Figure 1. Mustard microgreens grown under sole-source (SS) lighting using light-emitting diode (LED) arrays.

Sole-Source Lighting In Horticulture: Microgreens Production

Researchers examine the effects of sole-source LED lighting on microgreen production to achieve the highest quality crop possible in an energy efficient manner.

by **JOSHUA K. CRAVER**, **JOSHUA R. GEROVAC** and **ROBERTO G. LOPEZ**

THE promotion of healthy eating has proven to be a topic of particular interest in our society today. As such, many consumers are looking for new or interesting products that may assist in cultivating a healthy lifestyle. Therefore, it is in the best interest of any grower involved in specialty crop production to be aware of upcoming trends or popular crops. In this third article of a four-part series highlighting the multiple uses of high-intensity light-emitting diodes (LEDs), we will discuss how this technology can be utilized in the production of microgreens.

Microgreens are a specialty crop commonly sold in many upscale markets and restaurants (Figure 1). For those who may not be familiar with the term, microgreens consist of many different species of vegetables and herbs that are marketed and consumed at a very young growth stage. Specifically, seedlings are harvested at the base of the hypocotyl, just as the first set of true leaves begin to emerge.

Chefs and consumers will often use this crop as a garnish or to enhance the flavor, color and texture of various foods (Figure 2A). Additionally, many consumers are interested in microgreens due to their health benefits, as several species contain high concentrations of health-promoting phytochemicals.

However, the appeal of microgreens is not limited to the consumer. Many commercial greenhouse growers and urban farms have recently become interested in producing microgreens due to their high market value and relatively short production time. When sold in a wholesale market, prices can range anywhere from $30 to $50 per pound for microgreens packaged in clamshell containers. With some species of microgreens taking as little as one to two weeks for harvest, the combination of a high-value crop with an incredibly short production time is enticing for many growers.

Figure 2A. **Microgreens are used as an edible garnish on this plated meal.**

Figure 2B. **Close-up of Brassica microgreens used as a garnish.**

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While many different vegetables and herbs are commonly selected for microgreens production, species from the *Brassica* genus (Figure 2B) have become a popular choice due to the ease of germination, short production time and wide offering of intense flavors and colors.

Sole-Source Lighting

One common form of producing microgreens involves the use of hydroponic systems. As such, several commercial growers are currently utilizing various types of soilless media or capillary mats placed in troughs or trays to produce these greens. Alongside hydroponics, one of the most lucrative means of producing microgreens involves the use of indoor, multi-layer vertical growing systems. For many of these systems, a combination of hydroponics

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and sole-source (SS) lighting is utilized to produce the crop (Figure 3). With the use of a system such as this, many benefits are gleaned from the maximization of space, precision of the environmental controls and consistent quality throughout the year.

Many operations in Japan began using SS lighting in multi-layer vertical growing systems in the early 2000s. While fluorescent lamps were at first the primary means of lighting, growers have begun replacing these lamps with high-intensity LED arrays for a variety of reasons. Of the reasons in support of LED SS lighting, some of the most important include their energy efficiency and low output of radiant heat. As a result, several operations worldwide have begun implementing this technology especially as the cost of purchasing these LED arrays continues to become more affordable.

Microgreens Sole-Source Lighting Research

To date, there is limited research looking into the production of microgreens under SS lighting. We decided to conduct research at Purdue University looking at how growers can produce microgreens under SS lighting and achieve the highest quality crop possible in an energy efficient manner. For this research, we evaluated three *Brassica* species, which included purple kohlrabi (*Brassica oleracea* var. *gongylodes*), mustard (*Brassica juncea* 'Garnet Giant') and mizuna (*Brassica rapa* var. *japonica*).

Figure 3. Sole-source lighting in a multi-layer vertical growing system utilizing hydroponics for vegetable production.

For this study, we wanted to not only look at the color or quality of light that we were supplying to the plants, but also at the quantity or intensity of the light. To establish light quality treatments, we used three different commercially available LED arrays (Philips GreenPower Production Modules). These LED arrays provided light ratios (%) of red:green:blue 74:18:8 (R_{74}:G_{18}:B_{8}), red:blue 87:13 (R_{87}:B_{13}) or red:far-red:blue 84:7:9 (R_{84}:FR_{7}:B_{9}). For our light intensity treatments, we established a daily light integral (DLI) of 6, 12, or 18 $mol \cdot m^{-2} \cdot d^{-1}$. These DLIs were achieved by altering the number of modules within each treatment, as well as adjusting the height of the LED arrays on the shelving units.

