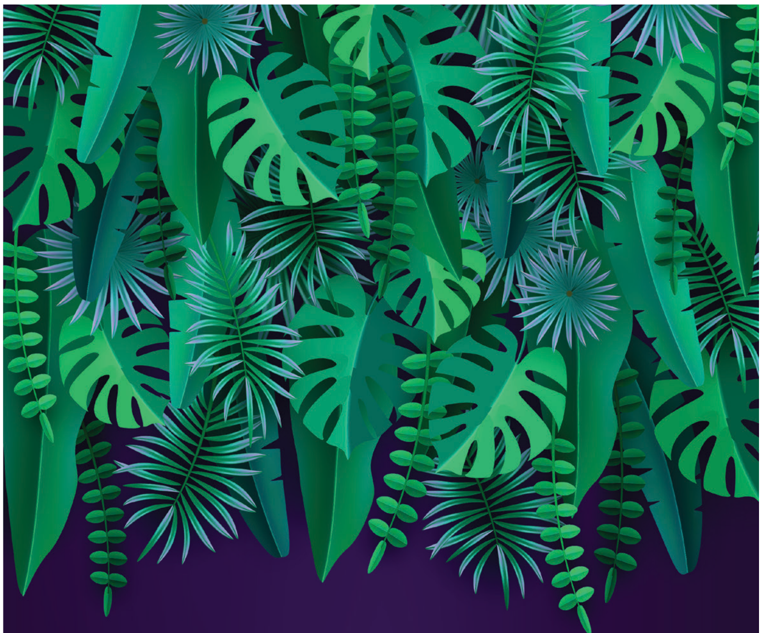


SOWING THE SEEDS OF SUSTAINABLE FOOD AND AGRICULTURE

From mildew control to insect dosing, research at the LRC is aggressively pursuing improvements in horticultural lighting

By Leora Radetsky, Ziggy Majumdar, Jaimin Patel and Rebekah Mullaney

Growers, lighting experts and researchers are actively working to sculpt the growth, shape, size, color and chemistry of crops and ornamentals. And for good reason: plants are photosynthetic, using light not only as fuel to grow but as a time-giver and modulator of chemical production. Much has been done and still remains to be understood regarding indoor agriculture, particularly for multi-wavelength interactions and the coupling of other environmental cues. Perhaps less advertised, is how to use light to combat pests and plant pathogens and even when to use light at night.

At the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute, we aim to apply our skills across the entire value chain: from seed to table, in controlled environments and in the field, day and night. Our goal is to use the science and technology of light to address multiple aspects of this major global challenge: how to feed more people with fewer resources, while reducing negative impacts on the environment, climate and health.

Interior horticultural environments need good quality lighting to support healthy growth, yet growers typically lack the knowledge and skills to select and design lighting and controls for these spaces. Lighting professionals already have the skills and knowledge to address lighting for a range of interior spaces, yet may require additional science-based information (spectrum, timing, duration, amount and distribution) to apply their skills to support plant growth and health. The Nuckolls Fund for Lighting Education recently awarded the LRC a two-year grant to create a graduate course in lighting for plants, and this course will also inform professional education offerings. This will enable the LRC to expand its legacy of education by building new curricula focused on plant growth and health. Collaborators include plant pathologists Dr. David Gadoury at Cornell University and Dr. Natalia Peres at the University of Florida, and Dr. Erik Runkle, a horticulture professor at Michigan State University.

How did the LRC get here? Five years ago, Drs. Mark Rea and Mariana Figueiro (former and present LRC Directors, respectively), began collaborating with Dr. Gadoury, using ultraviolet light (UV-B and UV-C) to control an aggressive plant disease known as powdery mildew that targets many important food crops. Early studies had indicated that high doses of UV light could suppress plant pathogens (Gadoury et al. 1992), but also damaged plants. A breakthrough occurred when collaborators at Norway's University of Life Sciences (Suthaparan et al. 2012) discovered that the UV dose could be drastically reduced if applied at night, which was the key to using UV at doses that did not cause plant damage, but were remarkably effective against pathogens and even certain insect pests.

