Drivers of microbial community composition in hydroponic leafy green production

Soledad Benitez Ponce
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benitezponce.1@osu.edu
@msbenitezponce

Plant bacteriology and agricultural microbiome lab

Ohio hydroponic producers

Lab members

Leslie Taylor
Timothy Frey
Fiama Guevara-Guillen
Melanie Medina-Lopez
Gustavo Garay
Ananiah Cohen
Alex Taylor
Robert Korir

Collaborators

Dr. Uttara Samarakoon
Dr. Melanie Ivey
Dr. Sanja Ilic
Dr. Christopher Taylor
Dr. Alison Bennett
Dr. Anna Testen

Bioinformatics and sequencing support

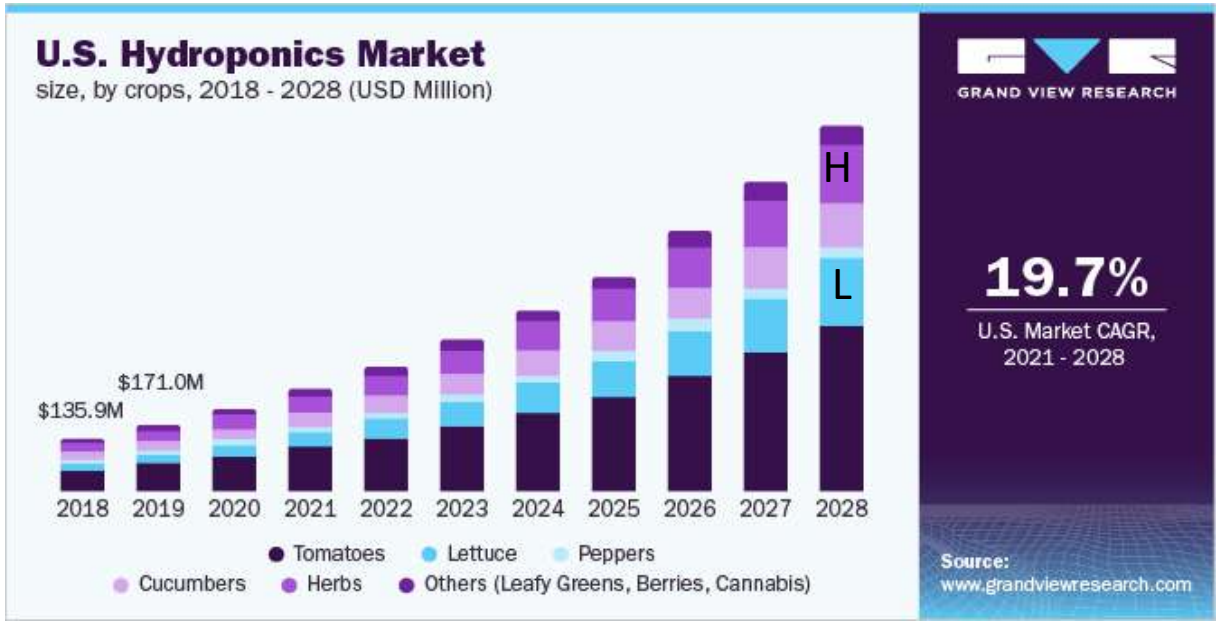
Dr. Antonino Malacrino
MCIC : Dr. Jelmer Poelstra
Dr. Wirat Pipatpongpinyo
The Genomics Shared Resources – JCC OSU

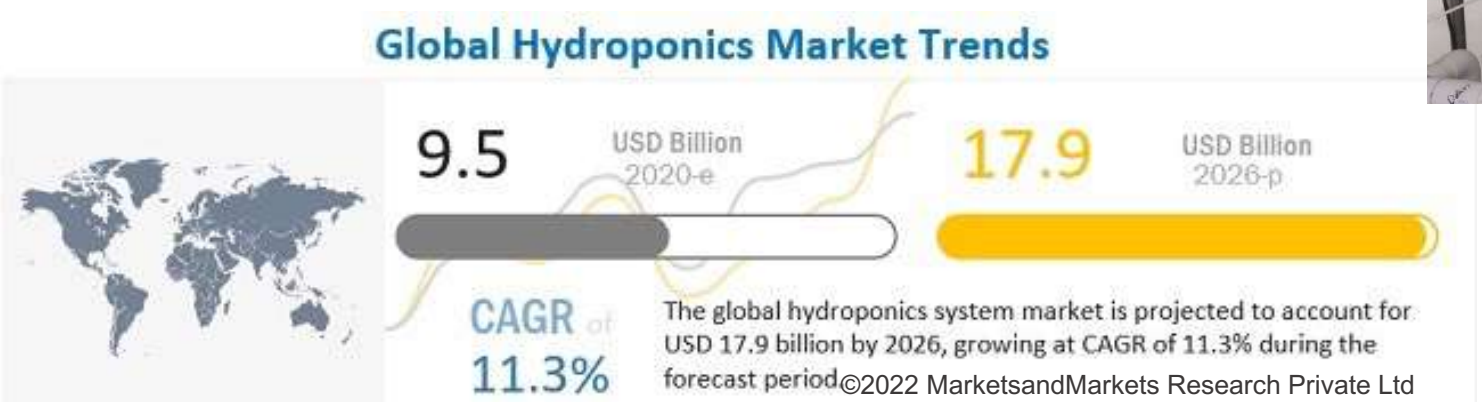
Hydroponic production is a growing CEA industry

CFAES

CEA: controlled environment agriculture

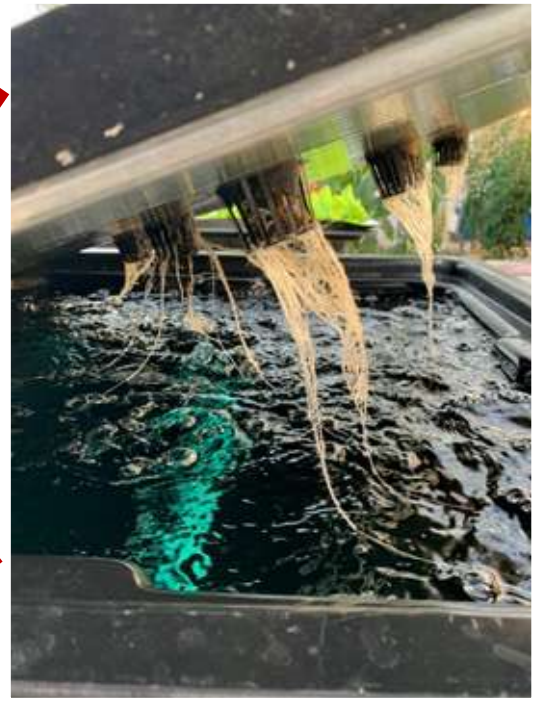
Hydroponic production is a growing CEA industry



