2016 NCERA-101 Report from Purdue University

1. **New Facilities and Equipment.** A recirculating aquaponics system has been installed in zone 5 of the Horticulture Greenhouse complex at Purdue University. This facility consists of six aquaponics units, each of which is composed of 3 major parts: an aquaculture rearing tank (378 L), a microbial biofilter (20L), and a hydroponic culture tank (378 L). Tilapia have been the fish test species of choice during the first year of operation. Stocking density of 20-25 kg tilapia/m^3 has been coupled with stands of vegetable crops including tomato, basil, and leaf lettuce, with the intervening microbial ecosystem including nitrifying bacteria. A research program has been launched to optimize management practices and achieve mass and energy balances under the direction of Dr. Hye-Ji Kim.
2. **Unique Plant Response.** Chinese Cabbage plants grown at Purdue in ground-based mock-ups of the "Veggie" plant-growth units that are growing salad plants on the International Space Station (ISS) developed leaf necrosis as well as chlorosis in addition to growth stunting under ISS environmental conditions.
3. **Accomplishment Summary.** Purdue University mimicked environmental and cultural conditions used on the International Space Station (except for microgravity) to grow Chinese cabbage and dwarf tomato in a growth chamber on the ground using ground-based mock-ups of the ISS "Veggie" plant-growth units. Unlike successful growth responses that have been reported on ISS for leaf lettuce, growth responses of Chinese cabbage and dwarf tomato to ISS and Veggie cultural and environmental conditions have been relatively poor. A number of stress control points have been identified, and effort is underway to eliminate or minimize stressors as well and their potential interactions.
4. **Impact Statement.** To enable a "pick-and-eat" salad-growth scenario for the crew of the International space Station, NASA has established on ISS a Veggie Plant-Growth Unit that is lighted by LEDs. In addition to the microgravity environment of ISS, plants grow under the ambient temperature (24.5 C days / 21 C nights), humidity (45% days / 55% nights), and CO_2 (2800 ppm average) environment of the ISS crew cabin. Initial trials involving a given cultivar of leaf lettuce grown on ISS resulted in normal plant growth compared to ground-based conditions. Trials of a promising cultivar of Chinese cabbage at Purdue varying combinations of growth-substrate composition, incorporated timed-release fertilizers, LED spectral composition, and total light intensity conducted in a growth chamber using Biomass-Production-Systems-for-Education (BPSe) units under ISS environmental conditions resulted in vastly inferior plant growth compared to greenhouse controls. Similar poor growth was found for a promising dwarf tomato cultivar under ISS conditions. Although multiple cultural and / or environmental stressor combinations

are suspected to be causal, attempts to eliminate them one by one have failed to improve growth of Chinese cabbage, until CO_2 was reduced from 2800 PPM to near Earth-normal ambient. Since modification of ambient crew-cabin CO_2 concentration is not an option for plant growth in Veggie on ISS, investigations are underway at Purdue to alleviate other-CO_2 environmental / cultural stressors in effort to determine if eliminating those interactions can significantly reduce plant response to supra-optimal CO_2. Parallel efforts are investigating whether genetics and / or genetics x environment interactions are responsible for the negative response of the Chinese cabbage cultivar thus far tested to supraoptimal CO_2 in combination with other ISS plant-growth conditions.

Published Written Works.

Book Chapters:

Dorais, M., C. Mitchell, and C. Kubota. 2016. Lighting greenhouse vegetables. In: R. Lopez and E. Runkle (eds.). Light Management in Controlled Environments, Meister Media, publ. (In press).

Mitchell, C. 2016. From the Earth to the Moon-and back again! In: R. Lopez and E. Runkle (eds.). Light Management in Controlled Environments. Meister Media, publ. (In press).

Mitchell, C. and G. Stutte. 2016. Sole-source lighting for controlled-environment agriculture. In: R. Lopez and E. Runkle (eds.). Light Management in Controlled Environments. Meister Media, publ. (In press).

Lu, N. and C.A. Mitchell. 2016. Supplemental lighting for greenhouse-grown fruiting vegetables. In T. Kozai et al. (eds.), *LED Lighting for Urban Agriculture.* DOI 10.1007/978-981-10-1848-0_16.

