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Researchers at Michigan State University have used the Controlled-Environment Lighting Laboratory to study the effects of different colors of light on the growth of leafy greens. Photo courtesy of Erik Runkle, Mich. St. Univ.

What Impact Does Light Have On Controlled Environment Leafy Greens Production?

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By David Kuack, UrbanAgNews.Com

OptimIA researchers are studying the impact light and its interaction with other environmental parameters can have on indoor leafy greens production.

When members of the OptimIA project contacted controlled environment agriculture industry members about their concerns about the growing environment, light was at the top of the list. The OptimIA's project objectives were based on feedback from indoor farm representatives, growers and lighting manufacturers related to the production of food crops.

"Lighting is one of the biggest costs not only for purchasing the fixtures, but also for operating them," said Erik Runkle, horticulture professor at Michigan State University and director of the OptimIA project. "Operating lighting fixtures is a big sink of electricity and therefore a major operating cost. Another large operational cost for indoor farms is air conditioning, but typically it is not as big as lighting.

"Looking at some of the other environmental control issues that indoor farms have had in the past, excessively high humidity was caused by inadequate HVAC systems. Humidity and temperature are tightly linked because temperature influences how much moisture the air can hold. We thought if we study humidity we should also study temperature. Temperature dictates the rate of development of plants."

Runkle said carbon dioxide gets added to the environmental mix when looking at light intensity.

"The benefit of carbon dioxide increases as light delivered to plants increases," he said. "Early on when we started this project we were delivering, what is considered by today's standards, relatively low light intensities, so the value of adding supplemental carbon dioxide was minimal.

"Indoor farms are increasingly delivering higher light intensities, in which case carbon dioxide becomes more important. We knew that carbon dioxide is one of the factors to consider with indoor farms, but it was not considered one of the top factors like light, temperature and relative humidity."

Divvying up the research projects

Prior to receiving $2.4 million in USDA funding in September 2019 for the OptimIA project, Runkle had started the Controlled-Environment Lighting Laboratory at Michigan State.

"The lab is a unique facility that has capabilities that few other researchers at the time had," he said. "Having access to the lab, it made sense for me to focus on light quality or the different colors of light and how they affect growth. A lot of what each team member focused their project research on was imposed by their expertise in the topic and whether they had the facilities to conduct the research.

"Developing these research facilities is quite expensive, and usually with these types of research proposals, large equipment budgets are not favorably reviewed. OptimIA team members thought rather than requesting a large equipment budget, we would determine who had the equipment and facilities to do lighting studies. Also, we looked at who had past research expertise so it just made sense for them to perform the various environmental studies."

Light was the single environmental factor that the OptimIA researchers keyed in on. Every member of the OptimIA team, other than its ag economists, has done some type of light manipulation research.

Growth chambers at Michigan State University have been used to study the interaction of light, relative humidity, temperature and carbon dioxide on different lettuce cultivars. Photo courtesy of Roberto Lopez, Mich. St. Univ.

Studying different aspects of light

The three major areas of light study were: 1. light intensity or the brightness of the light; 2. the different colors of light, primarily blue light, far-red light and ultraviolet (UV) light, and 3. the uniformity of light, which is often an overlooked dimension of light.

"The brightness, the colors and how many hours light fixtures are operated per day are usually the focus of light research," Runkle said. "Light distribution uniformity is often overlooked, but we have seen that uniformity can be an issue in indoor farms.

"For OptimIA researcher Cary Mitchell at Purdue University one of the focal points of his research is the positioning of light fixtures trying to reduce the amount of light that spills into areas where there are no plants. There is light that reaches the target within a crop, but there is also light that spreads out beyond where the plants are located. This is light that is wasted because it doesn't reach the plants. Trying to deliver as much light from the fixtures to the plants can improve efficiency because the light is reaching the plants and is not wasted."

The relationship between environmental parameters

OptimIA researcher Roberto Lopez, associate horticulture professor at Michigan State, is studying the interaction of light, temperature and carbon dioxide on leafy greens production.

"Previous research between these environmental parameters had been done in greenhouses," Lopez said. "We are using walk-in growth chambers to provide more control over the light environment. Unlike in a greenhouse, there isn't any sunlight in indoor farms that can impact the results.

"We wanted to see how carbon dioxide and temperature interact with light. Light and temperature studies can be done in a greenhouse, but carbon dioxide studies are going to be challenging. Being able to do the studies indoors makes it more feasible."

Prior to the start of his OptimIA studies, Lopez was using dimmable white light LEDs in the growth chambers.

