Energy-Efficient Annuals: Angelonia & Browallia

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 annual bedding plants in flower for specific market dates is of increasing importance to greenhouse growers. Plants not in flower when planned or in flower too early can create greenhouse space challenges, delay shipping and reduce plant quality.

During the past several years at Michigan State University (MSU), we have performed experiments with seed propagated annuals to quantify how temperature and daily light integral (DLI) influence flowering time and plant quality. In the 11th article of this series, we present crop timing and scheduling information on angelonia (*Angelonia angustifolia*) and browallia (*Browallia speciosa*), and then use that information with Virtual Grower to estimate greenhouse heating costs at different locations, growing temperatures and finish dates.

Materials & Methods

Seeds of angelonia 'Serena Purple' and browallia 'Bells Marine' were sown in 288-cell plug trays by C. Raker & Sons, then grown in controlled environmental growth chambers at MSU at a

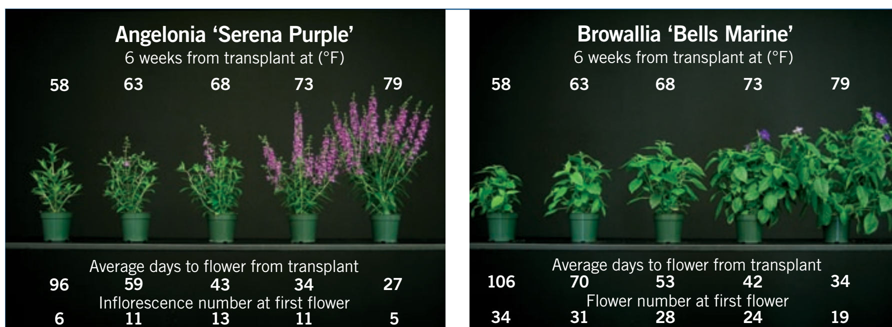

Figure 1. The effects of average daily temperature on time to flower and number of flowers or inflorescences (at first flowering) in angelonia 'Serena Purple' and browallia 'Bells Marine.' Plants were grown under a 16-hour photoperiod and an average daily light integral (DLI) of 10 mol·m^{-2}·d^{-1}. Photographs were taken six weeks after transplant from a 288-cell plug tray that was grown under a DLI of 9 to 11 mol·m^{-2}·d^{-1}.

Market Date	Average Temp.	Date Of Transplant Of 288-Cell Plugs For Desired Market Dates	
		Angelonia	Browallia
April 1	63°F	February 1	January 21
	68°F	February 17	February 7
	73°F	February 26	February 18
	79°F	March 5	February 26
May 15	63°F	March 17	March 6
	68°F	April 2	March 23
	73°F	April 11	April 3
	79°F	April 18	April 11

Table 1. Date of transplant of 288-cell plug trays of angelonia 'Serena Purple' and browallia 'Bells Marine' to achieve first flowering when grown at different temperatures for two market dates. Time to flower is presented in Figure 1. Plugs were grown at 68°F for 40 days 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.

constant 68°F (20°C). Inside the chambers, the photoperiod was 16 hours and the DLI was 9 to 11 $mol \cdot m^{-2} \cdot d^{-1}$. This DLI is typical of that received in greenhouses in early spring in the Northern United States.

When plugs were ready for transplant (40 days after seed sow), 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. Angelonia and browallia are day-neutral crops and thus, day length has no effect on flowering time.

The average DLI during the finish stage ranged from 4 to 16 $mol \cdot m^{-2} \cdot d^{-1}$. 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 finish dates and in seven locations in the U.S.

Results

In both angelonia and browallia, time to flower decreased as average daily temperature increased from 58 to 79°F. Under a DLI of 10 $mol \cdot m^{-2} \cdot d^{-1}$ and at 79°F, plants flowered 32 to 36 days earlier than plants grown under the same DLI, but at 63°F (Figure 1). The low temperature at which plant development was predicted to stop (sometimes referred to as the base temperature) was estimated to be 48 to 50°F for both crops. Not surprisingly, these high base temperatures indicate angelonia and browallia are cold-sensitive plants.