Mitchell, C., J. Burr, M. Dzakovich, C. Gomez, R. Lopez, R. Hernandez, C. Kubota, C. Currey, Q. Meng, E. Runkle, C. Bourget, R. Morrow, and A.J. Both. 2015. *LEDs in Horticulture.* Horticultural Reviews 43: 1-87.

Refereed Journal Articles:

Dzakovich, M., M. Feruzzi, and C. Mitchell. 2016. Manipulating sensory and phytochemical profiles of greenhouse tomatoes using environmentally relevant doses of ultraviolet radiation. J. Agr. & Food Chem. DOI: 10.1021/acs.jafc.6b02983.

Gomez, C. and C. Mitchell. 2016. Physiological and productivity responses of high-wire tomato as affected by supplemental light source and distribution within the canopy. J. Amer. Soc. Hort. Sci. 141 (2): 196-208.

Dzakovich, M., C. Gomez, and C. Mitchell. 2015. Tomatoes grown with light-emitting diodes (LEDs) or high-pressure sodium (HPS) vs. HPS supplemental lighting are of comparable quality. HortScience 50 (10): 1-5.

Proceedings:

Mitchell, C. 2016. LEDs for plant research and controlled-environment agriculture. Horticultural lighting conference. PenWell Corp., The Palmer House, Chicago, IL, October 12. hlc_2016_conference_proceedings.pdf.

Mitchell, C. 2016. LED lighting as a plant-growth regulator: an historical perspective. 43rd annual conference of The Plant-Growth Regulator Society of America (PGRSA), Raleigh, NC, Mitchell, C. 2016. July 18. http://pgrsa.org/conference/2016-conference.

Gomez, C. and C. Mitchell. 2016. In search of an optimized supplemental lighting spectrum for greenhouse tomato production with intracanopy lighting. Acta Hortic. 1134. ISHS 2016. DOI 10.17660/ActaHortic.2016.1134.8. Proc. VIII Int. Symp. on Light in Horticulture, C.J. Currey et al., Eds.

Gomez, C., M. Clark, and C. Mitchell. 2016. Effect of intracanopy lighting and/or root-zone temperature on high-wire tomato production under sub-optimal air temperature. Acta Hortic. 1134. ISHS 2016. DOI 10.17660/ActaHortic.2016.1134.9 Proc. VIII Int. Symp. on Light in Horticulture C.J. Currey et al., Eds.

Mitchell, C. 2015. Academic research perspective of LEDs for the horticulture industry. HortScience 50(9): 1293-1296.

Poster Presentations:

Burgner, S. and C. Mitchell. 2016. Optimized light quality and fertilizer composition for crop production on the International Space Station. American Society for Gravitational and Space Research, 32nd annual meeting, Cleveland, OH, October 26-29.

Kim, H-J, C. Gomez, and C. Mitchell. 2016. Comparison of LED and HPS supplemental light quality on greenhouse tomato production in northern states during winter months. American Society for Horticultural Science, 113th annual conference, Atlanta, GA, August 8-11.

Burgner, S. and C. Mitchell. 2016. Optimized light quality and fertilizer composition for crop production on the International Space Station. American Society for Horticultural Science, 113th annual conference, Atlanta, GA, August 8-11.

Invited Keynote Presentations:

Mitchell, C. 2016. LEDs for plant research and controlled-environment agriculture. Horticultural lighting conference. PenWell Corp., The Palmer House, Chicago, IL, October 12.

Mitchell, C. 2016. Peri-urban agriculture in greenhouses and warehouses using LEDs and renewable energy. Workshop on "Energy from renewables: confronting global collapse". University of Minnesota, Minneapolis, October 1.

Mitchell, C. 2016. Reducing energy for plant-growth lighting in space and on Earth. Plants-in-Space Symposium, Australian Academy of Sciences, The Shine Dome, Canberra, Australia, September, 21.

Mitchell, C. 2016. LED lighting as a plant-growth regulator: an historical perspective. 43rd annual conference of The Plant-Growth Regulator society of America (PGRSA), Raleigh, NC, July 18.

Oral Contributed Presentation:

Kim, H-J and C. Mitchell. 2016. Evaluating water use of greenhouse tomato as affected by light quality of LED and HPS supplemented during winter months. American Society for Horticultural Science. 113th annual conference, Atlanta, GA, August 8-11.