Purdue NCERA-101 Station Report-2012

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Impact Nugget: Purdue University found that intracanopy supplemental lighting with red + blue LEDs stimulated fruit yield to the same extent as overhead HPS lighting did relative to unsupplemented controls but expended only 25% as much electrical energy doing so during winter-to-summer high-wire tomato production studies in the greenhouse.

New Facilities and Equipment:

LEDs for cutting propagation. The **Lopez Lab** received three LED arrays from Orbital Technologies (ORBITEC). Each LED array consists of bars containing 24 627- or 450-nm LEDs. Each array consists of seven 1.88 cm square and 1.22 m-long and 1.3 mm-wide hollow square aluminum bars with seven red (100% R) or four red and three blue (85R:15B and 70R:30B) bars alternating, spaced on 22-cm centers on across a 1.82-m bar. Each bar is cooled with a single 3.6-W axial blower mounted on the end of each bar.

Greenhouse Overhead LED lights: A year-long propagation experiment is being conducted by **Celina Gomez** in the **Mitchell Lab** to evaluate ORBITEC's open-bar, overhead LED arrays as an alternative lighting source for the propagation of greenhouse-grown tomatoes. Tomato cultivars 'Maxifort', 'Komeett', 'Success', 'Sheva sheva', 'Liberty', and 'Felicity' are grown monthly for 3 weeks in a glass-glazed greenhouse. Five lighting treatments are being tested: natural light (control), natural + supplemental light from a 100-W high-pressure sodium (HPS) lamp, or natural + supplemental LEDs using either 80% red and 20% blue, 95% red and 5% blue or 100% red. A variant solar daily light integral (DLI) occurs naturally for all treatments, and a constant DLI of 5 $mol \cdot m^{-2} \cdot day^{-1}$ is provided to the seedlings receiving supplemental lighting. The experiment will continue throughout the rest of the year and results for different growth parameters will be compared across seasons to determine when supplemental lighting is needed for acceptable plant growth and at what point of the year it is necessary to supplement with blue light. Shoot biomass production per kW-h of energy consumed is being compared for the different treatments.

Experimental setup for high-wire production supplemental lighting. In 2011, the **Mitchell lab** installed a soilless high-wire greenhouse-tomato production system in one of the Purdue research greenhouses. Tomato seeds were donated by DeRuiter Seeds to evaluate commercial cultivars for year-round production using LEDs vs. HPS lamps. Preliminary trials for the rest of the year focused on learning grow-out techniques. ORBITEC delivered nine LED towers designed for high-wire greenhouse tomato production intracanopy supplemental lighting to the Mitchell

Lab in January of 2012. Each 2.5-m-tall LED tower rectangular LED zone has two opposite lighting panels, each containing aluminum mounts and fans that draw greenhouse air into the center of each tower and dump waste heat either above the canopy in summer or below the canopy in winter. The towers can be operated manually or automatically and temperature and energy consumption can be monitored via custom software. Following delivery of the towers, the greenhouse was divided into six half-row sections (3.7 m × 4.9 m) by hanging three layers of polyethylene plastic from the upper frame of the structure midway between rows to avoid light pollution across lighting treatments. Cultivars 'Komeett' and 'Success' were grafted onto 'Maxifort' and randomly selected for each lighting treatment. Each section was one replicate of a treatment consisting of eight double-headed plants (four Komeett/Maxifort and four Success/Maxifort) and one non-grafted, double-headed plant at each section border (guard plant). The lighting treatments were started on Jan. 28th, 2012. Supplemental lighting was kept at an average DLI of 9 $mol \cdot m^{-2} \cdot d^{-1}$ from either overhead 1000-W HPS lamps or intracanopy LED towers programed to mix 95% and 5% blue light. A control treatment was also included for which no supplemental light was provided. The experiment was terminated on June 28th, 2012.

