COLLEGE OF AGRICULTURE & NATURAL RESOURCES

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CONTROLLED ENVIRONMENT Food safety issues when growing greenhouse and CEA leafy greens

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CFS³ CENTER FOR FOOD SAFETY AND SECURITY SYSTEMS

DEPARTMENT OF PLANT SCIENCE & LANDSCAPE ARCHITECTURE

NORTHEAST GREENHOUSE CONFERENCE AND EXPO 2023

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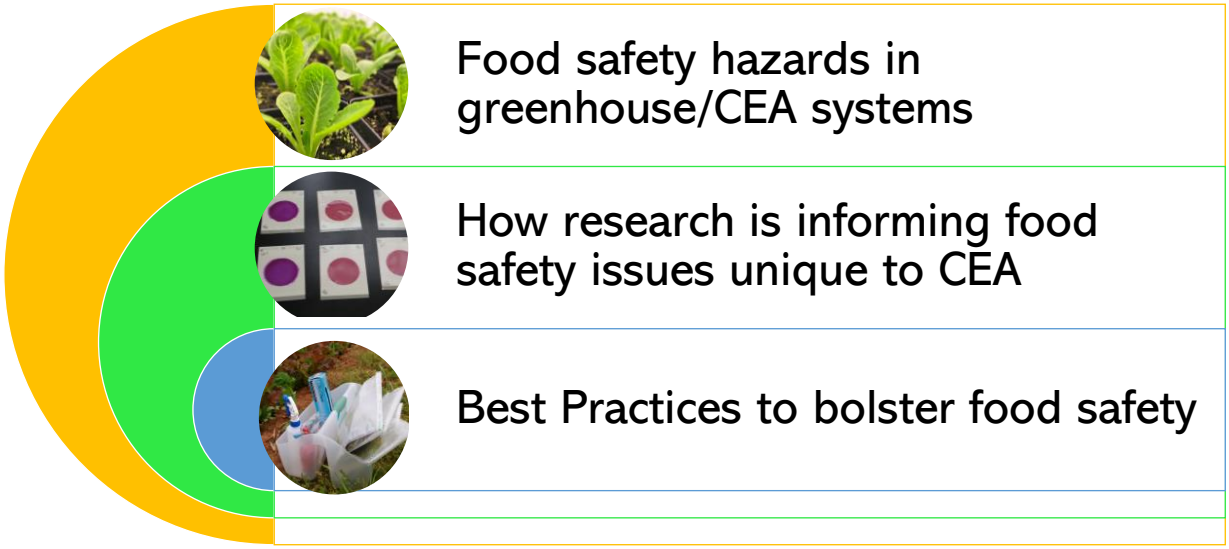
I'll talk about …



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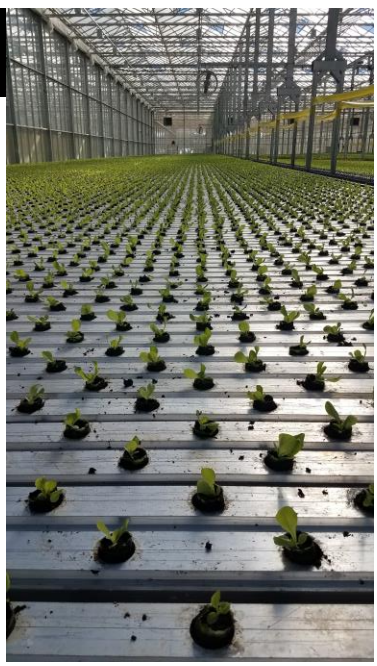
How does food safety in controlled environments differ from open field agriculture?

Greenhouse and CEA Systems - advantages

- Optimal water, nutrient, light needs
- Control environmental conditions such as temp
- Reduced/eliminated weed pressure
- Reduced macrofauna problems/herbivory pressure
- Reduced plant disease
- Reduced risk of airborne hazards
- Reduced risks at harvesting



Photos: S. Micallef

Greenhouse and CEA Systems – food safety lens

- Optimal water, nutrient, light needs
- Control environmental conditions such as temp
- Reduced/eliminated weed pressure
- Reduced macrofauna problems/herbivory pressure
- Reduced plant disease
- Reduced risk of airborne hazards
- Reduced risks at harvesting
- Inputs, materials, equipment

Microbial water quality!

