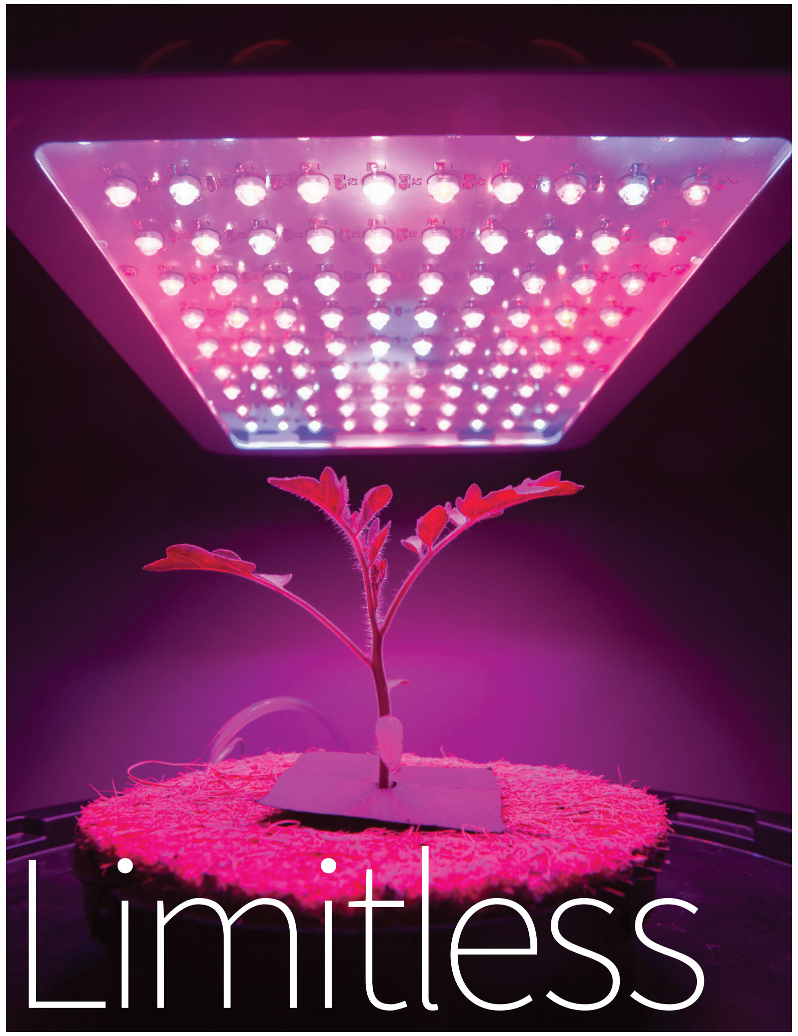

Limitless

From designer plants to genetic engineering, LEDs show infinite possibilities in agricultural applications

BY LEONORA DESAR

It's a wide-known fact that LEDs have long since crossed the threshold from technological wunderkind to mainstream staple. We see them everywhere—in commercial settings and classrooms, in offices and homes—even in your old-fashioned aunt's upgraded bathroom. Now you can also find them in agriculture. From cutting-edge vertical farms to poultry and swine production, the industry is getting hip to how LEDs can advance science—as well as benefit the bottom line. Indeed, according to a forecast by Research and Markets, the LED grow light market is expected to rise to more than $1.9 billion by 2020.

"LEDs inherently emit a narrow-band spectrum," says Mark Rea, director of the Lighting Research Center (LRC) at Rensselaer. With fluorescent or high-pressure sodium lamps, you get the whole spectrum, whereas with LEDs, it's like keys on a piano. You can play whatever frequency you want, by what key you push. You can tailor your spectrum to be any shape you want."

This means that you can tune the spectrum to suit photosynthesis, helping plants to grow more quickly. "Scientists have identified that the red and blue spectrum are the most efficient for photosynthesis," says Yan Ren-Butcher, product manager for NutriLED and staff horticultural scientist. "Since LEDs can be designed using only red and blue, they're more efficient than a traditional light source like high-pressure sodium, which contains a lot of the green and yellow spectrum."