Germicidal UV-C directly damages the pathogen's DNA and provides lethality with high efficacy when the pathogen is exposed. But pathogens have a natural defense mechanism at the cellular level that is recharged by blue light. During the daytime, there is always plenty of blue light, and the pathogen repairs the DNA damage (photoreactivation), rendering daytime UV applications ineffective unless the dose is very high. But at night, the DNA repair process is not active. By using UV at night, with at least four hours of darkness following treatment, far lower doses of UV-C are required, enabling a practical dose to reduce disease severity while minimizing host damage.

We found that "precision light dosing," which accurately measures and applies a specific spectrum, timing and dose of light, can be a powerful agent to combat plant disease—in this case, outperform ing a chemical pesticide. It also helped re-define "light" to include wavelengths outside of the visible spectrum. What follows is a look at several "precision light dosing applications":

- **"The Dragon."** The UV-solution works well in controlled environments and in the field. In a greenhouse application, UV-B luminaires can be energized for only a few minutes at night, five nights per week, to control powdery mildew. The LRC, together with collaborators at the University of Florida and Cornell, through a USDA Organic Agriculture Research and Extension Initiative (OREI) grant, developed a tractor-pulled UV-dosing machine called "The Dragon." This technology has been used for three growing seasons at the University of Florida to control powdery mildew on strawberries, and is as effective as the best available fungicides (Onofre et al. 2018).

  Building on this success, we recently secured funding from USDA's Crop Protection and Pest Management (CPPM) program, the New York Farm Viability Institute (NYFVI) and USDA's Sustainable Agriculture Research & Education (SARE) program to develop cost-effective "dragon" designs for strawberry powdery mildew in Florida and California, summer squash powdery mildew in New York, and cucumber downy mildew in Massachusetts and New York. For each project, we work closely with producers to adapt to their farm equipment and fields and teach safe operating procedures. The goal of each project is to enlighten, educate and enable farmers to use open-source specifications and build their own "dragons" in commercial field applications. Life-cycle costs and UV efficacy compared to conventional fungicides are being tracked for each project.

Photo: Lighting Research Center

"The Dragon" employs UV light to control strawberry powdery mildew in field applications and has been shown to be as effective as the best available fungicides.

