NCERA-101 Station Report from Georgia, 2014

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1. New Facilities and Equipment

A new LED research facility is being installed, with LED installed inside Conviron E15 growth chambers. The LEDs will be used for research on the development of a biofeedback LED light control system. The goal is to control the light output from the LEDs based on the efficiency of the crop's light use efficiency. The project is in conjunction with start-up company PhytoSynthetix and funded by the Georgia Research Alliance.

We have developed a new low-cost irrigation controller, using open source prototype boards (Arduino). We used Arduino microcontrollers and soil moisture sensors to build an automated system to monitor and log substrate moisture content and to control irrigation based on real-time soil moisture measurements. The controller can control both 24VAC valves and latching 9VDC valves. The Arduino is programmed to read the raw output from the soil moisture sensors, convert it into VWC, log the data, send the results to a computer screen, and control irrigation based on the comparison of sensor readings and VWC thresholds. Thresholds varied from 0.2 to 0.5 $m^3\ m^{-3}$ and were applied to four pots with *Hibiscus acetosella* 'Panama Red'. The Arduino was reliable and successfully used to build an automated system to monitor substrate VWC and to control irrigation based on soil moisture sensors. The system worked properly during a 53-d trial, requiring little maintenance and irrigating the pots when the substrate VWC dropped below the set thresholds. The hardware cost of the irrigation control system, excluding the soil moisture sensor and valve is approximately $40.

2. Unique Plant Responses

Quantum yield and electron transport rates in response to changing *PPF*

We are using chlorophyll fluorescence measurement to determine the quantum yield (fraction of absorbed light that is used by the leaf to drive electron transport, a proxy for photosynthesis) and the electron transport rate (ETR). As expected, the quantum yield decreases as PAR increases (Fig. 1), while the ETR increases with increasing PAR. However, there are important differences among

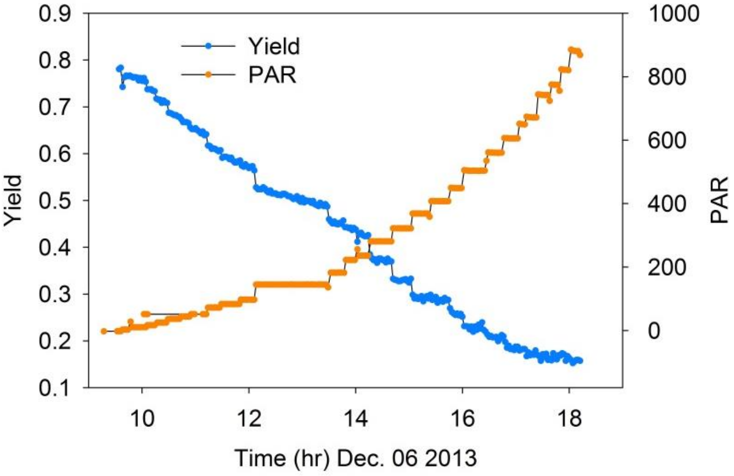

Figure 1. Quantum yield of lettuce exposed to different PAR levels.

species. ETR of sweet potato increases up the PAR levels of 900 µmol·m^{-2}·s^{-1}, while ETR of lettuce levels of at approximately 300 µmol·m^{-2}·s^{-1}. Our goal is to use real-time measurements of ETR for control of LED lights, where the PAR level can be automatically adjusted based on the photosynthetic performance of the plants.

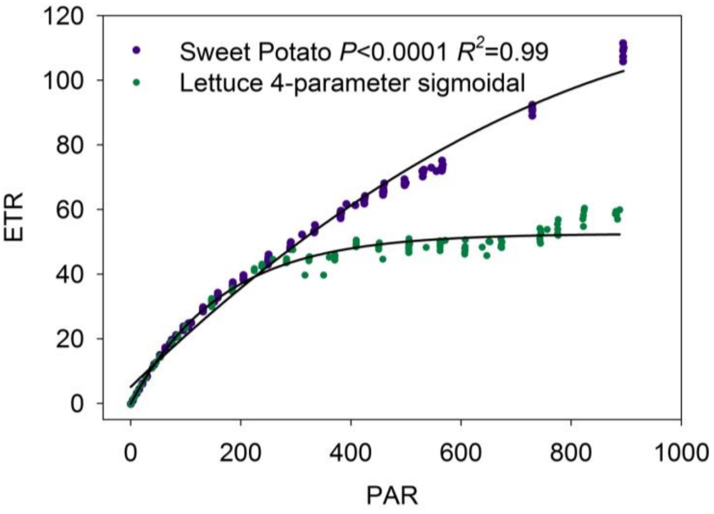

Figure 1. Quantum yield of lettuce and sweet potato as a function of PAR.