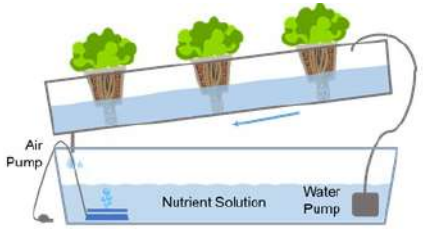


In hydroponics, leafy green roots are suspended in a defined nutrient solution

DWC: deep water culture

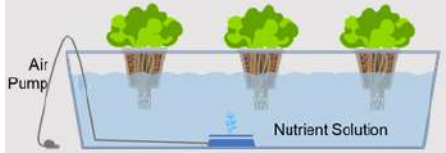


NFT: nutrient film technique



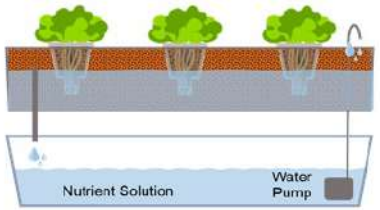
NUTRIENT FILM TECHNIQUE

- ✓ Active System
- ✓ Water-Culture
- ✓ Recirculates water



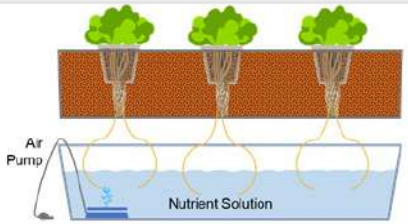
DEEP WATER CULTURE

- ✓ Passive System
- ✓ Water-Culture
- ✓ Does Not recirculate water



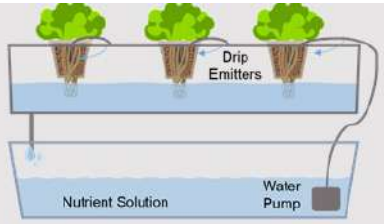
EBB & FLOW

- ✓ Active System
- ✓ Media-Based
- ✓ Recirculate water



WICK SYSTEM

- ✓ Passive System
- ✓ Media-Based
- ✓ Does Not recirculate water



DRIP SYSTEM

- ✓ Active System
- ✓ Water-Culture
- ✓ Recirculates water

Source: Leaffin.com

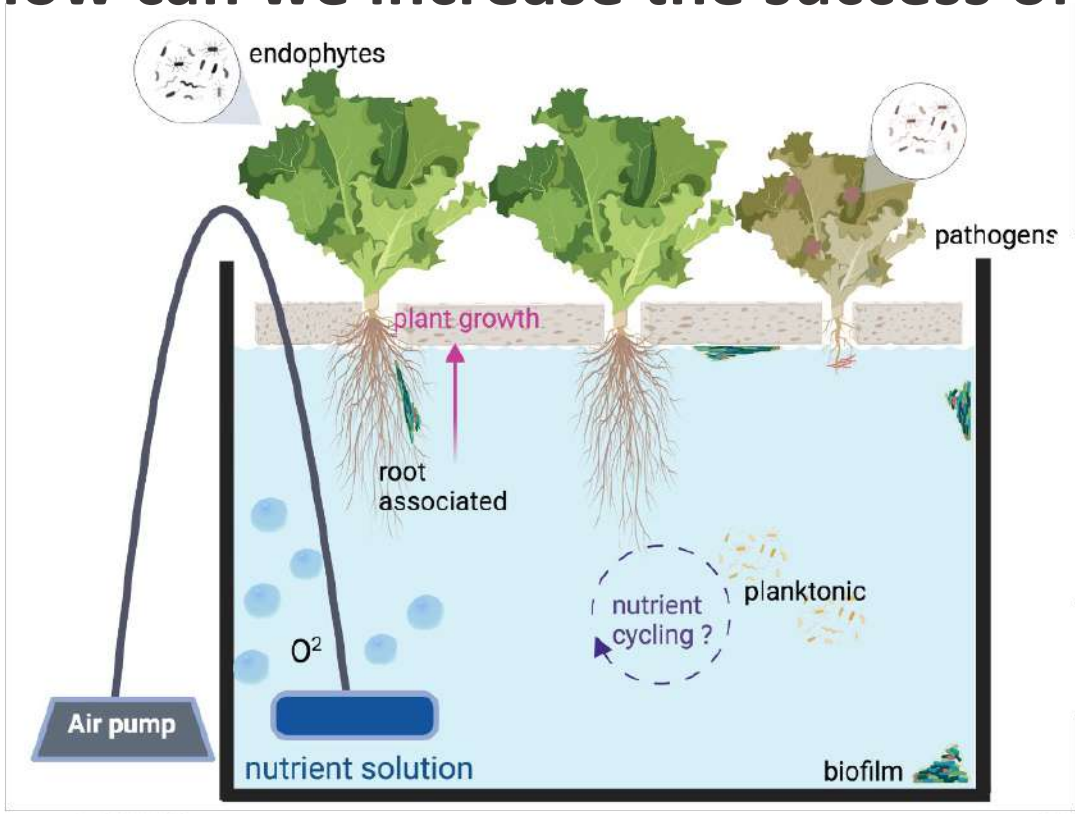
Nutrient solutions are designed to maximize leafy green growth

Crop	pH	EC (electrical conductivity)
Lettuce [a]	5.8-6.2	1.8
Basil [b]	5.5 – 6.0	1.0- 1.6
Spinach [b]	6.0 -7.0	1.8 - 2.3
Arugula [c]	5.8	1.5 – 1.8

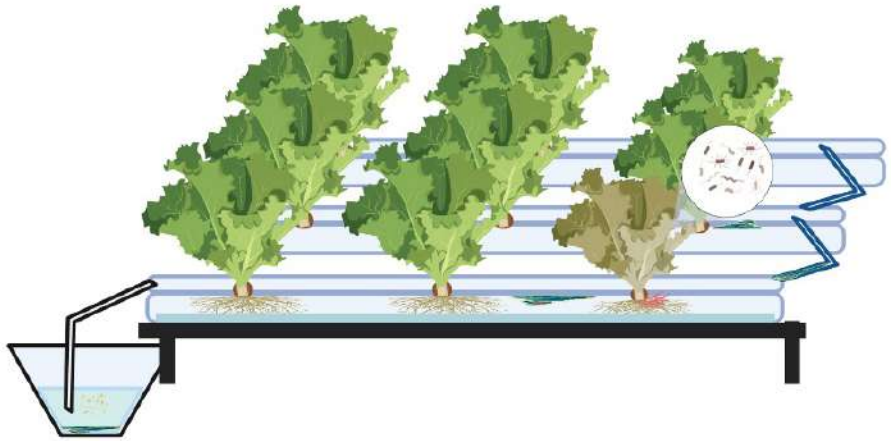
[a] Samarakoon et al 2020
[c] Tang et al 2021
[b] Meselmani 2022

Research questions

- What roles do microbial communities play in different compartments of a hydroponic system?
- How can we increase the success of microbial inoculant use?



DWC



NFT

Created in Biorender

What roles do microbial communities play in different compartments of a hydroponic systems?

