2019 NCERA-101 Purdue Station Report

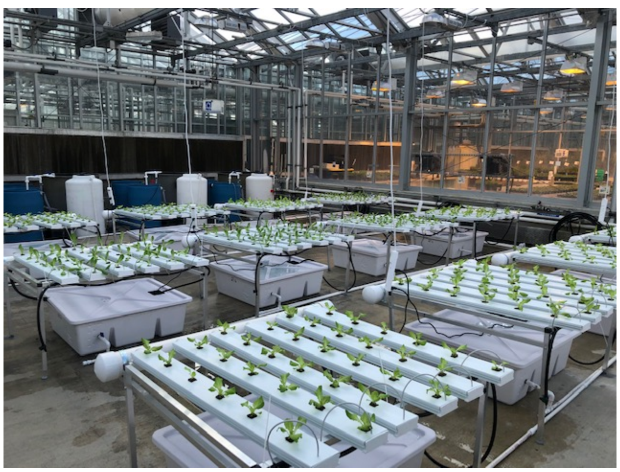
Nathan Deppe, Purdue Plant-Growth Facilities Manager:

New Facilities and Equipment

In 2018, we updated supplemental lighting for one of our shared teaching/research greenhouse bays that measures 9.1 m x 12.2 m. Existing 1000 W magnetic-ballast-powered high-pressure sodium fixtures were removed and 630-W broad-spectrum LEDs (FluenceBioengineering, VYPRxmPlus and PhysioSpec Greenhouse) were mounted at a rate of 1:1 9.5 feet above bench top. This design maintained a uniform irradiation field of 125 µmol/m²/s PAR. Additionally, drivers have been wired to provide two independent dimming circuits for research utilization.

Hye-Ji Kim, Sustainable Crop-Production Systems:

New Facilities and Equipment



Decoupled aquaponic systems were installed at Purdue HLA Greenhouse facilities, which can be scaled up to commercial aquaponics. The aquaponic systems consist of 3 aquaponic units, including three fish-rearing tanks (200 gallons each) to feed 12 nutrient-film technique (NFT) systems. The total water volume in each aquaponic unit (fish tank, sediment tank, biofilter, water reservoir, and four hydroponic nutrient containers) is 650 gallons. The sediment tank captures most suspended solids from the fish tank. After passing through the sediment tank, aquaculture wastewater flows into the biofilter filled with biomedia and then the water reservoir, where wastewater from the fish tank is optimized for plant crop production and recirculated within the hydroponic unit.

Unique Plant Responses

Plants grown in aquaponics perform better at a higher flow rate (HFR, 2 L/min, 1/5th to 1/10th of conventional flow rate) than at low flow rate (LFR, 0.7 L/min). Water-quality parameters were improved and associated with a higher growth rate and the total fresh and dry weight of crops grown at HFR. HFR-improved growth was more prominent in shoots than in roots and increased fish growth rate, biomass, and feed-conversion efficiency. The leaf greenness (SPAD value) and photosynthetic rate (*Pn*) of crops grown at HFR were significantly higher than those at LFR.

Regardless of supplemental light source (HPS lamps, R + FR LEDs), greenhouse high-wire tomato plants grown with low EC (1.8 µS/cm) maintained total dry weight, total fruit dry weight, dry weight per fruit, and DMR of the fruit to the levels of those grown with high EC (2.8 µS/cm). High EC promoted dry matter accumulation only in roots and dry matter partitioning from leaves to roots. Fruit harvest date was not affected by the reduction in EC. Notably, low EC improved the intensity of aroma regardless of light treatment, and tomatoes grown with HPS lamps and high EC or R + FR LEDs and low EC had a higher DOL score in sweetness, saltiness, and acidity compared to their counterparts.

Accomplishment Summaries

Several factors critically affect aquaponic crop production, including key nutrient elements, accumulation of harmful compounds, nutrient-management practices, water-flow rate, and pH of the aquaponic solution, which information will contribute to the successful operation of aquaponics.

