NCERA-101 Station Report – Texas A&M University

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Reporting period: April 2024-March 2025

Accomplishment summary

- We hosted the 6th Annual Conference in urban horticulture – Controlled environment conference at the Dallas Center in December 2024 with about 60 participants. The theme of the 6th CEH was on strawberry production under controlled environment. We received many positive feedback from the stakeholders and participants.
- Sang Jun Jeong (graduate student) et al found out that the significant impact of the interaction among multiple environmental factors: far red light, light intensity, photoperiod, and temperature, on plant growth, morphology, yield, and nutritional quality in indoor farming of lettuce. There are three-way interaction between light intensity/photoperiod, warm temperature, and FR light on plant morphology. Notably, in the absence of FR light, a low light intensity/long photoperiod and warm temperature synergistically promoted leaf expansion and crop yield, without reducing secondary metabolites and antioxidant capacity. However, under 20% FR light, the synergism shifted to stem elongation, leading to a reduction in plant biomass. Thus, these results suggest that the combination of low light intensity/long photoperiod and warm temperature can serve as an effective strategy to maximize crop yield and nutrient quality in the absence of FR light.
- 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 investigated the effect of different biostimulants (no application as control, non-microbial -Kelpak and several microbial based biostimulants - Spectrum DS,

MycoApply, and Tribus Continuum) on onion seedling and mini-bulb growth under controlled environment. We found that all microbial based biostimulants applied during seedling stages had carrying-over effect in mini-bulb stage, while Kelpak did not show any positive effect. These results may indicate that multiple applications of Kelpak may be necessary after transplanting to have a lasting positive effect. Additionally, we found that biostimulants have more significant positive effect when applied with organic fertilizers, indicating that biostimulants might aid mineralization of organic fertilizers and hence increasing the nutrient availability.

- Our research on organic vegetable seedlings production under controlled environment found that due to diversity of organic fertilizer ingredients, nutrient availability varies largely with type of organic fertilizer. Thus, the organic fertilizer labels can only be used as a reference. The actual availability has to be analyzed for each individual fertilizer. Applying biostimulants in tandem with organic fertilizer can enhance the nutrient availability.
- We conducted a hydroponic study on spinach. We found cultivar-specific responses of spinach to root zone cooling in deep water culture hydroponic systems. Our study consisted of three root zone temperatures (RZT): Control (ambient water temperature), RZT24 (24 °C), and RZT21 (21 °C) and four spinach cultivars (Lakeside, Hammerhead, Mandolin, and SV2157). Among the four cultivars, SV2157 performed equally well regardless of treatment, demonstrating superior heat tolerance among the other 3 cultivars. Mandolin exhibited the greatest benefit from root zone cooling, with increased growth in shoot and root and leaf area. Lakeside and Hammerhead generally benefited from root zone cooling, although the magnitude of growth increase was small or statistically insignificant. However, Lakeside and Hammerhead were highly responsive to lower ambient air temperatures, indicating that they are less heat tolerant compared to Mandolin and SV2157. Based on plant growth, physiological and biochemical traits, and electricity consumption, cooling root zone to 24 °C rather than 21 °C was recommended for hot summer with high air temperatures.
- Harvesting is one of the most labor-intensive operations for greenhouse production. We designed a robotic end-effector prototype for harvesting lettuce with a pair of shear blades and a two-finger gripper mechanism operated using a single linear actuator. Cutting and holding mechanisms work together using the first-class lever technique, where applied and acting forces are connected at the pivot point. The end-effector prototype was integrated into a linear arm connected to a two-directional linear manipulator system operated using an embedded controller. Validation experiments were conducted, and the results indicated a 95.15% success rate in cutting and a 94.45% success rate in securely holding the lettuce during harvest. The developed robotic end-effector serves as a pivotal component in lettuce harvesting automation.
- Crop disease scouting is the first critical step for controlling plant diseases. We employed lightweight deep-learning models to detect tomato diseases using digital images (bacterial spot, early blight, healthy, late blight, leaf mold, septoria leaf spot, two-spotted spider mites, target spot, and yellow leaf curl virus). Models were deployed on low-cost and low-power consumption Edge devices to investigate their performance capabilities as standalone Edge-AI solutions. Our lightweight models achieved accuracies of up to 98.25% in detecting tomato diseases. Edge device (Raspberry Pi) with AI accelerator

(Google Coral) achieved the best cost/Frame per second (FPS) performance of 0.14 compared to other Edge devices NVIDIA Jetson AGX Orin and NVIDIA Jetson Nano Orin with cost/FPS of 0.7 and 0.26, respectively. These results showed the potential of standalone Edge-AI solutions using low-cost and low-power-consuming software and hardware resources for early tomato disease detections.

