Purdue NCERA-101 Station Report for 2014-2015

Cary Mitchell

New Facilities and Equipment:

In addition to nine existing red + blue ORBITEC LED research towers that the Mitchell Lab has been using for high-wire crop supplemental lighting research, six additional custom-designed towers were received from ORBITEC in 2014 that also have far-red LED lighting capabilities. Since each waveband is independently dimmable, a wide range of blue : red : far-red ratios are now available for experimental testing. The three vertical panels of each tower also can be switched on or off independently, so in addition to substantial energy savings resulting from intracanopy supplemental lighting *per se* during bottom-up sequential on-switching, additional energy savings can result from sequential off-switching of panels during bottom-up fruit harvest and leaf pruning. The first experiments conducted with the expanded spectral array of LEDs took place during the winter-to-summer period of 2015.

Unique Plant Responses:

In winter-to-summer and summer-to-winter high-wire tomato production experiments conducted by **Celina Gomez** in 2014, supplemental lighting (SL) treatments from either overhead high-pressure sodium lamps (OH-HPS), intracanopy LED lighting (ICL-LED), or hybrid (OH-HPS + ICL-LED) lighting all stimulated metrics of fruit yield (total fruit fresh weight, number of fruits harvested, average cluster weight) relative to those of unsupplemented controls. However, there were no significant differences for those parameters among the three SL treatments. Photosystem II efficiency of reference leaves indicated no significant differences over time for plants going from winter to summer (increasing solar DLI), but did show a trend of decreasing efficiency for plants going from summer to winter (decreasing solar DLI). Light compensation point (LCP) of reference leaves was lower for control treatments than for any SL treatment during either seasonal experiment, but was not different among SL treatments. However, LCPs of summer-to-winter SL treatments all tended to be higher than those of winter-to-summer treatments, indicating a higher light environment for the reference leaves when they formed. On clear-sky days in the greenhouse during the winter-to-summer

experiment, reference leaf net photosynthetic rate (A) of controls was significantly lower than that of SL treatments including ICL-LED. A of controls also was lower than that of all SL treatments on overcast days. Exactly parallel responses occurred during the summer-to-winter experiment, but A for all treatments was much lower than for the winter-to-summer experiment. Stomatal conductance exhibited similar response trends to A for SL vs. control during both seasonal-transition experiments. A at saturating light intensity and quantum-use efficiency declined from top to middle to bottom leaf layers for all light treatments in the winter-to-summer experiment with unsupplemented controls having the lowest values. Both SL treatments including ICL-LED retained the highest efficiencies. This was particularly evident for the lowest leaf layer, which also included the oldest leaves.

A winter-to-summer high-wire tomato-production experiment was conducted in 2015 including use of the new LED towers with FR capabilities as well as R + B capabilities. A range of R/B, R/FR, and R/B/FR ratios were tested for yield as well as fruit-quality attributes. Although FR radiation does not possess significant PAR value, it does trigger photomorphogenic reponses that may indirectly affect harvest parameters via effects on leaf expansion and nutritional quality via effects on secondary metabolism.

Celina Gomez found that reference leaves in the mid-leaf layer of mature canopies receiving 25B-60R-15FR had a significantly lower stomatal index than those receiving 10B-90R. Perhaps the FR component of SL stimulated leaf expansion, thereby reducing stomatal index. On the other hand, stomatal conductance on a leaf area basis was higher for the 25B-60R-15FR treatment than for all other SL spectral treatments, including unsupplemented controls. The same treatment tended to be higher for photosynthetic rate than other treatments, especially those lacking a FR component of SL as well as for control. However, fruit yield per plant was the same for all SL spectral ratios tested, and they all were significantly higher than that of unsupplemented controls.

Michael Dzakovich investigated the incidence and specific content of various phytochemicals in tomato fruits harvested from plants supplemented with the above R/B/FR ratios. He found no differences in chromaticity, Brix (sugar concentration), titratable acidity, pH, sugar/acid ratio, lycopene, and all antioxidant compounds among spectral treatments or controls. Furthermore, there were no significant sensory differences among treatments for color, aroma, sweetness, acidity, aftertaste, texture, or overall approval according to both absolute and hedonic scales of organoleptic attributes. Both the increasing intensity of solar background as well as it's broadband spectral distribution may have canceled effects of specific SL spectra in this experiment, which is being repeated for a summer-to-winter transition in which the solar background will be ever decreasing.

Accomplishment Summary

Purdue University grew high-wire greenhouse tomato crops during different seasons of the year characterized by either increasing or decreasing daily light integrals (DLIs). Supplemental lighting (SL) from either overhead high-pressure sodium vapor lamps and/or intracanopy light-emitting diodes (LEDs) led to increases in fruit yield compared to unsupplemented controls during either seasonal transition. Physiological responses to SL related to photosynthetic productivity had no significant effect on yield. There were no significant effects of SL on flavor or nutritional attributes of harvested fruits compared to unsupplemented controls.

