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The Influence of Day and Night Temperature Fluctuations on Growth and Flowering of Annual Bedding Plants and Greenhouse Heating Cost Predictions

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***Abstract*. Volatile energy costs and lower profit margins have motivated many greenhouse growers in temperate climates to improve the energy efficiency of crop production. We performed experiments with dahlia (*Dahlia ×hybrida* Cav. 'Figaro Mix'), French marigold (*Tagetes patula* L. 'Janie Flame'), and zinnia (*Zinnia elegans* Jacq. 'Magellan Pink') to quantify the effects of constant and fluctuating temperatures on growth and flowering during the finish stage. Plants were grown in glass-glazed greenhouses with a day/night (16 h/8 h) temperature of 20/14, 18/18, 16/22 (means of 18 °C), 24/18, 22/22, or 20/26 °C (means of 22 °C) with a 16-h photoperiod and under a photosynthetic daily light integral of 11 to 19 mol·m^{-2}·d^{-1}. Flowering times of dahlia, French marigold, and zinnia (Year 2 only) were similar among treatments with the same mean daily air temperature (MDT). All species grown at 20/14 °C were 10% to 41% taller than those grown at 16/22 °C. Crop timing data and computer software that estimates energy consumption for heating (Virtual Grower) were then used to estimate energy consumption for greenhouse heating on a per-crop basis. Energy costs to produce these crops in Charlotte, NC, Grand Rapids, MI, and Minneapolis, MN, for a finish date of 15 Apr. or 15 May and grown at the same MDT were estimated to be 3% to 42% lower at a +6 °C day/night temperature difference (DIF) compared with a 0 °C DIF and 2% to 90% higher at a –6 °C DIF versus a 0 °C DIF. This information could be used by greenhouse growers to reduce energy inputs for heating on a per-crop basis.**

In many plant species, stem elongation is influenced by the difference between the DIF (Myster and Moe, 1995). 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 (*Lilium longiflorum* Thunb.; Erwin et al., 1989), pansy (*Viola ×wittrockiana* Gams.; Niu et al., 2000), and poinsettia (*Euphorbia pulcherrima* Willd. ex Klotz; Berghage and Heins, 1991). For example, Erwin et al. (1989) reported that plant height of Easter lily increased by 129% as DIF increased from –16 to +16 °C. During the production of floriculture crops, a –DIF is sometimes used by greenhouse growers to control height (Myster and Moe, 1995).

In temperate climates, high-energy inputs can be required to maintain a desirable greenhouse temperature, making fuel for heating one of the largest floriculture production expenses (Bartok, 2001). Greenhouse growers can reduce energy consumption by managing the greenhouse environment with dynamic temperature control (DTC) strategies (Körner et al., 2007; Lund et al., 2006). In DTC, in contrast to static temperature control, heating set points are lowered during periods when the greenhouse energy loss factor is high (e.g., outside temperature and incoming solar radiation are low) and increased when the energy loss factor is low (Körner et al., 2004). This environmental control strategy integrates temperature and maintains a target MDT over a 1- to 7-d interval (Körner et al., 2004; Körner and Challa, 2003). Lund et al. (2006) reported that a greenhouse in Denmark using DTC had 32% to 79% and 75% to 89% lower energy consumption for heating during winter and spring months, respectively, compared with a greenhouse using static temperature set points.

To achieve the greatest potential energy savings with temperature integration, a greenhouse environmental control computer with sophisticated software (e.g., DTC) is required (Aaslyng et al., 2005). However, 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 static 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 (Bartok, 2001). A low night temperature is compensated for by increasing the day temperature so that the target MDT is achieved.