Unique Plant Responses:

Herbaceous cuttings. Objectives of the **Lopez Lab** were to determine how biomass accumulation, allocation, and leaf morphology of *Impatiens hawkeri* (New Guinea impatiens) cuttings were influenced by photosynthetic DLI during root development in propagation. Cuttings of New Guinea impatiens 'Magnum Salmon' were inserted into propagation substrate in cell trays and placed under mist in environmental conditions for callus development (≈5 $mol \cdot m^{-2} \cdot d^{-1}$) for 7 days. After 7 days, cuttings were placed under DLIs of 2.5, 8.5, or 15.6 $mol \cdot m^{-2} \cdot d^{-1}$ for 14 days. Total, leaf, stem, and root dry mass increased for cuttings within each DLI over time, and dry mass generally increased with DLI. Dry mass partitioning was greatest into leaves for cuttings under 2.5 $mol \cdot m^{-2} \cdot d^{-1}$ and into roots for cuttings under 8.5 and 15.6 $mol \cdot m^{-2} \cdot d^{-1}$. Leaf area increased throughout the experiment for all cuttings, being highest under 15.6 $mol \cdot m^{-2} \cdot d^{-1}$. Leaf area ratio and specific leaf area increased for cuttings under 2.5 $mol \cdot m^{-2} \cdot d^{-1}$, but not under higher-light treatments. These results suggest cutting morphology and physiology is plastic in response to DLI during root development.

Overhead HELIAC lighting system. Lucie Poulet's Master's project in the **Mitchell Lab** focused on reducing energy for sole-source plant lighting. ORBITEC's HELIAC overhead LED lighting system was evaluated and retrofitted during the reporting period. Experimentation with leaf lettuce was subsequently conducted in a walk-in growth chamber. It was decided not to use the "automatic" detection mode of the system, which was unable to detect and selectively light widely spaced, small plants at its present stage of development. Preliminary experiments determined lighting conditions needed to grow plants under red and blue LED lights. A growth curve enabled us to characterize lag and exponential growth phases of leaf lettuce.

It was established that lettuce remains in a slow lag phase for the first 15 days of plant growth, after which it enters a rapid exponential phase. A series of experiments optimizing red : blue ratio was conducted, to find the optimizing fraction of blue light for seedling establishment and later lettuce growth. A ratio of 5:95 was found best for seedling establishment and plant growth using sole-source LED lighting. A series of experiments compared the efficiency of targeted LED lighting system to a system in which all LEDs were energized throughout each photoperiod. "Targeted LED lighting" refers to visual estimation of LED position relative to plant position and size. Measurements after 21 days of growth included hypocotyl length, leaf area, fresh and dry weight. The energy and power spent over the growth period was monitored and related to the mass of lettuces grown. This last type of experiment is still in progress but preliminary results indicate that lettuces can be grown productively with as little as 1 kWh/g plant DW.

Intracanopy supplemental lighting. Research related to the PhD project of **Celina Gomez** in the **Mitchell Lab** indicates that supplemental lighting hastened the beginning of tomato-fruit harvest for both overhead HPS as well as intracanopy LED supplemental lighting treatments compared to unsupplemented controls. However, no differences occurred between the two supplemental lighting treatments for any harvest parameter. Quality testing indicated that, in general, fruits produced using the intracanopy LED towers tasted/appeared no different from those produced under control but had slightly better overall consumer acceptability than those produced under HPS. The energy-consumption metrics indicated energy savings by using the intracanopy LED supplemental lighting technology relative to the overhead HPS technology. Results for kW-h/g of fruit FW indicated that the electrical conversion efficiency of intracanopy LEDs into fruit biomass was only 25% as much as that that for HPS supplemental lighting. Thus, the lighting cost per average fruit grown under the overhead HPS lamps was 408% greater than that of the LED towers.

For Plant-Growth Facilities Manager (R. Eddy):

Corn protocols. New corn-growing protocols have been implemented and expanded in three greenhouse rooms with independent projects using corn and sorghum. Seeds are direct-sown in 7.5-liter nursery containers filled with calcined clay (porous ceramic) granules, or a 1:1 mix of these granules and Fafard#2 soilless potting mix. The pots are irrigated every 3 hours for 3-5 minutes using a general-purpose fertilizer solution. This frequency and duration remains constant from seed to harvest, and plants of multiple ages may be present on the same irrigation system. Several hours of set-up time are required but labor is reduced thereafter, with the advantage of less contact with the plants that could potentially spread insects. Two-spotted spider mite is controlled effectively with a combination of sanitation, lower leaf removal, clear water "hose-offs" three times weekly, and application of *Phytoseiulus persimilis* predatory mites as needed. The system is easily adoptable, scalable, and repeatable across facilities. The protocols are described in detail in

