NCERA-101 Station Report from Georgia, 2016

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1. New Facilities and Equipment

Adaptive control of LED lights. We have designed and built a custom LED light that can be controlled based on how much light the crop receives. The principle is simple: the LED light provides just enough supplemental light to prevent the light level at the crop from dropping below a user-defined threshold. A quantum sensor measures the PPF at the crop level and a microcontroller uses the measured light level to calculate the required duty cycle of the LED light (fraction of time the LED light is on within a very short on/off cycle; Fig 1). The microcontroller can then send a signal to a pulse-width modulation control board to adjust the duty cycle. Our initial trials have shown that such an approach to lighting control can greatly reduce energy costs with little impact on growth and flowering of tuberous begonia.

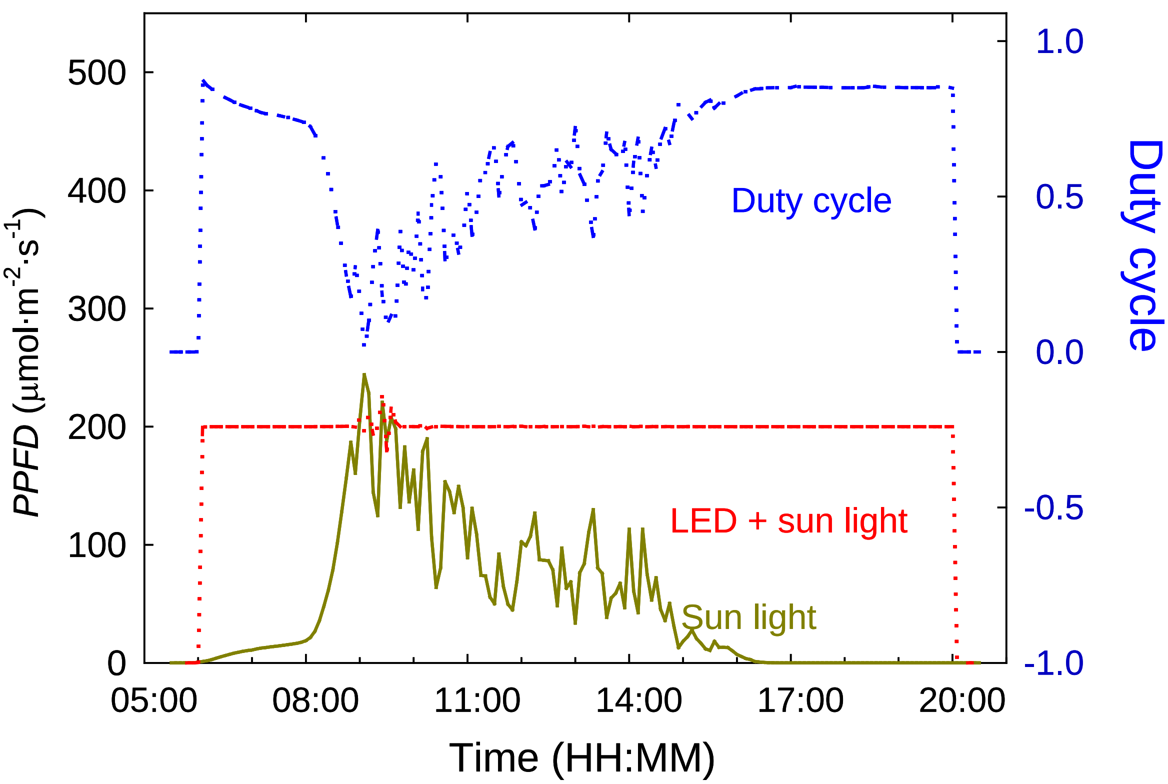

Figure 1. Illustration of the performance of the adaptive LED light. A quantum sensor measures the total amount of light (sun + LED) at the crop level. A microcontroller adjusts the duty cycle of the LED light to provide just enough supplemental light to maintain a stable light level (200 µmol·m^{-2}·s^{-1} in this example) at the top of the canopy. This results in stable light levels for the crop, despite constant changes in the amount of sunlight reaching the crop.

Indoor, controlled environment plant growth facility. Using an unused old cold room, we have constructed in indoor crop growth facility. The facility consists of three separate racks with three shelves for plants on each rack. Each shelf in turn is divided into 8 separate growing sections of 30 x 60 cm^2. The facility is outfitted with white LED lights and 48 of the 72 growing sections have far-red LED lights that can be controlled separately from the white LEDs. We plan to add separately-controlled red LEDs as well. The facility can be used to study the effects of light spectrum on plant growth and morphology.