A DTC or DIF strategy to reduce energy consumption assumes that plant developmental rate is controlled by the integrated MDT (Summerfield et al., 1991) and crop time is similar at different day and night temperatures (within limits) that deliver the same MDT. However, studies with bedding plants that compared flowering times at DIF and constant temperatures regimens with the same MDT have reported different responses among species. For example, geranium (*Pelargonium ×hortorum* Bailey) grown at an MDT of 18 °C flowered similarly at day/night (12 h/12 h) set points of 18/18 or 27/9 °C (White and Warrington, 1988). In contrast, Mortensen and Moe (1992) reported that petunia 'Ultra Red' (*Petunia ×hybrida* Vilm.-Andr.) flowered 5 d earlier at a day/night (16 h/8 h) of 21/15 °C compared with 19/19 and 17/23 °C, whereas red salvia (*Salvia splendens* F. Sello ex Roem & Schult.) flowered 5 d later at 17/23 °C compared with 19/19 and 21/15 °C. 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 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 and Methods

During Sept. 2008 (Year 1) and Mar. 2009 (Year 2), seeds of dahlia (*Dahlia ×hybrida* Cav. 'Figaro Mix'), French marigold (*Tagetes patula* L. 'Janie Flame'), and zinnia (*Zinnia elegans* Jacq. 'Magellan Pink') were sown in plug trays [288-cell size (6-mL volume)] by a commercial greenhouse (C. Raker & Sons, Litchfield, MI). In Year 1, zinnia received a foliar spray of paclobutrazol (Bonzi; Syngenta Crop Protection, Inc., Greensboro, NC) within 10 d of seed sow, at an unreported rate and volume, to suppress hypocotyl elongation.

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Ten to 17 d after seed sowing, plugs were received at Michigan State University (MSU) and were grown in a controlled environmental growth chamber at a constant temperature set point of 20 °C. A 16-h photoperiod was provided by 215-W cool-white fluorescent (CWF; F96T12CWVHO; Philips, Somerset, NJ) and 60-W incandescent lamps (INC; Philips) at a CWF:INC (by wattage) of 3.6 and at an intensity of 160 to 180 μmol·m^{-2}·s^{-1} at plant height. Plants were irrigated as necessary with well water acidified with H_2SO_4 to a titratable alkalinity of 140 mg·L^{-1} $CaCO_3$ and containing 95, 34, and 29 mg·L^{-1} calcium, magnesium, and sulfur, respectively. The water was supplemented with a water-soluble fertilizer providing (mg·L^{-1}) 62 nitrogen (N), 6 phosphorus (P), 62 potassium (K), 7 calcium (Ca), 0.5 iron (Fe), 0.3 copper (Cu), 0.3 manganese (Mn), 0.3 zinc (Zn), 0.1 boron (B), and 0.1 molybdenum (Mo) (MSU Well Water Special; GreenCare Fertilizers, Inc., Kankakee, IL).

Greenhouse environment. After 26 d (dahlia), 19 or 23 d (French marigold), and 23 or 16 d (zinnia) from seed sowing, seedlings were thinned to one seedling per cell and transplanted into 10-cm round plastic containers (480-mL volume) filled with a commercial soilless peat-based medium (Suremix; Michigan Grower Products, Inc., Galesburg, MI). At transplant, dahlia, French marigold, and zinnia had a mean of three, six, or six leaves, respectively. Fifteen plants of each species were randomly assigned to each of six glass-glazed greenhouse sections with constant day/night (16 h/8 h) temperature set points of 18/18 or 22/22 °C or fluctuating day/night (16 h/8 h) temperature set points of 20/14, 16/22, 24/18, or 20/26 °C. The temperature set points were chosen so that three treatments each had an MDT of 18 or 22 °C. In each greenhouse section, temperature set points were maintained by an environmental computer (Priva Intégro 724; Priva, Vineland Station, Ontario, Canada) that controlled steam heating, passive and active ventilation, and evaporative cooling pads when needed. The transition period between the day and night temperature set points was 3 min/°C. The experiment was performed twice with transplant dates beginning on 18 Oct. 2008 (Year 1) and 20 Mar. 2009 (Year 2).

