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Improving the Energy Efficiency of Greenhouse Crop Production
1. Flowering Responses to Temperature and Light

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BACKGROUND

Annual bedding plants represent the largest category of floriculture crop production in the U.S. The majority of them are produced in greenhouses from January through May, when high energy inputs can be required to maintain a desirable temperature. In the past decade, volatile fuel costs have threatened the profitability of greenhouses located in temperate climates.

One strategy to address this issue is to improve crop production efficiency so that less energy is consumed for greenhouse heating. Energy-efficient greenhouse production requires information on how each crop responds to temperature and photosynthetic daily light integral (DLI) so that crops can be precisely scheduled.

MATERIALS & METHODS

Seeds of 33 different bedding plant species and cultivars were sown in 288-cell plug trays and initially grown in controlled environment chambers at 68 °F (20 °C) with an average DLI of ≈10 $mol{\cdot}m^{-2}{\cdot}d^{-1}$ and a 16-hour photoperiod. Finished plugs were transplanted and grown in greenhouses with constant temperature set points of 57, 63, 68, 73, or 79 °F (14, 17, 20, 23, or 26 °C). At each temperature, plants were grown under a 16-hour photoperiod with two different DLIs provided by shade curtains and different light intensities from high-pressure sodium lamps. In each greenhouse environment, air temperature and light intensity were monitored and recorded using thermocouples and line quantum sensors connected to dataloggers. The experiment was performed twice with each species to obtain average DLIs from 3.5 to 21 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, which represents the range in which most bedding plants are commercially grown in greenhouses.

Data from these experiments were used to develop mathematical equations to model the effects of temperature and DLI on crop timing and plant quality.

RESULTS

Flowering Time

With almost all of the species studied, time to flower decreased as temperature and DLI increased. For example, under an average DLI of 10 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, the time to flower of petunia 'Wave Purple' decreased by almost 5 weeks as temperature increased from 58 to 73 °F (Figure 1). The low temperature at which flower development was predicted to begin (the base temperature) ranged from 34 °F in French marigold to 50 °F in

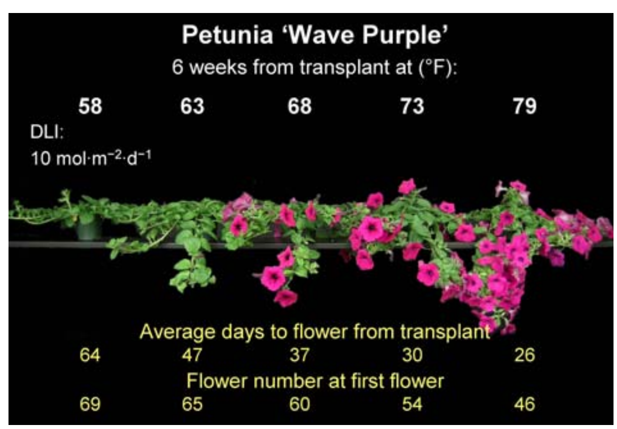

Figure 1. The effects of average daily temperature on time to flower and number of flower buds (at first flowering) in petunia 'Wave Purple'. Plants were grown under a 16-hour photoperiod and an average daily light integral (DLI) of 10 $mol{\cdot}m^{-2}{\cdot}d^{-1}$. Photograph was taken 6 weeks after transplant from a 288-cell plug tray that was grown under long days.

angelonia (Figure 2). Examples of crops that were low temperature-tolerant (base temperature less than 45 °F) include African marigold, dianthus, gazania, petunia, snapdragon, and viola. Those that were low-temperature sensitive (base temperature greater than 45 °F) include blue salvia, browallia, cosmos, moss rose, vinca, and zinnia.

Time to flower also decreased as the DLI increased until a saturating value was reached. For example, as the DLI increased from 4 to 10 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, time to flower of geranium grown at 73 °F decreased by 3 weeks. In most species studied, the estimated saturation DLI for the shortest time to flower ranged from 8 to 15 $mol{\cdot}m^{-2}{\cdot}d^{-1}$. In other words, increasing the DLI above these values did not shorten crop time.

Flower Number

In most species, the number of flower buds at first flowering generally decreased as temperature increased and as DLI decreased. Therefore, there is a trade-off between rapid cropping and plant quality. As expected, bedding plants grown at a warm temperature and under a low DLI produced poor quality plants (e.g., few flowers and branches), whereas plants grown at a cool temperature and under a high DLI were of highest quality.

CONCLUSIONS

Crop models were developed for over 30 species and cultivars of bedding plants to quantify how temperature and light influence crop timing and plant quality. Temperature and DLI influenced the crops differently, but those with similar responses could be grown together. Our cropping information has been incorporated into the computer program "Virtual Grower" (developed by the USDA-ARS and available free at www.virtualgrower.net).

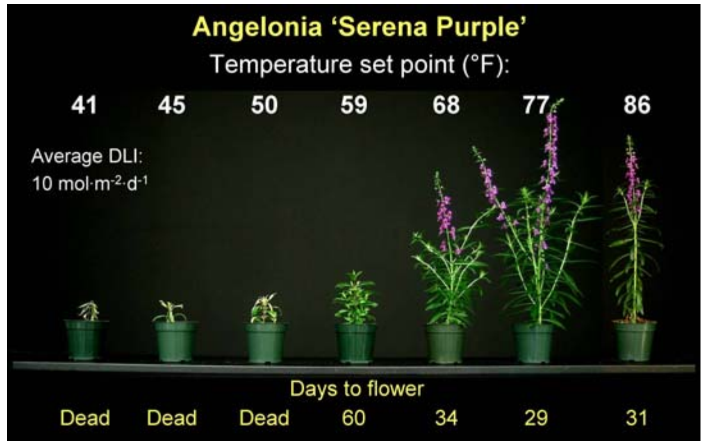

Figure 2. The effects of temperature on time to flower from a 288-cell plug tray in angelonia 'Serena Purple'. Plants were grown under a 16-hour photoperiod and an average daily light integral (DLI) of 10 $mol{\cdot}m^{-2}{\cdot}d^{-1}$. Angelonia is an example of a cold-sensitive crop with an estimated base temperature of 50 °F.

IMPACTS TO THE INDUSTRY

This research has generated new information on the effects of temperature and light on the growth and development of common bedding plants. This information will assist growers to produce crops in greenhouses in an efficient and cost-effective manner. Thus, growers can make informed decisions on temperature set points and accurately schedule crops for their market dates. In addition, supplemental lighting decisions can be made based on a crop's threshold DLI, which we have identified using the data generated in this project.

Acknowledgments

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For Additional Information

Contact: Erik Runkle at runkleer@msu.edu or read the 12-article series on energy-efficient scheduling of bedding plants published from March 2009 to February 2010 in Greenhouse Grower magazine. These articles are available at www.flor.hrt.msu.edu/annuals.