Possible temperature, air movement, RH control challenges

Reduced/ altered microbial diversity

Altered macrofauna

Requires well thought out harvesting plan

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Seeds

- Seeds can carry plant and human pathogens
- Storage considerations
- Seeds can attract wildlife
- Recalls and plans how to trace a crop affected by a recall
- Seed treatments

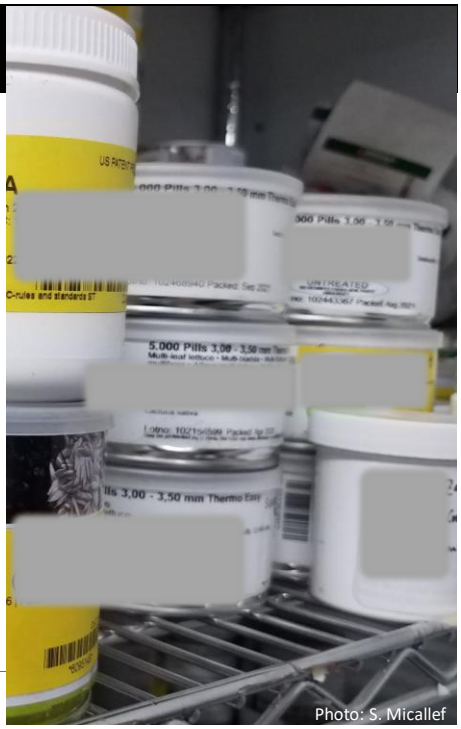

Photo: S. Micallef

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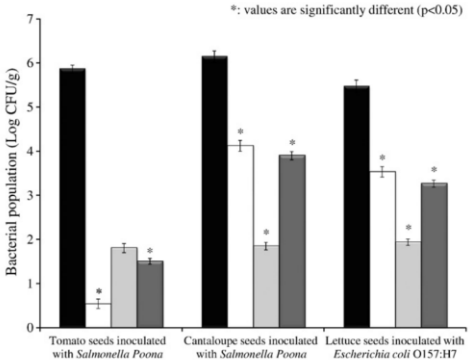
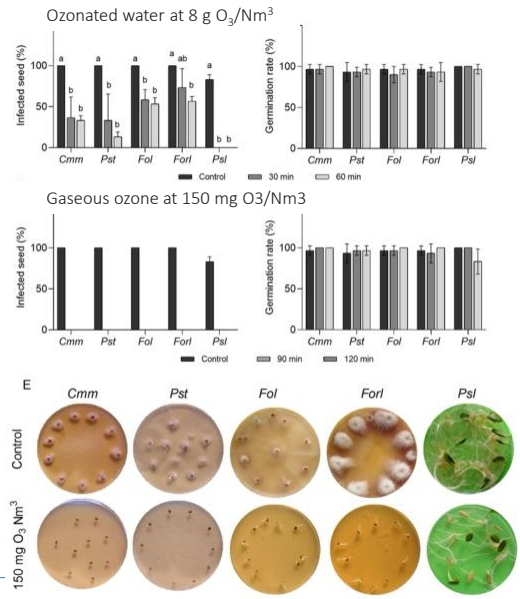
Research: Seed

- Disinfection can reduce pathogens
- Hypochlorite, chlorine dioxide gas, gaseous ozone, ozonated water
- Low concentration ozone can improve germination



Trinetta et al., 2011



Çetinkaya et al., 2022

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Substrates

- Germination is achieved on solid substrate
  - Peat moss
  - Coco coir
  - Perlite
  - Vermiculite
  - Rockwool cubes
  - Potting soil plugs

- Can you get verification that grow media are human pathogen safe?
- Are they being reused?
- Can they be sanitized?
- Storage?

