BIOVOLT: A NOVEL BIOELECTRIC SENSOR SYSTEM FOR ENHANCED PLANT GROWTH AND NUTRIENT UPTAKE

Click to watch our prototype demonstration!

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STEP 1: PROBLEM IDENTIFICATION

Food insecurity within Pennsylvania leads to health risks and increased wealth and racial gaps (*Feeding Pennsylvania, 2024).*

Agriculture is a major industry in PA, accounting for approximately $83.8 billion in direct economic output, but there are serious environmental outcomes *(Agriculture in Pennsylvania,* n.d.).

Therefore, methods to sustainably increase food production would benefit Pennsylvanians socially, economically, and improve their health.

STEP 2: DISCUSSION WITH BUSINESS

- Collaborated with local small farm, Milk House Farm Market
- Business faces challenges producing food sustainably while also earning a profit
- Supports low-income families with Farmer's Market Nutrition Program

Milk House Farm Market OPEN DAILY Fresh Eggs & Produce

MILKHOUSEFARMMARKET

Learn more about the farm on their instagram!

Researchers wanted to find a low-cost, sustainable solution to both increase produce quantity and nutritional value

STEP 3: BRAINSTORMING

Considered a variety of factors, including:

- Combining interests in plant science, public health, and neuroscience
- Sustainability-oriented solution
- Feasible with available materials and time
- Effective and supported by literature review

THE PROJECT IDEA

The researchers decided to create a sustainable and biodegradable hydrogel (structure that absorbs significant quantities of water) substrate for hydroponics that incorporates small electric pulses (inspired by human neurobiology systems) to simulate plant growth and nutritional uptake and monitor growth through pH recordings.

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UNIVERSAL DESIGN PRINCIPLES

- **Equitable Use:** Can be used by people of varying technical experience, and low-cost design increases accessibility
- **Flexibility in Use:** Adaptable to different plants and hydroponic setups based on user preference, device works independently
- **Simple and Intuitive Use:** Hydrogel is similar to other hydroponic substrates
- **Perceptible Information:** The system provides clear and perceivable outputs
- **Tolerance for Error:** Design prevents accidental voltage errors and includes materials that prevent risks; data is collected autonomously
- **Low Physical Effort:** Light hydrogel, can adapt to existing hydroponic system, and little intervention required after set up
- **Size and Space for Approach and Use:** Both compact and scalable, design allows for easy access to all components

STEP 4: HYDROGEL DESIGN

1. Wanted sustainable, water soluble, and electrically conductive materials that would be suitable as a hydrogel material to support plant growth:
   - **Acid Whey:** Waste product from greek yogurt production
   - **Carboxymethylcellulose (CMC):** Agricultural waste product, biodegradable
   - **Hydroxyethylcellulose (HEC):** Biodegradable thickener
   - **Citric Acid:** Cross-linking
2. Combined ingredients to get desired consistency and set in molds for shape for model hydroponic set up

Acid Whey extraction from plain yogurt

LITERATURE REVIEW

Click to read some of the articles that supported the prototype design

"A Novel Hydrogel Based on Renewable Materials for Agricultural Application" in the Journal of Polymer Science

"Effects of Pulsed Electric Field Technology on the Nutritional Value and Biological Function of Plant Food" in Frontiers in Sustainable Food Systems

"Recent Technological Advances in Bio-sensors for Soil and Plant Monitoring" in the Environmental Monitoring and Assessment Journal

STEP 5: DEVICE DESIGN

- Create a device that sends electrical pulses to the hydroponic stations in controlled amounts to improve nutrient intake
  - Prototype takes pH readings to measure the effectiveness of the electrical pulses
- Arduino sends pulses to the hydroponic stations with assistance from a potentiometer, diodes, and pins
- Millivolt readings from the pH probe are sent back to the Arduino, which converts it to pH values to be later sent to an SD card to store to monitor growth

Device with hydrogel hydroponic set up

STEP 6: FUTURE RESEARCH

- Perform experiments to determine optimal conditions to support plant growth; Use machine learning to find conditions optimal for all crops
- Add additional features to improve user experience such as greater autonomy through adjustments to changing conditions and growth requirements
- Improve sustainability by using a renewable power source
- Apply to traditional agriculture

SELECTED SOURCES

Agriculture in Pennsylvania: https://www.nature.org/en-us/about-us/where-we-work/united-states/pennsylvania/pennsylvania-agriculture/

Feeding Pennsylvania: https://www.feedingpa.org/2024/05/map-the-meal-gap-2024-feeding-pa/

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