Purdue Station Report - 2010

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1. Impact Nugget:

Purdue University performed controlled-environment optimization studies of strawberry, sweetpotato, corn, and ornamentals emphasizing lighting, temperature, and cultural variables. Crop gas-exchange cuvettes were developed that will enable real-time photosynthetic rates to be correlated with LED lighting parameters as well as CO_2 and temperature variables.

2. New Facilities and Equipment:

Gas-Exchange Cuvettes: On March 1, 2010, a gas-exchange cuvette was delivered that was designed and fabricated by Ideal Engineering Solutions. This cuvette is designed for overhead, close-canopy LED lighting using ORBITEC's HELIAC (High-efficiency lighting with integrated adaptive controls) detection and control capabilities. This lighting module is currently under construction at ORBITEC and will be delivered shortly for integration with the cuvette.

An intracanopy-LED-lit gas-exchange cuvette delivered in 2009 has been completely integrated, and pre-plant testing is nearing completion. This cuvette will support ~0.25 m^2 of hydroponically grown planophile crops. There are 16 vertical LED strips, each with red (640nm) and blue (440nm) LEDs that are controlled manually. Light engines are energized from the bottom up to keep pace with increases in crop height, and light outputs from red and blue LEDs are adjusted independently as desired. These LED "lightsicles" are reconfigurable, and several adjustable ceiling-slot configurations and plant positions in the lid of the hydroponic tub were designed to allow different arrangements of lights and plants. Cuvette design allows easy reconfiguration from one experiment to another, and new ceiling and lid plates with novel configurations can be machined as needed.

Both cuvettes will be run in an open configuration using a high-capacity blower, a differential and an absolute IRGA, and mass-flow valves allowing precise mixing of air and CO_2 for the inlet air stream. Both have humidification capabilities, temperature controls, and redundant temperature and humidity sensing. In addition, each cuvette is outfitted with a computer-controlled pan/tilt stage and digital camera with zoom capability allowing observation of the canopy and lighting system within the closed cuvette. Both cuvettes have integrated hydroponic systems with separate gas environments and ports for rhizosphere-head-space gas sensing. Nutrient solutions will recirculate between the hydroponic tub contained in the cuvette and an external reservoir where solutions are maintained, allowing long-term closed-cuvette experimentation.

Electronic ballasts: ParSource (Hydrofarm) 1000-watt electronic ballasts were replaced in our growth rooms and greenhouses due to high failure rate. Installed in 2007, we have previously reported that they were operating well. But after a little more than a year, these model GXE55100A ballasts began to fail. New models without fuses were installed with same results. New lamps (SunPulse 100W MH) designed to be more compatible with the electronic ballasts also failed, some of them within hours after installation. Note that we were using the 110V version of these ballasts. Higher voltage models may not have the high failure rate. ParSource replaced them with standard magnetic ballasts under warranty.

3. **Unique Plant Responses.**

Strawberry: Day-neutral strawberry plants ('Seascape') were grown long-term under 10-h photoperiods in three reach-in chambers set to day/night temperatures (°C) of 16°/8°, 18°/10°, or 20°/12°. Plants were grown for 282 days with fruit collection beginning at 65 days after planting. Fruit were collected, weighed and counted, and pH, Brix, and titratable acidity were measured. Overall, the warmest two temperature regimes produced the highest number of fruit, but the middle temperature regime, 18° day/10° night, produced the highest fruit fresh weight. Yields oscillated over time, with plants grown under warmer conditions fruiting earlier than those under cooler conditions. Brix averaged 10 for the first half of the harvest period but dropped to 8.4 during the latter half, indicating fruit may become less sweet as plants age. Titratable acidity averaged 0.6 but increased slightly during the middle of the harvest period. The highest yielding group (18°/10°) generally had the lowest Brix and highest tritatable acidity, indicating that fruit became less sweet and more tart over time. Fruit from the coolest treatment generally had higher Brix and lower titratable acidity and were slightly higher in pH than fruit from the other treatments.

