NCERA-101 Station Report – Texas A&M University

Genhua Niu, Texas A&M AgriLife Research at Dallas (genhua.niu@ag.tamu.edu)

Joe Masabni, Texas A&M AgriLife Extension, joe.masabni@ag.tamu.edu

Azlan Zahid, Texas A&M AgriLife Research at Dallas (azlan.zahid@ag.tamu.edu)

Shuyang Zhen, Depart. Horticultural Sciences, Texas A&M University, College Station (shuyang.zhen@tamu.edu)

Reporting period: April 2023-March 2024

Accomplishment summary

- A deep learning model was developed to detect and classify strawberries based on maturity level (mature, semi-mature, immature). A function was developed for counting strawberries. The results showed a mean average accuracy of 95% for classification and counting strawberries without compromising precision and satisfying real-time requirements. The developed algorithm can be deployed on edge devices for autonomous monitoring in greenhouses.
- An integration of image analysis, data imbalance handling, and AI-assisted models were evaluated for early detection of diseases in tomato plants in a greenhouse environment. The evaluation's indicated that Generative Adversarial Networks (GANs)-based approach for resampling performed best, with an average classification accuracy of 97.69% for the target disease. The developed algorithm can be deployed on edge devices for autonomous disease monitoring and management in the greenhouses.
- An innovative, non-destructive AI-assisted approach was developed to estimate lettuce growth parameters. The AI model showcases exceptional performance in predicting lettuce phenotypic parameters, achieving R^2 values of 0.968, 0.953, 0.943, 0.906, and 0.965 for fresh weight, leaf area, dry weight, plant diameter, and plant height, respectively. Using this model, we identified that nutrient solution temperature (Temp: 30ºC, Nitrogen: 150ppm) affects the fresh and dry weights.
- We hosted the 5th Annual Conference in urban horticulture – Controlled environment conference at the Dallas Center with about 100 participants. We received many positive feedback from the participants.
- Graduate student Sangjun Jeong's research (supervised by Shuyang Zhen and Genhua Niu) indicated that blue (B) and green (G) light and temperature interactively regulate growth, morphology, physiology, and phytochemicals of two lettuce cultivars 'Rex' and 'Rouxai'. For example, In 'Rex', substituting G light for B light up to 30% increased total leaf area at 20 and 24 ℃, but not at 28 ℃. In 'Rouxai', increasing G light from 0% to 40%, coupled with decreasing B from 40% to 0%, linearly increased total leaf area at all three temperatures (22, 24, and 28 C). Secondary metabolites (e.g., phenolics and flavonoids) and antioxidant capacity consistently decreased with increasing G light (or

decreasing B from 40% to 0%), but the decline was more pronounced at warmer temperatures.

- We conducted a study in a greenhouse with hydroponic lettuce grown in two root zone temperatures (20 or 30 C) and three nitrogen (N) levels (75, 150, or 300 mg/L), which was repeated 4 times (2 times in spring and 2 times in summer). Results showed that root zone temperature of 20 C reduced lettuce yield, regardless of the growing season, indicating that optimal root zone temperature for lettuce is higher than 20 C. High N level (300 mg/L) in summer increased lettuce yield but not in the spring, indicating interactive effect between N level and greenhouse environment.
- We investigated the effect of different biostimulants (no application as control, Kelpak, Spectrum DS, MycoApply, and Tribus Continuum) on onion seedling growth under well-watered and drought stressed (50-60% field capacity) conditions. Results showed that all biostimulants significantly increased shoot weight, leaf area, plant height, and root weight compared to the control. Notably, Spectrum DS, MycoApply, and Kelpak specifically enhanced root morphology by increasing root length, root area, and root volume compared to the control, we conclude that the application of the investigated biostimulants shows promise for enhancing drought tolerance in onion seedlings.
- We conducted a ten-cultivar spinach trial in a deep water culture (DWC) system with three different nutrient solutions: the original Hoagland nutrient solution, a magnesium (Mg)-enhanced Hoagland nutrient solution, and a potassium (K)-enhanced Hoagland nutrient solution. The results showed that the Mg-enhanced nutrient solution increased the relative chlorophyll content (SPAD value) in spinach leaves. However, the enhanced Mg and K nutrients did not affect the yield of spinach compared to the original Hoagland nutrient solution. Different cultivars resulted in diverse plant morphology and yield. Our results that enhancing Mg and K in nutrient solutions did not increase spinach yield, but enhancing Mg in nutrient solutions can increase the greenness of spinach leaves.
- We conducted studies over the past year to better understand how end-of-production lighting could be optimized to improve the nutritional value of red leaf lettuce while achieving energy savings. Our results indicate that blue light intensity and application duration co-regulate anthocyanin production, and sufficient anthocyanin production could only be achieved when both the threshold of blue light intensity and a minimal application duration are met. We further compared the effectiveness of different light spectra at enhancing the nutritional quality of indoor-grown lettuce and identified that ultraviolet-B and blue light treatments were significantly more effective at improve crop phytonutrients than other spectral regions within the biologically active radiation range.
- We investigated the responses of lettuce growth and quality to sulfur supplementation in a hydroponic system. Specifically, we quantified the effects of sulfur supplementation to a commercial one-bag hydroponic fertilizer on lettuce growth and quality and identified the optimal level of S supplementation for lettuce production.