Intracanopy LED supplemental lighting, an energy-efficient light source, promotes earlier and higher yield of greenhouse tomato, reduces water and fertilizer usage, and produces higher quality tomato fruit than does conventional HPS lamps.

Impact Statements

New knowledge was generated on nutrient profiles in the wastewater derived from ingested fish feed and nutrient dynamics during the production, which is critical to develop nutrient management guidelines in aquaponics and improve crop yield and quality.

Optimal light environment (red plus far-red LEDs) was identified for high-wire greenhouse tomato production, which produces a higher yield and better flavor than HPS lamps to a degree that consumers find more acceptable. This will contribute to the development of production guidelines of greenhouse tomatoes to improve yield and flavor.

Published Written Works

Kim, H.J.*, M.Y.Lin[†], and C. Mitchell. 2018. Light spectral and thermal properties govern biomass allocation among vegetative and reproductive structures of tomato through morphological and physiological changes. Environmental and Experimental Botany. https://doi.org/10.1016/j.envexpbot.2018.10.019

Colla, G., H.J. Kim, M.C. Kyriacous, and Y. Rouphael. 2018. Nitrate in fruits and vegetables. Scientia Horticulturae 237: 221-238.

Kim, H.J.*, T. Yang[†], M-Y, Lin[†], and P. Langenhoven. 2018. Plant propagation for successful hydroponic production. Acta Horticulturae 1212, 109-116 DOI: 10.17660/ActaHortic.2018.1212.22.

Presentations

M.Y. Lin[†] and H.J. Kim. 2018. Effects of light quality on high-wire tomato ion uptake, partitioning, and fruit quality. American Society for Horticultural Science, Washington, D.C., WA. Jul. 30-Aug. 3. (poster).

M.Y. Lin[†], A. Liceaga, and H.J. Kim. 2018. Far-red light-emitting diodes during production improves quality and flavor of tomato fruits. American Society for Horticultural Science, Washington, D.C., WA. Jul. 30-Aug. 3. (poster).

M.Y. Lin[†], and H.J. Kim. 2018. Light resource influences high-wire tomato ion accumulation, partitioning, and fruit quality. American Society for Horticultural Science, Washington, D.C., WA. Jul. 30-Aug. 3. (oral).

Yang, T[†]. and H.J. Kim. 2018. Performance and yield of vegetable crops are affected by water flow-rate in aquaponics systems. American Society for Horticultural Science, Washington, D.C., WA. Jul. 30-Aug. 3. (oral).

Yang, T[†], Y.J. Wang[†], and H.J. Kim. 2018. Performance of crop species with different thermal requirements in aquaponics systems. American Society for Horticultural Science, Washington, D.C., WA. Jul. 30-Aug. 3. (poster).

Krishna Nemali, Controlled Environment Edible and Floriculture Production:

New Facilities and Equipment

Dr. Nemali's lab built a system using LED lights that is capable of growing plants under different intensities of red, green, blue, and far-red light. A controller attached to the system will aid in changing intensities of individual wavelengths. In addition, his lab purchased a spectrophotometer that can expose samples in the range of UV and visible light. A handheld nitrogen sensor that can be interfaced to a smartphone also was built.

Unique Plant Responses

We found that LED fixtures containing more than 70% red-light output outperformed white LED fixtures in both indoor and greenhouse hydroponics systems. In addition, spectral composition of LED light affected greenhouse lettuce growth when supplemental lighting was provided during nighttime.

Accomplishment Summaries/ Impact Statements

We have trained nearly 80 growers in Indiana with greenhouse and indoor hydroponic production during workshops and conferences conducted last year. In addition, our research indicated that spectral composition of artificial light is an important factor affecting energy-use efficiency in indoor and greenhouse hydroponic production. Our work at Purdue has resulted in developing a handheld nitrogen sensor that can estimate tissue nitrogen content in groups of plants using an image-analysis technique. This sensor costs approximately $150 and will be made available to several growers for testing.

