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MANIPULATING DAY AND NIGHT TEMPERATURES TO CONTROL FLOWERING AND REDUCE HEATING COSTS OF BEDDING PLANTS

By Matthew Blanchard and Erik Runkle

BACKGROUND

In many crops, stem elongation is influenced by the difference between the day and night temperature (DIF). Stem elongation is promoted when the day temperature is higher than the night temperature (+DIF) and suppressed when the day temperature is lower than the night temperature (–DIF). The effect of DIF on plant height has been studied in many common greenhouse crops, such as Easter lily, pansy, and poinsettia. For example, plant height of Easter lily increased by 129 percent as DIF increased from –29 to +29°F. During the production of floriculture crops, a –DIF is sometimes used by greenhouse growers to control height.

In northern climates, high energy inputs can be required to maintain a desirable greenhouse temperature, making fuel for heating one of the larger floriculture production expenses. Greenhouse growers can reduce energy consumption by managing the greenhouse environment with dynamic temperature control (DTC) strategies. In DTC, heating set points are lowered during periods when the greenhouse energy-loss factor is high (for example, on a cold and cloudy day) and increased when the energy-loss factor is low (on a warm or sunny day). This environmental control strategy integrates temperature and maintains a target average daily temperature (ADT) over a one- to seven-day interval.

To achieve the greatest potential energy savings with temperature integration, a greenhouse environmental control computer with software is required. However, in the United States, not all greenhouses use environmental control computers, and of those that do, relatively few use DTC strategies. An alternative and simple energy-saving approach is to use a +DIF with constant day and night heating and ventilation set points. With a +DIF, the heating set point is lowered during the night, when energy consumption for heating is highest. A low night temperature is compensated for by increasing the day temperature so that the target ADT is achieved.

A DTC or DIF strategy to reduce energy consumption assumes that plant developmental rate is controlled by the integrated ADT, and crop time is similar at different day and night temperatures (within limits) that deliver the same ADT. However, studies with some crops have reported different flowering times at DIF and constant temperatures regimens with the same ADT. Therefore, the benefits of using DIF to reduce energy inputs or to suppress stem elongation may not be practical for all bedding plant species if crop time is delayed. The objectives of this research were to (1) quantify the effects of constant and fluctuating day/night temperatures on growth and flowering during the finish stage of three bedding plant species and (2) predict greenhouse heating costs for different crop finish dates, at different locations in the United States, with different DIF regimens.

MATERIALS & METHODS

In 2008 and 2009, seeds of dahlia 'Figaro Mix' (Dahlia ×hybrida), French marigold 'Janie Flame' (Tagetes patula), and zinnia 'Magellan Pink' (Zinnia elegans) were sown in 288-cell plug trays by C. Raker & Sons, then were grown in controlled environmental growth chambers at Michigan State University at a constant 68°F. Inside the chambers, the photoperiod was 16 hours and the photosynthetic daily light integral (DLI) was 9 to 11 mol·m–2·d–1.

Plugs were transplanted (2 to 4 weeks after seed sow) into 4-inch (10-cm) pots and 15 plants of each species were randomly assigned to each of 6 glass-glazed greenhouse sections with constant day/night temperature set points of 64/64 or 72/72°F or fluctuating day/night (16 hour/8 hour) temperature set points of 68/57, 61/72, 75/64, or 68/79°F. The temperature set points were chosen so that 3 treatments each had an ADT of 64 or 72°F. The experiment was performed twice, with transplant dates beginning in October (Year 1) and March (Year 2).

The photoperiod was maintained at 16 hours and consisted of natural photoperiods (43 °N lat.) with day-extension lighting from 6 a.m. to 10 p.m., provided by high-pressure sodium lamps. The day and night temperature set points started at the beginning and end of the day, respectively. The actual temperature during the experiment was within 2.3°F of the greenhouse temperature set points for all treatments in both years and the actual ADT was 64.0°F or 72.0°F. The average DLI from transplant to flowering ranged from 10.6 to 12.3 mol·m–2·d–1 in Year 1 and 15.7 to 19.1 mol·m–2·d–1 in Year 2.

The date of first open inflorescence (flowering) was recorded and time to flower was calculated for each plant. When each plant flowered, plant height and the number of inflorescences were recorded.