But horticulturalists can take it a step beyond photosynthesis, says Rea. By fine-tuning LEDs to a specific wavelength, you can change the actual shape or chemistry of the plant. For instance, you can use spectrum to "fool" a plant into thinking it's in sunlight or shade, altering its growth pattern. The plants in sunlight will have a squat appearance, while the plants in shade will grow to be long and stringy. "You are basically cultivating a special chemical signature for this plant that you wouldn't get by planting them in a field," Rea says. "Carving out certain regions of the spectrum gives you the ability to potentially create designer plants."

It also allows you to alter taste. Basil, for instance, may taste differently based on how it's illuminated—though not all basil responds the same. "This spectral tuning is still not completely understood," Rea says. "It's not like there's one simple solution."

Currently, the LRC is working with Dr. David Gadoury at Cornell University on mitigating powdery mildew in plants using visible and ultraviolet light. Understanding the circadian rhythm of both the pest and plant host is key, Rea says. "Rather than just using chemistry to mitigate pests, the goal is to use light, which is a non-toxic treatment. By identifying what time of day the pest is most sensitive to the light treatment, it becomes commercially viable—you don't need a lot of energy to do it."

The researchers are also looking into how LED can trick pests into thinking it's nighttime, which is when they are most vulnerable to UV treatment. "Powdery mildew has built up a resistance to ultraviolet during the daytime," Rea says, "but it is very vulnerable to it at night. The same dose of UV that would have a marginal effect in the daytime can now eradicate the pest entirely."

INDOOR REVOLUTION

These days, LEDs are seeing a lot of action in vertical farms. In an indoor vertical farm, one has total control of the environment, and plants are stacked in layers to maximize space. "The whole idea is that you're close to your markets," Rea says, "and you don't have to ship [products or plants] as far. People have made the case that it's more sustainable to do it this way, because the plants are grown right next to the grocery store."

After the tsunami in Japan damaged agricultural output, the Japanese government worked with GE and the indoor farming company Mirai, Inc. to turn a former Sony factory into a 25,000-sq ft indoor farm. Using 17,000 LED fixtures, the farm began producing 10,000 heads of lettuce a day using only 1 percent of the amount of water used in a traditional farm, and in 1 percent of the square footage.

LEDs can benefit vertical farming far more than traditional light sources, says Robert Spivock, Technology Manager at Current powered by GE. "LEDs are really enabling vertical farms to exist. Compared to traditional lighting technology like fluorescent and HPS, LED not only brings energy savings needed to get a payback, it also optimizes floor space for an indoor farm. Traditional sources of light radiate and conduct heat, which can lead to searing and damage of the plants. LEDs do not put out the same heat, and can be moved closer to the plants. This translates to more racks and higher density of crops needed to take advantage of costly square footage in dense urban environments."

Growth Spurt

LEDs are no longer just for illumination.
They can also help:

- ✓ Make chickens male or female
- ✓ Alter the taste, shape and chemistry of plants
- ✓ Trigger animal behavior—from feeding and locomotion to reproduction and sleep

LEDs also don't have restrike time, adds Jim Brodrick, solid-state lighting technology manager at the U.S. Department of Energy. "You can turn them on and off in a matter of nanoseconds, unlike HIDs, which are low-pressure plasma. If the light goes off, you have to let the plasma cool down, and then you restrike. LEDs are also small. You have more flexibility where you locate them on these growing racks."

Though some indoor farmers still use traditional lighting technology, Spivock predicts that LEDs are the wave of the future. "What we're doing indoors is reproducing what happens outdoors," Spivock says. "We want to make sure that we give the plants the wavelengths that they need to grow. LEDs are able to target wavelengths, allowing further energy savings."

POULTRY 4.0

Plants are not the only lifeform affected by spectral wavelengths of light. LEDs are now being used to trigger biological responses in animals, such as feeding, sleep, reproduction and locomotion. "At first you have to understand how animals perceive color and what biological responses are controlled by it, and then you can mimic it with animal-centric lighting," says Zdenko Grajcar, CEO at Once Inc, a company specializing in photobiology and optogenetics. "We

LIGHTING FOR AGRICULTURE

An indoor vertical farm in Japan uses LEDs from Current, powered by GE, to grow 10,000 heads of lettuce per day.

