Figure 1.
An experimental plant factory at Osaka Prefecture University in Japan, which is also used as a prototype for commercial growers, utilizes LEDs and fluorescent tubes to produce lettuce.

Growing Seedlings Under LEDs

In part one of a two-part series, Michigan State University researchers share their findings in germinating seedlings with LED lights.

by **HEIDI M. WOLLAEGER** and **ERIK S. RUNKLE**

LIGHT-EMITTING diodes (LEDs) are of increasing interest among commercial greenhouse growers. They are currently being explored and developed in the horticultural industry for low-intensity photoperiodic lighting applications, as well as for high-intensity lighting.

Low-intensity LED lighting at night can promote flowering in long-day crops and inhibit flowering in short-day plants. High-intensity supplemental lighting in greenhouses increases the daily light integral (DLI), which can increase photosynthesis and thus, plant growth.

LED Technology Is Intriguing But Costly

With their increasing electrical efficiency and potential to deliver specific ratios of light, LED technology provides appealing opportunities for plant production. For example, the light spectrum emitted from LED lamps could be tailored for specific crop stages of production or for desired growth characteristics. In addition, LEDs can be installed closer to plants than conventional lamps because energy consumed that is not converted to light (heat) is separate from the light emitted.

The cost of LEDs is the primary limitation to widespread use in the horticulture industry. In addition, for high-intensity lighting, exist-

In This Series

Part One: How plants acclimate to different wavelengths of red LED lighting, with constant blue and green light levels.

Part Two: Results of experiments with green and blue LED lighting on seedling growth and plant architecture.

ing systems cannot be retrofitted with LEDs. The benefits of using supplemental lighting in greenhouses when the DLI is low (<10 $mol \cdot m^{-2} \cdot d^{-1}$) have been well established, but there is a decreasing benefit of supplemental lighting as the growing season progresses. By mid-spring, ambient light levels are generally high enough that the benefits of supplemental lighting to ornamental crops are limited. Therefore, LEDs often have a long return on investment for greenhouse applications.

Other factors to consider with LED lighting include: their efficiency in

Figure 2.

LED modules were constructed for research at Michigan State University to investigate how different colors of light influenced growth of bedding plant seedlings.

Photo courtesy of Osram Opto Semiconductors

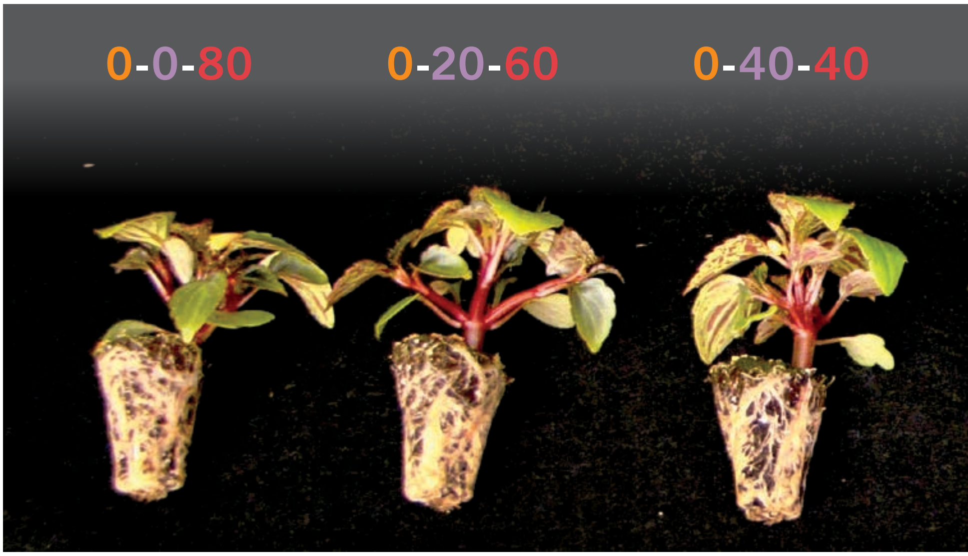


Figure 3.
Impatiens 'SuperElfin XP Red' grown at the same light intensity but with different percentages of orange, red and hyper red light from LEDs had similar characteristics after 43 days at 68°F. All treatments also received 10 percent blue light and 10 percent green light.

converting energy into light (µmol·Watt), availability of rebates from power companies, electricity costs, the intensity and directionality of light, the spectral output and the reputation of the manufacturer. Many of these factors vary considerably among LED manufacturers.

Using LEDs In Plant Factories May Offer Economic Value

In some situations, LED lighting may be economically practical when growing high-value crops, such as microgreens, propagaules or high-wire vegetable crops, especially where land is expensive and electricity costs are high.