Sweetpotato: Sweetpotato vines were grown with different fertilizer concentrations. Vines were planted two-per-pot in Profile™ calcined clay and maintained as single vines trained around cylindrical wire frames to reduce the area occupied. Plants were fertigated with Scotts Miracle Gro® Excel® Cal-Mag, a 15-5-15 commercial fertilizer formulation, at 1000 $mg \cdot L^{-1}$. This standard fertilizer solution contains (in $mg \cdot L^{-1}$) 200 N, 29 P, 167 K, 67 Ca, 30 Mg, and micronutrients, and is pH adjusted to 6.0 - 6.3 and alkalinity to 100 mg/L $CaCO_3$. Plants were treated with 100% fertigation solution and dilutions of 75%, 50%, 25%, or 0% in one experiment, and a second experiment examined 10%, 20%, 30%, 40%, or 50%. Dilutions were made with tap water acidified to pH 6.2. In terms of root yield, 75% and 50% concentrations exceeded 100% in the first experiment, but yields declined sharply at 25% concentration of the fertigation solution. Stem weight declined gradually with fertilizer concentration from 100% down to 25% and then fell sharply with 0%, so root:shoot ratio was higher at all fertilizer concentrations compared to 100%. In a second experiment, root yields decreased gradually between 50% and 20%, with a large decline when 10% was used. Stem weight also declined as concentration decreased between 50% and 10%, so shoot-to-root ratios were generally consistent. Concentrations in the range of 50-75%, therefore, produce the best root yield while controlling stem growth, whereas concentrations below 50% limit root productivity.

Tomato: Two cherry-tomato cultivars ('Small Fry', 'Husky Cherry Red') were grown hydroponically comparing intracanopy (IC) or overhead (OH) LED lighting. The experiment set-up is described in detail in the 2009 Purdue Station Report. Final results demonstrated much more edible and inedible biomass yield by the 'Husky Cherry' cultivar (209% more edible and 979% more nonedible dry weight compared to 'Small Fry'). Plants grown with IC lighting produced 229% (dry weight) more biomass than those grown under OH lamps, and the more-productive 'Husky Cherry' also produced 126 % (dry weight) more fruit with IC lighting than with OH. 'Small Fry' was significantly more sensitive to high-temperature stress and developed leaf intumescence (oedema), likely due to lack of UV light coming from the LED arrays. This comparative finding indicates that crops grown under narrow-wavelength solid-state lighting may have to be tested cultivar-by-cultivar.

Corn: Several corn-growth experiments were conducted in a 12-ft- tall growth chamber and in a standardized growth room. Experiments in the chamber examined pot size and temperature DIP

effects on yield and growth rate of a semi-dwarf corn line (PI 587154) compared to a conventional temperature regime. Experiments in the growth room used the same breeding line to examine effects of MH, HPS, or combinations of the two lamp types on growth and yield. Temperature was measured at pot height and canopy level for the different lighting conditions since earlier observations indicated that temperature varied at the same PPF. Differences in low-wave radiation between lamp types and wattages were confounding efforts to match up PPF. Preliminary results indicate that corn yields as well or better in small (7.5"x6"x5-5/8") pots than in a larger size (10"x9"x8-1/8") given adequate irrigation and humidification.

As part of the development of *Purdue Methods: Optimizing Greenhouse Corn Production*, 24 controlled studies of corn have been performed in the Purdue Greenhouses. Photographs and statistical analysis are available on the website. Nutrient deficiencies are reduced and seed yield increased using automated drip irrigation delivering fertilizer solution to a root media of calcined clay, or porous ceramic. Methods are easily adopted and eliminate the need for the cumbersome handling of field soils (digging, drying, grinding and pasteurizing) and the need for soil mixing equipment. Watering frequency and fertilizer formulation were constant over the life of the plants, seed to harvest, and supplemental fertilizers such as slow release granules were not required. In most cases, transplanting was not required and watering labor reduced to simple inspection of the system. Of most scientific value is our experiment that combined the application of uniconazole, in a method developed by Cary Mitchell's lab, with a tassel cold-storage technique that increased pollination period by 5 days. This resulted in a significant increase in seeds/plant (643) over controls (531). Due to subapical ears being successfully pollinated, seed yields were over 900 seeds/plant in some plants.