The cost to heat a 21,504 square foot greenhouse (about half an acre) to produce a flowering crop grown at day/night (16 hour/8 hour) temperature set points of 64/64, 68/57, 61/72, 72/72, 75/64, or 68/79°F for finish dates of 15 March, 15 April, or 15 May was estimated for Charlotte, NC; Grand Rapids, MI; and Minneapolis, MN by using the Virtual Grower 2.51 software (www.virtualgrower.net). Production time for each species was calculated from the greenhouse experiments by using the average time to flower at an ADT of 64 or 72°F. Flowering time for zinnia was calculated according to data from Year 2 only. The greenhouse characteristics used to estimate heating costs included 8 spans each 112 × 24 ft, arched 12-ft roof, 9-ft gutter, polyethylene double layer roof, polycarbonate biwall ends and sides, forced air unit heaters burning natural gas, 50 percent heater efficiency, no energy curtain, an air infiltration rate of 1 per hour, and day temperature set points from 6 a.m. to 10 p.m. These values and characteristics are typical of commercial greenhouses used to produce floriculture crops in the northern half of the United States.

RESULTS & DISCUSSION

FLOWERING TIME

Dahlia and French marigold plants grown at different day/night temperatures but with a similar ADT flowered at the same time (Figures 1A and 1B). For example, French marigold flowered 26 days after transplant when grown at 64/64, 68/57, or 61/72°F and 21 days when grown at 72/72, 75/64, or 68/79°F. Zinnia plants grown at a similar ADT flowered at the same time in Year 2, but not Year 1 (Figure 2, page 26). In Year 1, zinnia grown at 68/57°F flowered 3 to 7 days earlier than plants grown at 64/64 or 61/72°F. The similar flowering time among temperature treatments with the same ADT reinforces the paradigm that flowering rate is a function of the ADT and, within limits, the effects of day and night temperature on progress toward flowering are equal. Other similar studies with bedding impatiens, fuchsia, geranium, pansy, pinnate dahlia, pocketbook plant, potted rose, tuberous begonia, and vinca also reported that flowering time was controlled by ADT and not DIF.

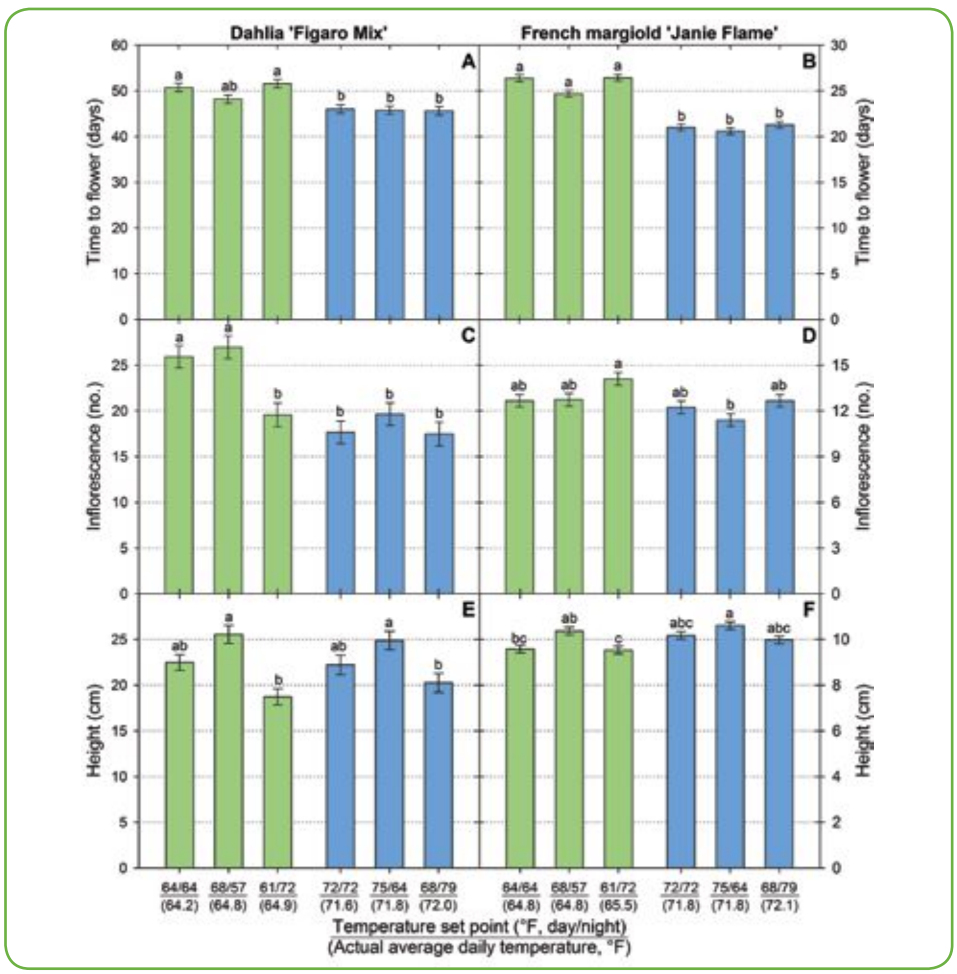

Figure 1. The influence of temperature on time to flower, inflorescence number, and height at flowering, in dahlia 'Figaro Mix' and French marigold 'Janie Flame' at constant and fluctuating day/night (16 hour/8 hour) temperature set points. Vertical bars indicate standard errors of treatment averages. Treatments followed by the same letter are not significantly different (P ≤0.01). For both species, data were pooled between replications.