2. Unique Plant Responses

Quantum efficiency of photosystem II is dependent on spectrum

During the past year, we have conducted research on how the quantum yield of lettuce is affected by the spectrum of the LED grow light. We have found that a mixture of red and blue light (peaks at 440 and 630 nm) is used much less efficiently by lettuce than warm white light (Fig. 4).

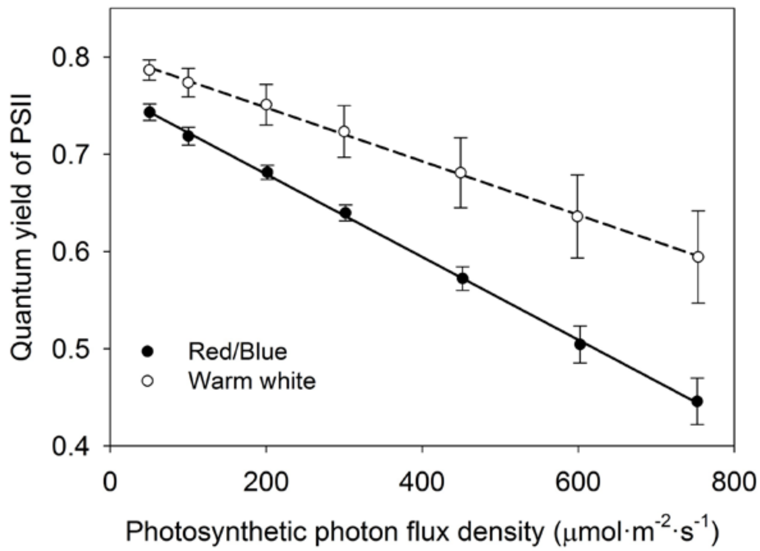

Figure 2. The effect of different levels or red/blue and white light on the quantum yield of lettuce.

The low quantum yield under red/blue light appears to be at least partly the result of a lack of far-red light: adding far-red light (peak at 730 nm) greatly increases the quantum yield of lettuce under red/blue LEDs (Fig. 3). This is consistent with Robert Emerson's work from the 1950s; he found that far-red light (700 nm) synergistically enhances the photosynthetic activity of leaves exposed to red light (670 nm). Emerson's work is mainly remembered because it led to the discovery that there are two different photosynthetic reaction centers that work together in the light reactions of photosynthesis. What is too often ignored is that his work also proves that **different wavelengths of light do NOT act independently in the light reactions of photosynthesis**.

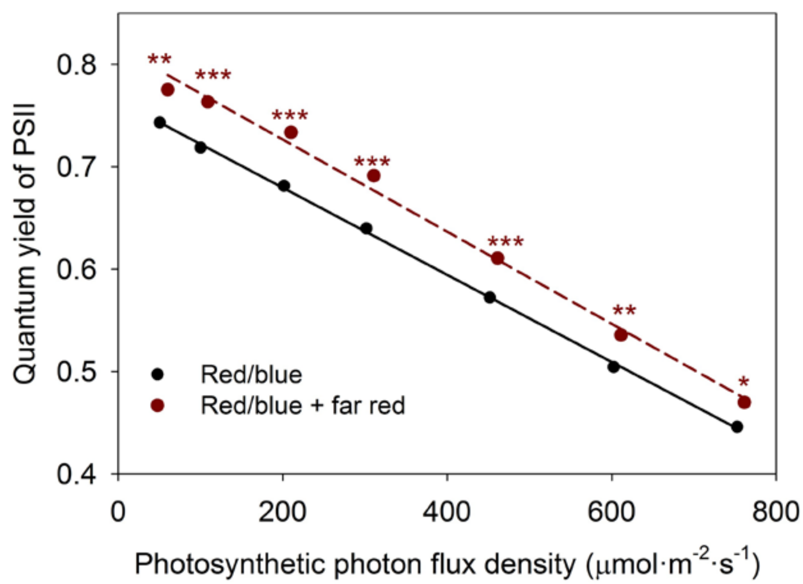

Figure 3. Adding far-red light (peak at 730 nm) to red/blue LED light increases the quantum yield.

