Developing LED Lighting Technologies and Practices for Greenhouse Crop Production

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ORBITEC’s BioProduction Systems Division

Light Source Development
- Patented LED lighting systems for biological and marine habitats
- Vehicle lighting
- Supplemental greenhouse lighting
- Science research

Control Systems
- Patent pending integrated lighting and environmental controls
- High efficiency driver and electronics design
- Off-grid power integration

Mechanical Design
- Thermal management
- Cooling system integration
- Functional design and analysis

Production Optimization
- Commercial lighting systems production
- Controlled Environment facility rental
- Lighting effects research

Contact: Dr. Robert Morrow  @  morrowr@orbitec.com
ORBITEC’s LED System Configurations

- Overhead panels, bars, or intracanopy configurations
- Single or multiple wavelengths
  - Violet/UV
  - Blue
  - Green
  - Red
  - Far red
  - White
- Intensities from 300 µmol/m²/s to >1800 µmol/m²/s
- Air or water cooled
- Digital or analog control options

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ORBITEC’s LED Lighting Applications

Supplemental greenhouse lighting tests

Testing of 1800 µmol m⁻²s⁻¹ LED array

Photoperiodic lighting system

LED lighting for growing plants on Space Station
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Objective
• For each type of specialty crop quantify factors of production per appropriate unit
  • Seedlings
  • Energy; heat and light
  • Water
  • Chemicals
  • Time
  • Labor
  • others?
• With conversion to LED, both in lab and in field, understand:
  • Change in factors of production
    • Includes variable and fixed costs
  • Change in value to buyer
• Hypothesis – conversion will reduce cost of production AND increase value to buyers
  • E.g. LED’s may allow better control of plant growth with reduced energy and chemicals
  • Benefits will likely vary by type of crop

Objective
• Understanding of adoption factors
  • Economic drivers and risk perception
  • Compatibility and complexity
• Analysis of existing lighting industry impact
  • LED’s represent a disruptive technology
  • Competitive response is likely
• Life cycle cost comparison
LED lighting system testing and evaluation

Goals:

• Testing of existing and prototype LED lighting systems
  ▪ Spectral output
  ▪ PAR output
  ▪ Electrical consumption
  ▪ Overall system efficiency

• Development of measurement protocols and guidelines, eventually resulting in industry standards for LED applications in horticulture

• Conducting plant growth experiments
  ▪ Photoperiod lighting
  ▪ Photosynthesis lighting

Logan Logendra
A.J. Both
LEDs for Photosynthetic Lighting of Ornamentals during Vegetative Propagation

Supplemental light quality requirement for ornamental cuttings under different background solar light integrals

Michael Ortiz, Chris Currey, and Roberto Lopez
LEDs for Photomorphogenic Lighting

End-of-day (EOD) light quality treatment for controlling morphology of ornamental seedlings

- To quantify the minimum EOD R and FR dose (intensity and duration) that influence internode elongation of ornamental seedlings.

- To determine if EOD and/or LED lighting are feasible non-chemical means to control plant height of seedlings and/or cuttings?
Using LEDs to Determine Effective Ratios of Red and Far-Red Light for Photoperiodic Lighting

Daedre Craig, Mike Olrich, Cathy Whitman & Erik Runkle
Department of Horticulture, Michigan State University
Flowering of many specialty crops, particularly floriculture crops, is influenced by the day length, or photoperiod.

Low-intensity (photoperiodic) lighting is used to create an artificial short night to promote flowering of long-day plants (e.g., petunia) and inhibit flowering of short-day plants.

Photoperiodic Lighting

- Incandescent lamps are commonly used because of their low cost, but they are energy inefficient and may not be available in the future.

Past research shows that fluorescent lamps emit a less effective spectrum.

Most petunia varieties flower earlier under a long day (short night).
Objective

- To use LEDs to quantify how the ratio of red (R) and far-red (FR) light influences flowering and plant architecture of a wide range of specialty crops.

Research in Progress

- Specialty crops are currently being grown in controlled-environment research greenhouses with 4-h night-interruption lighting emitting seven different R:FR ratios from LEDs, as well as from incandescent lamps (control).

Floriculture research greenhouses with LED treatments at Michigan State University.
LEDs in Current Experiments

- LED lamps were developed for this project by one of our industry partners (CCS, Kyoto, Japan).

- Based on the research results, LED prototypes with the prescribed R:FR will be developed and tested on a wider range of crops, in concert with university and industry partners.

![Experimental LED lamp](image)

Spectral attributes of LED treatments and incandescent lamps, with predicted phytochrome photoequilibrium (PPE).

**Table: Experimental LED lamp**

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Photons (umol·m²·s⁻¹)</th>
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<tbody>
<tr>
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<tr>
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</tbody>
</table>

**Light source and PPE:**

- Incandescent 0.64
- LED 0.89
- LED 0.85
- LED 0.80
- LED 0.72
- LED 0.63
- LED 0.46
- LED 0.16
LEDs for Photosynthetic Lighting: Supplemental light quality requirement for vegetable seedlings under different background solar light integrals (DLI)

Ricardo Hernandez and Chieri Kubota
LEDs for Photomorphogenic Lighting: End-of-day light quality treatment for controlling morphology of vegetable seedlings

(Chia and Kubota, 2010; Kubota et al., 2011)
Developing LED technology for sustainable tomato propagation and production in northern climates

Celina Gómez  Cary Mitchell
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http://leds.hrt.msu.edu