1. Microbiome dynamics in commercial hydroponic facilities
2. Factors that contribute to microbiome composition in lettuce hydroponics

Fiama Guevara
@FiamaGuevara

Leslie Taylor

Timothy Frey
@phytophthora

Gustavo Garay
@ggaray07

OHCEAC

USDA NIFA

Dr. Antonino Malacrino, Dr. Robert Korir, Alex Taylor, Niah Cohen

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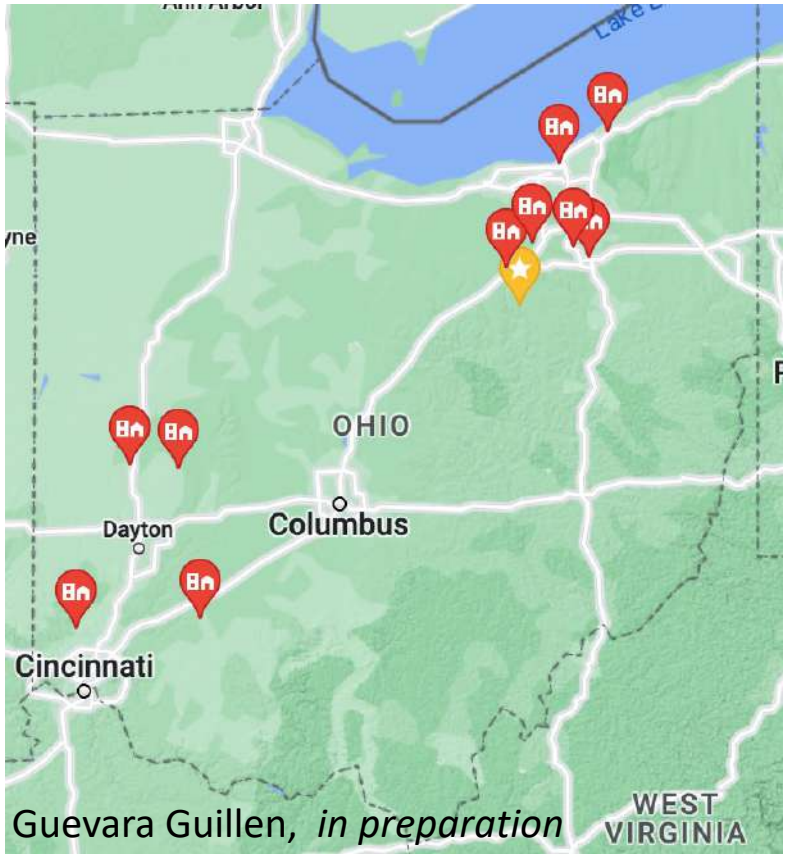
CFAES

1. Microbiome dynamics in commercial hydroponic facilities

1. Microbiome dynamics in leafy-green hydroponic facilities

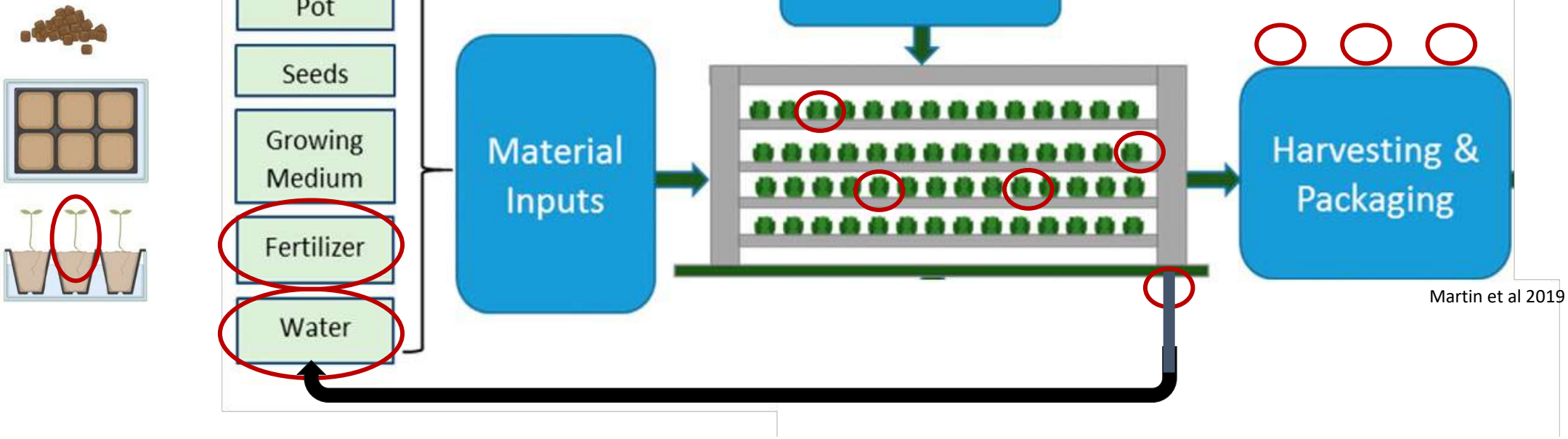


Guevara Guillen, *in preparation*

Facilities	Water source	EC	pH

• 10 facilities
• 23-13150 m^2
• System types
  • NFT
  • DWC
  • Other
	8/10 city water
	2/10 rainwater
		Type A: 1.8-2.2
		Type B: 1.2-1.8
		Type C: 1.5-2.2
			5.4 – 6.1

