Purdue NCERA-101 Station Report for 2021

Krishna Nemali Laboratory

A. Research Activities (2021):

1. It is estimated that 68.4% of global population live in urban areas by 2050. The population growth demands regular supply of fresh, nutritious, and safe food in urban areas. One concept that has evolved recently is to produce food in urban areas using indoor vertical farming. These farms can be fitted with customized LED lights for producing leafy greens and other small-statured crops. We are studying the effects of spectral composition of light ranging from 365 to 750 nm on phytochemical levels including beta-carotene (precursor to vitamin A), phylloquinone (precursor to vitamin K), and anthocyanins (anti-oxidants) in lettuce. The purpose is to understand the physiological mechanisms affected by light spectral composition that influence phytochemical levels in lettuce. Our goal is to increase nutritional value of lettuce with minimal negative effect on plant growth and quality. We have established a vertical production system where air temperature, light intensity, and spectral composition are tightly controlled. In addition, we have established assays to measure phytochemical levels in plant tissue.

2. Although there has been a double-digit increase in the demand for organic produce during the last three decades, low crop yields have been a persistent problem in organic farming. This is attributed mainly to low nitrogen (N) availability to plants and lack of synchronization between crop growth and N release from organic fertilizers. Organic yields can be improved by optimizing plant N levels. However, this requires regular monitoring and optimal management of plant N status. We are developing affordable and reliable IoT sensors for capturing and locally processing images, and estimating plant growth and N status. When developed, the sensors will effectively collaborate with each other and provide automated decision support on nutrient delivery to plants and managing optimal N status in plants. Currently, we are manually studying different organic recipes for lettuce that result in crop yields which are comparable to conventional hydroponic production. We will test the efficacy of the IoT sensor technology to automatically maintain high lettuce yields and optimize fertilizer use in organic hydroponic production using the developed organic fertilizer recipe.

3. Water scarcity, food insecurity, under-nourishment and unemployment are major issues faced by Egypt. With population growth expected to increase by 50 million in next 20 years, there is an increased risk of food insecurity in Egypt. Research has shown that hydroponic and aeroponic production systems can save 60 to 75 percent of irrigation water and produce yields similar or better than field based production. Hydroponic/aeroponic production under protected agriculture (e.g. greenhouse) can ensure year-round food production with less water requirement in Egypt. However, region-specific hydroponic production technologies need to be developed. The technology is medium to high in investment. To develop technologies that are feasible to small-scale growers in Egypt, it is critical that they are efficient and affordable. With support from USDA FAS, we are conducting research on screening best hydroponic/aeroponic technologies for Egypt. Best technologies that reduce water-use and maximize crop yield and nutritional quality will be validated in Egypt. Sustainability of new technologies in Egypt will heavily rely on developing

trained workforce. Our approach is to conduct extension and outreach activities in Egypt to train producers (especially women and small-scale producers) by demonstrating the benefits of developed technology.

Research Publications (2021):

1. Adhikari, R. and K. Nemali. (2021). Whole-Plant Tissue Nitrogen Content Measurement Using Image Analyses in Floriculture Crops. Journal of Environmental Horticulture (Accepted).
2. Zea, M, Souza, A, Yang, Y, Lee, L, Nemali, K. and Lori Hoagland. Leveraging high-throughput hyperspectral imaging technology to detect cadmium stress in two leafy green crops and accelerate soil remediation efforts. Environmental Pollution (Accepted).
3. K. Nemali (2021). History of Controlled Environment Agriculture: Modern Greenhouses. Hortscience (Accepted).
4. Kong, Y. and K. Nemali. (2021). Blue and Far-red Light Affect Area and Number of Individual Leaves to Influence Vegetative Growth and Pigment Synthesis in Lettuce. Frontiers in Plant Science. https://doi.org/10.3389/fpls.2021.667407.

Research Grants (2021):

1. Automated Monitoring and Management of Plant Nitrogen Status in Organic Farming Using Decentralized and Collaborative IoT Sensors and Image Analyses (Purdue Ag Seed, $26,984).
2. Increasing Crop Productivity and Consumer Accessibility of Hydroponically Grown Organic Lettuce in Indiana (USDA SCBG, $143,000)

C.A. Mitchell Laboratory

New Facilities and Equipment.

For the SCRI OPtimIA project, Phytofy LED arrays were replaced with ORBITEC/Sierra Space BPSE LED arrays for close-canopy lighting (CCL) experiments. Each BPSE unit is continuously variable in height, and red, green, and blue LEDs are distributed uniformly within the array, which is important for close lamp/crop separation distances. BPSE LEDs are dimmable by waveband, which also is important for control of spectral composition. Height is adjustable ranging from 15 cm as the closet vertical distance between lamp and crop surface to 45 cm, which is the control based on commercial settings.

For the AFRI Minitron III project, a CO_2 injection sub-system was added prior to the inlet port to the crop gas-exchange cuvette. A mass-flow valve (MFV) was installed within a stream of pure CO_2 prior to injection into a bulk air stream. MFV apertures are controlled from a computer keyboard. A CO_2 scrubbing sub-system was added to bulk airflow upstream of CO_2 injection for precise control of CO_2 concentration of cuvette inlet air. This was particularly useful for establishing CO_2 and light dose-response curves.

Unique Plant Responses.

Through gas-exchange analysis, baby-green and leafy-green crop stands followed the same pattern as they responded to various levels of CO_2 and light intensity in dose-response curves. Although the overall pattern was similar, leafy greens saturated at slightly higher concentration than did baby greens in CO_2 dose-response curves.

Accomplishment Summaries.

For the OptimIA project, CCL tended to capture more photons that otherwise would be lost by typical 120 to 130 degree beam spread outside the cropping area below LED fixtures. Use of white curtains helped to reflect back some photons that otherwise would be would be lost. Combining CCL and reflective curtains kept or retrieved the most light, and plants either grew more or saved more energy for lighting, depending on the CCL strategy being tested.

For Minitron III, crop gas-exchange measurements indicated that photosynthesis of baby and leafy greens saturates at CO_2 levels about half of what commercial growers use, and the low light level growers use likely is why they do not get more response to their elevated CO_2.

Impact Statements.

The goal of both OptimIA and Minitron projects is to save energy and resources for growing leafy-greens indoors. The overall approach combines close-canopy lighting, targeted lighting, and phasic optimization, utilizing timing and degree of CO_2 enrichment in combination with spectral and intensity optimization at different stages of baby and leafy greens production.

Published Written Works.

Mitchell, C. 2021. History of indoor agriculture and associated technology development. HortScience (In press).

Morsi, A., G. Massa, R. Morrow, R. Wheeler, and C. Mitchell. 2021. Comparison of two controlled-release fertilizer formulations for cut-and-come-again harvest yield and mineral content of Lactuca sativa L. cv. Outredgeous grown under International Space Station environmental conditions. Life Support and Space Research (submitted for publication).

F. Sheibani and C. Mitchell. CO_2 and light photosynthetic dose-response profiles for baby-green and leafy-green stages of 'Rouxai' lettuce production. Poster presentation, August 6, 2021. ASHS annual conference.

F. Sheibani and C. Mitchell. Close-canopy LED lighting as an energy-efficient and/or yield-enhancing lighting strategy for indoor production of baby greens. Oral presentation, August 9, 2021. ASHS annual conference.