Editor's Note: This is the fourth in a series of articles highlighting research by the USDA-ARS Greenhouse Production Research Group.

A Novel Approach to Reduce Greenhouse Energy Costs

HOW CAN YOU MINIMIZE HEAT AND LIGHT WITHOUT NEGATIVELY IMPACTING PLANT GROWTH?

By Jennifer Boldt

Irradiance, temperature, and carbon dioxide (CO_2) are three environmental parameters growers can control during greenhouse production to alter crop growth, quality, and timing. Significant costs are incurred every year, especially during winter and early-spring production, to heat and light the greenhouse in order to provide optimal growing conditions for plant growth and development. Small changes to the growing environment have the ability to greatly impact the bottom line (positively or negatively). Here, we introduce an approach that has the potential to reduce energy-related production costs without sacrificing plant quality.

Short-Term Fluctuations in Heating and Lighting

During winter months, especially in northern climates, it's going to be cold. That's a given. However, some days are sunny, while others are cloudy. Yet, we try to maintain a constant growing environment inside the greenhouse. This leads to higher heating costs on cloudy days due to a lack of radiant heating from sunlight. It also results in greater electrical usage because supplemental lights are turned on to compensate for the low natural DLI (daily light integral). Dr. John Erwin, a professor at the University of Minnesota, was asked by a grower whether it was really worth it to heat and light the greenhouse on cold, cloudy days. Or could you just lower greenhouse temperature set points, close the energy curtain, turn off supplemental lights, and let the plants "hibernate" for the day? Would it impact crop timing and quality? How often could you do this without negatively affecting the crop?

We set up an experiment to look at the effect of periodic temperature and light fluctuations on plant growth and development. We had two growth chambers, one designed to simulate a "normal" winter/spring greenhouse environment (72° F day/65° F night, 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$ irradiance) and one designed to simulate a cool temperature/low light ("reduced energy") environment (55° F day/50° F night, 50 $\mu mol \cdot m^{-2} \cdot s^{-1}$ irradiance). We selected five crops (begonia, impatiens, pansy, petunia and snapdragon) and moved them from the normal chamber to the cool/low-light chamber for zero, one, two, four, or seven days per week, every week, for six weeks. We anticipated that one or two days a week would be okay for some crops, but we were surprised that all were able to withstand reduced-energy conditions for two days per week without a reduction in plant quality or a huge delay in time to flower (four- to six-day delay in all crops except pansy, which flowered three days earlier).

I conducted a follow-up experiment this spring at a USDA-ARS greenhouse in Toledo, Ohio. We selected a range of cold-tolerant (dianthus 'Telstar Pink' and pansy 'Matrix Blue Blotch'), cold-intermediate (petunias 'Supertunia Vista Bubblegum' and 'Supertunia Mini Strawberry Pink Veined'), and cold-intolerant (angelonia 'Angelface Blue' and lantana 'Luscious Citrus Blend') crops. Angelonia, lantana and petunia were transplanted from 84-cell liners, and dianthus and pansy were transplanted from 288-cell plug trays into 4.5-inch round pots in mid-February. Plants were moved from "normal" greenhouse conditions to a cool/low-light greenhouse for zero, one, two, four or seven days per week (every week) until plants reached a marketable stage. The normal greenhouse was set at 72° F day/65° F night, with supplemental lighting from high-pressure sodium (HPS) lamps when ambient irradiance inside was less than 200 µmol m-2·s-1, and a 14-hour photoperiod. The cool/low light ("reduced-energy") greenhouse was set at 55° F day/50° F night and the energy curtain was closed continuously (which decreased light transmission by 50 percent). Supplemental HPS lamps were turned on only at dawn and dusk to provide day-extension lighting in order to achieve a 14-hour photoperiod.

Impact on Time to Flower and Plant Quality

A minimal delay in flowering, four days or less, occurred in five of the six crops trialed when plants were grown for two days per week in cool/low-light conditions (Figure 1). The exception was angelonia. Flowering was delayed by six days when plants were exposed to the cool/low-light environment for just one day per week. All plants grown continuously in the cool/low light greenhouse eventually flowered, except for angelonia, which had minimal flower bud development after eight weeks of growth. The delay in flowering for plants grown continuously in cool/low-light conditions was as little as four days in pansy, but as great as 26 days in lantana.

