2017 Purdue NCERA-101 Station report

The Department of Horticulture & Landscape Architecture at Purdue welcomes Dr. Krishna Nemali to its faculty ranks. Dr. Nemali has prepared a brief summary of his contact information, background, and startup activities in his role as a Controlled-Environment Agriculture faculty member.

Krishna Nemali
Assistant Professor, Controlled Environment Agriculture
Department of Horticulture and Landscape Architecture
Purdue University, West Lafayette, IN 47907
Tel: 76-494-8179
Email: knemali@purdue.edu
Website: www.purdue.edu/hla/sites/cea

Dr. Nemali joined the Purdue Horticulture and Landscape Architecture department in July 2016 as an assistant professor. He has responsibility for extension, research, and teaching activities related to controlled environment agriculture, which includes ornamentals and vegetables grown under protected culture. He has a Ph.D. from the University of Georgia focused on development of plant-uptake-based automated irrigation techniques using sensors and understanding the physiological responses of greenhouse crops to varying input (light, water, and nutrients) levels during production. Prior to joining Purdue, he worked at Monsanto company, USA for nearly 9 years as a controlled environment crop physiologist. His research at Monsanto significantly contributed to the commercialization of the first biotechnology-derived, drought-tolerant maize. His program at Purdue is focused on developing and making available affordable, robust, and feasible technologies and solutions that address current and future challenges and improve sustainability (i.e., reduce input waste, minimize environmental impact, and increase profits) in controlled environment agriculture.

New Facilities and Equipment:

1. Aris TopView Multi-Spectral Imaging Station
2. Apogee SS-110 Spectro-radiometer
3. Decagon NDVI/PRI Spectral Reflectance Sensors
4. Campbell Sci. CR300 Dataloggers
5. Campbell Sci. CS615 EC/Temp/VWC sensor
6. Decagon Pro-Check handheld Datalogger
7. Apogee Infrared Radiometer
8. FLIR-One Infrared Camera

Unique Plant Responses/Accomplishments:

1. Old technique with new application: Normalized difference vegetation index (NDVI) measurements were found to be correlated with supplemental light-use efficiency of plants. Petunia plants were exposed to drought stress to purposefully lower light use efficiency by lowering photosynthesis. Under drought stress, plants reflected relatively

more incident red light from supplemental lighting as measured by a lower NDVI value. In addition, NDVI measurements were found to be more useful under artificial lighting than under sunlight conditions.

2. Crop growth rate of several bedding plant seedlings, lettuce and tomato were non-invasively measured using top view image station. The image station fluorescence signal from the canopy as a mask to detect plant edges in the image and automatically calculates pixel area, which was further highly correlated to total leaf area and shoot dry weight. This technique offers a rapid way to detect plant responses to environment using imaging technique.

3. We are currently testing the use of canopy reflectance to estimate crop N status. Our preliminary results are very promising and suggest a potential use of calculating relative greenness index (intensity of green pixels in the image) and relative reflectance of red waveband to NIR waveband in estimating canopy N status. We use MultiSpec software to convert images to grayscale and calculate intensity of pixels in the image after exposure to a particular wavelength of light in the TopView Image Station. Our goal is to develop Smartphone based Apps to measure canopy N status in greenhouse plants.

4. We are currently using image-based approach to measure daily crop growth rate and required nutrient solution concentration for hydroponic lettuce. This approach seems promising as we adjust fertilizer EC based on N demand of the crop and not on a target level. Our preliminary results indicate that higher lettuce biomass can be produced by adjusting nutrient solution concentration based on crop growth rate compared to maintain a target EC. This approach has potential use in plant factories where it is difficult to manually monitor plants. Cameras have potential use in these production systems.

5. Joshua Craver, a Ph.D. student working with Dr. Nemali (graduate committee member) and Drs. Lopez and Mitchell (co-advisors), identified that higher fraction of blue light (50:50) in the spectrum increases photosynthesis rate of plants by increasing light saturation point, electron transport rate and mesophyll conductance in plants. Josh measured A-PPF and A-Ci curves on petunia seedlings grown under 90:10 (red: blue) or 50:50 (red: blue) light treatments using LED lights in a growth chamber. His research shows that total leaf area and biomass are higher under higher red light treatment as these plants preferentially allocated more biomass to leaf growth and thereby, intercepted more light than 50:50 (red:blue) treatment. This result emphasizing the importance of total light interception, and not the rate of photosynthesis *per se*, on dry matter accumulation and plant growth. An interesting finding in his research was that plants grown under 50:50 (red:blue) treatment showed preferential biomass partitioning to the root system, and may have potential benefit for stress tolerance. Moreover, plants in this treatment were found to be compact, a trait that is appealing to customers.

