NCERA-101 Station Report from Georgia, 2017

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1. New Facilities and Equipment

Photobiology research. van Iersel's Horticultural Physiology Lab (hortphys.uga.edu) has set up a dark room for photobiological studies, mainly used to study the effects of light intensity and spectrum on chlorophyll fluorescence and to determine leaf absorptance.

For chlorophyll fluorescence studies, we have multiple LED lights available, including red/blue LED, white LEDs, and an LED light with control over ratios and intensities of red, blue white, and far-red light. Fluorescence measurements are collected using a mini-PAM fluorometer (Walz, Germany). For leaf absorptance measurements, we use a combination of a Unispec spectrometer (PP Systems) for reflectance and spectroradiometer (Apogee Instruments) for transmission. Leaf absorptance is calculated as the fraction of light that is not transmitted or reflected.

Dedicated room for chlorophyll fluorescence measurements under LED lights

Chlorophyll fluorescence-based biofeedback system. Inside a Conviron E15 growth chamber, we have upgraded a system that can measure chlorophyll fluorescence and quantum yield of photosystem II and calculates electron transport rate. The system can autonomously adjust the light level to achieve a user-define electron transport rate. The initial setup used four white, 100-W LED modules controlled using pulse-width modulation (rapid on/off control of the LEDs, with intensity determined by the fraction of time that LEDs are on during an on/off cycle). We now have installed new LED lights (combination of red, blue, white, and far-red LEDs, donated by PhytoSynthetix, LLC) that provide a much more uniform light coverage. These lights are controlled using current control (*i.e.*, true dimming), which has eliminated almost all noise in chlorophyll fluorescence and light measurements. The setup can be used to test the effect of different lighting strategies on the plant's light use efficiency. The system can measure and maintain specific quantum yields of photosystem II or electron transport rates by adjusting the light intensity as needed.

Biofeedback system based on chlorophyll fluorescence measurements. Data collection and light intensity are controlled using a datalogger.

Spectral and intensity effects of LED light on plant growth

We have outfitted a room with six LED lights that provide independent control over the intensity of red, blue, white, and far-red light (donated by Aurora). This setup is used to study spectral effects on leaf elongation, light interception, photosynthetic physiology, and crop growth.

Shelves with fully controllable LED lights (intensity and spectrum)

Adaptive lighting control of LED lights in the greenhouse

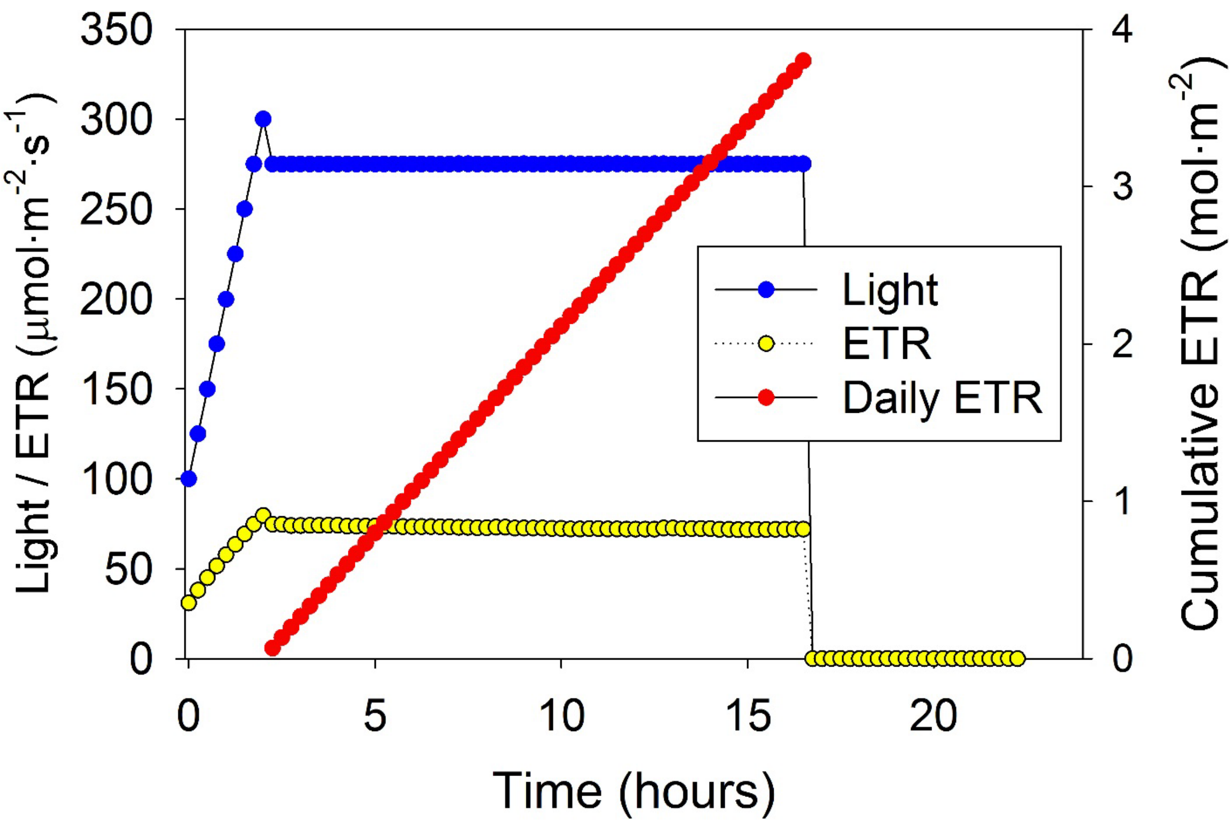
Based on the adaptive lighting controller described by van and Iersel and Gianino (2017), we have developed a system to test different supplemental lighting approaches. The system can implement five different lighting approaches (including one unlit control treatment). Five quantum sensors are used to measure the light level in each of the five treatments. A datalogger can then send a signal to the LED lights (SpydrX, Fluence BioEngineering) to adjust their light output. This allows for excellent control of light levels at the canopy level.

