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Growing Ornamental Seedlings Under Different Wavelengths of Red Light from LEDs

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By: Heidi M. Wollaeger and Erik S. Runkle

Editor's note: *This article is adapted from the following research paper, which received AmericanHort's Alex Laurie Award in 2014: Wollaeger, H.M. and E.S. Runkle. 2013. Growth responses of ornamental annual seedlings under different wavelengths of red light provided by light-emitting diodes. HortScience 48:1478-1483.*

Greenhouse growers are becoming increasingly interested in using light-emitting diodes (LEDs) to provide low-intensity lighting to regulate flowering and also for high-intensity lighting to increase photosynthesis and thus growth. A variety of horticultural LED lamps have become commercially available in recent years, and as the technology continues to improve, costs are decreasing and electrical efficiencies are increasing. Horticultural LED lamps are significantly more expensive than conventional lamps used in greenhouses, such as high-pressure sodium lamps. However, it's only a matter of time until LED lighting becomes economically practical, especially when growing high-value crops such as plugs and liners, microgreens, or high-wire vegetables, and where land and electricity are expensive.

In addition to the possibility of energy savings, LEDs can potentially provide other advantages for greenhouse growers, such as lamps can be placed much closer to the crop and their spectrum can be tailored to elicit desired responses. When choosing LEDs for horticultural applications, it is important to consider the wavelengths that are most effective and efficient in eliciting photosynthesis. Red is considered the most efficient color of light for photosynthesis, while blue light is generally the second most efficient. There are many types of LEDs with different peak wavelengths, so we sought to determine whether different shades of red light influence plant growth and architecture differently. Experiments were performed in a completely enclosed environment, without sunlight, which is when we would expect any treatment differences to be apparent.

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In pursuit of the answer, we started a series of research projects using different light qualities, or mixtures of light colors. We worked with Osram OptoSemiconductors to design and construct six LED growth modules (Figure 1), each containing blue, green, orange, red, and hyper red LEDs (peak wavelengths of 446, 516, 596, 634, and 664 nm, respectively). Each color could be independently dimmed to deliver the desired intensities and ratios of light. The modules were placed in an air-conditioned growth chamber and light intensity and air and plant temperatures were constantly measured using sensors connected to a datalogger.



Figure 1. Heidi Wollaeger and Erik Runkle evaluate seedlings grown under LED lighting (Photo credit: Osram OptoSemiconductors)

Materials and Methods

In the first experiment, tomato 'Early Girl,' marigold 'Deep Orange,' petunia 'Wave Pink' and impatiens 'SuperElfin XP Red' were sown in 128-cell plug trays by C. Raker & Sons. Seedlings were moved into the treatments at Stage 2 and were provided with $160 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ of photosynthetic light in each of the six lighting treatments. The percentages of orange, red, and hyper red were 0-80-0, 0-60-20, 0-40-40, 20-30-30, 0-20-60, and 0-0-80. Ten percent blue and 10% green light were delivered in all treatments. Seedlings were grown under an 18-hour photoperiod at a constant 68°F until they were deemed ready for transplant, which was 31 to 45 days after the start of treatments.

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In the second experiment, trays of the same varieties of tomato, impatiens, and petunia, plus salvia 'Vista Red', were obtained as emerging seedlings. Seedlings were grown under two light intensities, $125 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (low light) or $250 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (high light). Each treatment included 10% blue and 10% green light, with the remaining light from 80% red, 40% red + 40% hyper red, or 80% hyper red. Plants were grown under the light treatments for 32 to 39 days. Both experiments were performed twice and 10 plants of each species and treatment were selected at random and harvested. At harvest, the following plant attributes were recorded: leaf number, leaf area, plant height, shoot fresh weight and dry weight, and number of visible flower buds (if present). We also measured chlorophyll concentration of three random plants under each lighting treatment in the second replicate of the second experiment.

Results and Discussion

In the first experiment, plants grew similarly under the six different mixtures of red light with background blue and green light. Plants in all treatments had approximately the same height, shoot fresh weight and dry weight, and leaf number (Figure 2). This was not surprising, because the predicted differences in effective irradiance (based on the quantum efficiency of the different wavelengths) was only 1%. Therefore, the photons emitted by the colors of red LEDs likely elicited similar photosynthetic rates. Tomatoes in all treatments developed intumescences, or blistering, particularly along the veins of the leaves of the seedlings. Intumescence development has been reported previously in tomato and in other members of the nightshade family when there is not sufficient blue and/or UV light.



Figure 2. Young seedlings grown at the same intensity of photosynthetic light from light-emitting diodes (LEDs) using six different combinations of red wavelengths grew equally well.

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In the second experiment, leaf number, height, and fresh weight were usually similar among treatments (Figure 3). However, the dry shoot weight of plants grown under the high light intensity was the same or greater than plants grown under the low light intensity. This result contradicts the paradigm that plants produce more biomass with an increase in light. To try to resolve this finding, we measured chlorophyll concentration and perhaps not surprisingly, some plants grown under the lower light intensity had a higher chlorophyll concentration. In addition, some plants also had larger leaves under the lower light treatments, which enabled plants to capture more light. Thus, we conclude that plants acclimated to the lower light environment by increasing leaf chlorophyll concentration and/or leaf size in order to better capture the limited amount of light.



Figure 3. Young seedlings grown under different percentages of hyper red and red light grew equally well under each of two light intensities. Leaves under the lower light treatments often had more chlorophyll and were larger, enabling them to grow almost as well as plants under higher light.

Conclusion: Shades of red light are equally effective

Since plants grew similarly under the different colors of red light, the choice of red LEDs to be used for horticultural applications could depend on non-plant factors such as LED longevity, efficiency, and cost, without affecting plant quality. Future research is needed to determine whether there is any positive or negative effect of the LED-grown seedlings after transplant.

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Author Info Box

Heidi M. Wollaeger
Michigan State University Extension
3299 Gull Road, PO Box 42
Nazareth, MI 49074
269-384-8010
wollaeger@anr.msu.edu

Erik S. Runkle
Michigan State University
1066 Bogue Street, Room A288
East Lansing, MI 48824
517-355-5191 x1350
runkleer@msu.edu