The photoperiod was maintained at 16 h and consisted of natural photoperiods (lat. 43° N) with day-extension lighting from 0600 to 2200 HR provided by high-pressure sodium (HPS) lamps. The HPS lamps were operated by an environmental computer and were turned on when the outside light intensity was less than 290 μmol·m^{-2}·s^{-1} and turned off at greater than 580 μmol·m^{-2}·s^{-1}. The photoperiod and skotoperiod paralleled the day and night temperature set points, respectively. In Year 2, whitewash was applied to the greenhouse glazing so that the maximum photosynthetic photon flux (*PPF*) was 1200 μmol·m^{-2}·s^{-1} at plant height. A maximum vapor pressure deficit of 1.2 kPa was maintained during the night by the injection of steam into the air. Horizontal airflow fans positioned 1.4 m above the growing surface operated if the ridge vent was less than 90% of the maximum opening and provided air movement at ≈0.1 m·s^{-1} at plant height [as measured with an air velocity transducer (8475; TSI, Inc., St. Paul, MN)].

Environmental monitoring and plant culture. Air temperature was independently measured in each greenhouse by an aspirated, shielded thermocouple (0.13-mm type E; Omega Engineering, Stamford, CT) positioned at plant level. In each temperature treatment, the *PPF* was measured by a line quantum sensor containing 10 photodiodes (Apogee Instruments, Inc., Logan, UT) positioned at 30 cm above the bench. Environmental measurements were collected every 10 s and hourly means were recorded by a data logger (CR10; Campbell Scientific, Logan, UT). Temperature control during the experiment was within 1.3 °C of the greenhouse temperature set points for all treatments in both years and the actual MDT was 18.0 ± 0.4 °C or 22.0 ± 0.2 °C (Figs. 1 and 2). The mean photosynthetic daily light integral (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 (Table 1).

Plants were irrigated as necessary with reverse osmosis water supplemented with a water-soluble fertilizer providing (mg·L^{-1}) 125 N, 12 P, 100 K, 65 Ca, 12 Mg, 1.0 Fe, 1.0 Cu, 0.5 Mn, 0.5 Zn, 0.3 B, and 0.1 Mo (MSU RO Water Special; GreenCare Fertilizers, Inc.).

Data collection and analysis. The date of first open inflorescence (flowering) was recorded and time to flower was calculated for each plant. Plants were considered flowering when each species had an inflorescence with at least 50% of the ray petals fully reflexed. When each plant flowered, plant height and the number of inflorescences were recorded. Plant height was measured from the soil surface to the base of the first whorl of flowers on an inflorescence. Data were