Poinsettia: Ten poinsettia cultivars (*Euphorbia pulcherrima* Willd. ex Klotzsch.) were selected based on their early response attributes (6 to 8 week response time), moderate-vigor, and naturally large bracts. Rooted cuttings were grown at day/ night temperatures (12 h/ 12 h) of 24/ 19 °C with a 16-h photoperiod consisting of natural daylengths with day-extension lighting until 01 October. On 15 October, plants were transferred to day/ night temperatures (12 h/12 h) of 16/ 13 °C [Average daily temperature (ADT) 15 °C], 20/ 14 °C (ADT 17 °C), constant 17 °C, 21/ 17 °F (ADT 19 °C), constant 19 °C and 24/ 19 °C (ADT 22 °C). Time to anthesis from the start of short days increased from 60 to 76 days and from 55 to 68 days as temperature increased from 20/ 14 °C to 24/ 19 °C for 'Prestige Early Red' and 'Orion Early Red', respectively. Final height was not significantly influenced by reduced temperature forcing in either cultivar as temperature increased from 20/14 °C to 24/19 °C.

Yellow Trumpet Bush: *Tecoma stans* (yellow trumpet bush) is a potential new floriculture crop for greenhouse growers in the northern U.S. It produces funnel-shaped, bright yellow flowers that compliment the glossy green pinnate leaves. We quantified how the mean DLI during propagation influences morphological plasticity, rooting, growth and quality of *Tecoma stans* seedlings. Seeds were sown in 72-cell plug trays and maintained at 22.8 ± 2.5 °C under a 16-h photoperiod and a mean DLI ranging from 5.8 to 21.3 mol·m-2·d-1. Height, number of nodes, stem diameter, chlorophyll content (SPAD), leaf area, shoot dry weight (SDW), root dry weight (RDW), total dry weight (TDW), and root-to-shoot ratio increased with increasing DLI. For example, as DLI increased from 5.8 to 21.3 mol·m-2·d-1, height, stem diameter, SDW, and RDW increased linearly by 74%, 92%, 792%, and 1411%, respectively. Similarly, total dry weight and root-to-shoot ratio increased linearly by 78% and 917% when DLI increased from 5.8 to 21.3

mol·m-2·d-1. This experiment quantifies the importance of increasing photosynthetic DLI during propagation to maximize photosynthesis, increase rooting, growth and quality of seedlings.

INSV: To reduce incidence of Impatiens Necrotic Spot Virus that was killing *Arabidopsis* plantings, we implemented new management procedures. Previously, the multiple greenhouse rooms growing *Arabidopsis* in our facility were allocated to specific faculty. We eliminated this ownership and made them common rooms, but rotated their use so that we could empty them every three months, breaking the western flower thrips life cycle. Dedicated lab coats are also used, and a program to educate users about INSV has been implemented. Mass screening was done with immunostrip test kits to identify any plants that may be harboring the virus. We've not diagnosed any INSV in six months, but the true test will be this summer.

4. **Accomplishment Summaries.**

Studies at Purdue have demonstrated that the day-neutral strawberry cultivar 'Seascape' can be successfully grown in growth chambers under photoperiods ranging from 10 to 20 hours and day temperatures ranging 16˚ to 20˚ C. The coolest temperature, 16˚, somewhat reduces yield, but fruit have more sugars and tasters prefer them to fruit grown under warmer conditions.