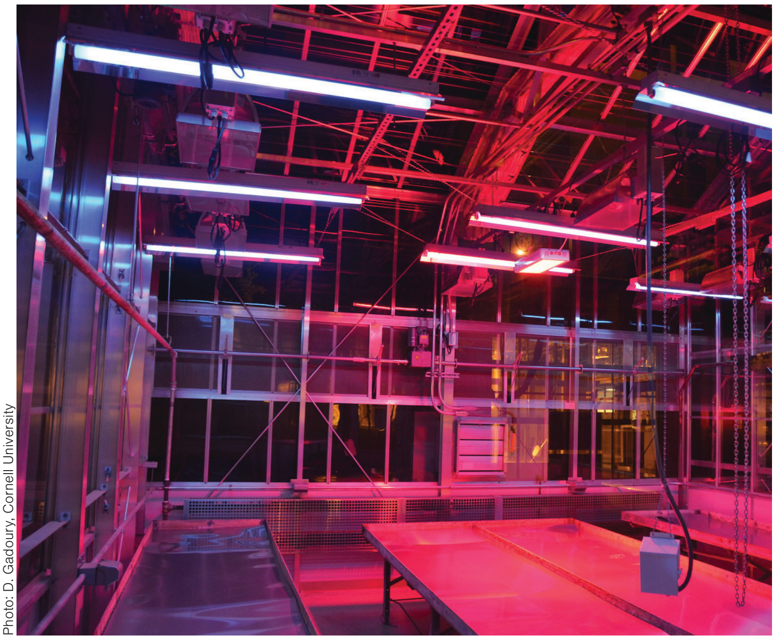


Photo: D. Gadoury, Cornell University

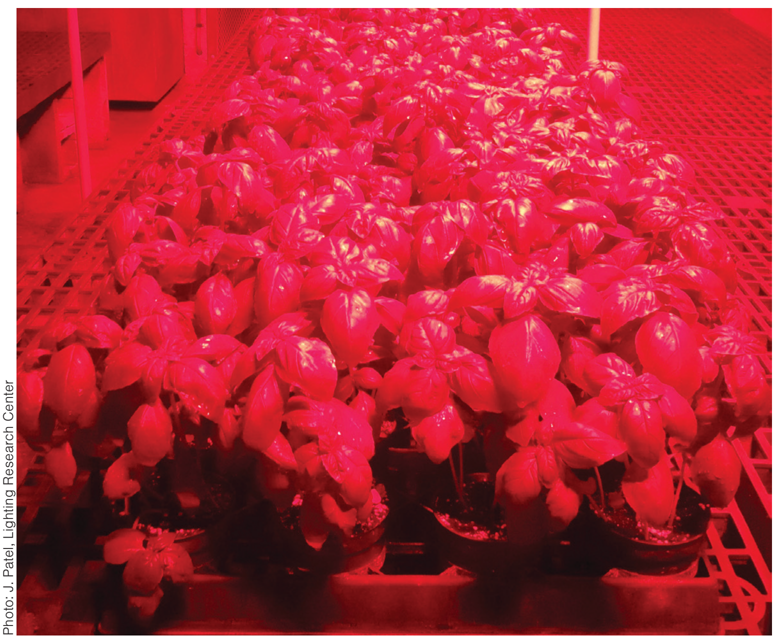


Photo: J. Patel, Lighting Research Center

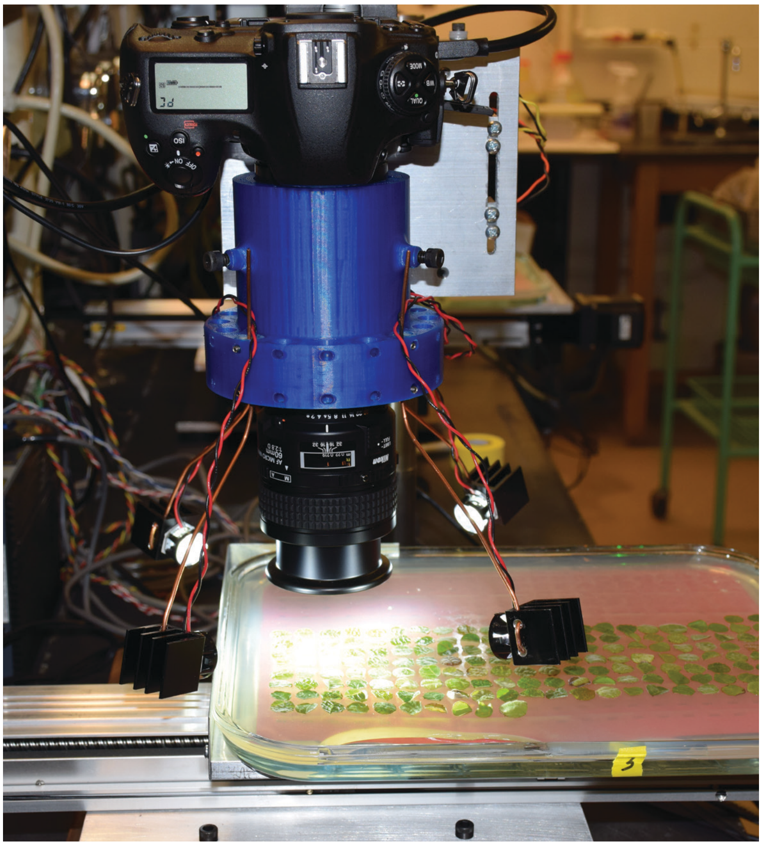
- **Red Light for Pathogens.** Red light at night can be used to control basil downy mildew, a particularly aggressive disease that is widespread and difficult to control (Patel et al. 2016). We are currently advancing this research, here at the LRC, developing a 24-hour lighting scheme for controlled environments, where lighting, controls and sensors are implemented to diagnose and treat pathogens and pests. Notably, light can be given after infection has occurred, so prescriptive chemical treatments could be reduced. One of our most recent studies found that red light at night can not only reduce pathogens, but will also increase yield (Patel et al. 2018).