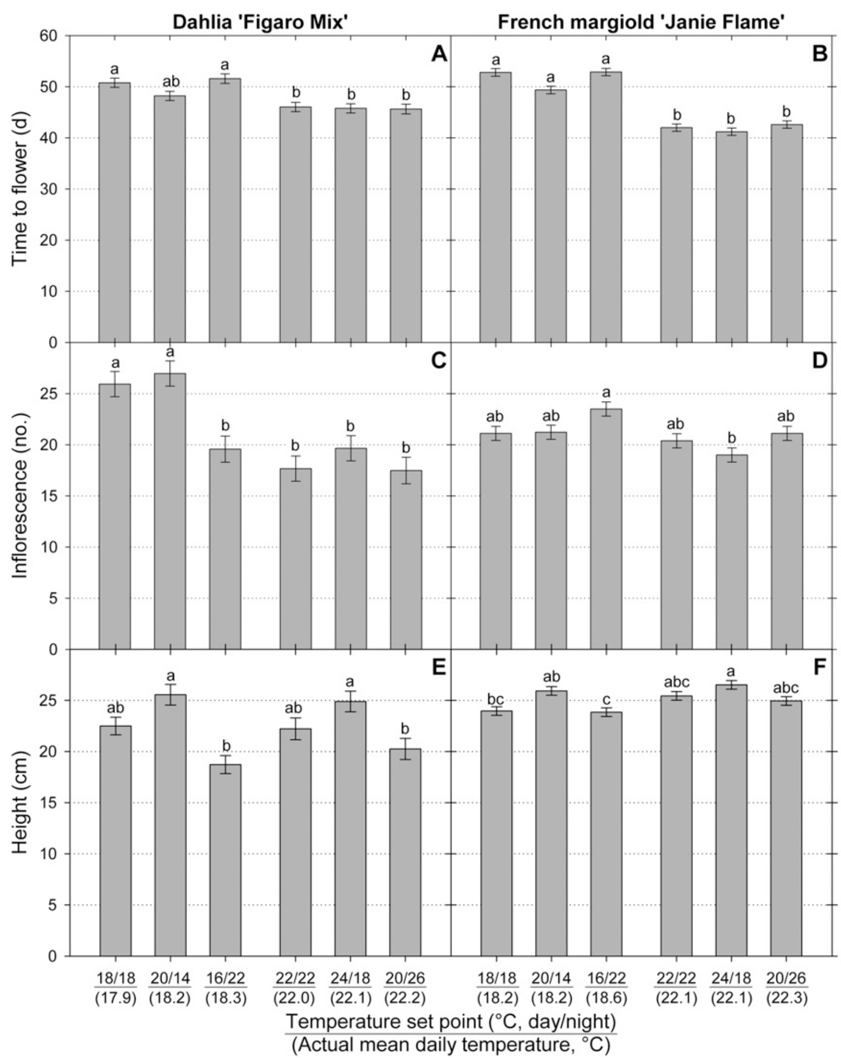

Fig. 1. The influence of temperature on time to flower (**A–B**), inflorescence number (**C–D**), and height (**E–F**) at flowering, in dahlia 'Figaro Mix' and French marigold 'Janie Flame' at constant and fluctuating day/night (16 h/8 h) temperature set points. Vertical bars indicate SEs of treatment means. Mean separation by Tukey's honestly significant difference test at $P \leq 0.01$. For both species, data were pooled between replications.

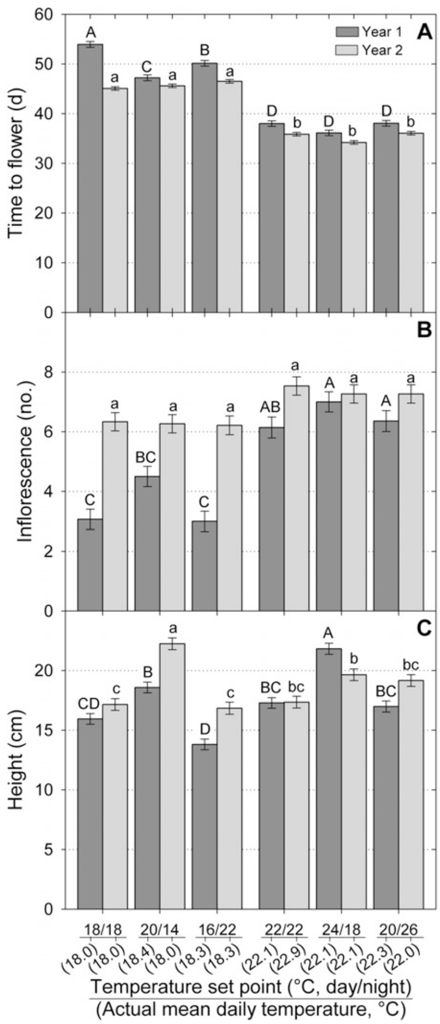

Fig. 2. The influence of temperature on time to flower (**A**), inflorescence number (**B**), and height (**C**) at flowering, in zinnia 'Magellan Pink' at constant and fluctuating day/night (16 h/8 h) temperature set points. Vertical bars indicate SES of treatment means. Mean separation by Tukey's honestly significant difference test at $P \leq 0.01$. Data were analyzed separately for each year.

Table 1. Mean daily light integral in temperature treatments during experiments in Years 1 and 2.

Day/night temp set point (°C)	Daily light integral ($mol \cdot m^{-2} \cdot d^{-1}$) Yr 1	Yr 2
18/18	11.6	15.9
20/14	11.0	16.3
16/22	11.0	16.9
22/22	10.7	19.1
24/18	12.3	15.7
20/26	10.6	18.3

analyzed with the SAS (SAS Institute, Inc., Cary, NC) mixed model procedure (PROC MIXED), and pairwise comparisons between treatments were performed with Tukey's honestly significant difference test at $P \leq 0.01$. Data were pooled between replications because the treatment × year interaction was not significant at $P \leq 0.01$. Zinnia data were analyzed separately for each year because a plant growth retardant was applied to seedlings during Year 1.