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In zinnia during Year 1, flowering time was different among treatments with an ADT of 64°F. The actual ADT among these treatments varied by only 0.1 to 0.4°F and plants received essentially the same DLI. Therefore, it is not clear why plants grown at 68/57°F flowered later than those grown at a constant 64°F or 61/72°F. The flowering delay could be at least partially attributed to a Bonzi® (paclobutrazol) application during the plug stage in Year 1 only, which has been shown to delay flowering in some crops.

PLANT HEIGHT

Plant height at flower in all species generally increased as DIF increased from –11°F to +11°F. Dahlia grown at a +11°F DIF (68/57 or 75/64°F) was 4.6 to 5.3 cm taller at flowering than plants grown at a –11°F DIF (61/72 or 68/79°F; Figure 1, page 25). Similarly, French marigold plants were 11 percent taller when grown at 68/57°F or 75/64°F versus 61/72°F. In Year 1, zinnia grown at 75/64°F were 17 percent to 58 percent taller at flowering than plants in all other treatments, whereas in Year 2, plants grown at 68/57°F were 13 percent to 32 percent taller than plants in all other treatments. For all species, there were no differences in height between plants grown at a 0°F DIF. Similar effects of DIF on plant height have been reported in many other bedding plants including geranium, pinnate dahlia, impatiens, pansy, petunia, red salvia, snapdragon, and zinnia.

HEATING COSTS

In all species and locations, heating cost predictions to produce a flowering crop for 15 April or 15 May were up to 41 percent lower when grown at a +11°F DIF compared with a constant temperature (Table 1, Figure 2). As finish date progressed from 15 March to 15 May, the relative difference in heating costs between a +11°F DIF and 0°F DIF increased. Heating costs per crop for all locations and finish dates were estimated to be greatest when grown at 61/72, 68/79, or 72/72°F. For example, dahlia grown in Minneapolis, MN, would consume 2 percent to 29 percent more energy if grown at 61/72°F versus 64/64 or 68/57°F. In nearly all instances, the least amount of energy consumed per crop of dahlia or French marigold occurred at 68/57°F. In contrast, the lowest energy input for a crop of zinnia was 75/64°F for a 15 March finish date and +11°F DIF for the later two finish dates. The estimated energy consumption for heating was greatest for dahlia grown at 68/79°F or constant 72°F, regardless of location or finish date. For French marigold and zinnia, greenhouse heating was greatest for a crop grown at a –11°F DIF. As finish date increased from 15 March to 15 May, heating costs at each temperature regimen decreased by 52 percent to 84 percent. For example, zinnia grown for 15 May at 68/57°F would require 77 percent less energy for heating than the same crop grown for 15 March.

