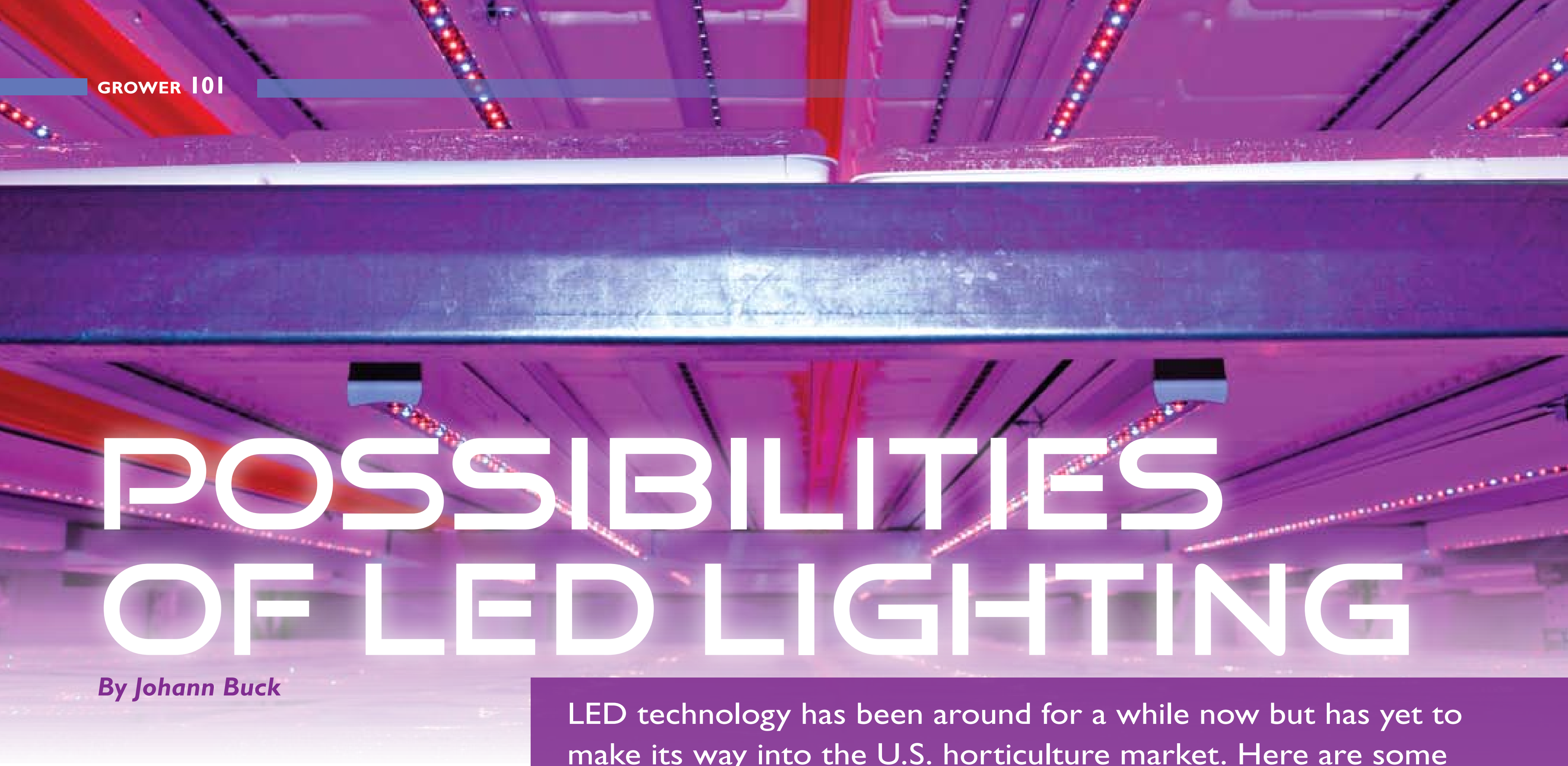


POSSIBILITIES OF LED LIGHTING

By Johann Buck

LED technology has been around for a while now but has yet to make its way into the U.S. horticulture market. Here are some considerations for those contemplating a transition.

