NCERA-101 Station Report

Station: Alabama Agriculture Experiment Station (Auburn University)
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1. **New Facilities and Equipment.**

Auburn University increased its capacity to run side-by-side greenhouse-scale trials by dividing one of its double bay (each 30x90 feet) greenhouses with a partition and installing separate controls in each bay. This enables the study of separate climate control regimes on energy use and plant performance. Each bay is outfitted with thermocouples, humidity sensors, light meters. Gas usage, electricity use, and fan operation are also monitored on each side.

We also constructed a pilot scale "poultryponics" system that treats wastewater from a poultry slaughterhouse for use as irrigation water for deep water lettuce production. This system uses two separate treatment trains (so comparison experiments can be conducted) in treating the water for lettuce growth trials.

2. **Unique Plant Responses.**

In our "poultryponics" system, we compared two different biological treatment approaches for poultry processing wastewater: one uses algae mixed with bacteria and the other only uses bacteria. For 2 of our 4 lettuce trials, we observed unusual lettuce morphology in the systems receiving effluent from our algal treatment system. We called it "cabbage" lettuce because the leaves were thicker and crunchier and the overall weight of the heads was quite high in one of the trials (even higher than those grown in hydroponic solution). We also observed some multiple heading on some plants. While still under investigation using metabolomics, microbial community sequencing, and LCMS, we believe that these changes may be triggered by hormones released by the upstream algae that affected downstream plant growth. This could be an important outcome for future use of bioponic type production systems.

3. **Accomplishments.**

    a. Short-term Outcomes:

- We operate the poultryponics system for 222 days of continuous operation and conducted 4 lettuce growth trials. Treated poultry processing wastewater produced lettuce heads about half the weight of hydroponic solution but this could be completely overcome with supplementation of deficient nutrients. Hence, there is no inherent inhibition from the wastewater. All lettuce tested negative for E. coli, Salmonella, and Campylobacter.
- Two production campaigns of tomatoes were carried out in aquaponics systems using substrate culture. The results showed that sludge deposition from the fish tank into the grow bed provided essential micronutrients to tomatoes (particularly Mn and B) that

were otherwise deficient in the aquaculture water (no supplementation was used in the study). While most aquaponics systems seek to minimize sludge transfer to the plant system, our results show that this sludge can be an important conveyer of micronutrients, helping the plants overcome deficiency based on leaf tissue analysis.

- Multiple tomato experiments were conducted in split root systems with high salt (NaCl) content on the side with nutrients. The Split-root system mitigates some of the effects of salinity in plants, plants in heterogeneous salinity conditions (different solutions on either side of the split-root) developed more roots, shoots and had a higher stem diameter than plants in homogenous salinity conditions (same solutions on both sides of the split-root). Regardless of whether the split-root was homogenous or heterogenous, the fruit size reduced with increasing salinity, however, the fruit sugar content increased with increasing salinity

b. Outputs:

- Higgins and many co-authors published two articles on aquaponics: one focused on modeling of macronutrients and carbon through a pilot scale biofloc aquaponics system with cucumber cultivation in media substrate. The other article reported the life cycle environmental impacts of this aquaponics system.

c. Activities:

- PhD student Shima Rezaei conducted aquaponics studies focused on how fish tank illumination and coupling versus decoupling affects aquaponics fish and tomato production.
- PhD student Wellington Arthur conducted studies on “poultryponics” to understand how biological treatment of the wastewater (using algae versus bacteria alone) impacts nutrient transformation and pathogen dynamics in the production of hydroponic lettuce.
- MS student Zach Morgan (now graduated) studied plant growth dynamics and nutrient status in the poultryponics system.
- MS student Arnold Katende studied tomato production in a split root system in order to enable growth of tomatoes on brackish water. The aim of this effort is to enable brackish water aquaponics (higher value fish) coupled to traditional vegetable production.
- We are actively developing new industry collaboration with Young’s Plant Farm, CEA producer of ornamentals in the Southeast.

d. Milestones:

- We celebrated the first year of accomplishments on our NIFA SAS project by holding our first annual GRACE symposium at Auburn University on 3/14-3/15.

- Auburn University completed greenhouse renovations and has begun side-by-side greenhouse trials in which a traditional tomato production approach is compared to a seasonal rotation of lettuce and tomatoes. The latter is expected to save energy and enable summer production in a hot/humid climate but at the expense of produce availability.

4. Impact Statements.

- Aquaponics: We showed that grow bed sludge is an important reservoir for micronutrients that are often deficient in aquaponics systems e.g. iron, manganese. This allowed plants to take up higher levels of several key micronutrients in coupled systems versus decoupled due to higher sludge deposition in the former. However, sludge deposition needs to be carefully managed via engineered systems so that excess sludge does not contribute to root asphyxiation.

- Poultryponics (bioponics): We proved that poultry slaughterhouse wastewater can be an effective source of irrigation water for hydroponic lettuce so long as deficient nutrients (mainly micronutrients) are supplemented. Results also showed that treatment eliminates detectable pathogens in the water and all lettuce tested negative throughout all 4 trials.

- Split root: Success in growing vegetables at 10 ppt salinity in split root vegetable production enables a move toward brackish water aquaponics. This change allow for the cultivation of higher value fish while still enabling vegetable production a potential game changer for the economics of aquaponics systems.

5. Published Written Works.

- Kalvakaalva, R.[2], M. Smith, S.A. Prior, G.B. Runion, E. Ayipio, C. Blanchard, D. Wells, D. Blersch, S. Adhikari, R. Prasad, T. Hanson, N. Wall[3], **B.T. Higgins[1]**. 2023. Mass-Balance Process Model of a Decoupled Aquaponic System. Journal of the ASABE. 66(4): 955-967.
- Kalvakaalva, R.[2], M. Smith, S.A. Prior, G.B. Runion, E. Ayipio, C. Blanchard, D. Wells, D. Blersch, S. Adhikari, R. Prasad, T. Hanson, N. Wall[3], **B.T. Higgins[1]**. 2023. Life cycle assessment of a decoupled biofloc aquaponics facility across seasons. Journal of Cleaner Production. 429. 139356.

6. Grants Awarded

- Auburn University is the lead institution on the NIFA SAS project, “Reimagining controlled environment agriculture in a low carbon world.” $9.95 million.