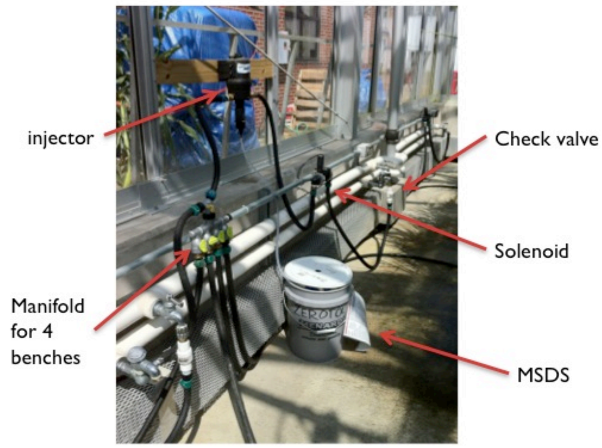
our e-publications, which include photos and results from our methods development testing.
http://www.hort.purdue.edu/hort/facilities/greenhouse/CornMethod.shtml

"Tabletop" corn. We conducted several experiments to attempt to grow corn in a smaller pot and use chemical growth regulators to keep it under one-meter tall while producing a full seed ear. We believe the advantages of such a protocol would include: ability to grow corn in a shorter greenhouse or a growth chamber; to keep the tassels from growing into HID fixtures; improve worker safety by reducing need for ladders for pollination tasks; and potentially improve ability for robotic production associated with phenotyping systems. After several attempts, we met with some success using tree nursery containers of 10-cm diameter and 36-cm depth, filled with calcined clay, automatically watered as described in corn protocol above, and applied with multiple soil drenches of uniconazole. Seed set was variable on these plants and the untreated controls due to the extreme greenhouse temperatures during the pollination period, but the study warrants further attempts.

During these studies we tried to refine lighting recommendations for greenhouse corn, since we were growing at close spacing that reduced light level to lower half of the plant. We believe low light to lower half of the plant simulates high planting density effects in the field that result in poor silk elongation and seed set. We propose the vertical habit of these plants and the differing plant spacing used by researchers makes instantaneous light intensity readings at the canopy an ineffective measure for predicting seed set, though many greenhouse managers in North America still provide these recommendations. We tracked daily light integrals in controlled studies and made measurements on other corn research crops in our facility across seasons. Our preliminary recommendation is that 2.5 mol/m2/d as measured *at the ear* is the minimum requirement for sufficient silk elongation for pollination.

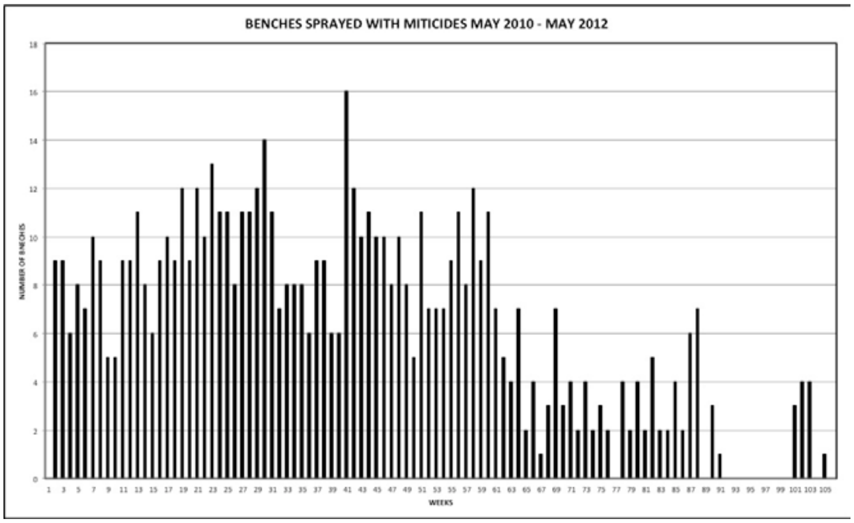
In our facility, a "typical" stand of greenhouse corn will lose 2/3 of light from canopy to ear, suggesting 7.5 mol/m2/day is the minimum needed for silk elongation/seed set at the canopy. At our greenhouse at latitude 40.3°, interior light without HID lamps can be below 5 mol/m2/day on cloudy winter days, and as high as 30 on bright summer days. HID lamps providing 100 µmol/m2/s for 14 hours results in addition of 5 mol/m2/d of DLI. This would seem to be the minimum for winter supplementation at our facility.

Algae control. We eliminated algae growth in sub-irrigation trays of rice research with an injector that delivers Zerotol (hydrogen dioxide 27%) at a ratio of 1:100 directly into the trays using drip irrigation emitters. The solution is siphoned directly out of the original container, so no mixing is required, reducing worker exposure. Zerotol is brought in at time of application, the suction tube for the injector dropped in, and the irrigation valve turned on for 5 minutes to fill the trays. There is no restricted entry following the application and no observed phytotoxicity. Weekly application is all that is required to maintain algae-free trays. Existing algae are killed after two applications.