Impact statement

Use of narrow-spectrum LEDs in the greenhouse with different spectral distributions for intracanopy lighting had no effect on harvest or quality attributes compared to overhead supplemental lighting from high-pressure sodium (HPS) lamps, stimulated yield to the same extent as HPS. But did so with an electrical energy cost of 40-50% that of HPS.

Book Chapter

Mitchell, C., J. Burr, M. Dzakovich, C. Gomez, R. Lopez, R. Hernandez, C. Kubota, C. Currey, Q. Meng, E. Runkle, C. Bourget, R. Morrow, and A. Both. 2015. LEDs in Horticulture. Horticultural Reviews (In press).

Invited Presentations

Mitchell, C. 2014. An academic plant researcher's perspective of LEDs for the greenhouse industry. Keynote speaker for the North Carolina Greenhouse Vegetable Grower's Association 42nd annual conference, Greensboro, October 20.

Mitchell, C. 2014. A plant physiologist's approach to year-round greenhouse tomato production. Keynote speaker for the North Carolina Greenhouse Vegetable Grower's Association 42nd annual conference. Greensboro, October 20.

Mitchell, C. 2014. Leveraging renewable energy for sustainable local off-season food production. Keynote speaker for the North Carolina Greenhouse Vegetable Grower's Association 42nd annual conference. Greensboro, October 21.

Published Abstracts and contributed presentations

Dzakovich, M. and C. Mitchell. 2014. Exploring plant-UV interactions with greenhouse tomatoes: stress, flavor, and phytochemicals. ASHS annual conference, Orlando: Produce quality, safety, and health properties (Oral session, July 28, P. 59) and Growth chambers and controlled environments 1 (Oral session, July 31, P. 100): delivered two times.

Gomez, C. and C. Mitchell. 2014. Growth responses of greenhouse tomato seedlings to different spectra of supplemental lighting are season-specific in a northern climate. ASHS annual conference, Orlando: Growth chambers and controlled environments 1 (Poster session, July 28, P. 55).

Gomez, C. and C. Mitchell. 2014. Are light-emitting diodes a viable supplemental lighting alternative to grow tomatoes in a northern climate? ASHS annual conference, Orlando: Growth chambers and controlled environments 1 (Oral session, July 28, P. 100) and Growth chambers and controlled environments 2 (Oral session, July 31, P. 113): delivered two times.

Poulet, L., G. Massa, R. Morrow, M. Bourget, and C. Mitchell. 2014. Significantly reducing energy for plant-growth lighting in space using targeted LED lighting and spectral manipulation. ASGSR annual conference, Pasadena: Enabling technology I, (Oral session, October 25, delivered by C. Mitchell). Abstract available at <www.asgsr.org/2014_Abstracts>.

Massa, G. and C. Mitchell. 2014. Environmental manipulation of strawberry yield and quality for dietary enhancement in a space bioregenerative life-support system. ASGSR annual conference, Pasadena: Life support/translational (Oral session, October 26). Abstract available at <www.asgsr.org/2014_Abstracts>.

Dzakovich, C. Gomez, and C. Mitchell. 2105. Using light to manipulate the nutritional and sensory properties of greenhouse tomatoes with red, blue, and far-red supplemental LEDs. ASHS annual conference, New Orleans: Produce quality, safety, and health properties (oral session).

Morsi, A., C. Gomez, and C. Mitchell. 2015. Plant responses and water uptake of lettuce grown under different spectra of supplemental lighting. ASHS annual conference, New Orleans: Growth Chambers and Controlled Environments 3 (poster session).

Gomez, C. and C. Mitchell. 2015. The search for an optimized supplemental lighting spectrum for greenhouse tomato production. ASHS annual conference, New Orleans: Growth Chambers and Controlled Environments 3 (oral session).

Refereed Journal Articles

Gomez, C. and C. Mitchell. 2014. Supplemental lighting for greenhouse-grown tomatoes: intracanopy LED towers vs. overhead HPS lamps. 2014. Proc. IS on New Technol. for Env. Control, Energy-Saving and Crop Prod. in Greenhouse and Plant Factory-GreenSys 2013, Eds.: Jung Eek Son et al. Acta Hort. 1037, ISHS: 855-862.

Yang, Y., G.D. Massa, and C.A. Mitchell. 2014. Temperature DIP at the beginning of the photoperiod reduces plant height but not seed yield of maize grown in controlled environments. J. Industrial Crops and Products 53: 120-127.

Poulet, L., G.D. Massa, R.C. Morrow, C.M. Bourget, R.M. Wheeler, and C.A. Mitchell. 2014. Significant reduction in energy for plant-growth lighting in space using targeted LED lighting and spectral manipulation. Life Sciences in Space Research 2: 43-53.

Massa, G.D. E.S. Chase, J.B. Santini, and C.A. Mitchell. 2015. Temperature affects long-term productivity and quality attributes of day-neutral strawberry for a space life-support system. Life Sciences in Space Research 5:39-46.

Gomez, C. and C. Mitchell. 2015. Growth responses of tomato seedlings to different spectra of supplemental lighting. HortScience 50 (1): 1-7.