An overview of 10 of the 25 growing areas where different lighting treatments can be tested.

2. Unique Plant Responses

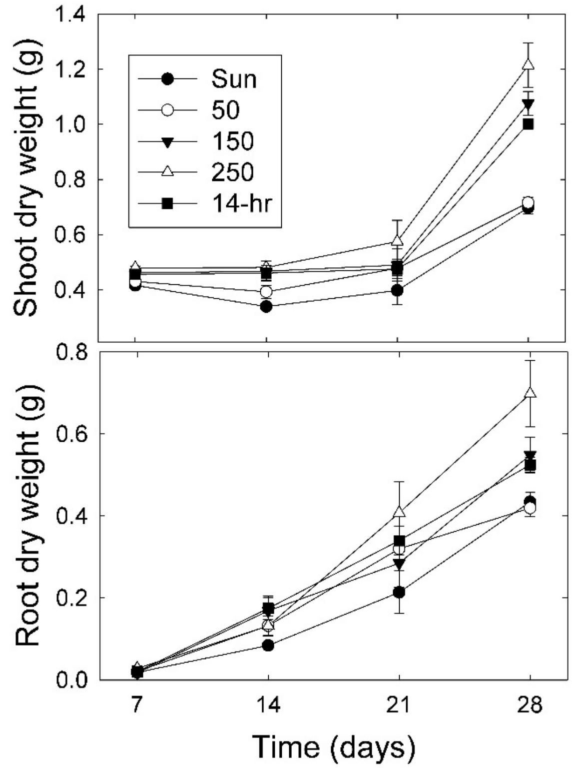
Automating determination of optimal light levels for different crops

We have developed a system that can automatically determine optimal light levels for a specific plant and then maintain those light levels. The system start with a light level of 100 µmol/m2/s and increase this by 25 µmol/m2/s every 15 minutes. The electron transport rate (ETR, a proxy for photosynthesis) is measured at each light level and the increase in ETR in response to the increase in light intensity is calculated. When the increase in light no longer results in a user-specified increase in ETR, the system returns to the previous light level and maintains that light level for the rest of the photoperiod. The light can be kept on either for a pre-determined amount of time, or when a specific integrated electron transport rate has been reached. Ultimately, the optimal light level for a specific crop should not merely depends on physiological measurements, but also account for the value of the crop and electricity prices. *(Michael Martin and Marc van Iersel in collaboration with PhytoSynthetix, LLC)*



Performance of the biofeedback system, using hellebore as a model plant. Initially the system gradually increases the light level and measures the corresponding change in the electron transport rate (ETR). Once the optimal light level has been identified, based on only a small increase in electron transport rate in response to an increase in light, the biofeedback system maintains that light level for a specific amount of time or until a threshold integrated electron transport rate has been, at which time the light is turned off automatically.

