duets

BY PETER KONJOIAN AND ERIK RUNKLE

Supplemental and Sole Source LED Lighting: Fast and Furious Change

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Joining me today is Erik Runkle, professor at Michigan State University. Erik is well known in this magazine for his "Technically Speaking" column appearing inside the back cover.

Peter: Erik, before starting I'd like to acknowledge years of insightful grower education on your part. Arriving at the last page to read about your topic of the month is a highlight for me. You've been working in the arena of crop lighting in two settings, as a supplement to sunlight in the greenhouse and as the sole source of light indoors. What's your position regarding the debate between high pressure sodium (HPS) and light emitting diodes (LED) in horticulture?

Erik: Back in 2009, I highlighted the potential benefits of LEDs (spectrum control, longevity, instant on/off, energy efficiency, etc.) as well as the major drawbacks at the time (low light output and high cost). I started working with LEDs for greenhouse lighting the following year, and my impressions were mixed, with excitement at the potential but also disappointment with the light output — it was too directional and intensity was lower than expected. Since then, LEDs have developed significantly while costs have come down.

Today, LEDs and HPS lamps both have places in modern greenhouse lighting. When supplementing sunlight, our research hasn't shown many consistent benefits with LED-enabled spectrum control and therefore, a decision about which lamp type is best in a greenhouse is situational and should primarily be based on economics. If you light more than three to four months of the year and your electricity cost is moderate to high, then LEDs *could* be the most cost-effective option. Start by calculating the costs to purchase different lighting technologies and estimate the payback period for the more expensive, yet more efficient LEDs.

LEDs have even more potential indoors, where they are the only source of light for plants. In this application, the spectrum has a pronounced effect on plant growth attributes such as leaf size, stem length and leaf color, and at least in some crops, flowering. For several reasons, LEDs have pronounced advantages for indoor lighting than HPS lamps. Peter, I know you've done your own research trials with LEDs, what are your impressions of the technology today?

Peter: Your explanation of where we are and where we are heading, in itself, could be our take-home message. Regarding my opinion of where we stand, I have some concern over the tendency of many to suggest production input choices must be a zero sum game. I don't agree with the position that one light source has to be declared the winner. Your explanation is correct Erik; HPS or LED, which is better? It depends.

Hand in hand with this point is that LED technology is advancing between blinks of our eyes. You reference 2010 as your starting point with LEDs and how much they've advanced in just a few years. I started in 2012 and find myself holding onto my seat to keep up with the advancement. Experiences with LED fixtures in 2010 and 2020 will be as different as night and day. Let's move on to an exciting feature of LEDs, spectrum control.

Erik: Using LEDs to grow crops indoors is really exciting primarily because of this feature. We can use light to elicit the crop attributes a grower wants for ornamentals (seedlings and liners) as well as high-value edible crops such as lettuce, basil and other herbs.

I recently developed the Controlled-Environment Lighting Laboratory (CELL) at Michigan State, which enables us to grow crops under an infinite number of light intensity and light quality treatments. We will use this facility to learn more about the benefits of changing the light spectrum either during the day or during different stages of growth. This will help us develop lighting recipes for specific crops and desired characteristics. Growers may even end up growing the same crop under different lighting conditions depending on what attributes the customer wants. Peter, can you elaborate a bit on the challenges of developing multi-channel LED arrays?

Peter: An engineer associate of mine experienced in LED fixture design explained the challenge of spectrum control. There's an economic barrier to incorporating this feature at two levels; hardware … the diode, and software … controlling the diode.

If we want to change red to blue from a common ratio of 4:1 (80 percent red – 20 percent blue), how does that happen? We can mount more blue diodes on the fixture and not use them until needed or we can turn off some red diodes when a higher blue ratio is needed. Having diodes not in use is expensive. An exception is research fixtures where the cost of idle diodes is less of a concern, perhaps the case in the new lab at Michigan State. This barrier will fall as LED costs drop. On the software side, controlling which diodes are on and off isn't necessarily expensive but manufacturers are charging a premium as they develop proprietary packages.