Sampling strategy



Martin et al 2019

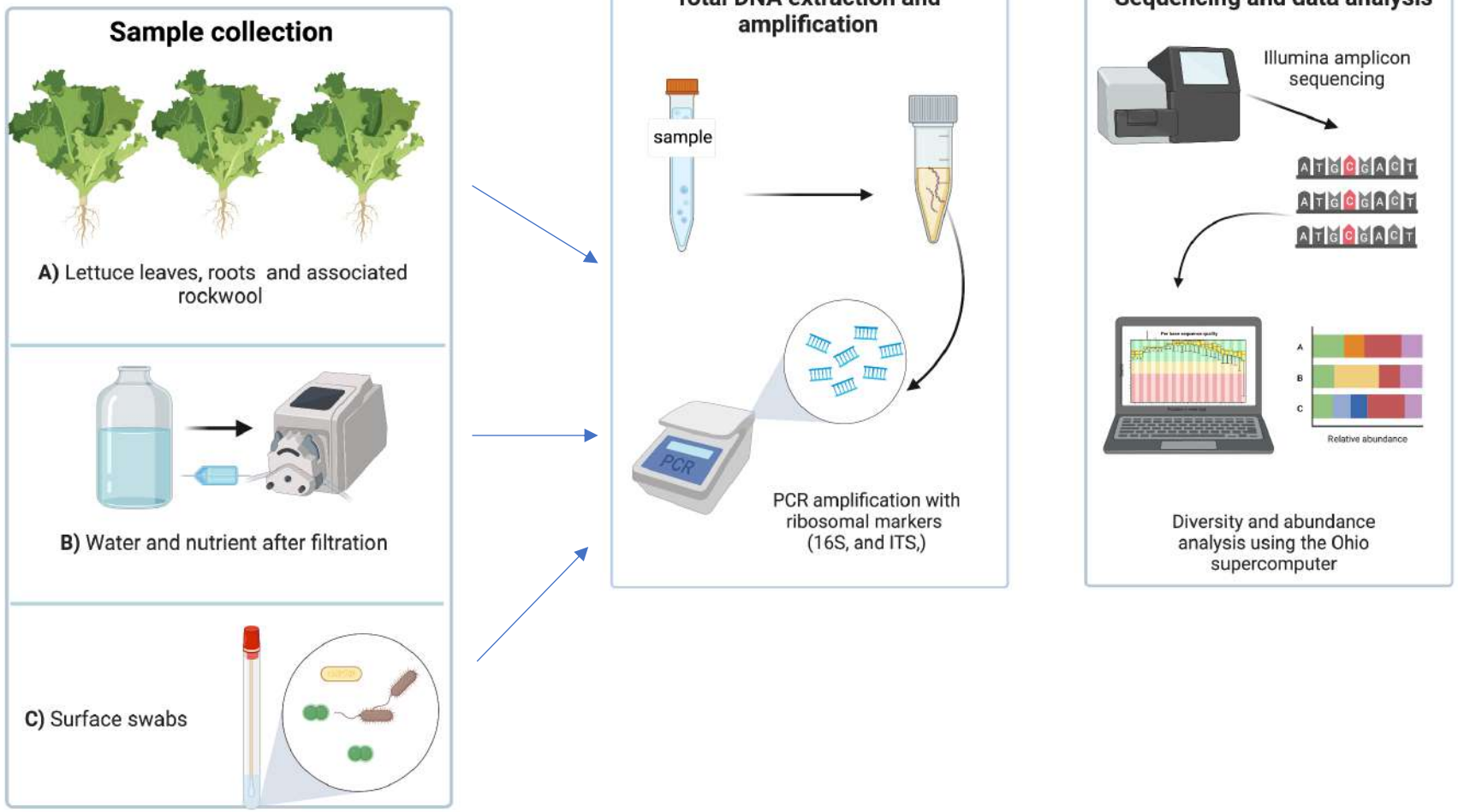
Seedling production

Nutrient input and output

Harvest ready lettuce

Surfaces

Sample processing



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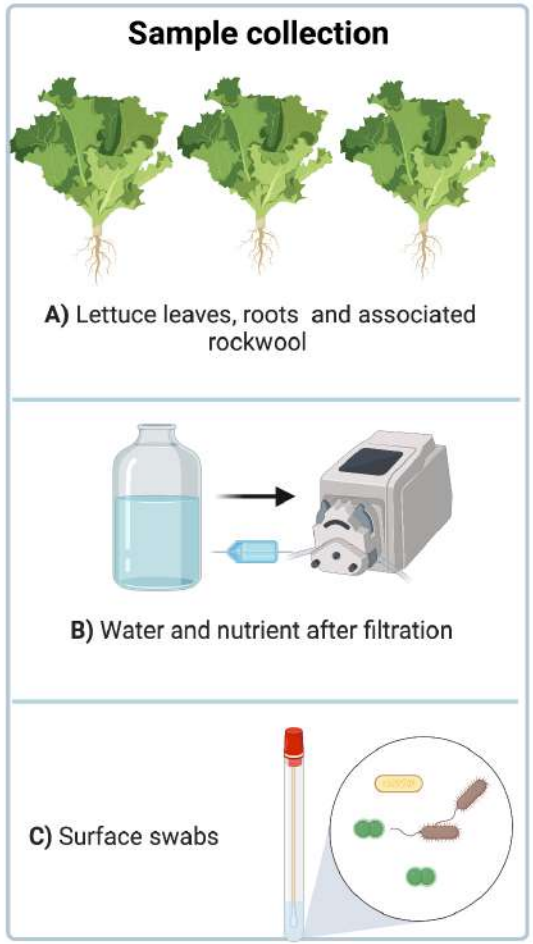
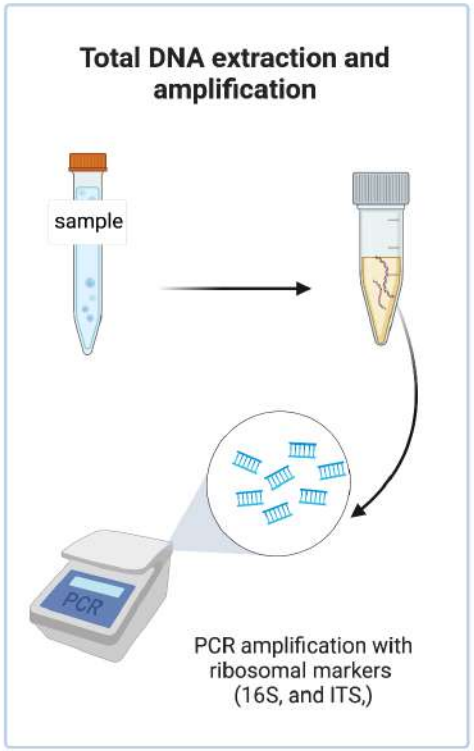
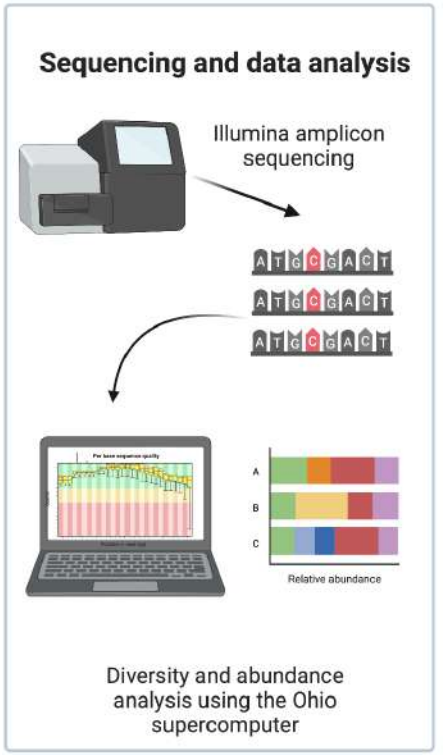
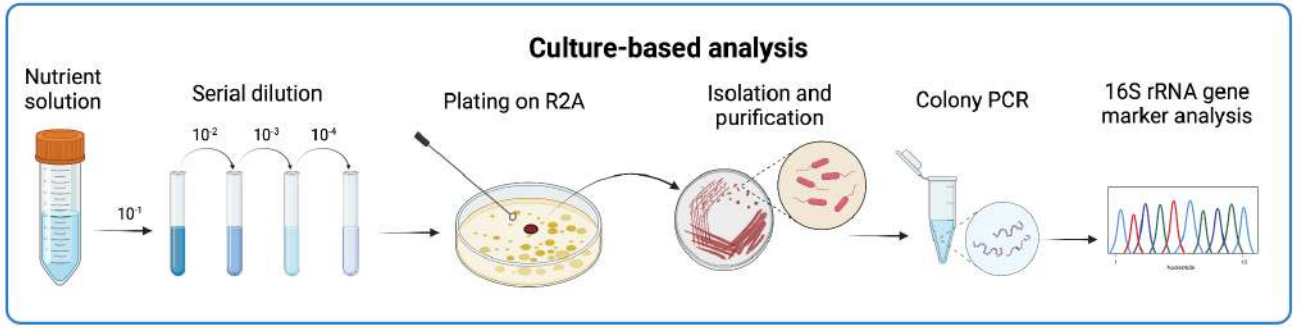