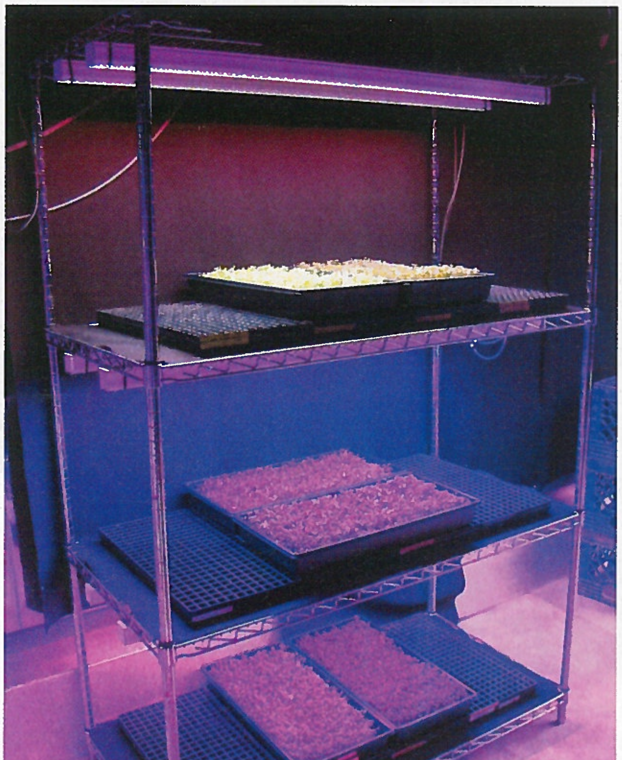

Figure 4. Microgreens produced under light-emitting diode (LED) sole-source (SS) lighting in a multi-layer vertical growing system using stainless steel shelves.

These treatments ultimately allowed us to look at how light intensity and quality, as well as the interaction between the two, affected many aspects of microgreens production. This experiment was conducted in a walk-in environmental chamber on stainless-steel shelves, where we were able to carefully control the light, temperature, relative humidity and carbon dioxide (Figure 4).

Effects Of Light On Growth

In terms of growth, the results from our study showed that light intensity (DLI) had the greatest effect on the microgreens we produced. We found that microgreens produced under the higher DLIs had decreased hypocotyl lengths and increased percent dry weights [(dry weight/fresh weight)×100]. However, fresh weight was only significantly impacted by DLI with mustard, where increased DLIs led to increased fresh weights.

Additionally, we found that leaf area often increased under the lower DLIs, especially for kohlrabi. While the light quality did occasionally produce significant effects, these results varied based on the species being evaluated, as well as the DLI within which the light quality was being observed.

Effects Of Light On Aesthetics And Nutritional Value

The red or purple coloration we observe in plants is often related to the concentration of anthocyanin pigments in the plant tissues. However, the advantages of increased anthocyanins are not solely related to aesthetics. Along with influencing color, anthocyanins may also have added health benefits including: increased visual acuity, reduction of coronary heart disease and antioxidant or anti-cancer properties. Therefore, an increase in anthocyanin pigments within microgreen tissues would not only make the crop more marketable from an aesthetic viewpoint, but would also present health-promoting attributes upon consumption.

In the current study, we found that microgreens produced significantly higher anthocyanin levels under increased DLIs. This is highly evident as we observe the increased red pigmentation in mustard seedlings as the DLI increased from 6 to 18 $mol \cdot m^{-2} \cdot d^{-1}$ (Figure 5). With kohlrabi microgreens, it was found that not only did the increase in DLI affect the anthocyanin levels, but also the light quality. It was observed that under a DLI of 18 $mol \cdot m^{-2} \cdot d^{-1}$, microgreens produced with a light ratio of R_{87}:B_{13} or R_{84}:FR_7:B_9 produced significantly higher levels compared to those produced with a ratio of R_{74}:G_{18}:B_8.