Photos: GE

can make them calmer, we can lower stress hormones, and we do this we do this by customizing the lighting to what each animal needs." Deep red illumination, for instance, stimulates sexual and reproductive activity in chickens.

Humans are also vulnerable to light stimulation, Grajcar says, but we are able to override the biological triggers with our minds. "There's a reason why certain places are called red light districts," Grajcar says. "The red light also stimulates sexual and reproductive activity in humans. But it's not a trigger—it can stimulate us but it does not compel the sexual response, whereas in animals it does. Unless the chicken is under significant environmental stress, the red light will set off reproductive activity."

LEDs are used to trigger biological responses in poultry.

Lettuce seed germination beneath NutriLED's mix of red and blue spectrum light.

Photo: Hubbell Lighting

To trigger biological responses, the spectrum also has to be specified based on the animal's age. "We developed animal-centric systems which use a mixture of UV, blue, green and red for the first 10 days of the chicken's life," Grajcar says. "But after day 10 you want to remove the red color out of the spectrum, because red stimulates locomotion in young chickens. You want those chickens to be calm. When they are calm they are consuming feed and gaining weight."

The potential of LEDs doesn't stop here, Grajcar says. LEDs not only stimulate biological processes in animals, but can be used to express or repress certain genes. In 2009, ONCE began developing a way to illuminate chicken embryos with a narrow spectrum of light, and choose whether

Where There's Smoke

Medical marijuana is now legal in 24 states, the District of Columbia and Guam, with recreational use legalized in Oregon, Alaska, Colorado, Washington and the District of Columbia. But even with this built-in niche, many manufacturers have shied away from the cannabis sector when marketing new products for agricultural lighting. One exception is Lighting Science Group.

In February, the company rolled out its VividGro line of LED grow fixtures (above), marketed specifically to "legal cannabis growers" as a more energy-efficient solution than high-pressure sodium. According to the company, one trial with the product saw a 27 percent increase in finished product yield, 47 percent less energy consumed and a 48 percent increase in conversion efficiency from electrical power to finished product.

Leonora Desar

the embryo would grow into a male or female. "The determining transcription factor of the sex gene is protein which absorbs the light, but it's only a very narrow spectrum that will be absorbed by that protein," Grajcar says. "You don't want to trigger unnecessary biological processes within that embryo, so you are literally hitting only very specific proteins or very specific genes at very specific times."

Grajcar adds that this is not playing God, and that sexual differentiation can occur in the animal kingdom regardless of an animal's chromosomal makeup. "It's happening in nature," he says. "Vertebrates employ varied strategies, both chromosomal and non-chromosomal, to determine the sex of the developing embryo. Sea turtles hatched in lower temperatures are male, while turtles hatched in higher temperatures are female. We know how it is happening, but not why."

ONCE is working on developing light-based technologies which increase the motility, or viability, of animal sperm. In agricultural pig reproduction, the sperm is taken from the boars and artificially inseminated into the sows. After semen is collected it has to be stored, where it becomes less effective in fertilizing the egg. But by treating the sperm with red spectrum light, ONCE found that they could supercharge it, if only temporarily. "The sperm becomes very active for a short period of time," Grajcar says, "and then you have to inseminate it. It's ultimately like a battery. If you put a small solar cell on the top of a flashlight you're able to recharge it."

In addition, ONCE is working on increasing metabolism in chicken eggs using red spectrum light, thereby increasing hatchability. "If that embryo is weak, the additional boost of energy from the red light can save it," Grajcar says. "It's kind of like the incubators used for early-born children." ONCE has used these technologies on millions of chicken embryos. They are currently in commercial trials.

SCIENCE DRIVES CHANGE

What else does the future of LEDs hold? Rea predicts that as science and technology become more sophisticated, manufacturers may use lighting to customize cannabis, so that you have the medicinal benefits without the hallucinogenic effects. Japanese studies have also found that if you counter-phase the frequency of blue and red light, plants don't grow as well as they would beneath coordinated frequencies. This may have implications for killing weeds, Rea says, though right now it's still a research question.

"There are so many more degrees of freedom now with solid-state lighting that we didn't have before" Rea says. "With this technology we can ask scientific questions that would have been difficult or impossible to ask 10 years ago." ☐