Impact Statements

- The majority of the strawberry production operations are performed manually. Harvesting is one of the most labor-intensive operations, accounting for approximately 40% of the total production cost. Real-time information for strawberry maturity, size, weight, count, and localization (distance/position information) is essential for robotic operations in indoor production. The deployment of AI-based computer vision models for strawberries could improve the performance, efficiency, and remote interactivity of autonomous yield estimation and robotic harvesting operations, reducing labor requirements and production costs. AI-assisted computer vision-based solutions in combination with crop growth models could assist growers in decision-making for optimizing management processes for indoor strawberry production, improving resource use efficiency.
- Early identification of vegetable disease using automated computational systems is essential for improving detection accuracy in a timely manner. The aim of the non-destructive sensing is to develop a site-specific crop disease management system. The work will enable the development of future precision autonomous system to apply spraying chemical in correct amount and the right place, which will reduce environmental pollution, and serve general public interests. The work provides a general workflow of a disease detection system, which can be expanded to other diseases and crop stresses. The developed AI-assisted system could assist farmers in decision-making, ultimately boosting profitability and promoting sustainability.
- Collecting crop performance data, including fresh weight, dry weight, leaf area, plant diameter, and plant height, is critical for data analytics and resource management. Traditionally, crop monitoring is carried out manually, which makes it unfeasible to collect data daily to get actionable insights for high yield. The developed AI-assisted predictive analytics could optimize resource usage, reducing costs and improving the sustainability of the US greenhouse industry. The AI-based crop growth monitoring approach holds promise for efficient data aggregation from multiple sensors and predictive analytics to assist growers in decision-making for resource optimization.
- Developing lighting strategies in indoor farms and supplemental lighting strategies in greenhouses have benefited CEH industry by improving crop yield and quality without significantly increasing costs, although the exact percentage of reduction in costs depends on production scale and systems.
- Our research in indoor farms indicated that co-optimizing environmental conditions along with culture practices can reduce production costs while achieving high crop yield and better quality.
- Sulfur is an essential plant nutrient but is often absent from one-bag hydroponic fertilizers marketed as ‘complete’ fertilizers. Our results can help develop guidelines for sulfur supplementations for hydroponic growers who use one-bag fertilizers that lack sulfur.
- Our annual CEH conference continued to educate the reginal CEH industry with positive feedback from participants.

Publications

Refereed journal articles

Ojo, M.O., A. Zahid, & J.G. Masabni. 2024. Estimating hydroponic lettuce phenotypic parameters for efficient resource allocation. Computers and Electronics in Agriculture, 218, 108642. https://doi.org/https://doi.org/10.1016/j.compag.2024.108642

Bashir, A., M. Ojo, & A. Zahid. 2023. Real-time Estimation of Strawberry Maturity Level and Count Using CNN in Controlled Environment Agriculture. In 2023 ASABE Annual International Meeting (p. 1). ASABE. https://doi.org/https://doi.org/10.13031/aim.202300625

Ojo, M.O., & A. Zahid. 2023. Non-Destructive Biomass Estimation for Hydroponic Lettuce Production. In 2023 ASABE Annual International Meeting (p. 1). ASABE. https://doi.org/https://doi.org/10.13031/aim.202300776.

Zhang, Q, J. Masabni, and Niu, G. 2024. Organic fertilizer type and dose affect growth, morphological and physiological parameters, and mineral nutrition of watermelon seedlings. PeerJ DOI 10.7717/peerj.16902.

Sun, Y., G. Niu, and J. Masabni. 2024. Growth, gas exchange, and mineral nutrition of Punica granatum 'Wonderful' irrigated with saline water. Technology in Horticulture, 4: e002; https://doi.org/10.48130/tihort-0023-0030.

Jeong, S., Niu, G., Zhen, S. 2024. Far-red light and temperature interactively regulate phytochrome activities, plant growth, and morphology of lettuce and basil. Environmental and Experimental Botany, vol. 218, February 2024, 105589. https://doi.org/10.1016/j.envexpbot.2023.105589.

Yu, P., Qin, K., Niu, G., Gu, M. 2023. Alleviate environmental concerns with biochar as a container substrate: A review. Frontiers in Plant Science, Vol 4, https://doi.org/10.3389/fpls.2023.1176646.

Kong, Y., J. Masabni, and G. Niu. 2023. Effect of temperature variation and blue and red LEDs on the elongation of arugula and mustard microgreens. Horticulturae 2023, 9, 608. DOI.org/10.3390/horticulturae9050608.

Kong, Y., J. Masabni, and G. Niu. 2023. Temperature and light spectrum differently affect growth, morphology, and leaf mineral content of two indoor-grown leafy vegetables. Horticulturae 2023, 9, 331. doi.org/10.3390/horticulturae9030331.