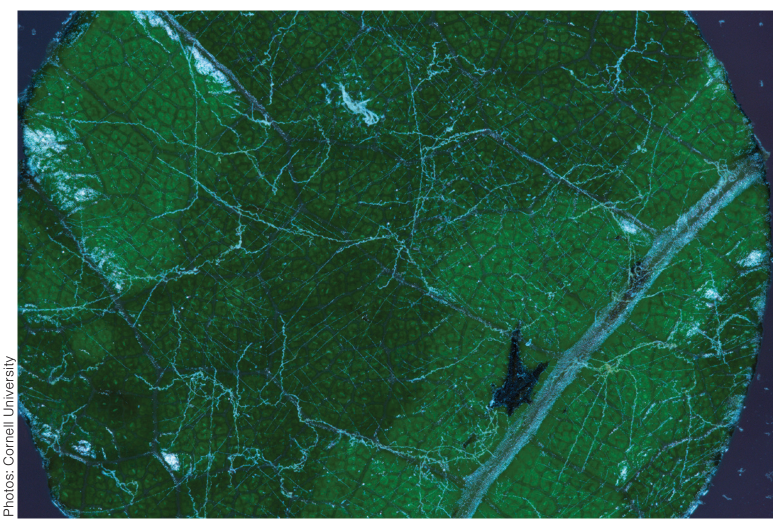
- **Pest Management.** We are also investigating spectra that can build resistance to certain pests, and pursuing pest management strategies in other crops such as beets, apples, grapes and ornamentals. The LRC has been sponsored by the American Floral Endowment to investigate a lethal UV dose for managing tiny insects called thrips, in collaboration with researchers at the University of Vermont. Given that many biological mechanisms are at play in plant, pest and beneficial organisms, we see many opportunities for new and innovative precision light dosing solutions.

Other emerging themes in agriculture include "precision agriculture," "digital agriculture," and "high-throughput phenotyping" that make use of advanced sensors and algorithms. Together with Dr. Lance Cadle-Davidson at USDA-ARS and Dr. Gadoury at Cornell, LRC researchers developed a neural network machine vision system to accurately identify grape leaf samples for powdery mildew resistance, resulting in a greatly accelerated and automated procedure compared to traditional human evaluation (Lighting Research Center 2018). The system will help researchers develop grapes that are more resistant to powdery mildew, the most devastating disease for vineyards. We are now building on this with reflectance and fluorescence spectroscopy for early detection of plant disease. Our goal is not only to develop better tools for researchers, but to offer practical solutions for end users in the field, such as growers, crop consultants and extension agents.

Finally, apart from producing better food, there are energy benefits. Considering that the U.S. food system as a whole consumes about 15% of U.S. energy annually (Center for Sustainable Systems 2018), it is a looming problem. If we could show the path for improving the efficiency by 1% or more in any part of the food chain, it would translate to significant impact. The opportunities that we see for making such an impact include expanding the use of light to address more pests for more crops and tackle issues of spoilage, storage and cold-chain requirements, as well as efficient design strategies for crop growth with integrated pest management. This autumn, we will be dedicating one "pillar" of our annual research conference, as

Red light can be used to control basil downy mildew and increase yield when applied during the night in indoor controlled environments such as greenhouses and vertical farms.





Photos: Cornell University

well as follow-on activities to these issues. This "deep dive" will help to identify more specific gaps and how we can address them. We are seeking like-minded collaborators and key partnerships to help drive this vision forward and overcome challenges of scalability and adoption. Stay tuned and be in touch. ◎

The neural network machine vision system can accurately identify grape leaf samples for powdery mildew resistance. Bottom: A grape leaf image captured by the new system.

STAKEHOLDERS AND SPONSORS

At the LRC, industry alliances are formed to fund pilot studies and to translate research results into practice. We have recently formed an industry alliance called the Illumination for Plant Health (IPH) Alliance, with Cree and OSRAM as founding members. Through IPH, we aim to develop sustainable disease management solutions using lighting, apply the research results in practice, and educate stakeholders on the use of light to control plant diseases.

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