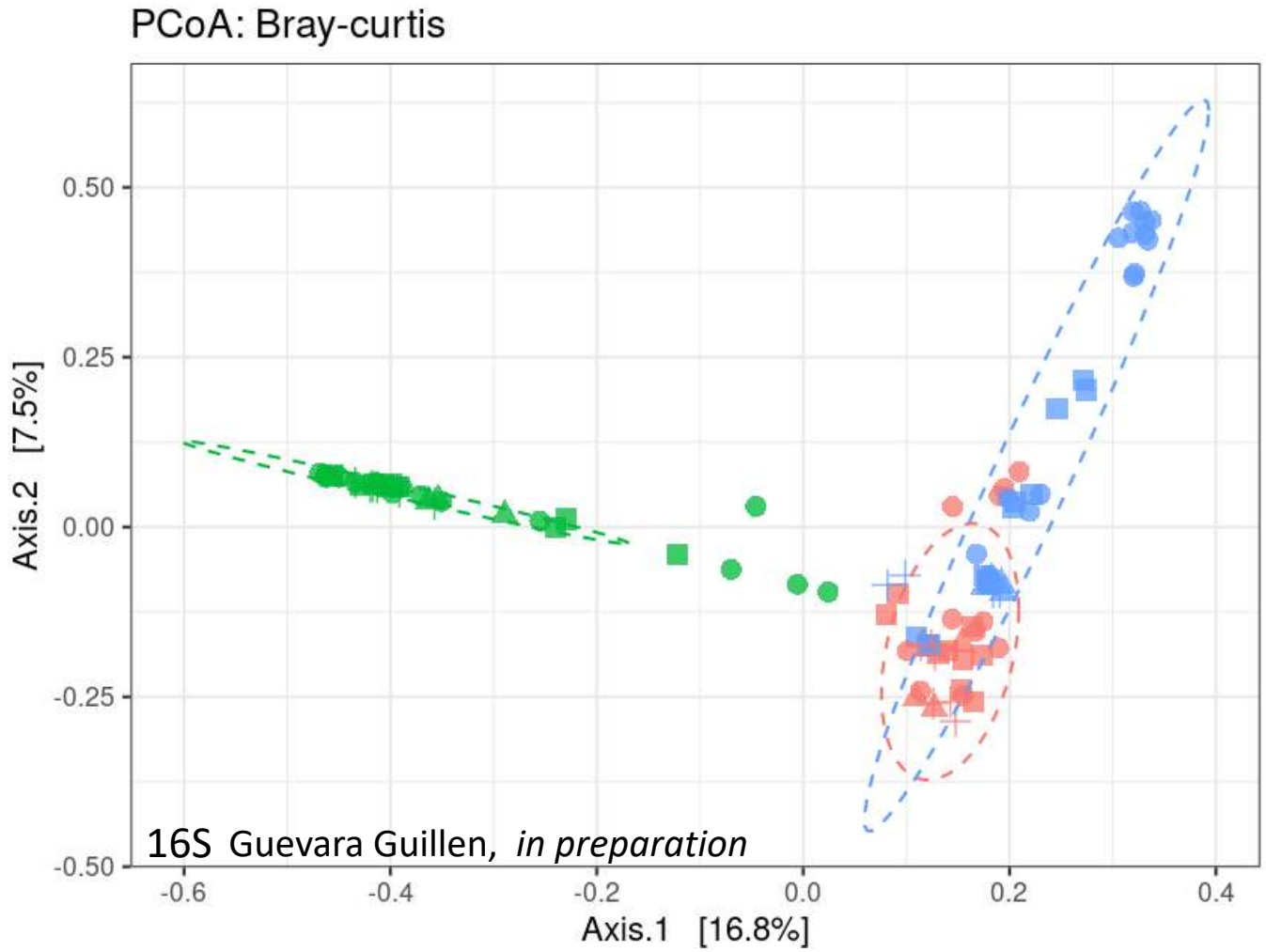






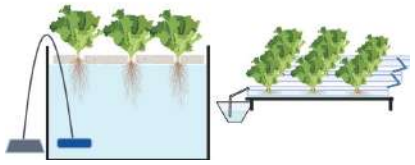
Guevara Guillen, *in preparation*

Bacterial and fungal communities differed between sample types



system design

- DWC
- other
- NFT

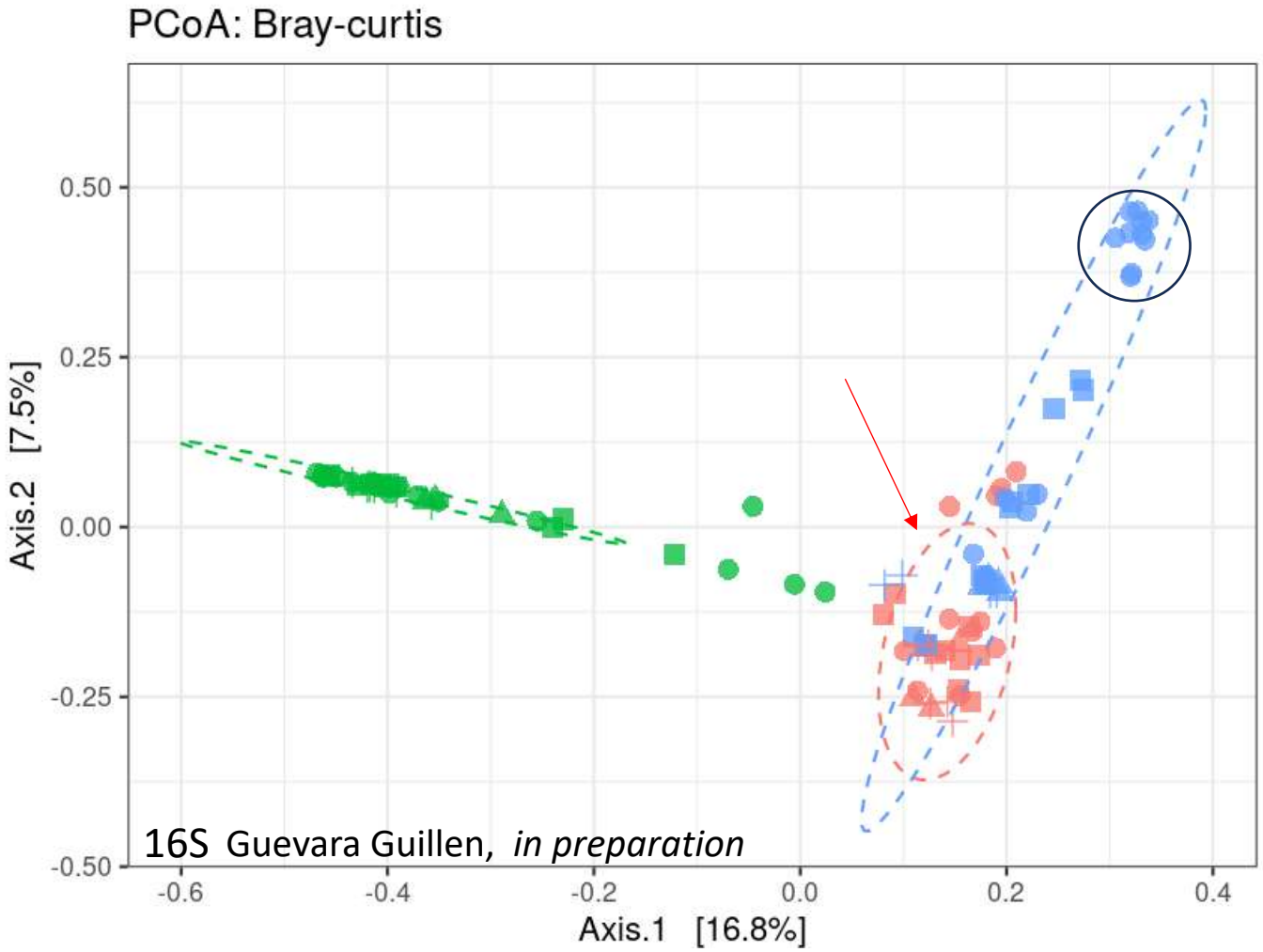


sample type

- Filtered water/nutrient solution
- Leaves
- Roots

Bacterial and fungal communities differed between sample types

CFAES

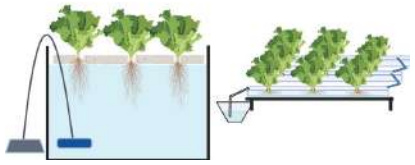


system design

DWC

other