Concurrent to overcoming this economic barrier, our research needs to define specific spectrum recipes, identify the crop benefits they create, and quantify how those benefits are leveraged into profit. Until then, deciding how much to spend for spectrum control is difficult for growers, making the *right* decision remains risky. Kudos to you, CELL research is taking direct aim at the barrier we're describing.

Another feature of LEDs is that diodes can be variably powered to emit more or less light. But, driving them at higher than optimal power to emit more light reduces their impressive life expectancy. This can be avoided by increasing the fixture's heatsink to dissipate the extra heat generated by driving the diode harder (brighter and hotter). Naturally, this adds cost to the fixture so a balance needs to be struck between adjustable spectrum capability and fixture infrastructure cost. Again, in a research setting, diode life is less of a concern allowing us to march on and explore how to harness spectrum control while the engineering evolves.

Until having extra diodes on board for occasional use is economical we're left with turning off some red diodes to increase the blue ratio or driving all of the red diodes at lower power to achieve the same result. Either way works to adjust the ratio but then another challenge surfaces. By turning down the red we've lowered the total light output thereby changing the PAR level. Side by side red vs. blue comparisons could be muddied by different daily light integrals. For research, we can lower the fixture closer to the crop to equilibrate PAR levels and tolerate the smaller footprint or we can run the higher PAR fixture at lower power to match up the daily totals. I'll pause here and say adjustable spectrum remains in the easier-said-than-done realm but the technology is advancing before our eyes and in a couple years these paragraphs will be irrelevant.

Lettuce growing in CELL lab at Michigan State University (Photo: Erik Runkle)

Erik: Good points, Peter. While we have an appreciation for the engineering challenges of developing LED fixtures for plants, I think engineers have also developed an appreciation for horticulture, sometimes learning the hard way that growing plants isn't that simple. To advance both industries, collaboration or partnerships with both sets of expertise are needed.

Peter: Here's to the value of collaboration as horticulture becomes more technical. I have invited the engineer introduced above, Alex Bodell, to join me in this space in an upcoming issue to help growers understand LED back stories better in order to make good decisions. He and I operate with an agreement that each may address the other as grasshopper; he teaches me about LED engineering and I teach him about plants, illustrating your point about working together. Moving on to research, Erik, it's being conducted at a fast and furious pace. What areas do you consider promising?

Erik: I'm most excited by the potential of blending different colors of light to produce commercial crops with specific characteristics. Light is surprisingly complex because of its different dimensions including intensity, quality, duration and uniformity. And, these dimensions interact with each other, as well as other environmental variables (especially temperature and CO_2). In addition, crops sometimes respond differently, so what works best for one crop for one market can be very different from another crop or another market. So, we've got a long way to go before we can truly optimize production (based on crop and economic metrics) for each market.

A lot of effort now is focused on growing leafy green crops indoors under LED lighting. There are many production challenges, and LED lighting is just one of them. Others include nutrient management and control of other environmental factors including temperature, humidity and air movement.

Peter: Pushing your description of light's complexity, I see a two-step objective. Step one is to recreate sunlight indoors accounting for the variables you list. Can we operate an LED fixture to mimic sunlight's changing intensity, a bell-shaped curve peaking at noon, throughout a day? Next, can we recreate sunlight's changing spectrum throughout the day, higher in red at dawn and dusk, etc. You mentioned this as a CELL objective. Our current knowledge plateau has us using a fixed intensity the entire day coupled to a fixed spectrum. That blink of an eye pace of LED development is getting us closer to achieving this objective with each blink.

Once we succeed in recreating sunlight indoors, step two will be improving it. Reproduce the sun, then optimize it in the ways you stated by crop species, cultivar, stage of maturity, desired response and so on. How exciting these areas of research are. There's so much to learn, we've only touched the tip of the iceberg.

Erik, thank you for joining me today. Your research and teaching contribution to our knowledge base in this arena is commendable.

Erik: Thank you Peter; it's been a pleasure. gpn