"Live in rooms full of light."
— Cornelius Celsus

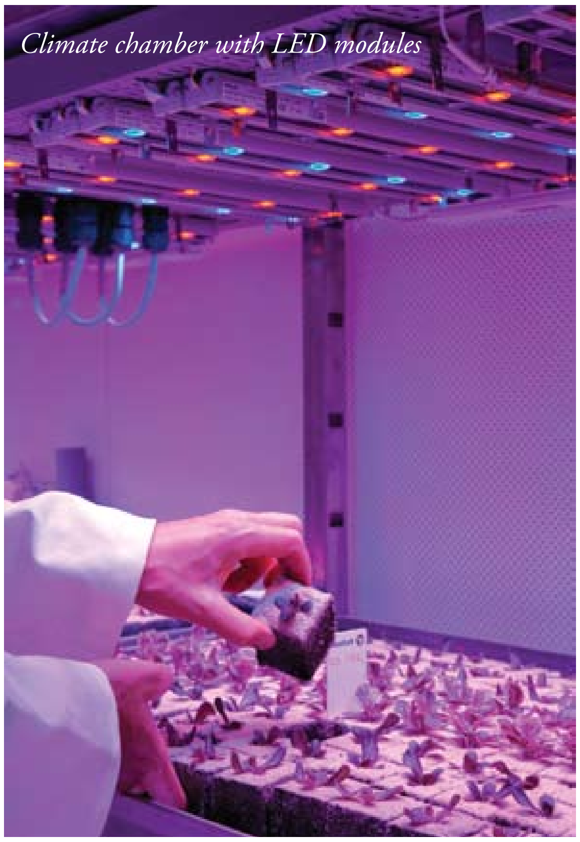
That's an interesting quote especially when placed into the context of growing plants. We can prescribe the correct mineral nutrition and temperature to our plants. We can supply PGRs when necessary. We can control the environment in the greenhouse and supply numerous inputs that steer our crops in order to meet our objectives.

What about light? With the use of supplemental lighting, day length can be extended. We can create night time interruptions. Light can be blocked out completely when necessary. However, the light our plants receive is dependent on the sun and limited by several factors. These limitations include the sun's duration and angle in the sky, cloud cover, structural shading, etc. Growers have been using supplemental lighting techniques for many years to compensate for these limitations. One limitation to current supplemental lamps is spectral quality. What if, in addition to optimal nutrition and temperature, you were able to supply your plants with both the right quantity of light *and* the right quality? By right light we are referring to photosynthetically active radiation (PAR), which is light between 400 and 700 nm (nanometers) and measured in $\mu mol \cdot m^{-2} \cdot s^{-1}$.

Without getting into phytochrome and light ratios, we'll keep it simple. Generally speaking plants use light in the blue (450 nm) and red (660 nm) region of PAR for photosynthesis. Imagine illuminating your plants with more of the right light from a lamp that only produces light your plant will use versus a lamp that also produces wasted light. Now, imagine your plants living in rooms full of the right light, completely devoid of sunlight. Well, there is a relatively "new" supplemental light source creating a lot of discussion at the expos and professional conferences that aims to do just that — provide the right light.

The Light Emitting Diode (LED) is probably something you have heard or read about by now. LEDs can be found in everything from automobile head lights and tail lights to traffic lights, and even handheld flashlights. LEDs have even been tested as a wireless LAN alternative. Simply put, LEDs are becoming commonplace. The LED is more like that of a computer chip than a light bulb because it is a solid-state semiconductor device. It has been estimated that in 2008, LEDs occupied 7 percent of global lighting market share. In 2010, that number rose to 20 percent. By 2020, LEDs are estimated to occupy 75 percent of global lighting. Although LEDs may seem to be a relatively new light source, they were actually invented in the 1920s. However, a visible light (380 to 780 nm) version was not developed until the early 1960s and it was red (~660 nm) in color. Additional wavelengths (green, yellow, orange and even blue) were developed through the 1970s. The first high-brightness blue LED was developed in the early 1990s. The color of light emitted by any LED is determined by the type

Top: *Philips GreenPower LED research module.* ***Bottom:*** *Philips GreenPower LED production module.*



Climate chamber with LED modules

A production center wher you can see the new installation with LED production modules as well as the old fluorescent lighting installation

of semiconductor material and the impurities used to form the LED. With the addition of a phosphor coating to the blue LED, the white LED was created. In addition to being short waveband specific, LEDs offer many positive attributes over traditional lighting sources.

