Cleveland, Ohio	0.27	0.23	0.22	0.22	0.11	0.10	0.11	0.11
Fort Worth, Texas	0.07	0.07	0.07	0.08	0.01	0.01	0.02	0.04
	Petunia 'Wave Purple'							
San Francisco, Calif.	0.14	0.16	0.18	0.20	0.11	0.12	0.14	0.16
Tallahassee, Fla.	0.15	0.13	0.13	0.14	0.05	0.04	0.04	0.05
Grand Rapids, Mich.	0.58	0.45	0.40	0.37	0.28	0.21	0.20	0.19
New York, N.Y.	0.40	0.35	0.31	0.30	0.17	0.13	0.13	0.14
Charlotte, N.C.	0.26	0.19	0.19	0.20	0.09	0.08	0.09	0.10
Cleveland, Ohio	0.54	0.43	0.37	0.34	0.23	0.19	0.18	0.18
Fort Worth, Texas	0.17	0.14	0.14	0.15	0.03	0.03	0.04	0.05

Table 2. Estimated heating costs to produce flowering petunia 'Dreams Neon Rose' and 'Wave Purple' (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 2.01 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.

of petunia 'Dreams Neon Rose' grown for April 1 in San Francisco, Calif., Tallahasee, Fla., Charlotte, N.C., or Fort Worth, Texas, would be 13 to 38 percent lower at a constant 58°F versus 73°F (Table 2). To produce the same crop in northern locations such as Grand Rapids, Mich., New York, N.Y., or Cleveland, Ohio, heating costs per square foot would be 22 to 29 percent higher at 58°F versus 73°F. In other words, it is more energy-efficient for growers in the north to start spring production later and grow at a warmer temperature.

Petunia 'Wave Purple' grown under 10 $mol \cdot m^{-2} \cdot d^{-1}$ for April 1 in Grand Rapids, Mich., New York, N.Y., or Cleveland, Ohio would cost 9 to 21 cents less per square foot if grown at 68 or 73°F versus 58°F. Therefore, a grower with a half-acre greenhouse would save $1,960 to $4,574 on heating costs per crop by transplanting later and growing warm. In addition, 'Wave Purple' grown at 68 or 73°F would flower four to five weeks earlier than at 58°F, which would make production space available for additional crops.

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. **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.

A Special Thank You

The authors thank research technician Mike Olrich for his greenhouse assistance; Project GREEEN, the American Floral Endowment, the Fred C. Gloeckner Foundation, the USDA-ARS Floriculture and Nursery Research Initiative, and private floriculture companies for their financial support. They also thank Paul Fisher at the University of Florida for his assistance with the development of the crop models.

American Floral Endowment
Floriculture & Nursery Research Initiative
The Fred C. Gloeckner Foundation, Inc.
USDA ARS
Project GREEEN