Adaptive lighting in greenhouses can result in energy-efficient supplemental lighting for the propagation of roses in greenhouses. We compared five different lighting treatments (sun only, 82 µmol/m2/s of supplemental lighting for 14-hr/day, and adaptive lighting with thresholds of 50, 150, and 250 µmol/m2/s). In the adaptive lighting treatments, the LED lights were controlled to provide just enough supplemental light to prevent the light level at the canopy from dropping below the thresholds. The 50 µmol/m2/s adaptive lighting treatment resulted in similar root and shoot growth of rose cuttings as sun light only (because it provided little supplemental light). The 150 µmol/m2/s adaptive lighting treatment increased root growth about 25% more than 14-hr/day of supplemental light, but with similar energy use. The 250 µmol/m2/s adaptive lighting treatment used almost twice as much energy as 14 hr/day of supplemental lighting, but increased root weight three times as much. Adaptive lighting with 150 or 250 µmol/m2/s thresholds increased root growth with 25-50% greater energy efficiency that standard supplemental lighting. *(Marc van Iersel and Sue Dove in collaboration with PhytoSynthetix)*



Development of an efficient method for screening of sorghum phosphorus efficiency and evaluation of root morphology and architecture under controlled P-concentration

A phenotype screening and selection method for tolerance to low-phosphorus stress conditions was developed at the Georgia Envirotron. Methodology that uses P-loaded alumina as a phosphorus buffer in quartz sand culture (Coltman et al., 1982) was modified to perform efficient, economical, high throughput sorghum screening for P-efficiency under controlled nutrition conditions. The solid-phase sand-alumina culture system provided stable, diffusion-limited, slow-release conditions with varying P availability to plants. This technique provided better media conditions control and reproducibility compared to a complex soil systems and, at the same time, better mimicked natural conditions compared to hydroponic cultures. Sorghum was selected due to its wide range adaptability to abiotic stress (such as drought and barren soil). Significant genetic variation in tolerance to abiotic stress exists in sorghum germplasm and cultivars. Simulated incremental plant responses to the six different P concentrations comparable to those found in soil proved the effectiveness of the technique and allowed to select low-P and close to optimal-P phosphorus concentrations of 3-5µM and 40-50µM PO_4^{3-} respectively. The sand-alumina culture medium was used to screen 6 sorghum varieties including those presumably efficient at low-phosphorus stress conditions. Sand-alumina medium revealed promising abilities for studying root development and architecture. It allows to apply nondestructive *in situ* electrical capacitance tomography (ETC) method for monitoring root development with greater accuracy due to media and plants consistency. The developed media also allows limited disturbance during root separation from the medium, preserving the intact root system architecture and allowing 3D imaging and subsequent root architecture analysis.

This method demonstrated a good example for screening sorghum and other plant species growing in soils with low-P availability. The identified materials may be used in plant breeding programs for development of cultivars with high phosphorus use efficiency. (*Viktor Tishchenko, Georgia Envirotron, University of Georgia, Griffin Campus; In cooperation with Ming Li Wang, USDA (PGRCU) and Daniel Sabo, Georgia Institute of Technology*)

3. Accomplishment Summaries

The University of Georgia has developed a control system for LED lights that automatically determine the optimal light level for different crops, based on user-provided input. Once the optimal light level has been determined, the system can then maintain that light level for a user-specified amount of time or until a user-specified total daily amount of electron transport has been achieved.

The University of Georgia has shown that 'adaptive' control of supplemental lighting results in more energy-efficient stimulation of root growth of cuttings than standard supplemental lighting. Adaptive lights provide just enough supplemental light to reach user-specified threshold. Because of that, they provide most of the supplemental light when there is little sun light and plants can use the supplemental light most efficiently. This technology has the potential to provide great cost savings to propagators.