Impatiens Necrotic Spot Virus. We had an outbreak of this viral disease that is deadly to *Arabidopsis* in several of our greenhouses, but feel that our protocols for control—developed years ago after a similar outbreak—were proven successful. Aggressive control of Western Flower Thrips—the only known vector of the disease—were combined with strict sanitation and entry restrictions. Diseased plants were identified with immunostrip test kits. Researchers were notified if their plants were infected, and asked to discard all but the most valuable among them. Greenhouses with infected plants were quarantined so that researchers could not enter another greenhouse for 30 minutes following entry of an infected area. Dedicated lab coats were worn in each greenhouse room. Since we already had a room rotation in place that ensured that no more than one generation of *Arabidopsis* was produced in a room before being emptied and cleaned, the disease was kept contained. After 3 months, the last of the infected plants were harvested with no further infection of younger ones. Researchers were somewhat inconvenienced by stricter protocols but appreciated this approach as compared with being told all plants—healthy or infected—must be discarded once a room had become infected. This disease control methodology is documented in our "101 Ways to Grow Arabidopsis" e-publications so that other facilities can benefit from our experience. Two North American greenhouses report that the protocols have helped them eliminate the disease.

Two-Spotted Spider Mite Control. We have experienced severe outbreaks of *Tetranychus urticae* in our greenhouses, due to continuous cropping of some susceptible plants, which led to pesticide resistance over the years. We applied the same strategy as described in the corn protocol to many greenhouse rooms with susceptible plants, with a resulting reduction in pesticide sprays required. The figure shows a reduction in number of greenhouse benches that were sprayed each week over a two-year period. On week 42 of the figure, a combination of sanitation, lower leaf removal, clear water “hose-offs” three times weekly, and application of *Phytoseiulus persimilis* predatory mites was implemented.



Research crop protocol e-publications updated. Many of our protocols on greenhouse production of *Arabidopsis*, corn, and rice were updated this year to reflect our on-going observations or testing results. For each crop, a single-page summary of pot size, substrate, fertilization, irrigation, lighting and other growth system components is provided, with additional e-pubs detailing each of those aspects in FAQ format. All told, there have been over 19,000 downloads globally of these protocols.

Accomplishment Summaries: all accomplishment summaries are included in the brief *Unique Plant Responses* section of this report.

Impact Statements: Impact statements are included in the brief *Unique Plant Response* sections of this report.

Published Written Works:

For the Lopez Lab:

Currey, C.J., R.G. Lopez, and N.S. Mattson. 2011. Flower induction of annuals. HO-249-W:1−10. http://www.extension.purdue.edu/extmedia/HO/HO-249-W.pdf

Camberato, D.M, C.J. Currey, and R.G. Lopez. 2011. Plant growth regulators for greenhouse production pocket reference. HO-248-B-W:1−2. http://www.extension.purdue.edu/extmedia/HO/HO-248-B-W.pdf

Torres, A.P., D.M. Camberato, and R.G. Lopez. 2011. El control de algas en las lagunas de riego. Purdue Cooperative Extension Publication. HO-247-SW:1−5. http://www.extension.purdue.edu/extmedia/HO/HO-247-S-W.pdf

Taylor, J.M., R.G. Lopez, C.J. Currey, and J. Janick. 2011. The Poinsettia: History and Transformation. Chronica Horticulturae 51(3):23−28.

Currey, C.J. and R.G. Lopez. 2011. Early Flurprimidol Drench Applications Control Final Height of Four Poinsettia Cultivars. HortTechnology 21(1):35–40.

Whipker, B.E., I. McCall, J. Barnes, W. Buhler, B. Krug, C. Currey, and R. Lopez. 2011.

Flurprimidol Preplant Bulb Soaks Control Growth of Potted Liliums. Acta Horticulturae 900:79−88.

Currey, C.J. and R.G. Lopez. 2011. Control Stem Length with Liner Dips. Greenhouse Grower 20(10):26−28.

Lopez, R.G. and C.J. Currey. 2011. Basics of Monitoring: Graphical Tracking. Greenhouse Grower 20(9):22−30.

Hutchinson, V.A., C.J. Currey, J.L. Beckerman, and R.G. Lopez. 2011. Maintaining Annuals in Midwest Landscapes. Midwest Regional Turf Foundation Field Day Handbook 2011: 32−35.