- Energy consumption per unit area can be reduced by increasing the crop yield per unit area by optimizing planting density. We developed an AI model (Ensemble Seg) that combines Mask RCNN (instance segmentation) and DeepLabV3 (semantic segmentation) to adjust the spacing between NFT channels for optimal greenhouse space utilization. Images were collected daily throughout the growth cycle, capturing the full development period of the lettuce plants. Our model resulted in a segmentation accuracy of 0.95. To assess plant overlap, segmented masks of each plant and its neighboring plants were identified based on the distances between each plant's center. Overlapping was then determined by pixels with identical coordinates in an image across the segmented masks. The developed model can be used for intelligent decision support to optimize space use in greenhouse hydroponic production.
- Sustaining human life during long duration space exploration requires reliable, efficient fresh food production systems that leverage in situ resources and adapt effectively to the unique space environments. We examined the suitability of lunar regolith (i.e., moon dust) simulants as growing media for lettuce production through assessing seed germination, seedling growth, and biomass accumulation over three consecutive plantings. We found that regolith simulants supported seed germination but resulted in severely stunted growth in the absence of nutrient supplementation. Nutrient supplementation enhanced plant growth in regolith, however, plant growth was substantially reduced compared to the control treatments (plants grown in rockwool and peat), even when supplemented with the same nutrient solution. Growth in regolith simulants with nutrient supplementation improved with subsequent plantings. These results highlight regolith's potential to support crop growth with proper nutrient management strategies and recycling for lunar agriculture, underscoring the possibility for using in situ lunar resources for food production for long-term lunar habitation.

Impact Statements

- Developing lighting and temperature control 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.
- Our annual CEH conference continued to educate the reginal CEH industry with positive feedback from participants.
- Autonomous leafy greens harvesting system could address labor shortages in CEA. This project's outcomes can potentially reduce production costs for growers, making locally

grown lettuce more accessible and affordable for consumers. The broader public will benefit from this project's activities through the advancement of agricultural automation, which directly contributes to more sustainable and efficient food production systems.

- Our study provides growers with affordable, real-time disease detection tools that operate independently of internet connectivity. This approach is especially valuable for small- and medium-scale farmers, as it reduces reliance on expensive infrastructure and external expertise, which are usually the case for new growers. Furthermore, identifying diseases early enables more precise/targeted interventions (precision autonomous system), reduces crop losses, minimizes chemical treatments, and reduces environmental impact, thereby supporting environmentally friendly and sustainable farming practices.
- The ability to optimize plant spacing minimizes overcrowding, reducing the risk of diseases and competition for light, water, and nutrients. This ensures healthier plants and higher-quality produce for consumers. From an environmental perspective, better space utilization translates to more efficient use of greenhouse infrastructure, lowering energy consumption and reducing the environmental footprint of food production.