As average temperature decreases toward the base temperature, production time is increasingly delayed. For example, plants flowered an average of five weeks later at 58°F versus 63°F. A temperature below 60°F can cause chilling damage on these crops and thus, should generally be avoided. To illustrate the effect of temperature on angelonia and browallia crop times, we identified dates 288-cell plugs would need to be transplanted for two market dates when finished under an average DLI of 10 $mol \cdot m^{-2} \cdot d^{-1}$ (Table 1).

When the DLI was low, an increase in DLI accelerated flowering. For example, an increase in DLI from 4 to 8 $mol \cdot m^{-2} \cdot d^{-1}$ decreased time to flower by five days in angelonia and 18 days in browallia when grown at 68°F. The estimated saturation DLI (the minimum DLI for rapid flowering) was 8 $mol \cdot m^{-2} \cdot d^{-1}$ for angelonia and 16 $mol \cdot m^{-2} \cdot d^{-1}$ for browallia. In other words, an increase in the DLI above these values did not shorten crop time.

In angelonia, inflorescence number at first flowering increased as average daily temperature increased from 58 to 68°F, and as DLI increased (Figure 1). In browallia, flower number increased as average temperature decreased and as DLI increased from 4 to 10 $mol \cdot m^{-2} \cdot d^{-1}$. For example, at 68°F, increasing the DLI from 4 to 10 $mol \cdot m^{-2} \cdot d^{-1}$ increased the number of flower buds by 35 percent in angelonia and by 55 percent in browallia. Branch number also increased as DLI increased.

Heating Costs

The production temperature that had the lowest estimated heating costs to produce a flowering crop varied among locations and market dates. To produce a flowering crop of angelonia and browallia for April 1, a greenhouse located in Grand Rapids, Mich., New York, N.Y., Charlotte, N.C., Cleveland, Ohio, Tallahassee, Fla., or Fort Worth, Texas is estimated to consume 9 to 41 percent less heating per square foot if the crop was transplanted later and grown at 73 or 79°F compared to the same crop transplanted earlier and grown at 63°F (Table 2).

In other words, a warm temperature and short crop time consumed less energy for heating per crop compared to a cool temperature and longer crop time. In contrast, heating costs for a greenhouse located in San Francisco, Calif. would be 10 to 12 percent greater if these crops were grown for April 1 at 79°F instead of 63 or 68°F.

For a market date of May 15, the most energy-efficient temperature varied by location and crop. For example, a greenhouse in Grand Rapids, New York and Cleveland would consume the least energy per crop at 73 or 79°F. In San Francisco and Fort Worth, heating costs would be similar at 63 to 73°F. Therefore at these two locations, other factors could be considered when selecting a growing temperature.

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

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
Angelonia								
San Francisco, Calif.	0.20	0.20	0.21	0.22	0.16	0.16	0.17	0.18
Tallahassee, Fla.	0.19	0.17	0.16	0.16	0.05	0.06	0.06	0.07
Grand Rapids, Mich.	0.64	0.48	0.41	0.38	0.31	0.24	0.22	0.20
New York, N.Y.	0.45	0.37	0.34	0.31	0.19	0.16	0.15	0.16
Charlotte, N.C.	0.30	0.21	0.22	0.22	0.11	0.11	0.12	0.11
Cleveland, Ohio	0.55	0.45	0.38	0.37	0.27	0.21	0.20	0.20
Fort Worth, Texas	0.20	0.17	0.16	0.17	0.05	0.05	0.06	0.08
Browallia								
San Francisco, Calif.	0.25	0.25	0.26	0.28	0.20	0.20	0.21	0.22
Tallahassee, Fla.	0.23	0.23	0.21	0.21	0.09	0.07	0.09	0.10
Grand Rapids, Mich.	0.77	0.64	0.55	0.49	0.40	0.31	0.29	0.27
New York, N.Y.	0.58	0.48	0.43	0.48	0.27	0.21	0.20	0.21
Charlotte, N.C.	0.39	0.31	0.27	0.28	0.17	0.14	0.15	0.16
Cleveland, Ohio	0.70	0.60	0.50	0.46	0.37	0.31	0.27	0.26
Fort Worth, Texas	0.26	0.23	0.22	0.22	0.08	0.08	0.09	0.11

Table 2. Estimated heating costs to produce flowering angelonia 'Serena Purple' and browallia 'Bells Marine' from a 288-cell plug tray (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: 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.

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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