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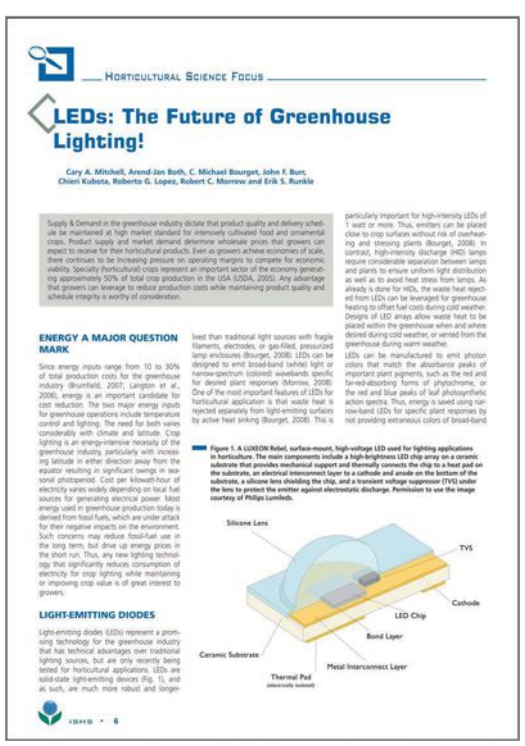
Lighting the Way with LEDs

Light-emitting diodes (LEDs) are one of the trendiest technologies in the greenhouse industry. There are particularly interesting opportunities with LEDs in the production of young plants (plugs and liners) and high-wire vegetable (tomato, cucumber and pepper) crops.

The question is not if, but when, LEDs will become commonplace for plant lighting in commercial greenhouses. Opportunities also exist for LEDs in completely enclosed environments, especially when there are prospects to produce plants during much or all of the year.

It's probably obvious, but light is critical to plant growth and development. Light controls growth of leaves, stems and roots; plant architecture (plant height and branching); and flowering (time to flower and flower quality). The growth and development of LEDs is based on human applications — both indoor lighting (homes and offices) and outdoor lighting (street lights and parking garages). Although there are some similarities to lighting for plants as there are for people, there are also many differences. People don't flower, and people don't branch or elongate based on the light environment. Most people prefer white light whereas that's not necessarily true for plants.

Our team wrote a review article about LEDs for plant applications that appeared in Chronica Horticulturae*, a publication of the International Society for Horticultural Science. To download the article, visit http://leds.hrt.msu.edu/publications.*



HORTICULTURAL SCIENCE FOCUS

LEDs: The Future of Greenhouse Lighting!

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Supply & Demand in the greenhouse industry dictate that product quality and delivery schedule be maintained at high market standard for intensively cultivated food and ornamental crops. Product supply and market demand determine wholesale prices that growers can expect to receive for their horticultural products. Even as growers achieve economies of scale, there continues to be increasing pressure on operating margins to compete for economic viability. Specialty (horticultural) crops represent an important sector of the economy generating approximately 50% of total crop production in the USA (USDA, 2005). Any advantage that growers can leverage to reduce production costs while maintaining product quality and schedule integrity is worthy of consideration.

ENERGY A MAJOR QUESTION MARK

Since energy inputs range from 10 to 30% of total production costs for the greenhouse industry (Brumfield, 2007; Langton et al., 2008), energy is an important candidate for cost reduction. The two major energy inputs for greenhouse operations include temperature control and lighting. The need for both varies considerably with climate and latitude. Crop lighting is an energy-intensive necessity of the greenhouse industry, particularly with increasing latitude in either direction away from the equator resulting in significant swings in seasonal photoperiod. Cost per kilowatt-hour of electricity varies widely depending on local fuel sources for generating electrical power. Most energy used in greenhouse production today is derived from fossil fuels, which are under attack for their negative impacts on the environment. Such concerns may reduce fossil-fuel use in the long term, but drive up energy prices in the short run. Thus, any new lighting technology that significantly reduces consumption of electricity for crop lighting while maintaining or improving crop value is of great interest to growers.