NFT



sample type

Filtered water/nutrient solution

Leaves

Roots

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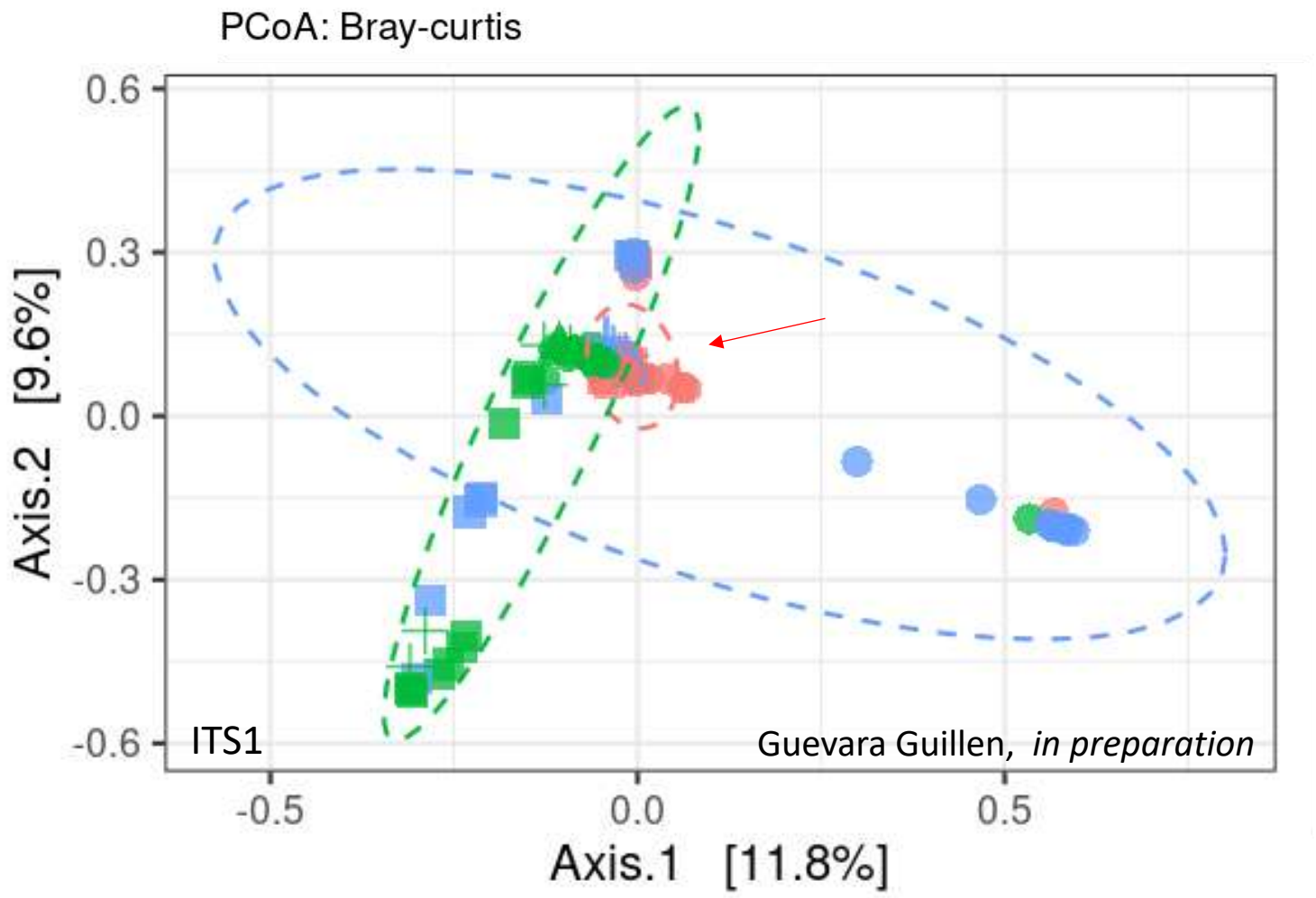
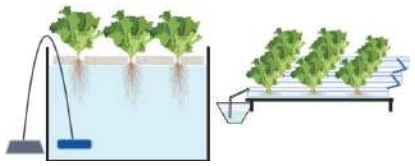


system design

DWC

other

NFT



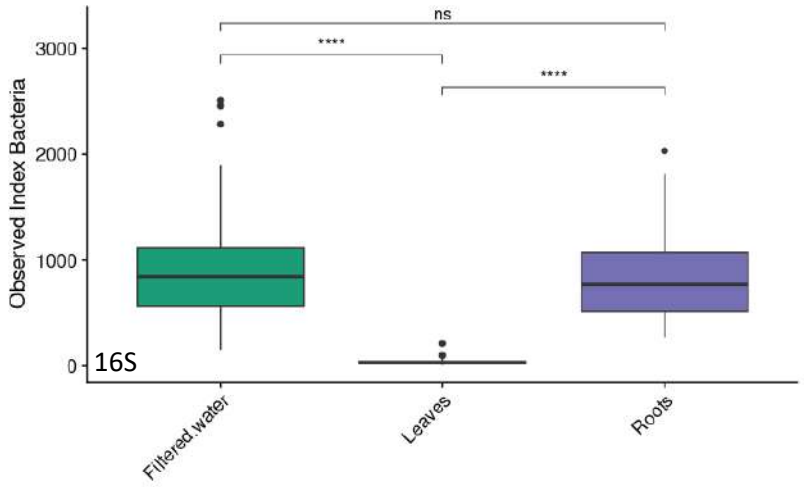
sample type

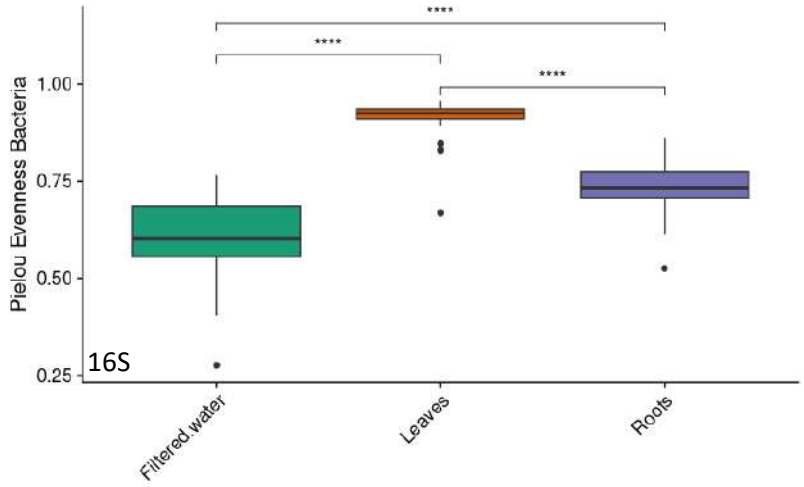
Filtered water/nutrient solution

Leaves

Roots

Lower number of bacteria and fungi recovered from leaves, than other sample types