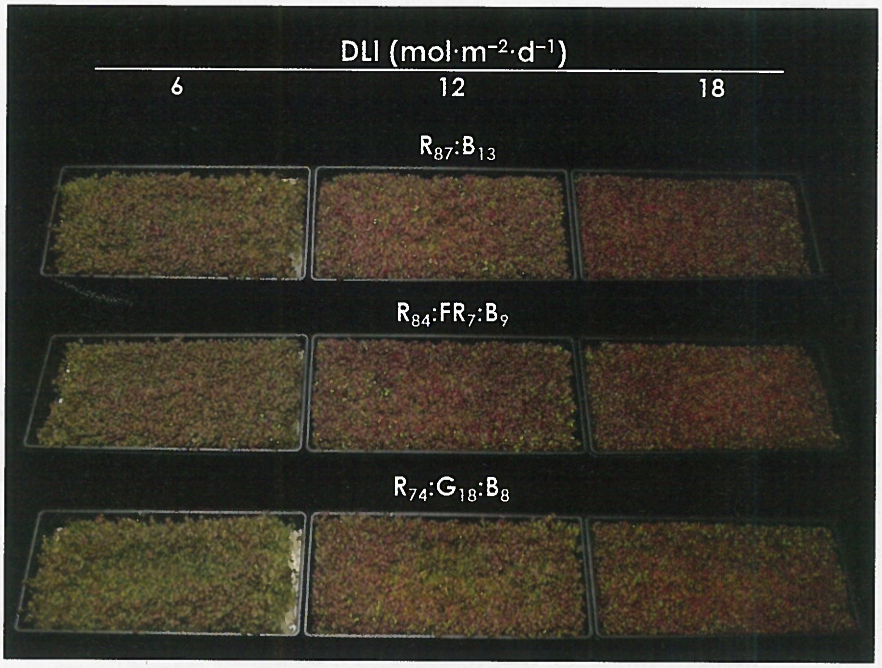

Figure 5. **Mustard microgreens placed under daily light integrals (DLIs) of 6, 12 or 18 $mol \cdot m^{-2} \cdot d^{-1}$ delivered from sole-source (SS) light-emitting diodes (LEDs) with light ratios (%) of red:green:blue 74:18:8 (R_{74}:G_{18}:B_8), red:blue 87:13 (R_{87}:B_{13}) or red:far-red:blue 84:7:9 (R_{84}:FR_7:B_9) for 14 days.**

Electrical Energy Consumption

While the production of a high quality crop is of significant importance to the vast majority of growers, it is also critical to consider the costs related to the production. For growers utilizing indoor, multi-layer vertical growing systems, electrical energy consumption ($kWh \cdot d^{-1}$) is always a primary concern. For that reason, with our study on the production of microgreens under SS lighting, we wanted to determine the energy input required by each of our LED arrays to equip growers interested in this technology with the knowledge required to make an informed decision concerning the light qualities and intensities they select.

Table 1. **Energy consumption (kWh·d^{-1}) of sole-source (SS) light-emitting diodes (LEDs) with light ratios (%) of red:green:blue 74:18:8 (R_{74}:G_{18}:B_8), red:blue 87:13 (R_{87}:B_{13}) or red:far-red:blue 84:7:9 (R_{84}:FR_7:B_9) providing a daily light integral (DLI) of 6, 12 or 18 mol·m^{-2}·d^{-1} and a 16-hour photoperiod to a growing area of 0.75 m^2.**

Light quality (%)	Daily light integral (mol·m^{-2}·d^{-1})		
	6	12	18
	kWh·d^{-1}		
R_{74}:G_{18}:B_8	1.02 ± 0.04	2.04 ± 0.08	3.06 ± 0.12
R_{87}:B_{13}	1.03 ± 0.02	2.06 ± 0.03	3.10 ± 0.05
R_{84}:FR_7:B_9	1.03 ± 0.04	2.06 ± 0.07	3.09 ± 0.11

Regardless of which LED array was used, the electrical energy consumption was nearly identical across the various light ratios (Table 1). Where we did find significant differences was in the DLIs selected. Specifically, we found that the electrical energy consumed at a DLI set point of 6 mol·m^{-2}·d^{-1} increased ≈100 percent or 200 percent as the DLI increased to 12 or 18 mol·m^{-2}·d^{-1}, respectively.

In terms of energy costs, a grower may be paying two to three times more in energy costs to produce microgreens under these higher DLIs. Overall, it is important to carefully consider the added value these higher DLIs provide the microgreens and determine whether the benefits warrant the increased electrical energy consumption.

Grower Recommendations

Guidelines for what constitutes a high-quality microgreen are limited at this point and may vary based on the specific market. Therefore, it is important for a microgreens producer to evaluate their costs, current market demand and price per pound to make decisions related to SS lighting that will increase their profitability. The results displayed in this article will hopefully assist growers in the selection of their lighting parameters as they evaluate their own operations and the potential for SS lighting applications. **GG**

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