Impact Statement

The Controlled Environment Agriculture lab at Purdue University is developing sensors to remotely measure crop growth, plant N status, and crop light use in greenhouses. Our approach is to conduct the discovery work using state-of-the art equipment and use the generated algorithms and techniques to develop affordable and robust technologies (ex: Smartphone Apps with embedded software for analysis) that can be broadly disseminated to industry and research professionals. We have established algorithms to non-invasively measure crop growth rate (based on shoot dry weight) and leaf area using imaging technique. We obtained promising results to develop remote sensing techniques for crop N and light use efficiency measurements.

Website:

A new website called Purdue Controlled Environment Agriculture lab has been developed by Dr. Nemali. The website can be accessed at this link: www.purdue.edu/hla/sites/cea. The website hosts information on research, extension and teaching related activities in controlled environment agriculture.

Report from the C.A. Mitchell (CAM) laboratory:

1. **New Facilities and Equipment.** The CAMLab continues to develop the Minitron III controlled-environment/crop-cuvette system that will measure gas-exchange rates of hydroponic crop stands in the same environmental conditions as those under which they are grown. The recirculating hydroponic root system is compartmented separately from the flow-through cuvette headspace, the height-adjustable cuvette compartment is capped with a dimmable LED light array, and cuvette temperature is maintained by an external temperature-controlled recirculating bath pumping coolant through a heat exchanger in the cuvette plant-growth space. The cuvette space has recirculating fans for air mixing, temperature sensors, a quantum light sensor, computer-controlled air-flow rate through the cuvette space, and injection and control of CO_2. Return air from the cuvette flows through an infrared gas analyzer (IRGA), and CO_2 differential between sample air and cuvette bypass air going through a reference cell is used, along with air-flow rate and plant-growth area, to determine photosynthetic rate as a function of crop stage, light intensity or spectrum, CO_2 concentration, and/or cuvette temperature. The computer-controlled and monitored controlled-environment/gas-exchange system is anticipated to be routinely functional by fall, 2017.

2. **Unique Plant Response.** Preliminary screening of Chinese cabbage (*Brassica rapa* cv.Tokyo Bekana) in growth chambers at KSC using peat/arcillite media incorporating controlled-release fertilizer with capillary-wicking irrigation, cool-white fluorescent lighting at a PPFD of 400 $\mu molm^{-2}s^{-1}$ and 400 $\mu molmol^{-1}$ CO_2 indicated that cultivar to be particularly productive and a top candidate for growth in the 'Veggie' plant-growth unit on the International Space Station (ISS) for astronaut pick & eat activity. However, when grown at Purdue in Veggie analogues in controlled environment conditions on the ground mimicking ISS environmental conditions (except for microgravity), growth impairment and multiple symptoms of stress occurred, which have not been observed for other salad species (viz. lettuce, radish) on the ground or on ISS.

3. **Accomplishment Summary.** Several different cultural and/or environmental stressors seem to be present in the ISS-mimicked growth-

chamber environment that may have contributed to growth inhibition and chlorosis/necrosis of Chinese cabbage 'Tokyo Bekana'. Systematic research to eliminate them one by one failed to alleviate all stress symptoms. Incremental improvements typically were seen as stress candidates were varied. Chronically high CO_2 mimicking what is present on the ISS has emerged as a major candidate stressor, but LED spectral composition, polymer-coated fertilizer ratios and dose, and even the arcillite growth medium *per se* all loom as potential contributors to the growth reduction of this sensitive Chinese cabbage cultivar seen under ISS-normal environments and Veggie growth conditions at 1 x g.

4. **Impact statement.** Chinese cabbage cv. Tokyo Bekana appears to be a very sensitive indicator species of environmental stress that unexpectedly reacted negatively to multiple ISS-normal stressors, possibly in a synergistic way. Because the few other salad species that have been grown in space have not reacted negatively to the ISS cabin environment, 'Tokyo Bekana' may be a valuable indicator species for plant-growth stressors in space, known or unknown, compared to Earth-normal growth conditions in which it has been shown to thrive.

Published Written Works.

Scientific Publications:

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.

Book Chapters:

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.

Dorais, M., C. Mitchell, and C. Kubota. 2017. Chapter 17: Lighting greenhouse fruiting vegetables. In: R. Lopez and E. Runkle (eds.). Light Management in Controlled Environments, Meister Media, publ.

Mitchell, C. 2017. From the Earth to the Moon-and back again! In: R. Lopez and E. Runkle (eds.). Light Management in Controlled Environments. Meister Media, publ.

Mitchell, C. and G. Stutte. 2016. Chapter 5: Sole-source lighting for controlled-

environment agriculture. In: R. Lopez and E. Runkle (eds.). Light Management in Controlled Environments. Meister Media, publ.

Conference Proceedings:

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.

Conference Presentations.

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.

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.

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. 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. 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.

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.