At harvest (four weeks for petunia, six weeks for dianthus and pansy, and eight weeks for angelonia and lantana), flower number was inversely related to the number of days per week plants spent in the cool/low-light environment (Figure 1). In pansy, for example, flower number was 17 when plants were grown continuously in the normal greenhouse, 16 when plants were grown in cool/low-light conditions for two days per week, and eight when plants were grown in cool/low-light conditions for four days per week. In petunia 'Supertunia Vista Bubblegum', flower number declined from 52 when plants were grown continuously in normal conditions to 35 and 19 when grown in cool/low-light conditions for two or four days per weeks, respectively.

Visually, plant quality was not negatively impacted in any species when plants were grown for up to two days per week in the cool/low-light greenhouse. Even plants grown for four days per week in a cool/low-light environment were of acceptable quality, although they were smaller than the control plants grown continuously at normal conditions and had some delay in flowering. Interestingly, dianthus plants grown for four or seven days per week in the cool/low-light greenhouse were slightly taller (Figure 2), most likely the result of stretch due to the low light levels, but none of the other crops exhibited this classic low-light response.

Figure 1. Plants were grown in cool/low-light greenhouse for 0, 1, 2, 4 or 7 days per week (from left to right, respectively), with the remaining days per week spent in normal greenhouse conditions. Pictures were taken at harvest.

Angelonia 'Angelface Blue'
(8 weeks after transplant)

DAYS PER WEEK IN "REDUCED-ENERGY" CONDITIONS

DAYS TO FLOWER	47	53	54	63	-
FLOWER NUMBER	72	57	43	9	0
PLANT DRY WEIGHT (G)	13.4	11.5	9.6	5.3	0.9
ENERGY SAVINGS (%)	-	4%	12%	27%	**

* Energy savings are based on the reduction in energy costs relative to growing plants continuously in normal greenhouse conditions.
** Estimated energy savings were not calculated since the actual number of days to first flower was not recorded.

Lantana 'Luscious Citrus Blend'
(8 weeks after transplant)

DAYS PER WEEK IN "REDUCED-ENERGY" CONDITIONS

DAYS TO FLOWER	36	35	40	53	62
FLOWER NUMBER	25	29	25	16	2
PLANT DRY WEIGHT (G)	12.4	11.8	9.8	6.3	2.4
ENERGY SAVINGS (%)	-	6%	9%	18%	48%

Petunia 'Supertunia Vista Bubblegum'
(4 weeks after transplant)

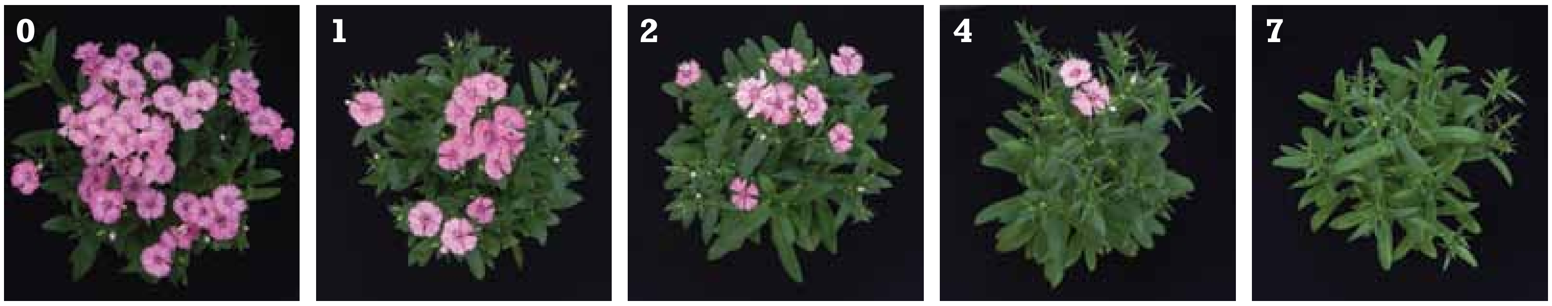
DAYS PER WEEK IN "REDUCED-ENERGY" CONDITIONS

DAYS TO FLOWER	13	13	15	14	25
FLOWER NUMBER	52	50	35	19	6
PLANT DRY WEIGHT (G)	10.4	9.9	8.2	5.9	4.2
ENERGY SAVINGS (%)	-	6%	8%	29%	32%

continued on pages 18-22...