Rob Eddy has developed a website entitled *Purdue Methods: Optimizing Greenhouse Corn Production.* Results of studies of corn growth are summarized into FAQ format for ease of understanding, much like our popular website *101 Ways to Grow Arabidopsis*. The project goal was to devise a growing system for optimized corn growth that would be repeatable, reportable and scalable. Very little new discovery is offered—most of the components and techniques have been pioneered by Purdue faculty, other facilities, and by NASA. Here these have been integrated into a well-documented plant growth system for corn that can be adopted across facilities, independent of their level of technology.

The holiday poinsettia is the number one potted flowering crop sold in the U.S., with a reported wholesale value of $154 million in 2008. Profitability is increasingly threatened as the cost to heat greenhouses has increased by over 90% in the last 10 years. As energy costs continue to increase and poinsettia prices remain relatively constant, growers are seeking cultivars that can be finished at cooler temperatures. Our objectives were to quantify how reduced temperature finishing influences time to anthesis, height, bract area and bract expansion of poinsettia. Our results indicate that reduced temperature finishing of certain cultivars is a viable option that greenhouse growers can use to help reduce energy costs.

Photosynthetic daily light integral (DLI) is an important variable closely related to growth and quality of greenhouse grown crops. DLI can be a limiting factor for greenhouse production especially during winter and early spring, when most floriculture crops are propagated. We quantified how the mean DLI during propagation influences morphological plasticity, rooting, growth and quality of yellow trumpet bush seedlings. Large linear increases in response to increasing DLI were demonstrated in quality characteristics such as height, stem diameter and dry weight, quantifying the importance of increasing photosynthetic DLI during propagation.

4. **Impact Statements.**

Crop production in space will have to be done with a minimum of energy and other inputs, and the area to grow plants will be small. Work at Purdue has focused on reducing these inputs, such as the energy needed to grow strawberries and the fertilizer and space requirements of

sweetpotatoes. These studies impact the amount and types of crops that can be grown in space, and lessons learned can be applied to controlled-environment production on Earth. Work on cold finishing in poinsettia demonstrates the potential for significant energy savings in a commercial production scenario by decreasing average daily temperature by 5°C while maintaining product quality.

The Mitchell lab at Purdue has worked with engineering and LED lighting designers to develop custom gas-exchange cuvette systems for small crop canopies. These systems will allow us to measure productivity responses of crops to intracanopy or overhead LED lighting in real-time. These dynamic systems will enable rapid determination of optimum combinations of light, temperature, and carbon dioxide at different growth stages of crop plants such as cowpea, tomato, strawberry, and lettuce.

Studies at Purdue aimed at improving yield while reducing height of corn in growth chambers found differences in the ways this crop might be grown in controlled environments. Corn is a potential pharmaceutical-producing crop, but contained, consistent production of pharma proteins and bio-active molecules in this crop will require a controlled environment, and our research will help define that environment and enable this new industry. The Purdue corn production methods website will help many producers to optimize their growth systems.

5. **Published Written Works.**

Barrett, J., J. Dole and R.G. Lopez. 2009. New poinsettia releases for 2009. Greenhouse Product News 19(2):18, 20, 22–24.

Beckerman, J.L. and R.G. Lopez. 2009. Disease Resistant Annual and Perennial Production. Purdue Cooperative Extension Publication.ID-416-W:1–5. http://www.extension.purdue.edu/extmedia/ID/ID-416-W.pdf

Burnett, S.E., R.G. Lopez, and N.S. Mattson. 2009. Evaluate your greenhouse to save energy. Greenhouse Management and Production. 29(9):20,22–24,26.

Camberato, D.M., R.G. Lopez and M.V. Mickelbart. 2009. pH and Electrical Conductivity Measurements in Soilless Substrates. Purdue Cooperative Extension Publication. HO-237-W:1–6. http://www.extension.purdue.edu/extmedia/HO/HO-237-W.pdf

Dole, J., J. Barrett and R.G. Lopez. 2009. Best performing cultivars from 2008 National Poinsettia Trials. Greenhouse Product News 19(5):22–26.

Hall, T.J., J.H. Dennis, R.G. Lopez, and M.I. Marshall. 2009. Factors affecting growers' willingness to adopt sustainable floriculture practices. HortScience. 44(5):1346–1351.