3. Accomplishment Summaries

We have developed a control system for LED lights that automatically adapts to changing light levels, providing more light, when there is little sun light and dimming as there is more sunlight. To the best of our knowledge, this is the first lighting control system that controls LED lights based on the amount of sunlight that reaches the crop. The system has been tested with multiple crops and has shown to be greatly reduce power requirements for supplemental lighting. We expect that implementation of this technology in greenhouses will give growers better control over crop growth and will reduce electricity costs. The system also has great value for research facilities, since it can reduce experimental variability induced by varying light levels.

Our work on spectral effects on photosynthetic efficiency has clearly shown that far-red light can increase photosynthetic light use efficiency of crops that are grown with LEDs as sole-source lighting. The effects of far-red light are greater when red/blue LEDs are used than when white LEDs are used, presumably because white LEDs already provide some far-red light. These findings have important implications for the design of LED grow lights, if they are intended for use as sole-source lights. Including far-red LEDs in such light allows plants to use the provided light more efficiently.

4. Impact Statements

Electricity costs for photosynthetic lighting make plant production in controlled environments very expensive. The adaptive lighting system, developed in the Horticultural Physiology Lab at the University of Georgia, can greatly reduce energy use by automatically dimming the lights in response to increasing sun light. The technology is easy and cheap to implement and thus has a very quick return on investment.

Many commercial LED grow lights use red and blue or white light. Research in the Horticultural Physiology Lab at the University of Georgia has shown that adding far-red light allows plants to use the provided light more efficiently. Adding far-red light to red/blue or white LED grow lights that are intended to be used as sole source lighting (*i.e.* indoor production) can thus increase photosynthesis and the overall energy efficiency of controlled environment production systems.

5. Published Written Works

Refereed journal articles

Niu, F., D. Zhang, Z. Li, M. van Iersel, and P. Alem. 2015. Morphological response of eucalypts seedlings to phosphorus supply through hydroponic system. *Scientia Horticulturae* 194:295-303.

Ferrarezi, R.S., M.W. van Iersel, and R. Testezlaf. 2015. Uso da subirrigação para imposição de estresse hídrico em sistema semi-contínuo para medição de CO_2. (Use of subirrigation for

water stress imposition in a semi-continuous CO_2-exchange system). Advances in Ornamental Horticulture and Landscaping 21:235-242. (in Portuguese)

Ferrarezi, R.S., G.M. Weaver, M.W. van Iersel, and R. Testezlaf. 2015. Subirrigation: Historical overview, challenges, and future prospects. *HortTechnology* 25:262-276.

Bayer, A., J. Ruter, and M.W. van Iersel. 2015. Optimizing irrigation and fertilization of *Gardenia jasminoides* for good growth and minimal leaching. *HortScience* 50:994-1001.

Alem, P., P. A. Thomas, and M.W. van Iersel. 2015. Controlled water deficit as an alternative to plant growth retardants for regulation of poinsettia stem elongation. *HortScience* 50:565-569.

Alem, P., P.A. Thomas, and M.W. van Iersel. 2015. Substrate water content and fertilizer rate affect growth and flowering of potted petunia. *HortScience* 50:582-589.

Ferrarezi, R.S. and M.W. van Iersel. 2015. Monitoring and controlling ebb-and-flow subirrigation with soil moisture sensors. *HortScience* 50:447-453.

Alem, P., P.A. Thomas, and M.W. van Iersel. 2015. Use of controlled water deficit to regulate poinsettia stem elongation. *HortScience* 50:234-239.

Bayer, A., J. Ruter, and M.W. van Iersel. 2015. Automated irrigation control for improved growth and quality of *Gardenia jasminoides* 'Radicans' and 'August Beauty'. *HortScience* 50:78-84.

Ferrarezi, R.S., S.K. Dove, and M.W. van Iersel. 2015. An automated system for monitoring soil moisture and controlling irrigation using low-cost open-source microcontrollers. *HortTechnology* 25:110-118.

Popular Articles

van Iersel, M.W. and J. Lea-Cox. 2015. Precision irrigation: how and why? Society of American Florists, 2015 Pest and Production Management Conference Proceedings: 64-69.

van Iersel, M.W., J. Lea-Cox, and S. Burnett. 2015. Precision irrigation: how and why? *Greenhouse Grower* 33(1): 60, 62, 64, 66.

Burnett, S., R.S. Ferrarezi, M. van Iersel, J.G. Kang, and S. Dove. 2015. Gain greater control of fertilizer with automated fertigation. *Greenhouse Grower* 33(1): 50, 52, 54, 56.