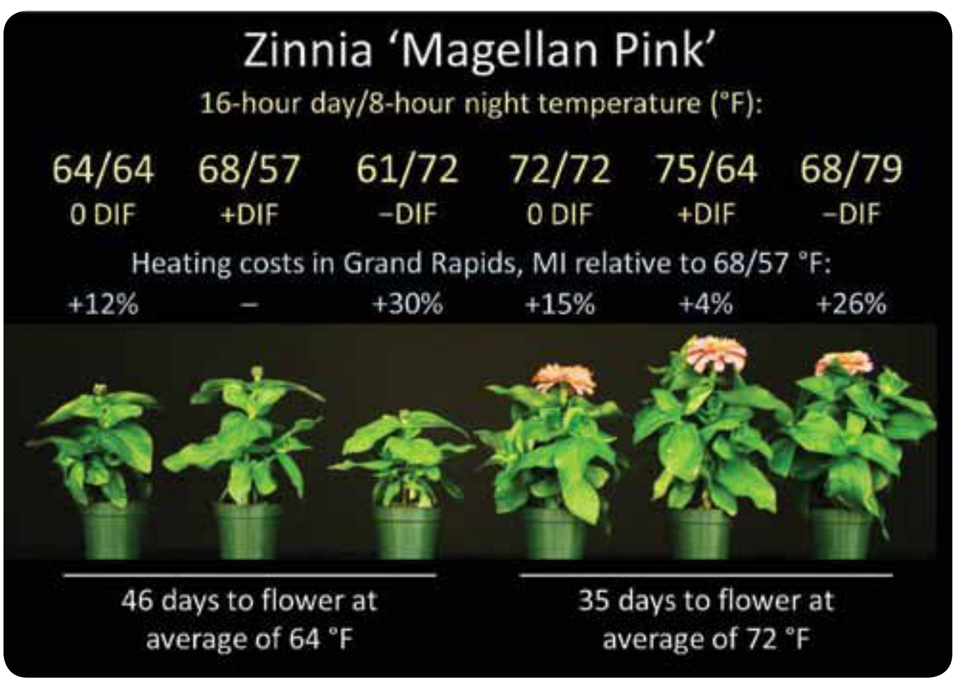

Figure 2 ◄. The influence of temperature on time to flower, plant height, and predicted energy used to heat a greenhouse in Grand Rapids, MI for production of zinnia 'Magellan Pink' grown at constant and fluctuating day/night (16 hour/8 hour) temperature set points and under long days. Heating costs were estimated using Virtual Grower using typical greenhouse characteristics and are relative to the lowest energy-consuming temperature of 68/57°F (day/night) for a finish date of May 15.

Average temperature (°F)	Day/night temperature set point (°F)	Charlotte, NC finish date			Grand Rapids, MI finish date			Minneapolis, MN finish date		
		15 Mar.	15 Apr.	15 May	15 Mar.	15 Apr.	15 May	15 Mar.	15 Apr.	15 May
Dahlia 'Figaro Mix'										
64	64/64	0.83	0.45	0.22	0.91	0.62	0.35	0.96	0.55	0.26
	68/57	0.79	0.39	0.17	0.91	0.60	0.32	0.96	0.53	0.24
	61/72	0.90	0.55	0.34	0.93	0.65	0.41	0.98	0.59	0.31
72	72/72	0.96	0.62	0.38	1.00	0.70	0.44	1.00	0.61	0.35
	75/64	0.91	0.55	0.29	0.98	0.67	0.40	0.98	0.58	0.31
	68/79	1.00	0.67	0.45	1.00	0.71	0.48	1.00	0.63	0.37
French Marigold 'Janie Flame'										
64	64/64	0.76	0.43	0.18	0.97	0.60	0.32	0.96	0.44	0.26
	68/57	068	0.35	0.11	0.95	0.57	0.27	0.95	0.42	0.21
	61/72	0.88	0.58	0.35	1.00	0.65	0.39	1.00	0.50	0.32
72	72/72	0.94	0.60	0.30	0.95	0.63	0.36	0.99	0.48	0.27
	75/64	0.86	0.49	0.18	0.92	0.59	0.30	0.97	0.44	0.23
	68/79	1.00	0.67	0.40	0.96	0.65	0.40	1.00	0.50	0.31
Zinnia 'Magellan Pink'										
64	64/64	0.91	0.51	0.27	0.97	0.64	0.38	0.97	0.55	0.27
	68/57	0.86	0.44	0.20	0.97	0.62	0.33	0.97	0.53	0.24
	61/72	1.00	0.63	0.40	1.00	0.68	0.43	1.00	0.59	0.33
72	72/72	0.89	0.61	0.35	0.93	0.64	0.39	0.87	0.49	0.30
	75/64	0.83	0.53	0.26	0.91	0.62	0.35	0.85	0.46	0.26
	68/79	093	0.66	0.43	0.94	0.66	0.42	0.87	0.51	0.33

Table 1 ▲. Predicted relative amount of energy used for greenhouse heating to produce 3 crops grown at different day and night temperature set points in different locations and finish dates. Values were calculated by dividing heating input by the highest input for each location and species and thus are unitless. Heating inputs were estimated using Virtual Grower software and include time from transplant to first flowering on 15 March, 15 April, or 15 May. Production time for each species was calculated from greenhouse experiments using the average time to flower at 64/64, 68/57, and 61/72°F or 72/72, 75/64, and 68/79°F.

CONCLUSIONS

These results collectively indicate that for many locations, a +DIF temperature regimen is an energy-efficient production strategy, and the energy savings with +DIF increases with later spring production dates. Because bedding plants grown at some +DIF treatments were taller than those grown at a constant or –DIF temperature regimen, the advantages and disadvantages of DIF should be considered. If a +DIF temperature regimen is used to save energy, growers may need to adjust their height control strategy, such as increase the application concentration of plant growth retardants. Growers are encouraged to perform their own predictions using Virtual Grower to better estimate heating cost implications for their greenhouse and growing situations.

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