Heating cost estimation. The cost to heat a 1991-m^2 greenhouse to produce a flowering crop grown at day/night (16 h/8 h) temperature set points of 18/18, 20/14, 16/22, 22/22, 24/18, or 20/26 °C for finish dates of 15 Mar., 15 Apr., or 15 May was estimated for Charlotte, NC, Grand Rapids, MI, and Minneapolis, MN, by using the Virtual Grower 2.51 software (Frantz et al., 2010). Production time for each species was calculated from the greenhouse experiments by using the mean time to flower at an MDT of 18 or 22 °C. Flowering time for zinnia was calculated according to data from Year 2 only. The greenhouse characteristics used to estimate heating costs included eight spans each 34.1 × 7.3-m, arched 3.7-m roof, 2.7-m gutter, polyethylene double-layer roof, polycarbonate biwall ends and sides, forced air unit heaters burning natural gas, 50% heater efficiency, no energy curtain, an air infiltration rate of 1.0/h, and day temperature set points from 0600 to 2200 HR. These values and characteristics are typical of commercial greenhouses used to produce floriculture crops in the northern half of the United States. Cities were subjectively chosen from a list of the largest garden plant-producing states in the United States (U.S. Department of Agriculture, 2010) and were selected if they had an outside MDT less than 10 °C during January, February, March, and April (U.S. Department of Energy, 1995).

Results

Dahlia and French marigold plants grown at a similar MDT did not differ in time to flower (Fig. 1A–B). For example, French marigold flowered 26 d after transplant when grown at 18/18, 20/14, or 16/22 °C and 21 d when grown at 22/22, 24/18, or 20/26 °C. Zinnia plants grown at a similar MDT flowered at the same time in Year 2 but not Year 1 (Fig. 2A). In Year 1, zinnia grown at 20/14 °C flowered 3 to 7 d earlier than plants grown at 18/18 or 16/22 °C.

Dahlia grown at 18/18 or 20/14 °C had a mean of eight more inflorescences than plants grown at 22/22, 24/18, 20/26, or 16/22 °C (Fig. 1C). French marigold had a similar inflorescence number among treatments, although those grown at 16/22 °C had a mean of three more than those at 24/18 °C (Fig. 1D). In Year 1, when the mean DLI was ≈11 $mol \cdot m^{-2} \cdot d^{-1}$, zinnia grown at an MDT of 22 °C developed two or three more inflorescences than plants grown at an MDT of 18 °C (Fig. 2B). In contrast, inflorescence number was similar among temperature treatments in Year 2, when the mean DLI was ≈17 $mol \cdot m^{-2} \cdot d^{-1}$.

Dahlia grown at a +6 °C DIF (20/14 or 24/18 °C) was 4.6 to 5.3 cm taller at flowering than plants grown at a –6 °C DIF (16/22 or 20/26 °C; Fig. 1E). In French marigold, plants were 11% taller when grown at 20/14 or 24/18 °C versus 16/22 °C (Fig. 1F). In Year 1, zinnia grown at 24/18 °C were 17% to 58% taller than plants in all other treatments, whereas in Year 2, plants grown at 20/14 °C were 13% to 32% taller than plants in all other treatments (Fig. 2C). For all species, there were no differences in height between plants grown at a 0 °C DIF.

In all species and locations, energy for heating predictions to produce a flowering crop for 15 Apr. or 15 May were up to 41% lower when grown at a +6 °C DIF compared with a constant temperature (Table 2). As finish date progressed from 15 Mar. to 15 May, the relative difference in heating costs between a +6 °C DIF and 0 °C DIF increased. Heating costs per crop for all locations and finish dates were estimated to be greatest when grown at 16/22, 20/26, or 22/22 °C. For example, dahlia grown in Minneapolis, MN, would consume 2% to 29% more energy if grown at 16/22 °C versus 18/18 or 20/14 °C. In nearly all instances, the least amount of energy consumed per crop of dahlia or French marigold occurred at 20/14 °C. In contrast, the lowest energy input for a crop of zinnia was 24/18 °C for a 15 Mar. finish date and a +6 °C DIF for the later two finish dates. The estimated energy consumption for heating was greatest for dahlia grown at 20/26 °C or constant 22 °C regardless of location or finish date. For French marigold and zinnia, greenhouse heating was greatest for a crop grown at a –6 °C DIF. As finish date increased from 15 Mar. to 15 May, heating costs at each temperature regimen decreased by 52% to 84%. For example, zinnia grown for 15 May at 20/14 °C would require 77% less energy input for heating than the same crop grown for 15 Mar.