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Photos: S. Micallef

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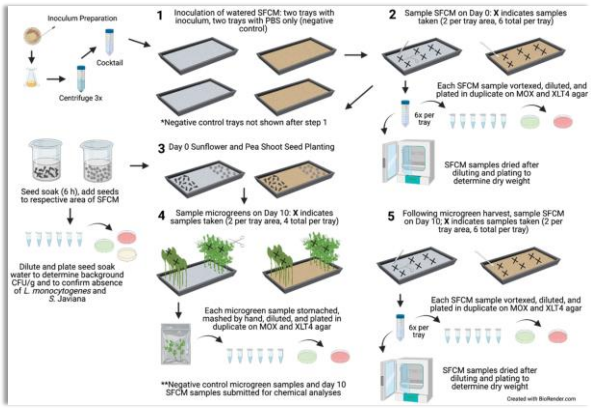
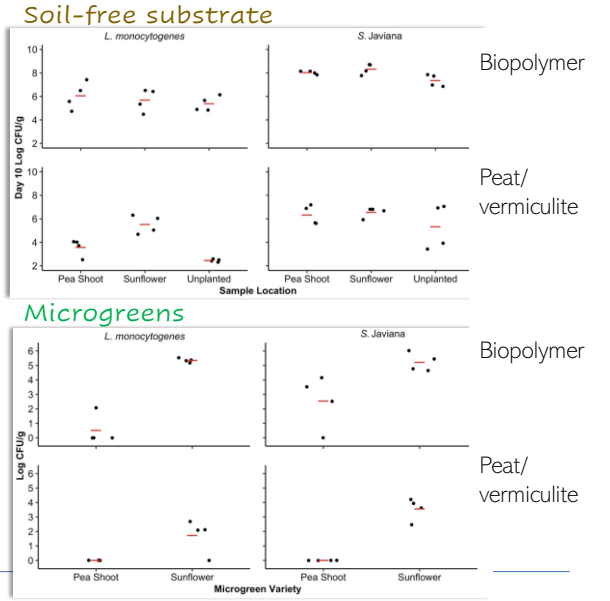
Research: Enteropathogen survival in substrate





Deng et al., 2021

Water: Why is water a risk?

- Provides ideal habitat (water, nutrients, temperature) for bacterial growth
- Can serve as a reservoir
- Can serve as a vehicle, spreading bacteria through the system
- Splashed/leaked water can be tracked throughout facility
- Can lead to biofilm development

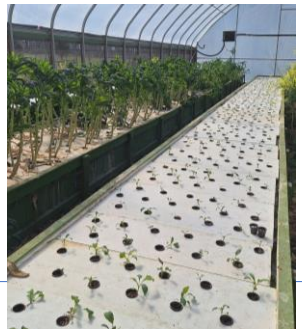
Water and Nutrient Solution

"Agricultural water … intended to, or is likely to, contact the harvestable portion of covered produce"

-sprinklers in high tunnel/greenhouse

-irrigation drip lines

-nutrient solution in NFT/deep water culture HP



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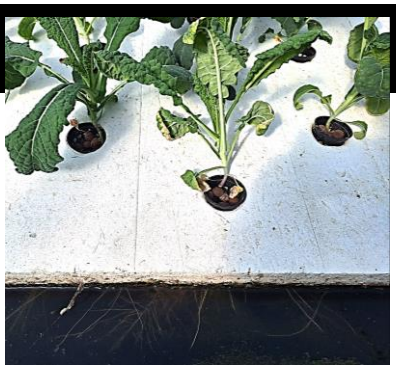
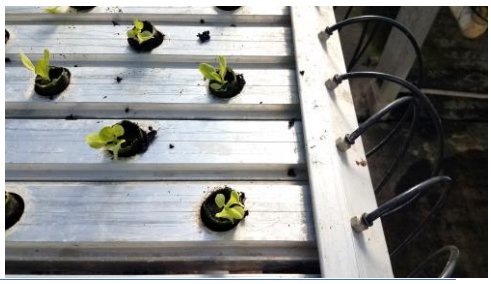
Open vs. closed hydroponic systems



- Open system:
  - Static/continuous contact with nutrient solution Roots may be in soil-free medium or in solution (e.g., deep water culture)
  - When crop cycle is complete, nutrient solution is drained as waste

- Closed system:
  - Nutrient solution is recirculating
  - (e.g., NFT)
  - Requires water treatment
    - Sand filters
    - UV illumination
    - Antimicrobial agent such as Cl, PAA or ozone



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Photos: S. Micallef

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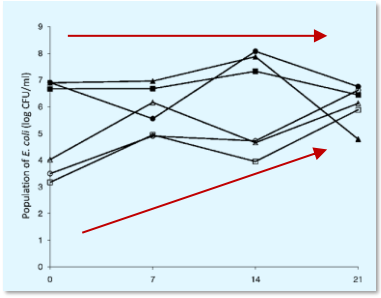
Research: Pathogens in Nutrient Solution