Currey, C.J. and R.G. Lopez. 2011. Basics of Monitoring: The Greenhouse Environment. Greenhouse Grower 29(8):34−40.

Currey, C.J., D.M. Camberato, and R.G. Lopez. 2011. Dealing with Bedding Plant and Garden Mum Nutritional Challenges. The Indiana Flower Grower 5(1):3–6.

Camberato, D.M. and R.G. Lopez. 2011. The potential of poinsettia trees. Greenhouse Grower 29(7):56−58.

Campbell, B., B. Behe, C. Hall, J. Dennis, R. Lopez, and C. Yue. 2011. Demand for sustainability: the value of biodegradable containers. Greenhouse Grower 29(4):40−44.

Behe, B., B. Campbell, J. Dennis, C. Hall, R. Lopez, and C. Yue. 2011. Demand for sustainability: no two consumers are alike? Greenhouse Grower 29(3):42−47.

Lopez, R., J. Dennis, B. Behe, C. Hall, C. Yue, and B. Campbell. 2011. What are growers doing about sustainability? Greenhouse Grower 29(2):32−36.

Hall, C., B. Behe, B. Campbell, J. Dennis, R. Lopez, and C. Yue. 2011. How appealing are biodegradable containers? Greenhouse Grower 29(1):72−76.

Lopez, R.G. and Neil Mattson. 2011. USDA Rural energy for America program grants (REAP) for greenhouse energy efficiency. OFA – An Association of Floriculture Professionals Bulletin 925(1):23−24.

For the Mitchell Lab:

Mitchell, C. 2012. Plant lighting in controlled environments for space and earth applications. Acta Hort. 956: 23-36.

Mitchell, C., A.J. Both, C. M. Bourget, J.F. Burr, C. Kubota, R.G. Lopez, R.C. Morrow, and E.S. Runkle. 2012. LEDs: The future of greenhouse lighting! Chronica Hort. 52 (1): 6-12.

Massa, G.D. and C.A. Mitchell. 2012. Sweetpotato vine management for confined food production in a space life-support system. Adv. Space Res. 49: 262-270.

1. Scientific and Outreach Oral Presentations:

For the Lopez Lab:

V.A. Hutchinson, C.J. Currey, and R.G. Lopez. *Daily Light Integral during Vegetative Propagation Affects the Subsequent Growth and Development of Annual Bedding Plant Species.* American Society for Horticultural Science Annual Meeting, Waikoloa, Hawaii. Waikoloa, Hawaii. September 26th, 2011.

Currey, C.J., V.A. Hutchinson, and R.G. Lopez. *Photosynthetic Daily Light Integral during Propagation Influences Rooted Cutting Morphology and Growth*. American Society for Horticultural Science Annual Meeting, Waikoloa, Hawaii. Waikoloa, Hawaii. September 26th, 2011.

Currey, C.J. and R.G. Lopez. *Photosynthetic Daily Light Integral in Propagation Impacts Biomass Accumulation, Partitioning, and Development of* Impatiens hawkeri *Cuttings*. Department of Horticulture and Landscape Architecture Research Retreat. West Lafayette, Indiana. May 11th, 2011.

Currey, C.J., V.A. Hutchinson, and R.G. Lopez. *Station Report, Purdue Floriculture*. NCERA-101 Committee on Controlled Environment Technology & Use Annual Meeting. Ames, Iowa. May 2nd, 2011.

Currey, C.J., M. Duff, D. Camberato, and R.G. Lopez. *Effects of Water pH and Alkalinity on PGR Efficacy*. Indiana Flower Growers Association 29th Annual Meeting. West Lafayette, Indiana. October 12th, 2011.

Currey, C., R. Lopez, J. Erwin, and E. Runkle. *Managing Photosynthetic Light for Production and Scheduling*. OFA Plug and Cutting Conference. San Jose, CA. September 14th, 2011.

Erwin, J., C. Currey, E. Runkle, and R. Lopez. *Managing Photoperiodic Light for Production and Scheduling*. OFA Plug and Cutting Conference. San Jose, CA. September 14th, 2011.

Currey, C., E. Runkle, J. Erwin, and R. Lopez. *Managing Temperature for Production and Scheduling*. OFA Plug and Cutting Conference. San Jose, CA. September 14th, 2011.

Currey, C., E. Runkle, N. Mattson, and B. Miller. *Unconventional Uses of Florel, Part 2.* OFA Short Course. Columbus, Ohio. July 10th, 2011.