The University of Georgia developed a novel screening technique to select for genotypes with high P-efficiency and to quantify root architectural and morphological responses to P availability. The method uses quartz sand and P-loaded alumina and is well suited for phenotyping and breeding for high P-efficiency.

4. Impact Statement

Electricity costs for supplemental lighting can be a major cost for greenhouses. 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. This results in more energy-efficient stimulation of growth: for rose cuttings, adaptive lighting promotes root growth 100 to 150% more efficiently than standard supplemental lighting.

5. Published Written Works

Refereed journal articles

Bayer, A., J. Ruter, and M.W. van Iersel. 2016. Elongation of *Hibiscus acetosella* under well-watered and drought-stressed conditions. *HortScience* 51:1384-1388. doi: 10.21273/HORTSCI11039-16

Chastain, D.R., J.L. Snider, J.S. Choinski, G.D. Collins, C.D. Perry, J. Whitaker, T.L. Grey, R.B. Sorensen, M. van Iersel, and S.A. Byrd. 2016. Leaf ontogeny strongly influences photosynthetic tolerance to drought and high temperature in *Gossypium hirsutum*. *Journal of Plant Physiology* 199:18-28. http://dx.doi.org/10.1016/j.jplph.2016.05.003

Ferrarezi, R.S., M.W. van Iersel, and R. Testezlaf. 2016. Plant growth response of subirrigated salvia 'Vista red' to increasing water heights in two substrates. *Horticultura Brasileira* 34: 202-209. http://dx.doi.org/10.1590/S0102-053620160000200009

Kang, J.-G., R.S. Ferrarezi, S.K. Dove, G.M. Weaver, and M.W. van Iersel. 2016. Increased fertilizer levels do not prevent ABA-induced chlorosis in pansy. *HortTechnology* 26-647-650. http://dx.doi.org/10.21273/HORTTECH03441-16

Litvin, A., M.W. van Iersel, and A. Malladi. 2016. Drought stress reduces stem elongation and alters gibberellin-related gene expression during vegetative growth of tomatoes. *Journal of the American Society for Horticultural Science* 141:591-597. doi:10.21273/JASHS03913-16

Montesano, F.F., M.W. van Iersel, and A. Parente. 2016. Timer versus moisture sensor-based irrigation control of soilless lettuce: Effects on yield, quality and water use efficiency. *Horticultural Science* 43:67-75. http://dx.doi.org/10.17221/312/2014-HORTSCI

van Iersel, M.W., G. Weaver, M.T. Martin, R.S. Ferrarezi, E. Mattos, and M. Haidekker. 2016. A chlorophyll fluorescence-based biofeedback system to control photosynthetic lighting in controlled environment agriculture. *Journal of the American Society for Horticultural Science* 141:169-176.

Symposium proceedings

Gianino, D and M.W. van Iersel. 2016. Adaptive LED lighting can benefit greenhouse production. *Proceedings of the SNA research conference* 61:76-80.

Lea-Cox, J.D., B.E. Belayneh, J. Majsztrik, A.G. Ristvey, E. Lichtenberg, M.W. van Iersel, M. Chappell, W.L. Bauerle, G. Kantor, D. Kohanbash, T. Martin, and L. Crawford. 2017. Demonstrated benefits of using sensor networks for automated irrigation control in nursery and greenhouse production systems. *Acta Horticulturae* 1150:507-514. DOI: 10.17660/ ActaHortic.2017.1150.70

van Iersel, M.W., M.R. Chappell, and P.A. Thomas. 2016. Optimizing growth, quality, and profits through precision irrigation in ornamental plant production. *Acta Horticulturae* 1131:57-63.

van Iersel, M.W., E. Mattos, G. Weaver, R.S. Ferrarezi, M.T. Martin, M. Haidekker. 2016. Using chlorophyll fluorescence to control lighting in controlled environment agriculture. *Acta Horticulturae* 1134:427-433.

Weaver, G. and M. van Iersel. 2016. Screening photosynthetic performance of bedding plants using chlorophyll fluorescence. *Proceedings of the SNA research conference* 57:321-323.

Zhen, S. and M. van Iersel. 2016. Modeling daily water use of bedding plants based on environmental factors and normalized difference vegetation index. *Proceedings of the SNA research conference* 57:321-323.