Advantages and Challenges

The two most commonly discussed advantages to using LEDs are efficiency and lifetime. LEDs are more efficient than incandescent and fluorescent lamps, and are essentially equivalent to high-intensity discharge (HID) lamps. White LEDs are less efficient because the phosphor coating must interact with the base color to create white light. There exists potential for significant cost savings of LEDs over other current horticultural lamps. Unlike traditional lamps, LEDs generally do not "burn out." Instead, the metric used is the LED's "lifetime," which is the time (in hours) required for the light output to drop below a percentage of the original maximum intensity under optimal operating conditions. Growers will generally replace their lamps when the light output drops below 90 percent. Therefore, a grower can expect a lifetime of approximately 25,000 hours at 90 percent. The long operational life of LEDs reduces the procurement, disposal and associated labor costs otherwise spent on replacement bulbs.

LEDs also offer the advantage of turning on and off instantly, and do not require warm-up time. They emit little or no radiant heat. However, there is a loss of heat from the diode junction. The thermal output can be significant when LEDs are used in high densities. Unlike fluorescent lamps, LEDs do not contain hazardous materials such as mercury. They don't produce damaging ultraviolet wavelengths as HID lamps can produce if the protective envelop breaks. Due to their size, LEDs offer flexibility in fixture design.

The primary difficulty that has prevented mass LED installations for greenhouse lighting has been cost. Although the initial cost may be higher than other supplemental light sources, the return on investment for LEDs is much shorter due to energy efficiency and lifetime. Secondly, the cost of LEDs is constantly decreasing and companies like Philips Lighting and others are offering affordable LED technology designed for horticultural applications. The primary technical obstacle to using LEDs for horticulture lighting has been low light output of wavebands of interest to horticulturists. Although an LED replacement to today's HID lamp does not exist, sources estimate that one will be available within three to five years. Nevertheless, LED modules of desirable wavebands exist and are currently being used for horticulture applications. Other LED lamps being produced have a standard E27 fitting, which allows for direct replacement in existing installations. No additional modifications are required.

Horticulture Applications

The ability to control spectral quality is of interest for crop production and is not easily achieved with broad-spectrum light sources. LEDs produce narrow-spectrum wavelengths and have been manufactured in highly plant-absorbed colors. Recall PAR? Since growers are using highly plant-absorbed colors, LEDs should produce much less wasted light and energy versus using non-productive wavelengths. Spectra can be customized and even modified to match a crop's needs and control the photoperiod or growth cycle. Therefore, it must be strongly emphasized that LEDs require a systematic approach that is dependent on the crop being grown and the goals of the grower.

So, you should ask yourself some questions.

Kalanchoe production under LED research modules

What do you expect from using LEDs? Are you interested in faster growing, increased plant quality, growing without daylight, multiple layer production or reducing a crop's time spent in the greenhouse? Are you interested in stretching a seedling's hypocotyl to create a better grafting candidate? Recall that LEDs emit very little if any radiant heat, which allows them to be operated close to the canopy. This also increases the light intercepted by the plant, further improving the use efficiency. The reduction in radiant heat also raises one concern: reduction in air temperature. HID lamps do radiate some heat toward the crop below. LEDs do not. How will this change greenhouse growing conditions? Perhaps when the LED replacement to the HID is ready for market we will have more answers.

The capability of using LEDs closer to the plant canopy provides options such as multilayer production of many crops including tissue culture. Multilayer production using other light sources is possible. However, with LEDs growers can install more shelves per unit volume. For example, one grower decreased his light energy consumption by more than 50 percent and increased multilayer production by 33 percent without additional production volume simply by switching to LEDs.

Consider This

LEDs possess several characteristics that make them an attractive horticulture supplemental light source. Control over the spectral composition is possible with LEDs, meaning more PAR and less wasted light. LEDs provide high light output with low radiant heat. Their small size offers flexibility in design and placement. Last, but not least, they are exceptionally long lasting and are more energy efficient than other supplemental light sources.

Disclaimer: proceed with caution. There are companies trying to gain a foothold in the horticultural industry that do not understand crop production. These companies recognize that greenhouse lighting is another area for which they can increase their market share. When considering using LEDs, consult with someone that knows our industry and understands crop production. Consider working with a partner that will help you design a system specific for your greenhouse operation and objectives.

Always ask questions. Find out how much research the company has invested on crop production with their product(s). That being said, the outlook for solid-state lighting technology is bright (pun intended). Consider testing LEDs in your operation. They are another tool available to help you increase surface area use efficiency, expand production, increase yield and improve quality. g

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