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New Equipment and Facilities

The controlled environment engineering (https://ceelab.ucdavis.edu/) lab has added two indoor farming facilities with autonomous control and nutrient management for researching energy optimization and control of indoor farming systems. Over the last year, CE lab purchased several pieces of equipment (light monitoring devices, pH meter, Raspberry Pi, Arduino), sensors (environmental control sensors, Ion-selective sensors), and other resources (LED lighting, florescent lamps) to set up the lab facilities for conducting research. We are currently working on fabricating shipping containers; the facility would be a great support for leading research with a focus of the CEE lab's on energy efficiency, optimization, renewable energy integration, and LCA analysis.

Accomplishment Summaries

The following is the summary of the accomplishments related to the research in controlled environment agriculture (CEA) at UC Davis:

- CEE lab at UC Davis developed autonomous microclimate and nutrient monitoring systems using Raspberry PI and Aurdino for two small-scale indoor farming systems for conducting energy efficiency and automation research activities for indoor farming.
- Dr. Ahamed worked with a group of experts in the Global CEA consortium (GCEAC) with a mission of partnering globally to accelerate profitable indoor horticulture through rapidly collaborative innovation. The group worked with various aspects, including the technology roadmap, demonstration facilities, strong partnership networks, collaborative innovation projects, improved sustainability, workforce development, and market development.
- CEE lab (Dr. Ahamed) published a comprehensive literature review on fodder production's current status and challenges in controlled environments. This study provides a comprehensive literature

review on techniques and control strategies for indoor environments and watering that are currently used and could be adopted in the future to achieve the economic and environmental sustainability of controlled environment fodder production (CEFP).

- A new graduate-level course, "Energy Sytems Modeling," for CEA facilities has been developed and will be offered (Dr. Ahamed) in fall 2022 at UC Davis.
- UC Davis team led by Dr. Ahamed and Dr. Lieth participated in urban greenhouse challenge 3, organized by the University of Wageningen from the Netherlands. UC Davis team placed 5th over 30 teams with over 260 students and professionals from 20 countries.

Impact Statement

1. Taylor's lab studied the potential of growing watercress on an indoor vertical farm and their potential health benefits. This work demonstrates the great potential of watercress in a new era of controlled environment agriculture to deliver improved health benefits to customers.
2. Three undergraduate student works with Dr. Ahamed as part of a senior year design project for designing autonomous indoor aquaponic systems. Also, three undergraduate interns (one form the University of Illinois Urbana-Champaign, one electrical and one mechanical engineer from UC Davis) work on developing indoor farming systems with potential opportunities for increasing lighting energy efficiency using the light guide.
3. Gross's lab at UC Davis produced an extension video for promoting the research finding for broader communities (https://www.youtube.com/watch?v=7qSiNjSicjA), "Is Fish Farming Factory Farming? Animal Welfare in Aquaculture"

Published written works

Refereed Journal Articles

1) Ahamed, M. S., Sultan, M., Shamshiri, R. R., Rahman, M. M., Aleem, M., & Balasundram, S. K. (2022). Present Status and Challenges of Fodder Production in Controlled Environments: A Review. *Smart Agricultural Technology*, 100080.
2) Qian, Y., Hibbert, L. E., Milner, S., Katz, E., Kliebenstein, D. J., & Taylor, G. (2022). Improved yield and health benefits of watercress grown in an indoor vertical farm. *Scientia Horticulturae*, *300*, 111068.
3) Buxbaum, N., Lieth, J. H., & Earles, M. (2022). Non-destructive Plant Biomass Monitoring With High Spatio-Temporal Resolution via Proximal RGB-D Imagery and End-to-End Deep Learning. *Frontiers in plant science*, *13*.

Symposium Proceedings, Oral and Poster Presentation

1. Ahsan, T. A., & Ahamed, M. S. (2022). Solar Trigeneration System to Achieve Net-zero Energy Greenhouse in Mediterranean Regions. In 2022 ASABE Annual International Meeting (p. 1). American Society of Agricultural and Biological Engineers.
2. Ahsan, T. A., & Ahamed, M. S. (2022). Potential of Solar-assisted Adsorption Cooling System for Mediterranean Greenhouses. In: Internation Horticultural Congress, 14-20 August 2022, Angers-France. (Poster)