Publications

Refereed journal articles

- Jeong, Sangjun, Qianwen Zhang, Shuyang Zhen, Genhua Niu. 2025. Lowering light intensity while extending photoperiod at a constant daily light integral synergistically interact with warm temperature to enhance leaf expansion and crop yield in lettuce in the absence of far-red light. Front. Plant Sci. 16:1529455. doi: 10.3389/fpls.2025.1529455
- Jeong, Sangjun, Qianwen Zhang, Genhua Niu, and Shuyang Zhen. 2024. The interactive effects between far-red light and temperature on lettuce growth and morphology diminish at high light intensity. Frontiers in Plant Science. DOI 10.3389/fpls.2024.1497672.
- Jeong, Sangjun, Qianwen Zhang, Genhua Niu, and Shuyang Zhen. 2024. Synergistic enhancement of biomass allocation from leaves to stem by far-red light and warm temperature can lead to growth reductions. Environmental and Experimental Botany. doi.org/10.101016/j.envexpbot.2024.106024.
- Liu, Jun, Qianwen Zhang, Joseph Masabni, and Genhua Niu. 2024. Low nitrogen availability in organic fertilizers limited organic watermelon transplant growth. Horticulturae 2024, 10, 1140.https://doi.org/10.3390/horticulturae10111140.
- Ali, Awais, Genhua Niu, Joseph Masabni, Antonio Ferrante, and Giacomo Cocetta. 2024. Integrated nutrient management of fruits, vegetables and crops through the use of biostimulants, soilless cultivation, and traditional and modern approaches – A mini review. Agriculture 2024, 14, 1330, https://doi.org/10.3390/agriculture1401330.
- Zhang, Qianwen, Joseph Masabni, Genhua Niu. Microbial Biostimulants and Seaweed Extract Synergistically Influence Seedling Growth and Morphology of Three Onion Cultivars. Horticulturae 2024, 10, 800. https://doi.org/10.3390/horticulturae10080800.
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- Majeed, Yaqoob, Mike O. Ojo, and Azlan Zahid. 2024. "Standalone Edge AI-Based Solution for Tomato Diseases Detection." Smart Agricultural Technology 9: 100547.
- Ikram, Muhammad, Sikander Ameer, Fnu Kulsoom, Mazhar Sher, Ashfaq Ahmad, Azlan Zahid, and Young Chang. 2024. "Flexible Temperature and Humidity Sensors of Plants for Precision Agriculture: Current Challenges and Future Roadmap." Computers and Electronics in Agriculture 226:109449.
- Bashir, Al, Yaqoob Majeed, and Azlan Zahid. 2024. "Development of an End-Effector for Robotic Harvesting of Hydroponic Lettuce." In 2024 ASABE Annual International Meeting, Paper Number: 2400401 doi:10.13031/aim.202400401
- Ojo, Mike O., Azlan Zahid, and Joseph G. Masabni. 2024. "Estimating Hydroponic Lettuce Phenotypic Parameters for Efficient Resource Allocation." Computers and Electronics in Agriculture 218: 108642.
- Zhu, Y., Singh, J., Patil, B., and **Zhen, S.**. (**2024**) End-of-production blue light intensity and application duration co-regulate anthocyanins and ascorbic acid production in red leaf lettuce. ***Scientia Horticulturae*** 335, 113333. https://doi.org/10.1016/j.scienta.2024.113333
- Kang, S., Parrish, C.H., Hebert, D., and **Zhen S.** . (**2024**) Luminescent quantum dot films increase the radiation capture and yield of lettuce and sweet basil compared to a traditional/neutral-density greenhouse glazing. ***HortScience*** *59*: 988-996 https://doi.org/10.21273/HORTSCI17921-24

Presentations

- Genhua Niu. Biostimulants can improve organic vegetable seedling growth. American Society for Horticultural Science, Horticultural Plant Reproductive Biology Interest Group Webinar, March 4, 2025.
- Liu, Jun, Joseph Masabni, and Genhua Niu. Beyond the label: Implications on fertilization management of organic watermelon transplant production. Southern region ASHS. Grapevine, TX, February 1-2, 2025.
- Liu, Jun, Joseph Masabni, and Genhua Niu. Combat root zone stresses organic hydroponics. Southern region ASHS. Grapevine, TX, February 1-2, 2025.
- Liu, Jun and Genhua Niu. 2025. Organic watermelon seedling production under controlled environment. Texas Organic Farmers and Gardeners Association Conference, January 27, Pflugerville, Texas.
- Genhua Niu, Qianwen Zhang, and Jun Liu. Biostimulants improved onion seedling and mini-bulb growth. Texas Organic Farmers and Gardeners Association Conference, January 27, Pflugerville, Texas.
- Khan, Md Noor E Azam, Joseph Masabni, and Genhua Niu. Optimizing hydroponic spinach cultivation in warm climates: effects of root zone cooling on growth and biochemical properties. Southern region ASHS. Grapevine, TX, February 1-2, 2025.
- Jeong, Sangjun, Genhua Niu, Shuyang Zhen. Blue and green light and temperature interactively regulate growth, morphology, physiology and phytochemicals of lettuce. ASHS, Hawaii, Sept 23-27, 2024.
- Jeong, Sangjun, Genhua Niu, Shuyang Zhen. Light intensity regulates the interactive effects between far-red light and temperature on lettuce growth, morphology, photosynthesis, and secondary metabolite. ASHS, Hawaii, Sept 23-27, 2024.

