

Scheduling Bedding Plants for Energy-Efficient Production

By Tasneem Vaid and Erik Runkle

Bedding plants are grown in greenhouses during some of the coldest months of the year, which can make greenhouse heating a large production expense. Volatile fuel prices, an increased emphasis on sustainable production practices, and eroding profit margins have motivated growers to schedule and grow crops as energy efficiently as possible. The average daily temperature (ADT), daily light integral (DLI), photoperiod, and starting size of plugs or liners can influence finish crop time. Plant responses to these factors vary widely among species, and therefore, species-specific information is needed to further improve the reliability of scheduling bedding plants. In this article, we discuss the effect of ADT and starting size of plugs on plant timing and quality of several different bedding plant species (Tables 1 and 2).

In the past several years, the floriculture research team at Michigan State University has been quantifying the effect of ADT on flowering time and quality of bedding plants. We continue to generate information on additional varieties. Plants are grown in controlled-environment research greenhouses with air temperature setpoints ranging from as low as 54°F to as high as 79°F, depending on the plant variety. A 16-hour long-day photoperiod is provided by high-pressure sodium lamps, and the DLI is measured. We record the starting number of leaves and the date of first flowering of each plant. Additional data are recorded when each plant flowers, such as leaf number on the primary stem, plant height, and flower number. After the experiment has been completed, the data are analyzed using different statistical procedures.

Flowering time and plant quality (flower number and branching) decrease as ADT increases, especially under light-limiting conditions. For example, the time from transplant of a 288-cell calendula 'Bon Bon Orange' plug to first flowering decreased by 15 days as temperature increased from 57 to 79°F (Figure 1). However, an increasing ADT also reduced the number of inflorescences per plant and apparently also decreased root mass and inflorescence diameter. Therefore, for calendula and many other floriculture crops, there is a trade-off between fast crop timing and high plant quality, especially when light conditions are limiting. Table 1 presents the number of days to first flowering from transplant at the temperatures tested, the plug sizes used, and under our growing conditions (long days and a moderate DLI).

One of the ways that we can characterize a plant's sensitivity to temperature is to estimate its base temperature. The base temperature is the variety-specific temperature at or below which the plant stops developing. For example, the estimated base temperature of gerbera 'Jaguar Deep Orange' is 36°F, which means that plants stop developing whenever exposed to a temperature of 36°F or lower. Using research data, we estimated

Species and cultivar	Plug size (initial leaf number)	Estimated T_{min} (°F)	Days to flower from transplant at: °F					Flowering time decrease (%) from 63 to 73 °F	Net crop heating savings (US\$ per ft ²)
			57	63	68	73	79		
Cold-tolerant ($T_{min} < 38^{\circ}\text{F}$)									
American Marigold 'Inca II Mix'	288 (6)	35	62	50	41	35	32	43	0.07
Calendula 'Bon Bon Orange'	288 (8)	37	45	38	32	28	26	36	0.02
Diascia 'Diamante Mix'	128 (8)	35	49	39	33	30	31	30	0.00
Gerbera 'Jaguar Deep Orange'	128 (7)	36	68	60	52	44	36	36	0.07
Heliotrope 'Blue Wonder'	128 (9)	35	56	45	37	31	29	45	0.06
Nemesia 'Poetry White'	128 (8)	36	38	34	29	25	20	36	0.01
New Guinea Impatiens 'Devine Cherry Red'	128 (9)	37	59	53	46	39	32	36	0.06
Osteospermum 'Asti Purple'	36 (18)	32	64	49	40	37	40	32	0.02
Petunia 'Bravo Blue'	288 (6)	37	46	37	30	25	22	48	0.04
Snapdragon 'Liberty Classic Cherry'	288 (12)	38	60	46	36	30	28	53	0.08
Stock 'Hot Cakes Purple'	128 (6)	35	35	31	27	23	19	35	-0.01
Cold-intermediate crops ($39^{\circ}\text{F} < T_{min} < 45^{\circ}\text{F}$)									
Cupflower 'Purple Robe'	288 (10)	42	61	47	37	31	29	52	0.08
Geranium 'Pinto Red'	288 (3)	44	81	71	61	51	41	39	0.08
Geranium 'Ringo 2000 Deep Red'	288 (3)	41	72	64	55	46	37	39	0.08
Flowering Tobacco 'Perfume Deep Purple'	288 (7)	42	62	48	38	31	27	55	0.09
Cold-sensitive crops ($T_{min} > 45^{\circ}\text{F}$)									
Globe Amaranth 'Gnome Purple'	128 (8)	52	84	57	38	27	24	111	0.29
Wishbone Flower 'Clown Blue'	288 (6)	49	66	49	35	27	23	81	0.16