Dianthus ‘Telstar Pink’ (6 weeks after transplant)

DAYS PER WEEK IN “REDUCED-ENERGY” CONDITIONS



	0	1	2	4	7
DAYS TO FLOWER	35	35	37	42	56
FLOWER NUMBER	39	29	28	10	1
PLANT DRY WEIGHT (G)	14.3	13.4	11.6	8.3	5.8
ENERGY SAVINGS (%)	-	8%	13%	27%	51%

Pansy ‘Matrix Blue Blotch’ (6 weeks after transplant)

DAYS PER WEEK IN “REDUCED-ENERGY” CONDITIONS

	0	1	2	4	7
DAYS TO FLOWER	18	19	16	20	22
FLOWER NUMBER	17	17	16	8	3
PLANT DRY WEIGHT (G)	7.7	7.9	7.2	5.1	3.6
ENERGY SAVINGS (%)	-	1%	23%	27%	50%

Figure 2. Dianthus 'Telstar Pink' at harvest (6 weeks after transplant). As plants spent more days per week in the cool/low-light ("reduced-energy") environment, plant height increased. From left to right: 0, 1, 2, 4 and 7 days per week in cool/low-light conditions.

Cost Effectiveness

Okay, so we can grow acceptable plants in this scenario by periodically subjecting them to a cool/low-light environment. But is it cost effective? Using Virtual Grower 3, a free decision-support software tool available from USDA-ARS that allows you to estimate greenhouse heating and lighting costs (www.virtualgrower.net), we "built" our research greenhouses and estimated energy costs for each crop.

Costs were estimated based on the number of days from transplant to a marketable stage, which we defined as three days after the first flower opened. This estimate was based on our location (Toledo, Ohio), time of year (February to April), greenhouse structure (triangular peak with glass roof panels), equipment (unit heaters and high-pressure sodium lamps), and fuel source. Actual cost savings for individual greenhouses will vary based on these factors, but this illustrates the potential benefit. Growing dianthus in a reduced-energy environment for two days per week reduced heating and lighting costs by 13 percent over the duration of the crop while delaying flowering by only two days (Figure 1). This might be an acceptable trade-off. In angelonia, energy costs were reduced by a similar amount (12 percent) but flowering was delayed by seven days. This may or may not be an acceptable trade-off, depending on your production schedule and the cost of tying up bench space for an additional two days.

Here are some points to consider when attempting to conserve energy with this approach:

• Potential energy savings will be greater in northern greenhouses than in southern locations.

• Potential cost savings will be greatest from late fall through early spring, when heating costs and the need for supplemental irradiance are greatest.

• The reduction in energy costs needs to be weighed against the cost of additional production time, if it will result in a delay in flowering.

• The potential overall cost savings will be greatest in crops that have a minimal delay in flowering or reduction in plant quality as the days per week in a cool/low-light environment increases.

• While we did not quantify actual water use, plants were watered less often when they were exposed to the cool/low-light environment. This resulted in reduced water and fertilizer usage over the duration of production.

• For cool-season crops, reducing temperature and light levels for up to two days per week has little to no delay in flowering (zero days for pansy, two days for dianthus and petunia, four days for lantana, and seven days for angelonia).

• Plugs and liners need to be healthy and vigorously growing at the time of transplant. Otherwise, delays in crop growth and development will be further exacerbated.

Practical Implications

This research demonstrates that it is possible to periodically reduce greenhouse temperatures and minimize supplemental lighting during crop production with minimal impacts on the timing and plant quality, up to two days per week for many species. This means you have the ability to look at the short-term forecast for your location and adjust the greenhouse temperature and supplemental lighting set points accordingly. If the weather is going to be cold and cloudy, you can lower the greenhouse temperature, close the shade curtain, and turn off supplemental lights (unless you are using them for photoperiodic or day extension purposes). Just limit it to one or two days per week, otherwise you will notice a delay in flowering and a reduction in growth. When Mother Nature provides you with sunshine, especially during winter and early spring, take advantage of it by opening the shade/energy curtain during the day to let in as much ambient light as possible and set the greenhouse temperature to an ideal temperature for your crop (65 to 75° F, depending on species). More work is needed to see which crops are more or less amenable to this approach, but this might be another option to consider when looking at ways to reduce energy costs during winter and early spring crop production. g

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