



# Energy-Efficient Annuals: Ageratum & Cosmos

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

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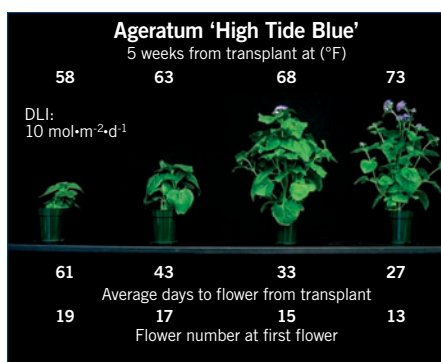
**S**CHEDULING annual bedding plants in flower for specific market dates is of increasing importance to many greenhouse growers.

During the past several years 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 fifth article of this series, we present information on ageratum and cosmos and then use crop timing data to estimate greenhouse heating costs at different locations, growing temperatures and finish dates.

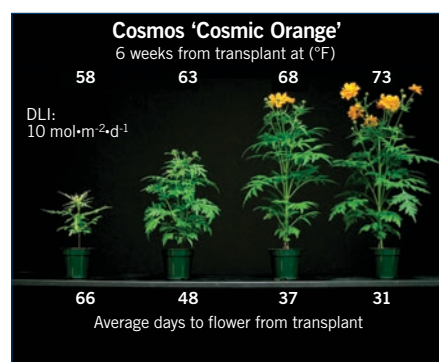
## Materials and Methods

Seeds of ageratum (*Ageratum houstonianum* 'High Tide Blue') and cosmos (*Cosmos sulphureus* 'Cosmic Orange') were sown in 288-cell plug trays by C. Raker & Sons, and 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<sup>-2</sup>·d<sup>-1</sup>.

When plugs were ready for transplant (27 days after seed sow for ageratum and 16 days for cosmos), they were transplanted into 4-inch pots and grown in greenhouses with constant temperature set points of 57, 63, 68 and 73°F (14, 17, 20 and 23°C). At each temperature, plants were grown under



**Figure 1.** The effects of average daily temperature on time to flower and number of flower buds (at first flowering) in ageratum. Plants were grown under a 16-hour photoperiod and an average daily light integral of 10 mol·m<sup>-2</sup>·d<sup>-1</sup>. The photograph was taken five weeks after transplant from a 288-cell plug tray.



**Figure 2.** The effects of average daily temperature on time to flower and number of flower buds (at first flowering) in cosmos. Plants were grown under a 16-hour photoperiod and an average daily light integral of 10 mol·m<sup>-2</sup>·d<sup>-1</sup>. The photograph was taken six weeks after transplant from a 288-cell plug tray.

Market Date	Average Temp.	Date Of Transplant Of 288-Cell Plugs For Desired Market Dates	
		Ageratum	Cosmos
April 1	58°F	January 30	January 25
	63°F	February 17	February 12
	68°F	February 27	February 23
	73°F	March 5	March 1
May 15	58°F	March 15	March 10
	63°F	April 2	March 28
	68°F	April 12	April 8
	73°F	April 18	April 14

**Table 1.** Date of transplant of 288-cell plug trays of ageratum 'High Tide Blue' and cosmos 'Cosmic Orange' 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<sup>-2</sup>·d<sup>-1</sup> during the finish stage.

a 16-hour photoperiod with two different DLIs provided by a combination of shade curtains and different light intensities from high-pressure sodium lamps.

Ageratum does not require long days

for flowering, but plants flower faster if long days are provided. Cosmos 'Cosmic Orange' is a day-neutral plant and flowers in the same time if provided with short or long daylengths. However, some

cosmos varieties flower faster when grown under short days.

The experiment was performed twice to obtain average DLIs that ranged from 3 to 19 mol·m<sup>-2</sup>·d<sup>-1</sup>. To give perspective, a DLI of 3 mol·m<sup>-2</sup>·d<sup>-1</sup> is received in a northern greenhouse on a cloudy day in the winter. A DLI of 19 mol·m<sup>-2</sup>·d<sup>-1</sup> is typical for a mid- to late spring day. The flowering date was recorded for each plant when ageratum had two open flowers and petals of cosmos were fully reflexed. When each plant flowered, plant height, number of leaves and branches and number of flowers and flower buds were recorded.

