Figure 1. **Floriculture research greenhouses at Michigan State University where the supplemental lighting experiments were performed.**

Supplemental Greenhouse Lighting to Produce Seedlings: LED or HPS?

Researchers at Michigan State University see if the results from producing high-quality seedlings with LEDs justify the high capital outlay for installation.

By Brian Poel and Erik Runkle

For several decades, ornamental greenhouse growers in temperate latitudes, such as the Northern U.S., have relied on supplemental lighting to produce high-quality seedlings during the winter and early spring. As profit margins continue to get tighter, growers and managers are investing in technologies that can reduce input costs.

While high-pressure sodium (HPS) lamps have traditionally been used to provide supplemental lighting, light-emitting diodes (LEDs) have become a tempting technology based on reduced power consumption from increasingly efficient LED fixtures. However, because of the greater initial capital cost of LEDs, growers must be confident there are no — or only positive — changes in plant quality when switching to a new supplemental lighting system. Therefore, we performed experiments to quantify plant quality parameters of seedlings when grown under different HPS and LED supplemental lighting treatments. Additionally, we investigated whether there would be any lasting effects of the supplemental lighting treatments on subsequent flowering of those seedlings.

Experimental Procedures

At the Michigan State University (MSU) floriculture greenhouses (Figure 1), we grew seedlings of petunia, geranium, snapdragon, pepper, and tomato in 128-cell trays under six different supplemental lighting treatments under low ambient light conditions, typical of winter in northern climates (Figure 2). Each lighting treatment was delivered continuously for 16 hours per day.

The four LED treatments were delivered by different models of Philips GreenPower LED toplighting, which we describe by their percentage emission of blue (400 to 500 nm), green (500 to 600 nm), and red (600 to 700 nm) light. The two HPS treatments

Table 1. **Intensity and spectral composition of six supplemental lighting treatments, where blue= 400 to 500 nm, green= 500 to 600 nm, and red= 600 to 700 nm. Values after the high-pressure sodium (HPS) treatments indicate the photosynthetic photon flux density, whereas those after the LED treatments indicate each waveband percentage.**

Lamp type	Intensity ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Blue (%)	Green (%)	Red (%)
HPS_{10}	10	6	61	33
HPS_{90}	90	6	61	33
$B_{10}R_{90}$	90	10	0	90
$B_{20}R_{80}$	90	20	0	80
$B_{10}G_{5}R_{85}$	90	10	5	85
$B_{15}G_{5}R_{80}$	90	15	5	80

are described by their photosynthetic photon flux density (PPFD; 400 to 700 nm) (Table 1). All LED treatments and one HPS treatment delivered a PPFD of 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and one HPS treatment delivered 10 $\mu mol \cdot m^{-2} \cdot s^{-1}$ to simulate conditions with practically no supplemental lighting while having the same photoperiod.

Seedlings were germinated at C. Raker & Sons and delivered to MSU, where they were all grown at a constant temperature of 68°F. Once seedlings reached the transplant stage, they were harvested, and plant quality characteristics were measured. Seedlings from each treatment were also transplanted into 4-inch pots and grown in a common environment under a 16-hour day from HPS lamps until flowering.

Spectral Effects on Seedling Quality

Through three replications and across all cultivars tested, generally plants grew similarly among the 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$ lighting treatments. Regardless of the spectrum from the supplemental lighting, as long as it delivered 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$, seedlings were usually of similar quality at time of transplant (Figure 3).

