# Growing Crops Cooler

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Spring brings longer days, higher light levels, and warmer temperatures outdoors. However, a substantial amount of energy is still needed to heat greenhouses during the spring in northern climates (Table 1), particularly at night (around 75-80% of the daily heating cost).

With the high price of fuel, many growers in cold climates have lowered their temperature setpoints to save money. However, we explain how a lower greenhouse temperature increases crop time, which can sometimes actually **increase** overall fuel cost.

Crop timing is primarily influenced by the average daily temperature, light intensity, and photoperiod. Regardless of light levels and daylength, plants develop and grow faster as temperature increases (Figure 1). Therefore, lowering the greenhouse temperature extends crop time.

| Month | Fuel cost/ month | Relative fuel use |
|---|---|---|
| Jan | $1,459 | 100% |
| Feb | $1,370 | 94% |
| Mar | $907 | 62% |
| Apr | $406 | 28% |
| May | $198 | 14% |
| Jun | $60 | 4% |
| Jul | $31 | 2% |
| Aug | $45 | 3% |
| Sep | $199 | 14% |
| Oct | $549 | 38% |
| Nov | $939 | 64% |
| Dec | $1,343 | 92% |

Table 1. Fuel cost each month, for one 30 x 100 ft double-polyethylene greenhouse located in Columbus Ohio, with $2.00/gallon heating fuel, and heated to 70 °F/65 F day/night temperature. Calculations are from the new USDA Virtual Grower tool available from http://www.ars.usda.gov/Research/docs.htm?docid=11449.

We have listed some examples of how crops respond to temperature based on research (Table 2). For example, if a typical forcing temperature for the herbaceous perennials *Campanula carpatica* and *Leucanthemum ×superbum* is 60 °F, then a 6 °F reduction in the temperature setpoint would delay flowering by 9 and 13 days, respectively. These crops can be considered "cold-tolerant" crops because they continue to develop acceptably at cool temperatures. If you are plan on running cool temperatures, do so with cold-tolerant plants such as ageratum, alyssum, nemesia, pansy, petunia, snapdragon, and many perennials. However, even with these crops build in extra crop time to ensure they are ready to sell.

Figure 1. The effect of temperature (left to right 57 °F, 63 °F, 68 °F, 73 °F, 79 °F) on the development of *Celosia argentea* var. *plumosa* 'Gloria Mix' (top) and *Salvia splendens* 'Vista Red' (bottom). Plants were grown from plugs at the temperatures indicated for 24 days (celosia) and 19 days (salvia). Plants were grown under an average daily light integral of 13 to 15 $mol \cdot m^{-2} \cdot d^{-1}$. Photos courtesy of Lee Ann Moccaldi.

Many "cold-sensitive" crops have an unacceptable delay at cool temperatures, and should be grown warm. Common examples of cold-sensitive crops include angelonia, blue salvia, celosia, hibiscus, New Guinea impatiens, pepper, and vinca. If celosia and vinca was normally grown at 60 °F but instead a grower sets the temperature at 57 °F (a 3 °F reduction), flowering would be delayed by 19 and 49 days, respectively! In addition to slow growth, some cold-sensitive crops turn chlorotic at low temperatures, such as celosia grown as plugs at 57 °F (Figure 2).

| Original temp (° F) | 60 | | 66 | | 72 | |
|---|---|---|---|---|---|---|
| Crop / Temp reduction (° F) | −6 | −3 | −6 | −3 | −6 | −3 |
| Campanula | 9 | 4 | 7 | 3 | 5 | 2 |
| Celosia | 69 | 19 | 15 | 6 | 5 | 2 |
| Coreopsis | 45 | 17 | 20 | 8 | 11 | 5 |
| Impatiens | 12 | 5 | 5 | 2 | 3 | 1 |
| Leucanthemum | 13 | 6 | 9 | 4 | 7 | 3 |
| Petunia | 17 | 8 | 12 | 5 | 7 | 3 |
| Salvia | 18 | 7 | 8 | 4 | 4 | 2 |
| Vinca | 190 | 49 | 40 | 15 | 18 | 7 |

Table 2. The delay in crop time (days) by lowering the average daily temperature by 3 or 6 °F when the original temperature setpoint was 60, 66, or 72 °F. For example, a red salvia crop usually grown at 66 °F takes approximately 8 days longer from plug to the finish stage if grown at 60 °F (6 °F cooler). All finish times are from transplant of a plug until first flowering.

Regardless of crop category, lowering the temperature by 3 °F has a relatively small effect when reducing from a warm 72 °F down to 69 °F, and a bigger impact when reducing from 60 °F to 57 °F. For example, a coreopsis crop would be delayed by 5 days by lowering from 72 to 69 °F, but would be delayed by 17 days when lowering from 60 to 57 °F.

There is a trade-off between the monthly fuel bill and crop time. A warmer greenhouse produces crops quicker, but it requires more fuel per day. We have performed computer simulations on energy consumption to determine which growing strategy consumes less energy per crop: (1) to grow a crop cool but with a longer production time, or (2) to grow a crop warm with a shorter production time.

Figure 2. Celosia plugs grown at 57 °F develop very slowly and become chlorotic. We have observed temperature-induced chlorosis on other cold-sensitive crops, including hibiscus. Photo courtesy of Lee Ann Moccaldi.

We found that the amount of energy consumed per crop can actually **increase** during the spring as temperature decreases because crops take longer to grow and greenhouses have to be heated during the earlier, cool months. In other words, less energy may be consumed per crop by growing it warm for a shorter period of time. Crops that are either grown with normal, warm temperatures or are transplanted from large-sized plugs and liners can be started later in the spring, when the temperature outdoors begins

to increase (Table 1). Conversely, energy use in the fall can decrease at cool temperatures when crops are started earlier during warm summer months.

Fuel is only one of the factors affecting profitability. Saving on fuel cost may decrease revenue with fewer crop turns per season, and does not address other important overhead costs, such as mortgage and labor payments.

Relative humidity can be higher in a cool greenhouse compared to a warm greenhouse, leading to more condensation, moist media and plant pathogen problems such as *Botrytis*, *Pythium* and *Rhizoctonia*. Initial root growth of seedlings and cuttings during the first two weeks after transplant is much faster with warm root temperatures – don't skimp on heat during crop establishment.

Although crops take longer when grown at cool temperatures, within limits a crop grown cool can be of higher quality compared to the same crop grown warm. Crops finished cool often have thicker stems, more branching, and produce flowers that are larger and more intense in color. This is especially true with cold-tolerant crops, including aquilegia, campanula, ivy geranium, and primula. For some tropical cold-sensitive crops, however, plant quality is highest when grown at a moderately warm temperature, usually above 70 °F.

We encourage growers to maintain their original temperature setpoints, especially for small plants, including seedling plugs and rooted cuttings.

In summary, lowering the greenhouse temperature can produce higher quality plants but they take longer to reach maturity and energy consumption per crop can be higher in the spring. In addition, a high humidity and slow drying of the media can lead to increased problems with pathogens. For other details on this topic, please see the January/February 2006 issue of the OFA *Bulletin* or visit http://www.hrt.msu.edu/florAoE/GreenhouseEnergy.htm.

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