Table 1. Flowering time, preliminary base temperature (T_{min}) estimations, and the corresponding decrease in flowering time (%) and net savings in heating costs when grown at 73°F versus 63°F for popular bedding plant cultivars. Heating costs were calculated using Virtual Grower software for Grand Rapids, Michigan for first flowering on April 1. Transplant dates assume a 16-hour long day and an average DLI of at least 10 mol·m⁻²·d⁻¹ and are calculated from data in the table. Greenhouse characteristics include: 8 spans each 112 × 24 ft, arched 12-ft roof, 9-ft gutter, polyethylene double-layer roof, polycarbonate bi-wall ends and sides, forced air unit heaters burning natural gas at \$1 per therm, 50 % heater efficiency, no energy curtain and an hourly air infiltration rate of 1.0.

the base temperature for a number of bedding plant species, and based on that value, we can subjectively categorize plants as cold-tolerant (base temperature less than 39°F), cold-intermediate (base temperature between 39 and 45°F), and cold-sensitive (base temperature greater than 45°F). At this point, these base temperature estimations are preliminary, and we are currently analyzing the data to further validate these values.

We have also estimated the heating costs for each species grown at 63°F and 73°F using Virtual Grower

Species	Cultivar	Initial leaf number at transplant		Average days to flower						
				63°F			73°F			
		Plug size								
288	128	36	288	128	36	288	128	36		
American Marigold	Inca II Mix	4	6	-	57	49	-	44	37	-
Geranium	Ringo 2000 Deep Red	4	6	-	70	65	-	-	49	48
Gerbera	Jaguar Deep Orange	-	7	7	-	57	56	-	46	46
Osteospermum	Asti Purple	-	9	9	-	51	52	43	41	-
Snapdragon	Rocket Mix	6	9	-	56	48	-	42	35	-

Table 2. Initial leaf number at transplant and flowering time for different plug sizes of popular bedding plant species when grown at 63 or 73°F. (- = Not tested)

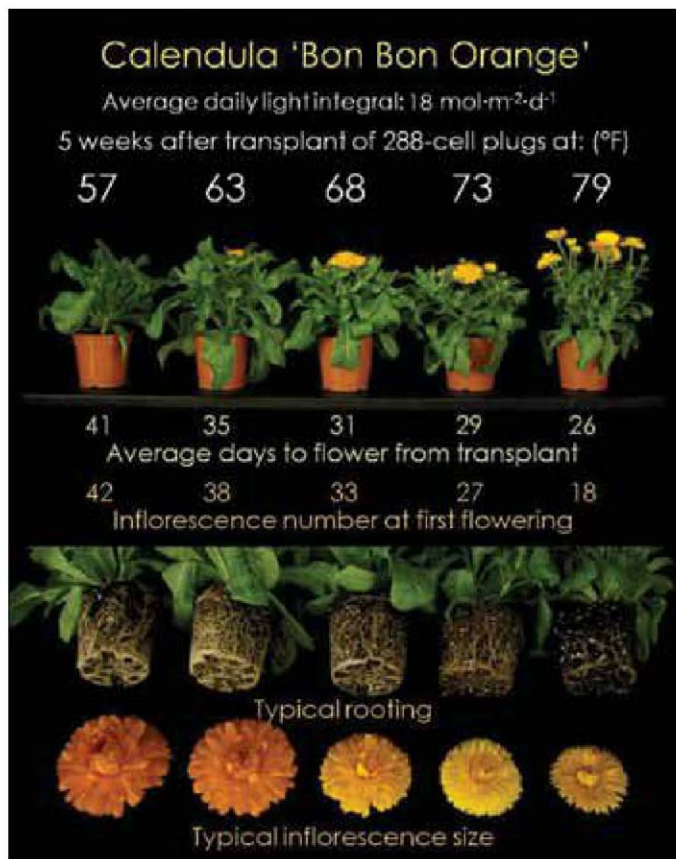


Figure 1. Flowering and rooting characteristics of calendula 'Bon Bon Orange' grown at five different greenhouse temperatures with a 16-hour long day.