Crop timing data was 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 ageratum and cosmos at three different constant temperatures to compare predicted flowering times with actual times. The Virtual Grower software (available free at [www.virtualgrower.net](http://www.virtualgrower.net)) was used to es-

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
<b>Ageratum</b>								
San Francisco, Calif.	0.13	0.15	0.16	0.17	0.10	0.11	0.12	0.14
Tallahassee, Fla.	0.13	0.12	0.11	0.12	0.03	0.03	0.03	0.04
Grand Rapids, Mich.	0.55	0.41	0.34	0.32	0.25	0.19	0.17	0.16
New York, N.Y.	0.38	0.30	0.27	0.25	0.14	0.11	0.11	0.11
Charlotte, N.C.	0.23	0.16	0.17	0.17	0.08	0.07	0.08	0.08
Cleveland, Ohio	0.47	0.38	0.31	0.31	0.22	0.16	0.15	0.16
Fort Worth, Texas	0.14	0.12	0.11	0.12	0.03	0.03	0.03	0.04
<b>Cosmos</b>								
San Francisco, Calif.	0.14	0.16	0.18	0.20	0.11	0.12	0.14	0.16
Tallahassee, Fla.	0.15	0.14	0.13	0.14	0.05	0.04	0.04	0.05
Grand Rapids, Mich.	0.60	0.46	0.40	0.37	0.29	0.22	0.20	0.19
New York, N.Y.	0.41	0.36	0.31	0.30	0.17	0.13	0.13	0.14
Charlotte, N.C.	0.27	0.20	0.19	0.20	0.10	0.08	0.09	0.10
Cleveland, Ohio	0.54	0.44	0.37	0.34	0.24	0.20	0.18	0.18
Fort Worth, Texas	0.17	0.14	0.14	0.15	0.03	0.04	0.04	0.05

**Table 2.** Estimated heating costs to produce flowering ageratum ‘High Tide Blue’ and cosmos ‘Cosmic Orange’ (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 were 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.

timate 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 both *ageratum* and *cosmos*, time to flower decreased as average daily temperature increased and DLI increased. For example, time to flower in *ageratum* 'High Tide Blue' grown under a DLI of  $10 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$  decreased from 61 days at  $58^\circ\text{F}$  to 27 days at  $73^\circ\text{F}$  (Figure 1). We were a bit surprised by the substantial flowering delay when *ageratum* was grown cool because many consider it a cool-growing (cold-tolerant) crop. Flowering time of *cosmos* 'Cosmic Orange' was similar: It decreased from 66 to 31 days as temperature increased from  $58$  to  $73^\circ\text{F}$  (Figure 2).

In both crops, higher light levels accelerated flowering more when plants were grown cool than at warmer temperatures. For example, as DLI increased from 3 to  $8 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ , time to flower in *ageratum* grown at  $58^\circ\text{F}$  and  $73^\circ\text{F}$  decreased by 15 days and seven days, respectively. There was no acceleration in flowering when the DLI exceeded  $10 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$  for *ageratum* and  $7 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$  for *cosmos*.

Using this crop timing data, we identified dates that 288-cell plugs need to be transplanted for two different market dates when grown at different temperatures (Table 1).

Temperature and DLI had different effects on the number of flower buds at first flowering in *cosmos* and *ageratum*. In *ageratum*, flower bud number was primarily influenced by temperature, whereas in *cosmos*, flower bud number was primarily influenced by DLI. For example, *ageratum* had six more flower buds when grown at  $58^\circ\text{F}$  versus  $73^\circ\text{F}$  (Figure 1). In *cosmos*, plants grown at  $63^\circ\text{F}$  and under a DLI of  $15 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$  had 15 more flower buds than plants grown at the same temperature, but under  $5 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ .

In both crops, as the DLI increased from 3 to  $19 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ , the number of lateral branches at flower increased by two to four. Therefore, although plants did not flower faster as DLI increased above  $10 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ , plant quality improved because plants had more flow-



ers. Plant height at flower increased as constant temperatures increased from 58 to 73°F. Under a DLI of 10 mol·m<sup>-2</sup>·d<sup>-1</sup>, ageratum and cosmos were 2.6 inches and 5 inches taller, respectively, at a constant temperature of 73°F versus 58°F.

### Heating Costs

We can use this crop timing informa-

tion with Virtual Grower to determine if it is more energy efficient to transplant a crop earlier and grow cool versus transplanting later and growing warm. For example, to produce an ageratum or cosmos crop for April 1 in Grand Rapids, Mich., New York, N.Y., or Cleveland, Ohio, heating costs per square foot would be 27 to 42 percent lower at 73°F versus 58°F (Table 2).

In contrast, to produce these crops for the same market date in Charlotte, N.C., and Fort Worth, Texas, a production temperature of 63 or 68°F would consume the least energy for heating. San Francisco was the only location tested that had lower predicted fuel consumption when crops were transplanted early and grown at 58°F for a market date of April 1.

At some locations, the production temperature that had the lowest heating costs per square foot per crop varied between market dates. For example, ageratum grown for April 1 in New York had the lowest predicted heating costs when grown at 73°F. In contrast, for a market date of May 15, estimated fuel costs were lowest if grown at 63, 68, or 73°F. In this example, because there is no difference in heating costs to produce ageratum for May 15 in New York at 63 to 73°F, other factors such as plant quality, availability of labor, overhead costs and opportunity costs could be considered when selecting a growing temperature. **GG**

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