Published Works

We published 2 scientific articles related to hydroponics and floriculture in HortScience and JASHS, respectively. In addition, we published 2 articles in trade magazines related to measuring crop nitrogen status and plant growth non-Invasively using image analysis.

Cary Mitchell, Space Biology and Controlled-Environment Technology:

• NASA ILSRA ground-based VEGGIE Project (from the work of Asmaa Morsi)

Unique Plant Responses

Mizuna "cut-and-come-again" studies. This study is being conducted with two main objectives: 1) Investigating cut-and-come-again procedure effect on biomass yield each time, as well as 2) effects on nutrient content of Mizuna grown under International Space Station (ISS) environmental conditions; and identifying optimum slow-release fertilizer (type/dosage) treatment for growing Mizuna under ISS environments.

Mizuna plants were grown in a growth chamber mimicking environmental and cultural conditions as for the Veggie plant-growth system on ISS. Plants grew for 56 days under one of two fertilizer treatments: 50%T70:50%T100 or 50%T70:50%T180, all components at 7.5 g/liter of growth medium. Large and medium-sized leaves from both fertilizer treatments were harvested two times during the experiment: The first harvest occurred at 28 days from planting, and the second harvest at 42 days from planting. In addition, whole plants were harvested at 56 days to end the experiment.

50%T70:50%T100 fertilizer treatment results. Mizuna plants grown under this treatment exhibited a significant increase in yield from first to second harvest, with average total fresh weight of 134g and 216g for first and second harvests, respectively. However, there were no significant differences in yield between second and third harvests.

50%T70:50%T180 fertilizer treatment results. Mizuna plants grown under this treatment exhibited a significant increase in yield from first to second harvest, with average fresh weight of 166g and 196g for first and second harvest, respectively. This trend was followed by a significant decrease in yield from second to third harvest, with average fresh weight of 136g for the third harvest. This experiment is being replicated to get better a idea about variations within T180 treatments.

Accomplishment summary

Mizuna plants grown under the mix of 50%T70:50%T180 had higher yield during the first harvest. However, plants grown under the fertilizer treatment of 50%T70:50%T100 had higher increase in yield during the second harvest and less decrease during the third harvest. So, T100 treatment ended up with higher total yield for the three harvests together; with total fresh weight of 593g and 497g for T100 and T180 treatments, respectively.

Lettuce cut-and-come-again study. We are conducting this experiment with the same objectives as the Mizuna experiment, and following the same materials & methods. However, this time our plant material was lettuce cv. Outredgeous.

50%T70:50%T100 fertilizer treatment results. Lettuce plants grown under this treatment showed significant increase in yield from first to second harvest with average fresh weight of 84g and 290.17g for first and second harvest respectfully. However, our data did not show significant differences in yield between second and third harvest.

50%T70:50%T180 fertilizer treatment results. Lettuce plants grown under this treatment showed significant increase in yield from first to second harvest, with average fresh weight of 87g and 244g for first and second harvest respectfully. However, our data did not show significant differences in yield between second and third harvest.

Accomplishment Summary

In terms of total fresh weight for the three harvests, Lettuce plants grown under T100 treatment had significantly higher fresh weight than plants grown under T180 treatment; with total fresh weight of 593g and 506g for T100 and T180 treatments, respectively.

Impact Statement

From this study we concluded that, both Mizuna and lettuce grow better under fertilizer treatment of 50%T70:50%T100. However, further studies are needed to understand variations in Mizuna response to T180 fertilizer treatment.

• NIFA AFRI Energy-efficient production of leafy vegetables indoors, leveraging unique properties of light-emitting diodes (LEDs) (from the work of Fatemeh Sheibani)