(www.virtualgrower.net) software to determine potential net savings by growing a crop warmer (Table 3). With few exceptions, in cold climates such as Michigan, less energy for heating is predicted to be consumed when growing crops at a warmer (73°F) than cooler (63°F) temperature. This is especially true for cold-sensitive crops, which are those with a base temperature greater than 45°F. Therefore, if growers have different greenhouses with different temperature setpoints, it could be advantageous to grow cold-sensitive crops separate from cold-tolerant ones and at a warmer temperature.

Bedding plants are available in different plug sizes. Intuitively, larger plugs should flower faster than smaller, less-developed plugs. In some species that we evaluated, indeed plants grown from 128-cell plugs flowered earlier than those grown from 288-cell plugs (Figure 2). In contrast, plants grown from 128- and 36-cell plugs had the same number of

Average temperature (°F)	Production time (days)	Estimated cost per pot (US\$)						Net profit (wholesale price - total cost) per pot		Net profit (wholesale price - total cost) per square foot week		
		Heating		Plugs		Labor & Overhead		Total Cost				
Snapdragon 'Rocket Mix'												
Plug size:	288	128	288	128	288	128	288	128	288	128	288	128
63	56	48	\$0.15	\$0.12	\$0.15	\$0.33	\$0.70	\$0.60	\$1.00	\$1.05	\$0.50	\$0.45
73	42	35	\$0.14	\$0.11	\$0.15	\$0.33	\$0.53	\$0.44	\$0.82	\$0.88	\$0.68	\$0.62
Geranium 'Ringo 2000 Deep Red'												
Plug size:	288	128	288	128	288	128	288	128	288	128	288	128
63	70	65	\$0.19	\$0.18	\$0.21	\$0.41	\$0.87	\$0.81	\$1.27	\$1.40	\$0.23	\$0.10
73	49	48	\$0.16	\$0.16	\$0.21	\$0.41	\$0.62	\$0.60	\$0.99	\$1.17	\$0.51	\$0.33

Table 3. Estimated production costs and net profits in starting with a 128- versus 288-cell plug to produce two bedding plants at 63 or 73°F for first flowering on April 1. Heating costs are calculated using Virtual Grower software for Grand Rapids, Michigan. Greenhouse characteristics are same as those mentioned in Table 1. Transplant dates assume a 16-hour long day and an average DLI of at least 10 mol·m⁻²·d⁻¹ and are calculated using average days to flower. Each 4-inch pot was assumed to occupy 0.25 sq. ft. of space. Labor and overhead cost of \$0.28 was calculated by updating the estimate of \$0.26/sq.ft./week from Fisher (2006) (which was based on a financial survey of New York commercial greenhouses by Cornell University) using the Consumer Price Index increase of 8% between 2006-2010. This figure was further updated to per sq.ft. of bench space per week by dividing \$0.28 by the space use efficiency (80%) to give the final labor and overhead costs at \$0.35 per sq. ft. per week. Wholesale selling price was assumed to be \$1.50 per 4-inch pot to estimate the net profit per pot and per square foot. Lighting and other variable costs (pots, media, tags, etc.) or differences in plant quality are not considered.

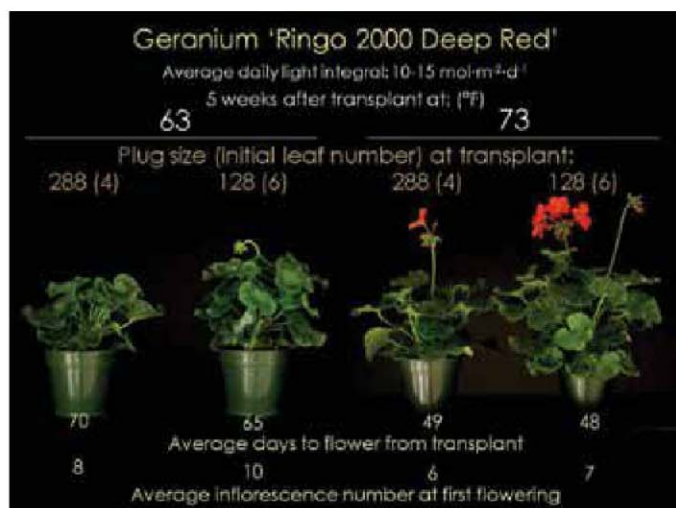


Figure 2. The effect of starting plug size and temperature on flowering of geranium 'Ringo 2000 Deep Red.' 288- and 128-cell plugs were transplanted at the same time and grown under 16-hour long days at a constant 63°F or 73°F.