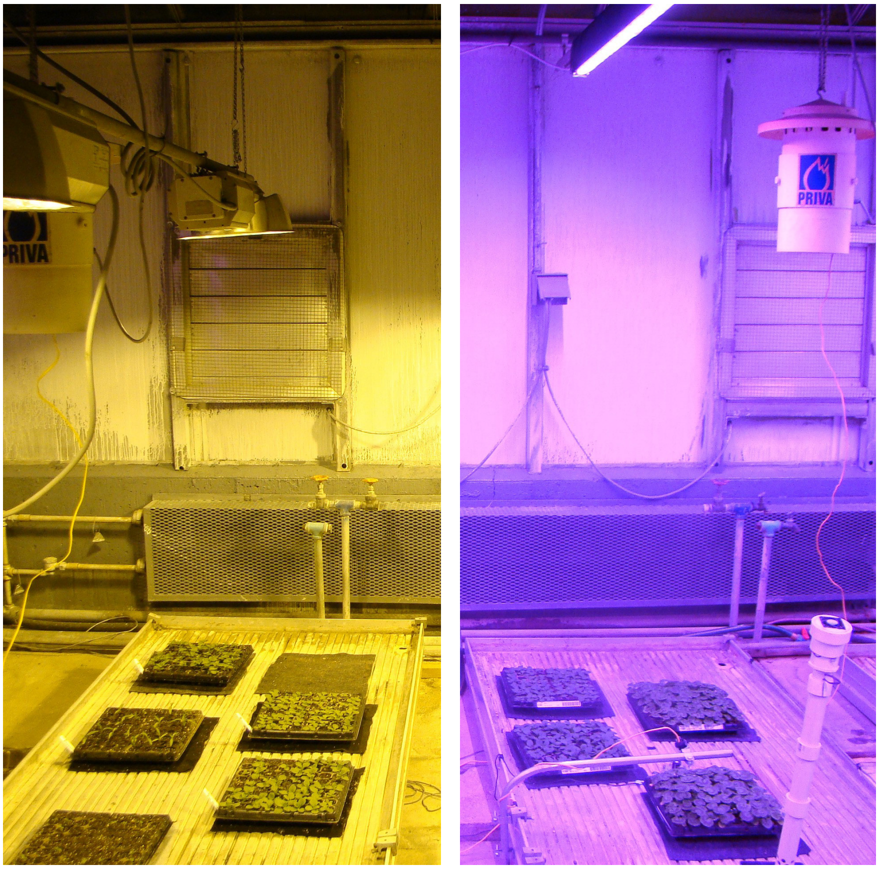

Figure 2. **Side-by-side comparison of two separate greenhouse sections with different supplemental lighting treatments delivered by high-pressure sodium lamps (left) and light-emitting diodes (right).**

When there were treatment differences, such as for tomato and both cultivars of petunia, seedlings grown under the 10 $\mu mol \cdot m^{-2} \cdot s^{-1}$ treatment had less growth (i.e., dry weights were lower) than under all 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$ treatments, reiterating how increased light can increase growth.

Similarly, subsequent flowering of transplants was generally not affected by the supplemental lighting spectrum. Geranium and petunia seedlings grown with 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of supplemental lighting flowered slightly earlier than those under the low-intensity HPS treatment (Figure 4).

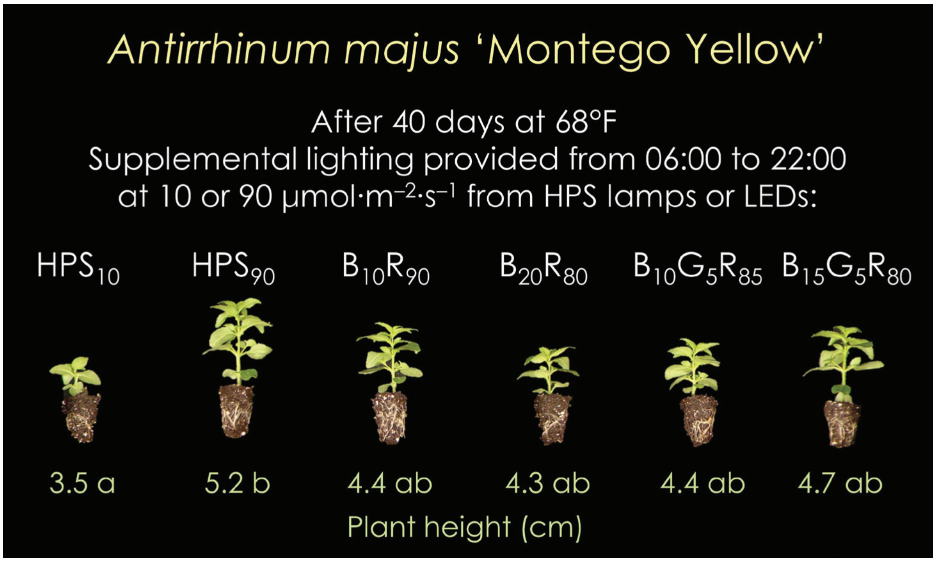

Figure 3. **Seedlings were generally similar when grown under different supplemental lighting treatments from high-pressure sodium (HPS) lamps or light-emitting diodes (LEDs) with different percentages of blue (B), red (R), and green (G) at 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (right 5 treatments). Growth was generally reduced under HPS lamps at 10 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (left treatment).**

