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Research moves LEDs from the theatre stage to the greenhouse

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The difference in size between plants grown under LEDs (left) and those grown under traditional lights is noticeable. Credit: Penn State Department of Public Information

(Phys.org)—It's a rare event when one technological breakthrough can have far-reaching effects in fields as diverse as stage lighting, horticulture, entomology, energy management, and potentially, space colonization. Penn State researchers from theatre arts and horticulture have collaborated with the Office of Physical Plant (OPP) to fine-tune lighting for improved plant growth and energy conservation in greenhouses.

Light-emitting diodes (LEDs) have been used for years because of their energy-efficient properties and theatre arts professionals are well aware of the lighting sources' ability to enhance drama on stage. But now a research grant, secured in 2010, is helping to show how the same lights can have a multi-pronged benefit in greenhouses.

As an undergraduate majoring in theatre production, Daniel Frechen noticed how easy it was to create realistic sunrises and sunsets using the extreme control flexibility of LEDs. Frechen has an agricultural background, and while finishing a minor in horticulture, he began to wonder if blue- and red-wavelength LEDs could benefit greenhouses and plant growth chambers. Frechen's initial Summer Discovery Grant to explore this potential led to a more comprehensive Sustainability Seed Grant, a program administered by Penn State Institutes of Energy and the Environment (PSIEE) in a partnership with Outreach, OPP, the College of Arts and Architecture and the College of Agricultural Sciences.

This sustainability grant brought together William Kenyon, associate professor of lighting design; Robert Berghage, associate professor of horticulture; Blair Malcom, electrical engineer from OPP; and Frechen, now a master of agriculture candidate. With Kenyon as lead investigator, the team explored how LED technology could reduce energy consumption in plant growth chambers, which could lead to its use in greenhouses and plant-growth rooms.

Traditional growth chambers use power-hungry fluorescent and incandescent lighting or high-pressure sodium and metal-halide. Bulbs often have to be replaced yearly at a high cost. The excess heat from these less-efficient sources has to be removed from the chamber by built-in compressors, and research data was often lost if this equipment turned off for even an hour. Industrial light sources for growth chambers are pretty standardized, and this study examined a totally new approach.

The experimental protocol was straightforward. The team retrofitted a growth chamber with LED lighting and ran growth tests with a second "stock" chamber as a control. All aspects of the chamber performance were evaluated, including electricity, heat, cooling, watering, humidity, maintenance and plant growth. The team anticipated and found great potential savings for both Penn State operations and research. LEDs not only provided substantial lighting savings but also reduced the need for compressor cooling, associated maintenance and watering. Since the chamber lighting runs cooler, there is less evaporation and less stress on the plants. LEDs also will last five to 10 years and need far fewer replacements than the old high-intensity fluorescent and incandescent bulbs.

Even though plants evolved in full sunlight, they don't actually utilize all the wavelengths that sunlight provides. Depending on the plant species, they like blue, medium-red and far-red wavelengths. LEDs can focus the spectrum energy and intensity where it is most beneficial to plant growth. Conventional lighting provides a full spectrum and generates a lot of excess heat, especially in a small growth chamber. Since LEDs can supply only the wavelengths needed, the excess heat is minimized. Additionally, LEDs are ideal for research purposes because each wavelength can be controlled independently.

Beth Johnson, a doctoral candidate in entomology, said, "LED lighting can be a powerful resource to plant biologists due to the manipulability of the spectrum." Her research is focusing on insect/plant chemical interactions. Currently she is growing tomato and squash plants under LEDs and intends to manipulate the red to far-red light ratio to see how that influences a parasites' ability to find a host. There is anecdotal evidence that the Dodder (Cuscuta), a genus of about 100 to 170 species of yellow, orange or red (rarely green) parasitic plants, is more effective at locating and attaching to a host under far-red light. The parasite originated in South America, but is now found globally and is attacking tomato and pepper plants across the United States. The LED growth chambers will allow precise testing of these observations and experimentally test these questions.

Malcom, who represented OPP throughout the study said, "The interesting thing is that the theatre faculty have experience with the control side and know how to select the different spectra using theatre lighting controls. It's exciting to bring research expertise from the two colleges (College of Agricultural Sciences and the College of Arts and Architecture) together, while conserving energy at the same time."

Tom Richard, PSIEE director, put it this way, "In this complex world, there is a need to understand the way science is done, not just within disciplines but between and among disciplines. Such interdisciplinary thinking can inspire novel, high-impact solutions, as this LED project elegantly demonstrates."

LED technology is rapidly evolving and refining. It is in fact, 90 percent more efficient than normal incandescent light-bulb technology, and Penn State first installed LEDs in the 5,700 exit signs on campus almost 15 years ago. That project cost OPP $70,000 to implement and paid for itself through energy savings in less than one year. Since then LEDs have been widely installed to reduce energy costs across campus. These cost-effective lights can now be found in campus elevators, scoreboards and major classrooms. LED street lighting continued on Curtin and Burrowes roads this summer and will spread to parking decks this winter. This is part of the Penn State Environmental Strategy that has reduced campus greenhouse gas emissions by 17.5 percent during the past five years. In this same time period, University Park building space grew by 1.1 million square feet.

The ability to provide stable growth-chamber environments and new avenues of research while reducing energy costs is welcomed by researchers. Prices for LEDs are dropping while output and quality are increasing. These savings can be implemented soon at University Park as a planned relocation of campus greenhouses is on the schedule. The technical cross-pollination between theatre arts, plant science and OPP may not be as serendipitous as it sounds. At Penn State, the academic/operations partnership adds to the existing cross-disciplinary approaches to find new answers to old paradigms.

There is one last future benefit of energy-efficient LED greenhouses. The 1972 film "Silent Running" predicted that in the future, giant greenhouse-like geodesic domes would be placed in orbit as a kind of super arboretum. That was fiction, but NASA is already researching LED greenhouses to provide vegetables for hungry astronauts. Some day, Martian colonists may sit down to eat a "Penn State Salad" grown by the same technology that is being tested today.

LED lighting benefits for greenhouses and growth chambers include: 70-percent energy reduction compared to traditional lighting;

- Stable chamber temperature and humidity;
- Spectrum control of blue, red and far-red wavelengths;
- Healthier plants and reduced need for herbicides;
- Less heat stress on plants;
- Reduced heat and less compressor maintenance;
- Reduced watering; and
- Increased food production through the control of light frequencies.

Provided by Pennsylvania State University

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