Kong, Y., Zhu, Y., Kang, S. , and Zhen, S. (2024). Sulfur Supplementation Enhanced the Growth and Photosynthesis of Lettuce in Hydroponic Production Using One-bag Complete Fertilizer. *HortScience*, *59*, 412-420. DOI: https://doi.org/10.21273/HORTSCI17644-23

Zhen, S. , P. Kusuma, and B. Bugbee (2024). Photons at the ultraviolet-visible interface: Effects on leaf expansion and photoinhibition. *Scientia Horticulturae* 326, 112785. https://doi.org/10.1016/j.scienta.2023.112785

Presentations

Zahid, Azlan, and Mike Ojo. 2023. "Digital Twins in Horticulture: Enabling AI for Crop Growth Monitoring." ASHS Annual Meeting

Bashir, Al, Mike Ojo, and Azlan Zahid. 2023. "Real-Time Estimation of Strawberry Size and Level of Maturity Using CNN." ASABE Annual International Meeting

Ojo, Mike, and Azlan Zahid. 2023. "Addressing Class Imbalance for Plant Disease Detection Based on Deep Neural Networks Model." ASABE Annual International Meeting

Ojo, Mike, and Azlan Zahid. 2023. "Non-Destructive Biomass Estimation for Hydroponic Lettuce Production." ASABE Annual International Meeting.

Niu, G. 2023. High-tech controlled environment agriculture as innovative and sustainable crop production systems. International Agricultural Innovation Conference. August 1, virtual – invited.

Jeong, S., S. Zhen, and G. Niu. 2023. Synergistical interactive effect between far-red light and warm temperature on hormonal and cell morphological changes, but not necessarily consistent with plant morphology. Annual Conference of ASHS, Orlando, FL July 31-August 4.

Jeong, S., G. Niu, and S. Zhen. 2023. Interactive effect among multiple light spectra and temperature on plant growth, morphology, and photosynthesis: Importance of co-optimizing light spectrum and temperature. Annual Conference of ASHS, Orlando, FL July 31-August 4.

Jeong, Sangjun, Genhua Niu, and Shuyang Zhen. 2023. Far-red light, light intensity, and temperature interactively regulate lettuce growth and morphology. Annual Conference of ASHS, Orlando, FL July 31-August 4.

Zhang, Qianwen, G. Niu, J. Masabni. 2023. Biostimulants can improve onion seedlings and early bulb growth: cultivar- and microorganism-specific positive effects. Annual Conference of ASHS, Orlando, FL July 31-August 4.

Zhang, Qianwen, G. Niu, J. Masabni. 2023. From waste to a useful product: onion peeling waste biostimulant enhances bok choy and radish production. Annual Conference of ASHS, Orlando, FL July 31-August 4

Masabni, Joseph, Qianwen Zhang, and Genhua Niu. 2023. Evaluating the use of microbial inoculants and pH on orthophosphate recovery of aquatic fish effluent. Annual Conference of ASHS, Orlando, FL July 31-August 4

Kong, Y., J. Masabni, and G. Niu. 2023. Temperature and light spectrum affect lettuce and pak choy growth and morphology. Lone Star Hort Forum, College Station, Jan 9-11.

Zhang, Q., J. Masabni, and G. Niu. 2023. Organic fertilizer type and rate affect watermelon seedling production. Southern Region ASHS. Feb 3-5, Oklahoma City, OK.

Jeong, S., G. Niu, and S. Zhen. 2023. The interactive effects between far-red light and temperature on plant growth and morphology in lettuce and basil. Lone Star Hort Forum, College Station, Jan 9-11.

Zhang, Q., J. Masabni, and G. Niu. 2023. Organic fertilizer type and rate affect germination and plant growth of watermelon seedlings. Lone Star Hort Forum, College Station, Jan 9-11.

Jeong, S., G. Niu, and S. Zhen. 2023. Light intensity regulates interactive effects between far-red light and temperature on plant growth and morphology in lettuce and basil. Southern Region ASHS. Feb 3-5, Oklahoma City, OK.

Zhen. 2023. Co-optimize Key Environmental factors for higher yield: light x temperature interactions. Department of Energy (DOE) Solid-State Lighting Program R&D Discussion Meeting – Horticultural Lighting Energy. December 15th, 2023 (Zoom)

Zhen. 2023. Re-visiting the photosynthetic activity of far-red photons. 40th annual Eastern Regional Photosynthesis Conference, Woods hole, MA.

Zhu, Y. and S. Zhen. 2023. Controlling end-of-production blue light intensity and photoperiod to enhance anthocyanins production in red lettuce. Annual Conference of ASHS, Orlando, FL. July 31 to Aug. 4.

Kang, S. and S. Zhen, 2023. Comparison of Orange Photons with Red Photons: Biomass and Photosynthetic Responses in Green and Red Leaf Lettuce. Annual Conference of ASHS, Orlando, FL. July 31 to Aug. 4.