Discussion

Flowering time of dahlia, French marigold, and zinnia (Year 2 only) was similar among temperature treatments with the same MDT. This response reinforces the paradigm that flowering rate is a function of the MDT and, within limits, the effects of day and night temperature on progress toward flowering are equal (Niu et al., 2000; Summerfield et al., 1991). Our results are in agreement with those of Mortensen and Moe (1992), who reported no difference in flowering time of fuchsia (*Fuchsia* ×*hybrida* hort. ex Sieb. and Voss), geranium, impatiens (*Impatiens walleriana* Hook.f.), pocketbook plant (*Calceolaria* ×*herbeohybrida* Voss), potted rose, and tuberous begonia (*Begonia* ×*tuberhybrida pendula*) grown at day/night (16 h/8 h) temperature set points of 19/19, 21/15, or 17/23 °C. Similarly, flowering time was controlled by MDT and not DIF in pinnate dahlia (*Dahlia pinnata* Cav.; Brøndum and Heins, 1993), pansy (Niu et al., 2000), and vinca (*Catharanthus roseus* L.; Pietsch et al., 1995).

Crop models that predict flowering time under different environmental conditions have been developed for several bedding plants such as celosia (*Celosia argentea* L. var. *plumosa* Voss), impatiens, petunia, and

Table 2. Predicted relative amount of energy used for greenhouse heating to produce three annual species grown at different day and night temperature set points in different locations and finish dates[z]

Day/night temp set point (°C)	Charlotte, NC			Grand Rapids, MI			Minneapolis, MN		
	15 Mar.	15 Apr.	15 May	15 Mar.	15 Apr.	15 May	15 Mar.	15 Apr.	15 May
				Dahlia 'Figaro Mix'					
18/18	0.83	0.45	0.22	0.91	0.62	0.35	0.96	0.55	0.26
20/14	0.79	0.39	0.17	0.91	0.60	0.32	0.96	0.53	0.24
16/22	0.90	0.55	0.34	0.93	0.65	0.41	0.98	0.59	0.31
22/22	0.96	0.62	0.38	1.00	0.70	0.44	1.00	0.61	0.35
24/18	0.91	0.55	0.29	0.98	0.67	0.40	0.98	0.58	0.31
20/26	1.00	0.67	0.45	1.00	0.71	0.48	1.00	0.63	0.37
				French marigold 'Janie Flame'					
18/18	0.76	0.43	0.18	0.97	0.60	0.32	0.96	0.44	0.26
20/14	0.68	0.35	0.11	0.95	0.57	0.27	0.95	0.42	0.21
16/22	0.88	0.58	0.35	1.00	0.65	0.39	1.00	0.50	0.32
22/22	0.94	0.60	0.30	0.95	0.63	0.36	0.99	0.48	0.27
24/18	0.86	0.49	0.18	0.92	0.59	0.30	0.97	0.44	0.23
20/26	1.00	0.67	0.40	0.96	0.65	0.40	1.00	0.50	0.31
				Zinnia 'Magellan Pink'					
18/18	0.91	0.51	0.27	0.97	0.64	0.38	0.97	0.55	0.27
20/14	0.86	0.44	0.20	0.97	0.62	0.33	0.97	0.53	0.24
16/22	1.00	0.63	0.40	1.00	0.68	0.43	1.00	0.59	0.33
22/22	0.89	0.61	0.35	0.93	0.64	0.39	0.87	0.49	0.30
24/18	0.83	0.53	0.26	0.91	0.62	0.35	0.85	0.46	0.26
20/26	0.93	0.66	0.43	0.94	0.66	0.42	0.87	0.51	0.33