leaves and not surprisingly, flowered at the same time. Therefore, there may be little "value" of starting with a larger plug unless the plant in the larger plug is more developed (meaning it has more leaves). And even if the larger plug has a more developed plant and flowers earlier, they may still be less economical than starting with a smaller (younger) plant. The situation depends thus on the maturity of the plug or liner, how much earlier the plant from the larger plug flowers, plant spacing, demand for greenhouse space, and the extra cost for the larger plug. Growers need to determine the most profitable strategy since outcomes are so situational.

Most bedding plant producers already have determined typical production times at a particular temperature and schedule their crops accordingly. However, probably few growers know how changing their ADT influences flowering

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time. FlowersOnTime, which is a recently-developed decision-support tool, was developed to help growers do just that (Figure 3). It was developed by Paul Fisher (University of Florida), Matthew Blanchard (Syngenta Flowers), Erik Runkle (Michigan State University) and John Erwin (University of Minnesota) and can be downloaded free as a Microsoft Excel file from the Floriculture Research Alliance web site at <http://floriculturealliance.org>, under the Grower Resources tab. A user selects one of the 60+ floriculture crops, then based on their own experience and growing conditions, specifies a “standard crop time” and “standard production temperature.” The program then predicts the effect of increasing or decreasing temperature at 2°F intervals and assumes all other conditions (such as photoperiod and DLI) are the same. The predictions are based on crop models developed mostly at Michigan State University and University of Minnesota, although a fair number of species were added using published research results from others. Additionally, flowering time models are in Virtual Grower. Finally, crop timing information and estimated heating costs for additional bedding plants can be found online at www.flor.hrt.msu.edu/annuals.

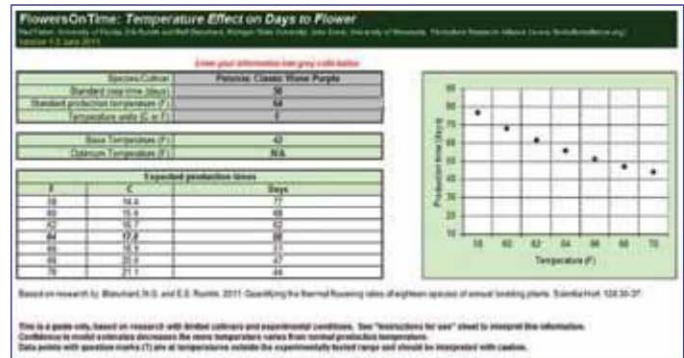


Figure 3. FlowersOnTime is a spreadsheet that can help users predict the effect of changing temperature on flowering time based on their typical growing conditions and finish times.

Reference

Fisher, P. 2006. The most profitable liner size? *Greenhouse Grower*, October issue, p. 36-40. Available at www.greenhousegrower.com/magazine/?storyid=495.

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Water Quality Series of Free Webinars and Articles

“Water, water, everywhere, nor any drop to drink”. *The Rime of the Ancient Mariner* reminds us that water quality is just as important as access to enough quantity for irrigation. With increasing competition for scarce water resources, growers are forced to use lower quality water from catchment ponds, recirculated run off, or partially treated municipal supplies.

Growers face water quality issues such as high alkalinity, waterborne pathogens, clogging of irrigation lines, and algae. In November, the Water Education Alliance for Horticulture launched a new series of webinars and articles on water quality and conservation in collaboration with OFA – The Association of Horticulture Professionals, Florida Nursery, Growers and Landscape Association, and University of Florida IFAS Extension. Topics include dealing with water sources; pH, alkalinity and salts; pathogen control; monitoring; equipment clogging; algae control and pond management; surface cleaning and sanitation; and design of water treatment systems. Expert presenters have been lined up from several universities and companies. Find out more about this series through the *OFA Bulletin* and e-newsletter, or you can go to www.ofa.org or www.watereducationalliance.org for more information.