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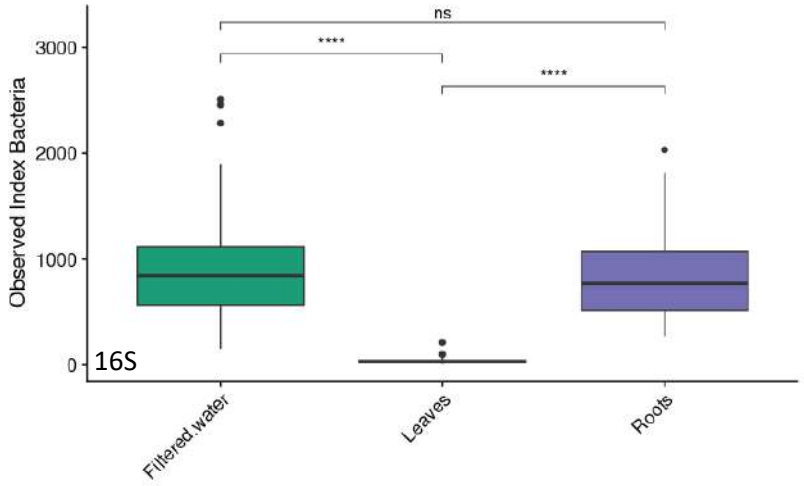

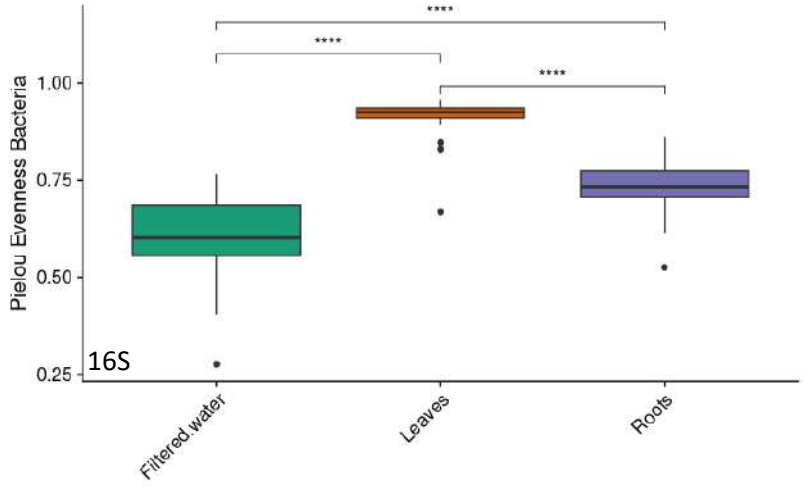

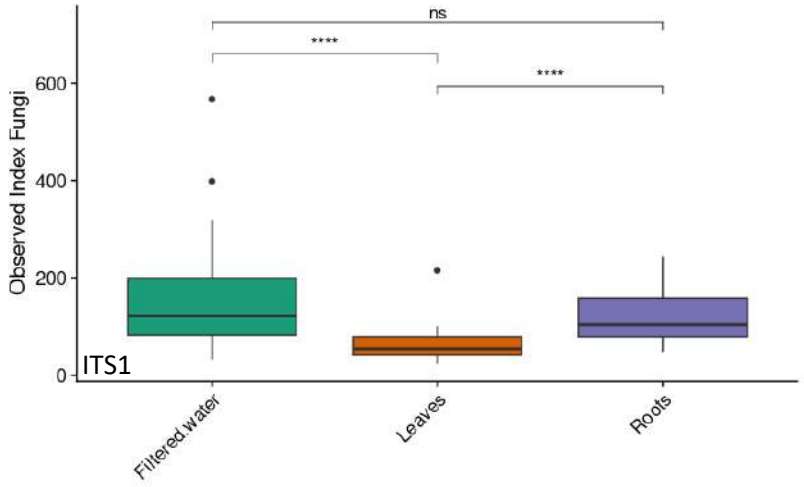

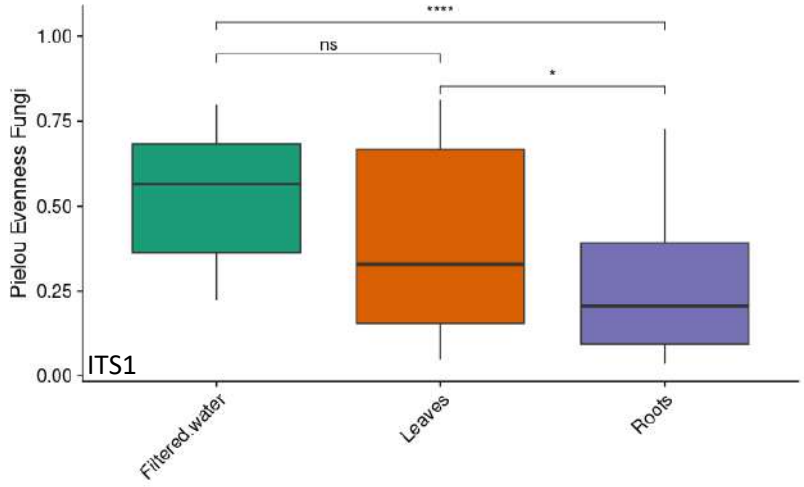

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1. Microbiome dynamics in leafy-green hydroponic facilities

Across 10 facilities in Ohio, we observed that:

- Sample type (bacterial habitat) drives community composition and diversity, with variability across facility/system design
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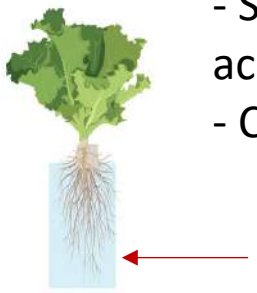