LIGHT-EMITTING DIODES

Light-emitting diodes (LEDs) represent a promising technology for the greenhouse industry that has technical advantages over traditional lighting sources, but are only recently being tested for horticultural applications. LEDs are solid-state light-emitting devices (Fig. 1), and as such, are much more robust and longer-lived than traditional light sources with fragile filaments, electrodes, or gas-filled, pressurized lamp enclosures (Bourget, 2008). LEDs can be designed to emit broad-band (white) light or narrow-spectrum (colored) wavebands specific for desired plant responses (Morrow, 2008). One of the most important features of LEDs for horticultural application is that waste heat is rejected separately from light-emitting surfaces by active heat sinking (Bourget, 2008). This is particularly important for high-intensity LEDs of 1 watt or more. Thus, emitters can be placed close to crop surfaces without risk of overheating and stressing plants (Bourget, 2008). In contrast, high-intensity discharge (HID) lamps require considerable separation between lamps and plants to ensure uniform light distribution as well as to avoid heat stress from lamps. As already is done for HIDs, the waste heat rejected from LEDs can be leveraged for greenhouse heating to offset fuel costs during cold weather. Designs of LED arrays allow waste heat to be placed within the greenhouse when and where desired during cold weather, or vented from the greenhouse during warm weather.

LEDs can be manufactured to emit photon colors that match the absorbance peaks of important plant pigments, such as the red and far-red-absorbing forms of phytochrome, or the red and blue peaks of leaf photosynthetic action spectra. Thus, energy is saved using narrow-band LEDs for specific plant responses by not providing extraneous colors of broad-band

Figure 1. A LUXEON Rebel, surface-mount, high-voltage LED used for lighting applications in horticulture. The main components include a high-brightness LED chip array on a ceramic substrate that provides mechanical support and thermally connects the chip to a heat pad on the substrate, an electrical interconnect layer to a cathode and anode on the bottom of the substrate, a silicone lens shielding the chip, and a transient voltage suppressor (TVS) under the lens to protect the emitter against electrostatic discharge. Permission to use the image courtesy of Philips Lumileds.

Silicone Lens
TVS
Cathode
LED Chip
Bond Layer
Ceramic Substrate
Metal Interconnect Layer
Thermal Pad (electrically isolated)

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In late 2010, a grant was funded by the USDA National Institute of Food and Agriculture through the Specialty Crop Research Initiative to investigate the development and application of LEDs in specialty crop production. This multidisciplinary team includes faculty and graduate students at Purdue University, the University of Arizona, Rutgers University and Michigan State University, as well as the company ORBITEC. We have a stakeholder group that includes a broad range of ornamental and vegetable crop producers, providing input and support (financial and otherwise) in this project.

Scientific research is a relatively slow and rigorous process. Experiments have to be conducted so plant responses can be specifically attributed to treatment effects, and not some other, potentially confounding variables. When we provide lighting treatments to crops, we have to carefully and meticulously ensure that other factors, such as light intensity, temperature and fertility, are similar among treatments. In addition, experiments are often repeated to ensure what happens the first time happens the second time. This helps improve the confidence we place in results from lighting treatments.

Recently, we developed a website for our LED project (http://leds.hrt.msu.edu) that provides information about our project's objectives, background information on the desirable attributes of LEDs, unbiased publications about greenhouse lighting from our group, and the people and companies involved. There are two recent additions to this website: 1) presentations delivered to scientific and grower groups, which provide updates on the research being conducted and 2) a frequently asked questions page that presents responses to 14 questions about LEDs for plant applications. Some of the questions we address are:

- Why use LED lighting in greenhouses?
- What color spectrum should be used and should it be adjustable?
- When selecting an LED system, what are the most important things to be considered?

Our team is certainly not the only group working with LEDs for plant applications; universities and companies throughout the world — especially in the Netherlands — are determining how to best use LED technology for different plant production situations. As we move forward, it is important for potential users of LEDs to be able to separate marketing claims and hype from scientific, research-based information. Presently, the limiting factor to the installation of LEDs in commercial greenhouses is cost. A return on investment will be more favorable in situations where lighting is used much of the year and where electricity costs are especially high. g

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