Sharma et al., 2009

E. coli O157:H7 in nutrient solution (pH 5.8) growing spinach at 25°C for 21 days

4 Log CFU inoculation of nutrient solution (pH 5.5-6.0) in NFT system growing butterhead lettuce at 12-30°C for 28 days

	Salmonella Typhimurium		*Listeria monocytogenes*	
Time Post-Inoculation	Reservoir Nutrient Solution [1]	Channel Nutrient Solution	Reservoir Nutrient Solution [1]	Channel Nutrient Solution
1 h	2.21 a [2]	2.19 ab	- [2]	- [2]
12 h	1.54 b	1.99 b	1.35 b [3]	1.22 c
24 h	2.22 a	2.30 a	1.13 b	1.35 c
7 days	0.93 c	0.54 c	1.87 a	2.22 a
14 days	0.44 d	0.65 c	1.90 a	1.89 ab
21 days	0.38 d	0.53 c	1.34 b	1.60 bc
28 days	0.30 d	0.28 d	1.85 a	2.12 a
p value	<0.0001	<0.0001	<0.0001	<0.0001

Ilic et al., 2022

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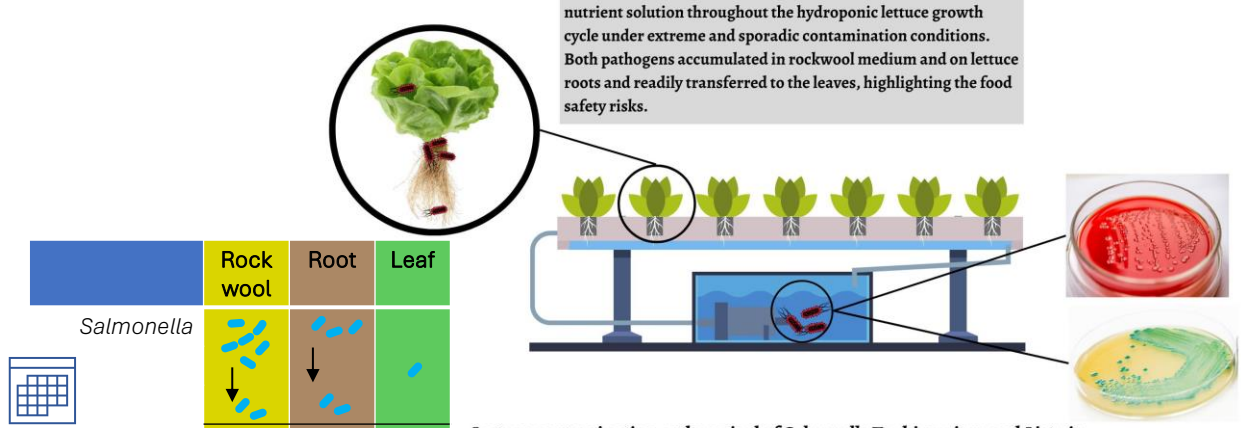
Research: Human Pathogens in NFT system

***Salmonella* Typhimurium and *Listeria monocytogenes* survived in nutrient solution throughout the hydroponic lettuce growth cycle under extreme and sporadic contamination conditions. Both pathogens accumulated in rockwool medium and on lettuce roots and readily transferred to the leaves, highlighting the food safety risks.**



Lettuce contamination and survival of *Salmonella* Typhimurium and *Listeria monocytogenes* in hydroponic nutrient film technique (NFT) systems

Ilic et al., 2022

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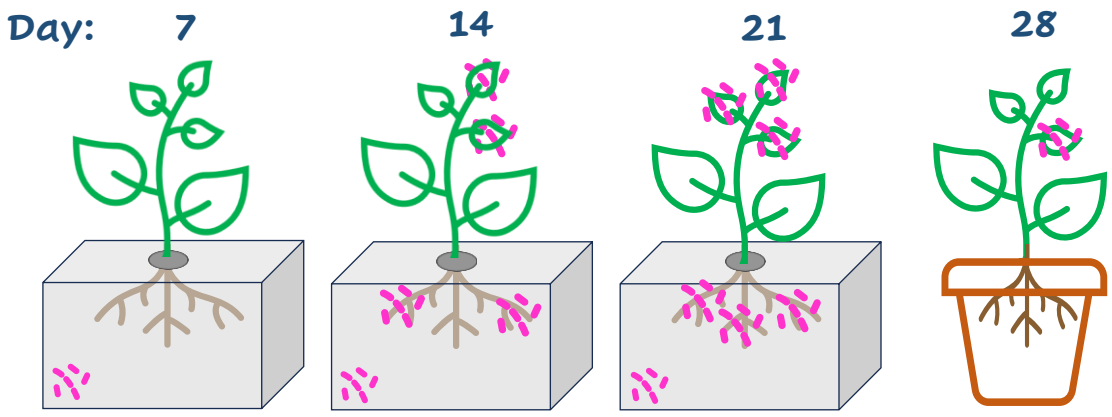
Research: Internalization into Crop