Hall, T.J., J.H. Dennis, R.G. Lopez, and M.I. Marshall 2009. OFA Fact Sheet: Factors affecting the willingness to adopt sustainable floriculture practices. OFA – An Association of Floriculture Professionals Bulletin 916:19–20.

Lopez, R.G. and B.A. Krug. 2009. Cold finishing up north. Greenhouse Grower 27(8):88–94.

Lopez, R.G., J. Dole and J. Barrett. 2009. 2008 Consumer choices. Greenhouse Product News 19(3):20–22

Lopez, R.G., J.T. Smith, D.M. Camberato, J.H. Dennis, B.K. Behe and C.R. Hall. 2009. Consumer perceptions of sustainably produced poinsettias. Greenhouse Grower 27(9):60–64.

Lopez, R.G., M.G. Blanchard, and E.S. Runkle. 2009. Propagation and production of Zamioculcas zamiifolia. Acta Hort. 813:559–564.

Lopez, R.G. 2009. OFA Fact Sheet: Successful poinsettia propagation. OFA – An Association of Floriculture Professionals Bulletin 915:3–5.

Massa G.D., J.B. Santini and C.A. Mitchell. 2010. Minimizing Energy Utilization for Growing Strawberries During Long-duration Space Habitation, In Press, Advances in Space Research.

Mattson, N.S. S.E. Burnett, B.A. Krug, and R.G. Lopez. 2009. Reducing crop shrinkage. Greenhouse Grower 27(5):26–32

Rob Eddy developed Purdue Methods: Optimizing Greenhouse Corn Production. http://www.hort.purdue.edu/hort/facilities/greenhouse/CornMethod.shtml

Torres, A.P. and R.G. Lopez. 2009. Propagación de Poinsettia (Flore de Pascua). Purdue Cooperative Extension Publication. HO-235-SW:1–5.
http://www.ces.purdue.edu/extmedia/HO/HO-235-SW.pdf

Williams, K., R.G. Lopez, and D.F. Warnock. 2009. Producing poinsettias sustainably. Greenhouse Grower 27(9):66–73.

6. **Scientific and Outreach Oral Presentations.**

Massa G.D., C.M. Bourget, R.C. Morrow, D. Whittinghill, and C.A. Mitchell. 2009. Light type, Placement, Automation and Modeling: Factors Important for Crop Uniformity and Energy Conservation in Controlled-Environment Production. Greensys 2009, Quebec City, QC, Canada.

Mitchell C.A., G.D. Massa, C.M. Bourget, and R.C. Morrow. 2009. Enabling ESM Reduction for Food Production at the Lunar Base, NASA Lunar Science Forum, Ames Research Center.

Massa G.D. and C.A. Mitchell. 2009. Cultural and Environmental Improvement of Three Strawberry Cultivars Grown in Controlled Environments for Long Durations. ASHS 2009, St. Louis, MO.

Mitchell C.A., G.D. Massa, R.M. Wheeler, G.W. Stutte, N.C. Yorio, O.A. Monje, C.M. Bourget, and R.C. Morrow. 2009. Energy-Efficient Plant-Growth Lighting: Key to Sustainability of the Lunar Base and Beyond, LEAG 2009, Houston, TX.

7. **Other relevant accomplishments and activities.**

Gioia Massa chaired a session at ASHS 2009 on “Horticulture Crops Culture and Management: Controlled Environments”

Cary Mitchell organized and ran a symposium on “Closed-Loop Regenerative Life Support for Sustainable Habitation in Space” at the American Society for Gravitational and Space Biology 2009 annual meeting.

Cary Mitchell and Gioia Massa participated in the Bioregenerative Life Support Roadmapping exercise organized by North Carolina Space Grant.

Cary Mitchell served on one of five USDA SCRI peer-review panels in 2009.

Cary Mitchell represented ASHS at the 2009 Council for Agricultural Science and Technology (CAST) meeting.