Our Results in Context With Other Studies

Previous experiments using LEDs as the only light source (indoor production) have shown that

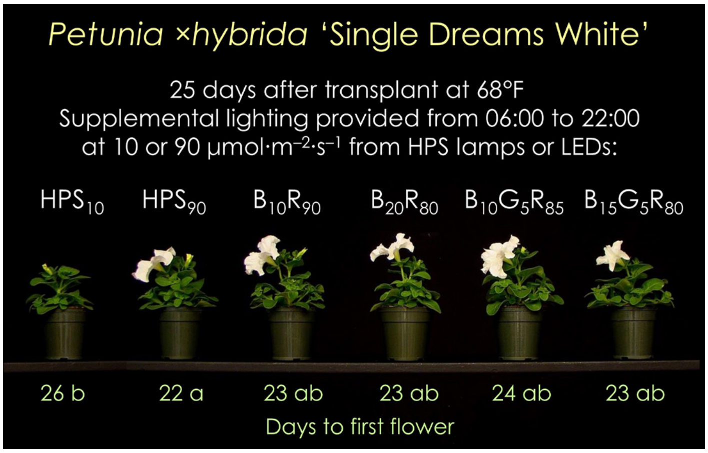

Figure 4. **Seedlings grown under different supplemental lighting treatments from high-pressure sodium (HPS) lamps or light-emitting diodes (LEDs) with different percentages of blue (B), red (R), and green (G) flowered similarly at 90 µmol·m^{-2}·s^{-1} (right 5 treatments), while flowering was slightly delayed when seedlings were grown under HPS lamps at 10 µmol·m^{-2}·s^{-1} (left treatment).**

growth can be modified by the light spectrum. In some species of ornamentals and leafy greens, increasing the percentage of blue light relative to red light produces progressively more compact seedlings. There is a possibility that this height control method could be applied to greenhouse seedling production by providing supplemental lighting with a greater percentage of blue light.

A 2014 study by Wesley C. Randall and Roberto G. Lopez at Purdue University reported eight of nine ornamental species were shorter when grown under supplemental lighting from LEDs with 15% blue and 85% red light compared to those grown under HPS lamps. However, in our experiment with 10% to 20% blue light, we did not observe height control effects compared to those grown under HPS lamps at the same intensity.

It is possible that in our experiment, the proportion of total light from the supplemental lighting treatments was lower than that in the study at Purdue. In their study, the supplemental lighting treatments provided 45% to 70% of the total light received by the plants, whereas in our study, it was 13% to 37% (depending on experimental replicate). Thus, it may be possible to manipulate plant height with supplemental lighting when it delivers a majority of the total light (sunlight plus electric lighting) available to plants, although more research is needed.

Power Consumption Considerations

Although we generally did not observe differences in plant growth or development under supplemental lighting from LEDs or HPS lamps at the same intensity, the LEDs delivered light much more efficiently. The reported efficacy of the Philips LEDs in our study was 2.2 to 2.3 $\mu mol \cdot J^{-1}$, while those for our older 400-Watt HPS lamps was around 0.9 $\mu mol \cdot J^{-1}$. This means that the LEDs produced the same amount of photosynthetic light but only consumed 40% of the amount of electricity.

LEDs Can Be a Suitable Replacement for HPS Lamps

In this study, our findings showed that the LED fixtures can be a suitable replacement for HPS lamps when producing ornamental seedlings. Without any appreciable differences in quality or effects on flowering after transplant, such a decision of which lamp type should primarily be based on economics.

Whether choosing LEDs or HPS lamps as your supplemental lighting source, consider factors in addition to plant growth. Your prospective lighting supplier should be able to provide a lighting map of intensity (in $\mu mol \cdot m^{-2} \cdot s^{-1}$) and uniformity, cost, and efficacy (in $\mu mol \cdot J^{-1}$) for your specific application. Explore your options for energy rebates. These vary by location, and a reputable lighting supplier may be able to help you with an application. Most importantly, your current electrical supply needs to allow for the use of supplemental lighting based on a proposed lighting plan. With this information, you can estimate the payback periods for different lighting options based on your anticipated lighting hours per year and electricity rate. **GG**


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