Schematic: S. Micallef

E. coli O157:H7 inoculated at low levels in nutrient solution. Surface sterilized spinach roots and shoots were tested after 7, 14 and 21 days. Plants were then transferred to soil and tested again.

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Sharma et al., 2009

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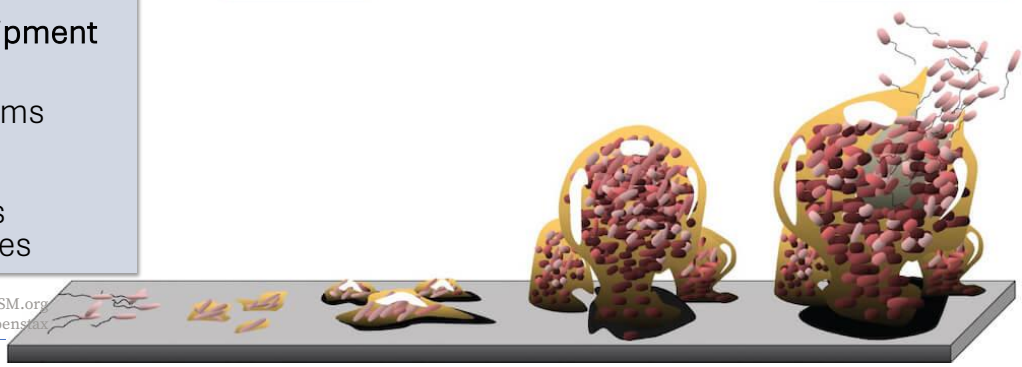
Food Contact Surfaces

Biofilms

1. Reversible attachment of planktonic cells. (seconds)
2. First colonizers become irreversibly attached. (second, minutes)
3. Growth and cell division. (hours, days)
4. Production of EPS and formation of water channels. (hours, days)
5. Attachment of secondary colonizers and dispersion of microbes to new sites. (days, months)

Maintaining/ Cleaning Equipment

- Ponds
- Gutter systems
- Trays
- Rafts
- Harvest bins
- Work surfaces



ASM.org
Source: Openstax

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Wildlife and Pest control

- Rodents
- Insects (aphids, thrips, whitefly), slugs, roaches
- Occasional wildlife (birds, frogs)

  - Feces
  - Movement/cross-contamination
  - Herbivory

➢ Monitor for signs
➢ Consider attractants, shelter
➢ Consider how trash, culled product is stored (inside and outside)
➢ Insect biological control ✓
➢ Traps ✓
➢ Poison X

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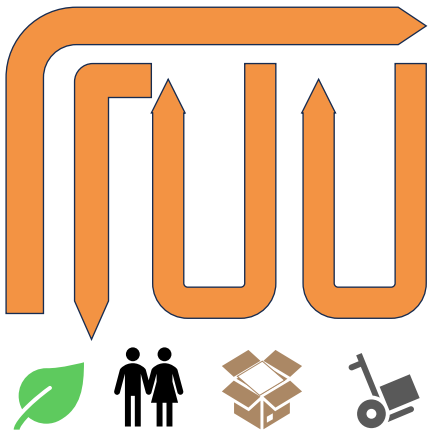
Harvest, Processing, Packing Workflow

- Direction of flow of people, crop, equipment
- Production water ≠ post-harvest water
- NFT *vs* deep water culture systems
- Harvest methods (roots or no roots?)



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Photos: S. Micallef

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In summary: Best Practices to consider

- In soil-less systems/hydroponics, consider seed disinfection
- Conduct Agricultural Water System Inspection (leaks, damage?)
- Do not allow for water to accumulate on floor or other areas
- Minimize contact between water and crop
- Consider water testing (generic *E. coli*)
- If recirculating water, consider best water treatment method
- Identify areas or steps where cross-contamination can occur
- Consider the workflow during production, during harvest (people, crop, tools)
- Develop a cleaning/sanitation plan
- Pest management plan
- Worker(s) training

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