- Zhang, Qianwen, Joseph Masabni, Genhua Niu. Biostimulants promoted onion seedling growth and helped mitigate drought stress. ASHS, Hawaii, Sept 23-27, 2024.
- Jeong, Sangjun, Genhua Niu, Shuyang Zhen. Light Intensity Regulates the Interactive Effects between Far-red and Temperature on Lettuce Growth, Morphology, Photosynthesis, and Secondary Metabolite. The X International Symposium on Light in Horticulture, Seoul, Korea, May 19-22, 2024.
- Zahid, Azlan. "AI-Enabled Sensing and Automation for Controlled Environment Agriculture." 2024 NTU-TAMU Bilateral Symposium on Sustainable Agriculture, Taipei Taiwan, Nov 12-14, 2024.
- Zahid, Azlan. "AI-Enhanced Computer Vision for Crop Monitoring in Controlled Environment Agriculture." American Society of Horticultural Sciences; Colloquium on AI in Horticulture, Hawaii, Sept 23-27, 2024.
- Zahid, Azlan, and Yaqoob Majeed. 2024. "Utilizing Deep Learning for Hydroponic NFT Channel Spacing Optimization." American Society of Horticultural Sciences, Hawaii, Sept 23-27, 2024.
- Zahid, Azlan. 2024. "AI-Enhanced Computer Vision for Crop Monitoring in Controlled Environment Agriculture." Ohio State University Controlled Environment Agriculture Conference, Columbus, July 15, 2024.
- Bashir, Al, and Azlan Zahid. 2024. "Edge AI-Enabled Cutting Point Localization for Robotic Harvesting of Hydroponic Lettuce." American Society of Agricultural and Biological Engineers (ASABE), Anaheim, July 27-31, 2024.
- Bashir, Al, and Azlan Zahid. 2024. "Development of a Robotic End-Effector for Harvesting Greenhouse Hydroponic Lettuce." American Society of Agricultural and Biological Engineers (ASABE), July 27-31, 2024.
- Ojo, Mike, and Azlan Zahid. 2024. "Leveraging Deep Learning for Multi-Step-Ahead Greenhouse Microclimate Prediction." American Society of Agricultural and Biological Engineers (ASABE), July 27-31, 2024.
- Majeed, Yaqoob, and Azlan Zahid. 2024. "Deep Learning-Based Plant Spacing Estimation for Efficient Resources Utilization in Controlled Environment Agriculture." American Society of Agricultural and Biological Engineers (ASABE), July 27-31, 2024.
- Zahid, Azlan. 2024. "Potential of Computer Vision for Crop Monitoring in Controlled Environment Agriculture." Controlled Environment Conference University of Wyoming, April 23-25, 2024.
- Ojo, Mike, and Azlan Zahid. 2024. "Enhancing Crop Health: An Embedded Edge AI Solution for Real-Time Disease Detection." AI in Agriculture Conference, April 15-17, 2024.
- Bashir, Al, and Azlan Zahid. 2024. "Real-Time Estimation of Strawberry Size, Weight and Level of Maturity: A Machine Learning Approach.", AI in Agriculture Conference, April 15-17, 2024.
- Majeed, Yaqoob, and Azlan Zahid. 2024. "Quality Index Measurement System for Tomatoes Based on Self-Attention Convolutional Neural Networks and Channel Pruning and Quantization." AI in Agriculture Conference, April 15-17, 2024.
- Zhen. 2025. The Role of Far-red Photons in Photosynthesis and Crop Lighting in Controlled Environment Agriculture. Molecular Plant Sciences Seminar Series. Michigan State University. East Lansing, MI 03/17/2025

- Zhen. 2024. Optimizing nutrient-rich food production in controlled environments: from greenhouses and indoor farms to space agriculture. Texas Plant Protection conference (TPPA). College Station, TX.
- Kang, S. and S. Zhen, 2024. Interactive effects between far-red photons and orange or red photons on growth, morphology, and fruit yield of dwarf tomatoes. Annual Conference of the American Society for Horticultural Science (ASHS). Honolulu, HI. Sept. 23-27.