Currey, C., E. Runkle, and N. Mattson. *Unconventional Uses of Florel, Part 1*. OFA Short Course. Columbus, Ohio. July 10th, 2011.

Currey, C.J. and R.G. Lopez. *Color Up Your Annuals*. Indiana Flower Growers Association Spring Bedding Plant Conference. Westfield, Indiana. February 16th, 2011.

Currey, C.J. *Starting a Greenhouse at Your Farm Market.* Indiana Horticultural Congress. Indianapolis, IN. January 20th, 2011.

Currey, C.J. *Topflor: A New Tool for Your PGR Toolkit*. Toledo Area Flower and Vegetable Growers Association Winter Conference. January 6th, 2011.

For the Mitchell Lab:

Dzakovich, M., C. Gomez, and C. Mitchell. 2012. LED vs. HPS supplemental lighting effects on fruit quality of greenhouse tomato. Oral presentation at the 2012 annual ASHS conference, Miami, Florida, August 1.

Gomez, C., and C. Mitchell. 2012. Light-emitting diodes (LEDs) as a sustainable alternative for lighting greenhouse-grown tomatoes. Oral presentation at the 2012 annual ASHS conference, Miami, Florida, August 3.

Mitchell, C. 2012. Developing LED lighting technologies and practices for sustainable specialty crop production. Oral presentation at Organization for Horticulture Professionals (OFA) annual shortcourse, Columbus, Ohio, July 15.

Mitchell, C.A., A.J. Both, C.M. Bourget, J.F. Burr, C. Kubota, R.G. Lopez, R.C. Morrow, and E.S. Runkle. 2011. Developing LED lighting technologies and practices for greenhouse crop production. Oral presentation at the 2011 annual ASHS conference, Waikoloa, Hawaii, September 27.

Mitchell, C. A., A.J. Both, C.M. Bourget, J.F. Burr, C. Kubota, R.G. Lopez, G.D. Massa, R.C. Morrow, E.S. Runkle. 2011. Developing LED lighting technologies and practices for greenhouse crop production. Oral presentation at GreenSys2011, Halkidiki, Greece, June 6.

Mitchell, C. 2011. Plant responses to LED lighting for space and earth applications. Oral presentation at Plant-Light Interactions and LED Technology Workshop sponsored by he New Zealand Controlled-Environment Laboratory, Palmerston, North, New Zealand, May 25.

Mitchell, C. 2011. Plant lighting in controlled environments at the dawn of the LED era. Oral presentation at Plant-Light Interactions and LED Technology Workshop sponsored by he New Zealand Controlled-Environment Laboratory, Palmerston, North, New Zealand, May 24.

Mitchell, C. 2011. The potential of controlled environment agriculture: coming of age in the 21st century. Two oral presentations at ITR Headquarters, Taiwan, April 12 and 13.

Other Relevant Accomplishments and Activities:

For the Lopez Lab:
Currey, C.J. Awards:

P. Allen Hammer Scholarship, Indiana Flower Growers Association.

African Violet Society of America Scholarship, African Violet Society of America.

Valent Biosciences Corporation Best Poster Presentation Award, 38th Annual Meeting of the Plant Growth Regulation Society of America Graduate Student Poster Competition.

James K. Rathmell Scholarship for Horticultural Study Abroad, American Floral Endowment.

Graduate Student Travel Grant, American Society for Horticultural Science.

PGRSA Travel Award, Plant Growth Regulation Society of America.

First Place Poster Presentation, NCERA-101 Committee on Controlled Environment Technology & Use Annual Meeting Graduate Student Poster

Competition. **D. Thomas Woods Memorial Fund to Support International Activity,**

Lopez, R.G. Awards:
Purdue Research Foundation International Travel (IT) Grant

For the Mitchell Lab:

Dzakovich, Michael. First place awards for outstanding undergraduate student oral research presentation and general horticulture competency test, at the 2012 annual ASHS annual conference, Miami, Florida, July 31 to August 3.

Gomez, Celina. Third place award for outstanding graduate student oral research presentation in the Controlled Environments category at the 2012 annual ASHS conference, Miami, Florida, July 31 to August 3.

Gomez, Celina. Second-place award for best poster at the 2011 NCERA-101 graduate student poster competition, Ames Iowa, April 30 to May 3.

Cary Mitchell received the American Institute of Aeronautics and Astronautics 2012 Jeffries Aerospace Medicine and Life Sciences Research Award for outstanding contributions to space life sciences through ground-based research and project leadership.