To maximize yield per square foot of land, "plant factories" have been emerging in highly populated areas such as Japan (Figure 1). A plant factory is a completely enclosed, air-conditioned plant production facility with multi-tiered shelving and usually with carbon dioxide injection systems. There are an estimated 120 commercial plant factories, mostly in Japan, and most of them currently utilize fluorescent lighting.

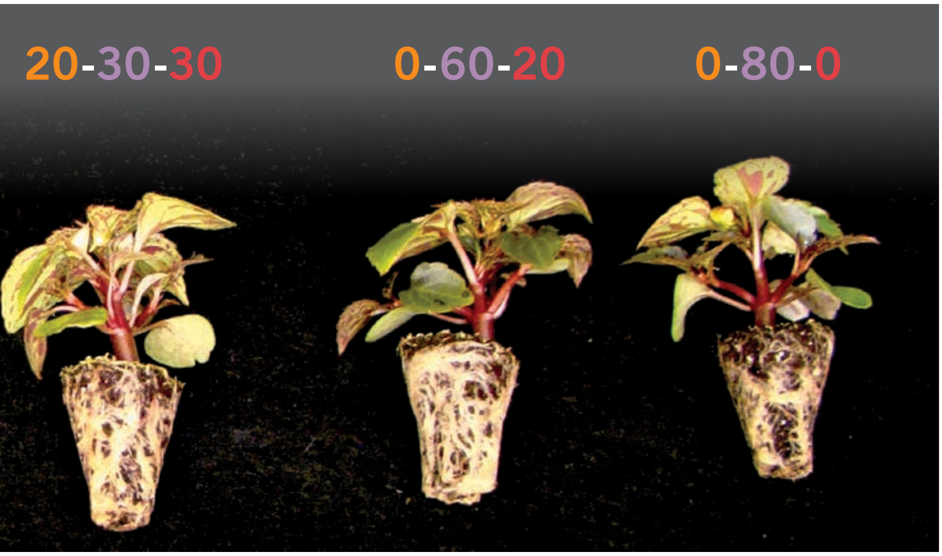
The plant factory concept has the potential to alter the way that high-value crops, including plugs, liners and tissue-culture propagules, are grown. Trial projects like the Smart Plant Factory Network in Japan aim to develop a proof-of-concept network between commercial growers and homeowners to produce food crops such as lettuce locally. Other plant factories in Japan and the Netherlands grow microgreens or high-value ornamentals.

While production in plant factories can be much greater than that produced in conventional greenhouses, only a minority of plant factories are reportedly making a profit. However, the economics of LEDs continue to improve and it's only a matter of time until they will be widely used in crop production.

Research Modules Show How Seedlings Respond To LED Lighting

In 2011, we started a research project with LEDs to investigate the concept of growing young plants under only LED lighting. Our goal was to further understand how the different colors of light influence growth so high-quality young plants could be produced commercially.

We partnered with Osram Opto Semiconductors to construct six custom LED growth modules (Figure 2), each containing blue, green, orange, red and hyper red LEDs (peak wavelengths of



446, 516, 596, 634 and 664 nm, respectively), which could be independently dimmed to deliver the desired ratios of light. Each module has fan-cooled driver boards that could be moved closer or further away from plants to provide a range of light intensities. 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.

In a series of experiments we performed, the first examined how plants acclimated to different wavelengths of red light while delivering a constant amount of blue and green light. Red is considered the most efficient light for photosynthesis, but there are different colors of red light and we didn't know if there was a benefit to delivering one color of red or another, or a blend of two or more reds.

Tomato 'Early Girl,' marigold 'Deep Orange,' petunia 'Wave Pink' and impatiens 'SuperElfin XP Red' were grown for 31 to 45 days under 160 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of photosynthetic light under six lighting treatments. The percentages of orange (peak at 596 nm), red (peak at 635 nm) and hyper red (peak 665 nm) 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 percent green light were delivered in all treatments.

Generally, plants grown under the different colors of red light grew similarly; shoot fresh and dry weight, seedling height and leaf number were usually the same (Figure 3). Tomatoes in all treatments developed edema, or blistering, especially along the veins of the leaves of the seedlings. This has been reported previously in tomato and a few other species in the nightshade family when there is not sufficient blue and/or UV light. Marigold developed purple speckling in all treatments, but otherwise developed normally along with the other plant species.

Since plants grew similarly under different colors of red light, the type of red LEDs to be installed for a horticultural lighting fixture could depend on other factors such as LED longevity, efficiency and cost, without affecting plant quality.

Part two of this article will discuss the results of additional experiments, which focused on the effects of green and blue light on seedling growth and plant architecture. **GG**

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