"Signify provided us with dimmable LED light fixtures which allow us to manipulate the spectrum," he said. "With the new fixtures we not only can deliver white light, but we can change the spectrum whenever we need to during the growth cycle.

"In some of our later studies we have been looking at manipulating the color of the foliage with the spectrum. This allows us to start growing the plants under white light and towards the end of the production cycle we can change the light spectrum to potentially manipulate the color of the foliage or increase the amount of anthocyanin and other nutritional compounds."

Impact of light intensity

Lopez said the impact of light intensity on lettuce production appears to be cultivar dependent.

"With some lettuce cultivars we found 150 micromoles of light is sufficient and with others we had to increase the light level to 300 micromoles to achieve an increase in yield," he said. "With other cultivars we found by doubling the amount of light there isn't an economic benefit to increase the light intensity. It wasn't worth increasing the light intensity in terms of the yield that we were able to achieve, at least when based on our economic assumptions."

Lopez said some indoor farm growers of leafy greens are increasing light intensity levels to 600 micromoles.

"Is that light level necessary? In our opinion—no," he said. "It doesn't make sense because at some point the plants become saturated with light and the growers are wasting money. The plants may not be utilizing the light if the other environmental parameters are not adjusted accordingly.

And economically it doesn't make sense. To achieve these light levels requires more lighting fixtures and there are increased electrical costs."

Having the ability to change the light spectrum during the production cycle could allow growers to manipulate the color of leafy greens foliage or increase the amount of nutritional compounds in the plants. Photo courtesy of Roberto Lopez, Mich. St. Univ.

Impact of light color

Results of OptimIA studies have confirmed the importance of blue light on plant growth.

"Blue light has a strong effect on inhibiting leaf size, which means plants are smaller compared to plants grown under lower intensities of blue light," Runkle said. "Blue light also controls the coloration of leaves as well as other quality attributes, including the nutrient density and perhaps taste.

"OptimIA researchers weren't the only ones to discover the effects of blue light, but we are building upon other blue light research to learn how important it is and what different intensities of blue light do to leafy greens crops."

Runkle said the light spectrum or the color of the light is more important in indoor farms than in greenhouses.

"In a greenhouse there is sunlight and the ability to change the spectrum is influenced by how much sunlight is entering the greenhouse," he said. "During winter when supplemental lighting is used the most in greenhouses, is when lighting is most valuable and the ability for the spectrum to influence plant growth is also the greatest. Because blue light has such a strong effect on the shape of plants, the percentage of blue light chosen for an indoor farm can be a much bigger decision than the percentage of blue light in a greenhouse."

Runkle said the verdict is still out on whether or not far-red light is necessary in indoor farms.

"Far-red light is similar to blue light and how much light should be given to plants," he said. "Blue light and far-red light act antagonistically. Far-red light increases leaf expansion, which often leads to more growth because the plants can intercept more light. This growth increase is somewhat countered by a decrease in the quality. Plants exposed to far-red light typically produce leaves that are lighter green in color or the leaf texture is affected, including thinner leaves and leaves that are not as crisp or firm.

"Applying far-red light can lead to tradeoffs between maximizing biomass and plant quality. There are usually tradeoffs between the harvestable index or what can be harvested and the quality of that harvest."

Verdict still out on UV light

There has not been a lot of research done with UV light in the indoor production of leafy greens.

"There are various reasons research with UV light hasn't been done," Runkle said. "LEDs that deliver UV light are not very efficient and they typically don't have a very long life span.

"We have done a few studies looking at the efficacy of using UV-A light compared to blue light. We found that blue light and UV-A light are similarly effective in terms of plant responses. But blue light is a lot cheaper to deliver. Blue light LEDs are cheaper and last a lot longer. If the same response can be achieved with blue light LEDs than UV-A LEDs, then at least in our research we haven't seen any reason to include UV-A light."

Relationship between light and carbon dioxide

Ambient carbon dioxide level is about 400 parts per million (ppm). Lopez did studies with lettuce supplementing plants with 400, 800 and 1,200 ppm.

"Going from 400 ppm to 800 ppm there was an increase in yield," he said. "Going above 800 ppm there wasn't much of an appreciable increase. There is definitely a limit and beyond 800 ppm, there wasn't any economic benefit as well.

"Whenever any of these three environmental factors are limiting, a grower could provide optimal light levels and the optimal temperature, but if carbon dioxide is limiting, then ultimately photosynthesis is limited, which impacts crop yields. It's important to measure, monitor and control all three parameters. In a greenhouse it is challenging to do this. With an indoor farm it is possible to have much more control of these environmental parameters."

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