Oxygen concentration in the rhizosphere (update from 2013)

Anoxic conditions in soilless substrates have been implemented in disease development, reduced growth rates, and denitrification, but there is little quantitative information on oxygen concentrations in soilless substrates. We measured the partial pressure of oxygen (pO_2) in peat-perlite substrate planted with petunia (*Petunia × hybrida*). There are distinct diurnal fluctuations in substrate pO_2, and these can be largely explained by changes in substrate temperature, which increase the amount of water vapor in the air in the substrate, diluting oxygen and other gases. Barometric pressure (p_{air}) and substrate volumetric water content (θ) also affected substrate pO_2. Substrate pO_2 decreased with decreasing p_{air} and with increasing θ. Photosynthetic photon flux had a highly significant, but small effect on pO_2. Substrate density had no significant effect on pO_2. Overall, substrate pO_2 was between 19.1 and 20.6 kPa, even after watering the substrate to container capacity. The high air-filled porosity of the substrate (approximately 0.40 m^3·m^{-3} after irrigation) may have prevented the development of anoxic conditions. Since such high levels of pO_2 are unlikely to induce any detrimental anoxic effects on plants, our data do not provide any supporting evidence for the idea that anoxia is an important potential problem in peat-perlite substrates.

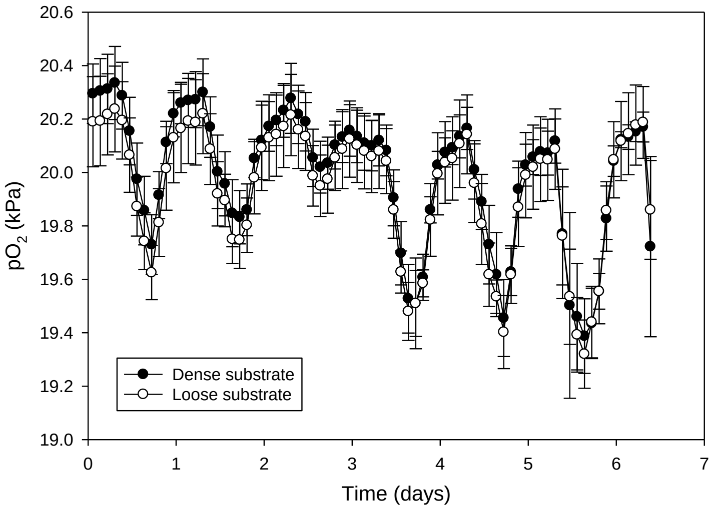

Fig. 3. Temporal dynamics of the partial pressure of O_2 (pO_2) in a peat-perlite substrate in a loosely and densely packed substrate. There was no significance effect of substrate density on the partial pressure of oxygen. Diurnal fluctuations in $pO_2$are closely correlated with substrate temperature.

3. Accomplishment Summaries

We have continued our testing of wireless sensor networks in commercial greenhouses and nurseries and found that soil moisture sensors can be very effective in automatically controlling irrigation. Growers see multiple benefits from these sensor networks, including water savings, shorter crop production cycles, less disease, and better quality. Based on estimates from the University of Maryland, implementation of these sensor networks by ornamental producers, assuming a 50% adoption rate, would result in annual water savings of 223 billion liters/year (enough for 400,000U.S. households) and reduce N and P discharges by 282,000 kg N and 182,000 kg P per year (Majsztrik et al., 2013). We expect a commercial release of the sensor networks in summer 2014.

There is a variety of automated irrigation controllers on the market, but many of them are either expensive or not designed for scientific research. Thus, we have develop an irrigation controller that can trigger irrigation based on soil moisture sensor readings and store the soil moisture data, as well as information on how often different plots get irrigated. Using an Arduino Uno microcontroller, we can build a system that can control irrigation in four separate plots for about $40. The system can easily be scaled up to 14 plots using an Arduino Mega microcontroller (at a cost of $90). Cost estimates do not include the needed soil moisture sensors or irrigation systems. Prototype systems have been running successfully at the University of Georgia and Purdue University.

4. Impact Statements

Wireless sensor networks can effectively control irrigation in commercial nurseries and greenhouses, based on soil moisture sensor readings. Growers have seen shorter production cycles, less disease, and better quality, along with large water savings. Implementation of this technology in greenhouses and nurseries will benefit both growers and society. Societal benefits include reduced water use and a decrease in agrochemical runoff.

5. Published Written Works

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Bayer, A., I. Mahbub, M. Chappell, J. Ruter, and M.W. van Iersel. 2013. Water use and growth of *Hibiscus acetosella* 'Panama Red' grown with a soil moisture sensor controlled irrigation system. *HortScience* 48:980-987.

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Thomas, P.T., M. Chappell, J.M. Ruter, E. Lichtenberg, and M.W. van Iersel. 2013. Wireless sensor networks for automated irrigation control in container nurseries: implementation and economic impact. HortScience 48:S179 (abstract).

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Starry, O., J. Kim, S. Dove, M. van Iersel, and J.D. Lea-Cox. 2013. Effects of water availability and temperature on CAM expression and water use efficiency by *Sedum album* and *Sedum kamtschaticum*. HortScience 48:S143 (abstract).

Ferrarezi, R.S., M.D. Ribeiro, M.W van Iersel, and R. Testezlaf. 2013. Subirrigation controlled by capacitance sensors for citrus rootstock production. HortScience 48:S142 (abstract).

Alem, P.O., P.A. Thomas, and M.W. van Iersel. 2013. Control of poinsettia stem elongation: height limits using deficit irrigation. HortScience 48:S141-142 (abstract).

Weaver, G. and M.W. van Iersel. 2013. Reducing transpiration of pansies (*Viola* x *wittrockiana*) with abscisic acid and 8' acetylene methyl-ester abscisic acid. GroSci 2013. The International Symposium on Growing Media and Soilless Cultivation. p. 121 (abstract).

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