New Facilities and Equipment

Accomplishment Summary. Activities during the report period focused on completing integration of Minitron III assembly toward being fully operational as a controlled-environment plant-growth/gas-exchange system with hydroponics and LED lighting. Minitron III will be a powerful analytical research tool that has been under development in Dr. Mitchell's lab combining knowledge of plant physiologists with the skills of Electrical and Mechanical-Engineering Technology upper-class undergraduate students who have contributed to system design, assembly, and computer-control programming. Minitron III is an environmentally controlled plant-growth system in which up to 48 leafy plants can be grown hydroponically from seed to harvest while LEDs are used for sole-source lighting. Crop-stand photosynthesis or dark respiration will be monitored continuously, and plant responses to environmental modifications will be recorded based on real-time gas-exchange analysis. CO_2 concentration, temperature, humidity, light intensity, light spectra, and photoperiod are individually controllable. All parameters will be set in the direction of energy-efficiency optimization through monitoring energy expenditure of LEDs as the lighting source of the system. Several system components have been upgraded or added to the system during the reporting period to ensure measurement accuracy and suitable environmental conditions for plant growth and development, including a multi-container CO_2 scrubber, a humidifier tower, and peristaltic pump. Ambient air will be scrubbed through 3 containers of soda lime, and pure CO_2 will be reinjected to maintain desired inlet CO_2 concentration. The humidifier was added to provide sufficient humidity, especially during early stages of plant development when higher relative humidity is required for successful germination and lag-phase growth during which leaf area is not well developed. The CO_2 scrubber and humidifier have been built from off-the-shelf components and fully designed by Mechanical Engineering Technology students. A constant-speed booster pump has been replaced by an adjustable-speed peristaltic pump to ensure accurate gas-exchange measurements. Also, programing in C# was tweaked in several cases based upon data streams from sensors and plant responses to environmental growth conditions. During the reporting period, several test runs of the system were conducted to enure that all mechanical and electrical components were working properly.

Another new and sophisticated component is being added to the system, including an LED array consisting of 48 LED light-engine modules developed by OSRAM Innovations with unique properties and capabilities for conducting plant research with the Minitron III system. All design, communications, and paper work have been done during the reporting period, and the array is ready for installation. Each LED module includes four channels of red, blue, green, and far-red wavebands of radiation. Each module is on/off switchable, and the combination of all modules are dimmable and tunable, by waveband. Self-monitoring and logging of power (kW) and energy (kWh) consumption have been designed in to this lighting system, which will assist in determining energy-use efficiency of the system. This lighting system also has a downward-pointing RGB camera in the center of the array that will enable researchers to monitor and perform quantitative, non-destructive image analysis of crop growth. Secondary optic lenses will be placed on each module to provide desired beam angle during the early stages of plants development, which adds another capability to this lighting system.

Impact Statement

The Minitron III plant-growth/gas-exchange system will enable real-time optimization of plant-growth environments for energy and resource savings for small crop stands continuously throughout the entire cropping period. It is expected to enable phasic optimization of growth environments for PPFD, spectrum, CO_2, temperature, and humidity. Crop photosynthetic responses to manipulation of mineral nutrition within the recirculating hydroponics system also will inform nutritional management of the hydroponic crops.

Published Written Works

Kim, H.J., M.Y. Lin, and C. Mitchell. 2019. Light spectral and thermal properties govern biomass allocation among vegetative and reproductive structures of tomato through morphological and physiological changes. Environmental and Experimental Botany. 157: 228-240. https://doi.org/10.1016/j.envexpbot.2018.10.019

Kong, Y., A. Nemali, C.A. Mitchell, and K. Nemali. 2019. Spectral quality of light can affect energy consumption and energy-use efficiency of electrical lighting in indoor farming. HortScience 54: 1-8. https://doi.org/10.21273/HORTSCI13834-18

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Mitchell, C. A. 2018. Growing food indoors year-round: lessons from NASA. Kiwanis, West Lafayette, IN, August 9.

Mitchell, C. A. 2018. Lighting Strategies for Energy Savings. Indoor Ag Science Cafe Ohio State/Michigan State/Purdue Universities, West Lafayette, IN, October 30.

Burgner, S.E., G.D. Massa, R.M. Wheeler, and C.A. Mitchell. 2018. Growth and photosynthetic responses of Chinese Cabbage to an ISS-like environment. American Society for Gravitational and Space Research. Bethesda, MD, November 3.