[z]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 (Frantz et al., 2010) and include time from transplant to first flowering on 15 Mar., 15 Apr., or 15 May. Production time for each species was calculated from greenhouse experiments using the mean time to flower at 18/18, 20/14, and 16/22 °C or 22/22, 24/18, and 20/26 °C. See "Materials and Methods" for greenhouse and heating parameter inputs.

pinnate dahlia (Adams et al., 1998; Brøndum and Heins, 1993; Pramuk and Runkle, 2005). In many of these experiments, models were generated with data from plants that were grown at constant temperature set points. For example, flowering models predicted that as constant temperature set points increased from 14 to 26 °C, time to flower in celosia and impatiens grown under a DLI of 15 $mol·m^{-2}·d^{-1}$ decreased by 38 and 15 d, respectively (Pramuk and Runkle, 2005). Data from our study presenting similar flowering times at different day/night treatments with the same MDT indicate that these crop models could also be used to predict flowering time at fluctuating temperature set points. Caveats of many crop models that predict flowering time are that they are valid only if the day and night temperatures are greater than or equal to a species-specific base temperature and less than or equal to the optimum temperature (Summerfield et al., 1991).

In zinnia during Year 1, flowering time was different among treatments with an MDT of 18 °C. The actual MDT among these treatments varied by only 0.1 to 0.4 °C and plants received a DLI within 0.6 $mol·m^{-2}·d^{-1}$. Therefore, it is not clear why plants grown at 20/14 °C flowered later than those grown at a constant 18 or 16/22 °C. Zinnia in Year 1 grown at an MDT of 18 °C also had a mean of three less inflorescences compared with an MDT of 22 °C. The flowering delay and reduced inflorescence number could be at least partially attributed to the paclobutrazol application during the plug stage, which has been shown to delay flowering in some crops (Blanchard and Runkle, 2007). These responses could also have been affected by the DLI that zinnia received. DLI can interact with MDT to influence flower developmental rate and plant quality (Pramuk and Runkle, 2005).

Plant height at flower in all species generally increased as DIF increased from –6 to +6 °C. These results are in agreement with Myster and Moe's (1995) findings that the relative promotion or suppression of stem elongation is influenced by the magnitude of DIF. Similar effects of DIF on plant height have been reported in other bedding plants, including geranium (Mortensen and Moe, 1992), pinnate dahlia (Brøndum and Heins, 1993), impatiens (Mortensen and Moe, 1992), pansy (Niu et al., 2000), petunia (Kaczperski et al., 1991), red salvia (Mortensen and Moe, 1992), snapdragon (*Antirrhinum majus* L.; Neily et al., 1997), and zinnia (Neily et al., 1997). For example, stem elongation during the vegetative stage in snapdragon and zinnia increased by 38% and 13%, respectively as DIF (13-h day/11-h night) increased from –5 to +5 °C (Neily et al., 1997).

Although a +DIF temperature regimen promoted stem elongation, greenhouse energy inputs to heat these bedding plants at these locations and finish dates were estimated to be lowest with a +DIF. For example, the estimated energy inputs to produce these three crops in Charlotte, NC, Grand Rapids, MI, and Minneapolis, MN, for a finish date of 15 Mar. were similar or up to 11% lower if plants were grown at +6 °C DIF instead of a constant temperature. In contrast, for a finish date of 15 May, energy inputs at the same MDT were estimated to be 9% to 42% lower at a +6 °C DIF compared with a 0 °C DIF. Similar results were reported in a simulated greenhouse study in The Netherlands: total annual energy consumption was 9%, 13%, and 23% lower during February, March, and April, respectively, with a +6 °C DIF compared with a –2 °C DIF (Körner et al., 2004).

These results collectively indicate that for many locations, a +DIF temperature regimen is an energy-efficient production strategy for these species, 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 use an alternative height control strategy to suppress stem elongation. An example of a height control strategy could be the application of a chemical plant growth retardant (Blanchard and Runkle, 2007). Plants grown under a –DIF had suppressed stem elongation but were estimated to require the highest energy inputs to produce. An economic analysis could determine whether it is more cost-effective to deliver a +DIF to save energy and use different height control strategies or to deliver a –DIF with more energy inputs but fewer height control requirements.

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