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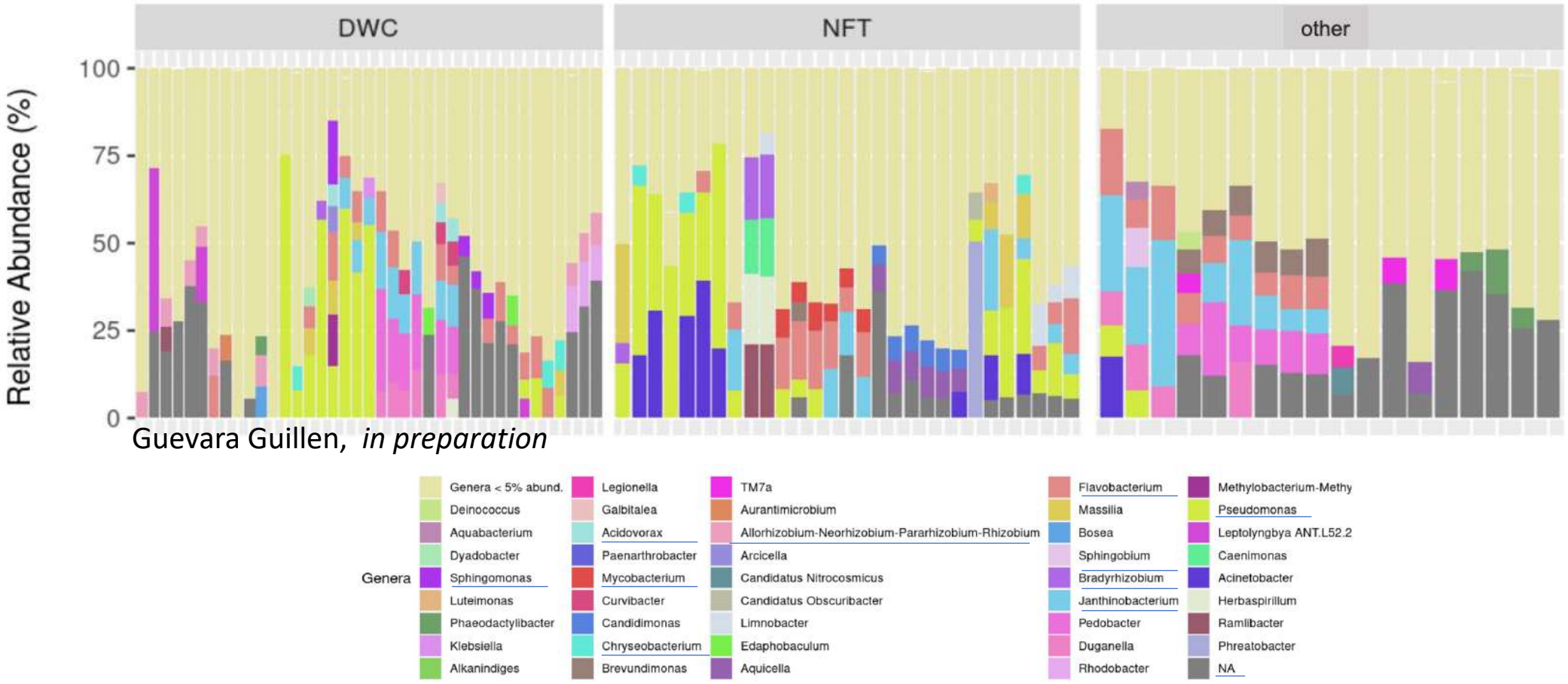
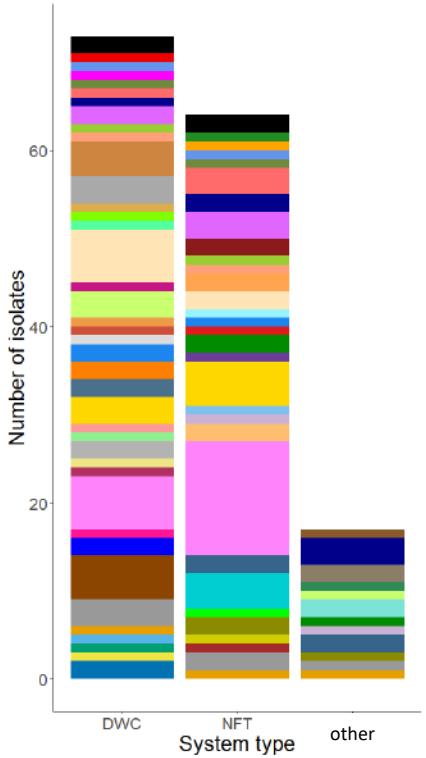
Consistent groups of bacteria recovered from nutrient solution (amplicon metabarcoding)



Guevara Guillen, *in preparation*

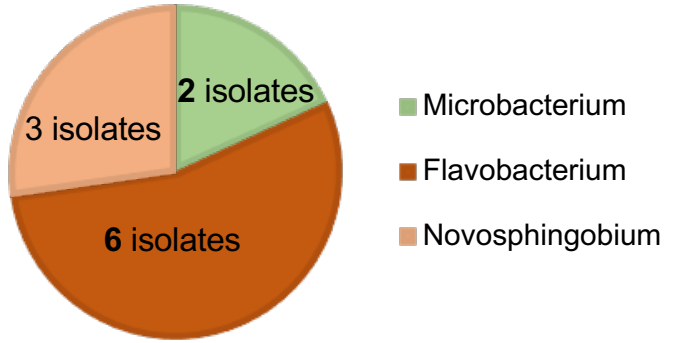
Consistent groups of bacteria recovered from nutrient solution (culture collection)



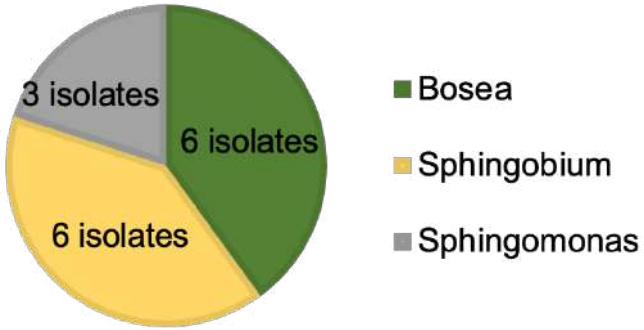
Genus

Acidovorax	Curvibacter	Mycobacterium	Rhizobium
Acinetobacter	Deinococcus	Neobacillus	Rhizorhabdus
Aminobacter	Duganella	Niveispirillum	Rhodanobacter
Ancylobacter	Dyadobacter	Nocardioides	Rhodococcus
Aquitalea	Emticicia	Novosphingobium	Sediminibacterium
Asticcacaulis	Flavobacterium	Paenarthrobacter	Shinella
Azospirillum	Flectobacillus	Paenibacillus	Sphingoaurantiacus
Bacillus	Frigoribacterium	Patulibacter	Sphingobium
Blastomonas	Gordonia	Pedobacter	Sphingomonas
Bosea	Hydrogenophaga	Pelomonas	Sphingopyxis
Brevundimonas	Janthinobacterium	Phenylobacterium	Stenotrophomonas
Candidimonas	Kocuria	Polaromonas	Thermomonas
Caulobacter	Mesorhizobium	Prosthecomicrobium	Variovorax
Chromobacterium	Methylobacterium	Pseudomonas	
Chryseobacterium	Microbacterium	Pseudoxanthomonas	
Comamonas	Micrococcus	Reyranella	

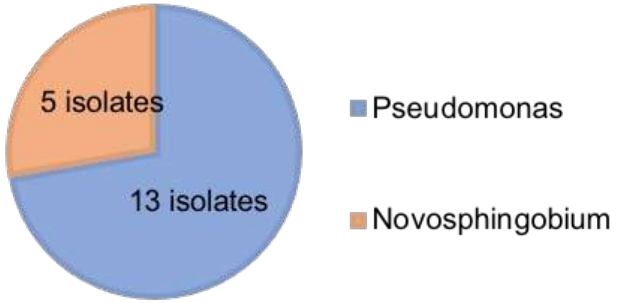
3 genera isolated in all DWC samples:



3 genera shared across system types:

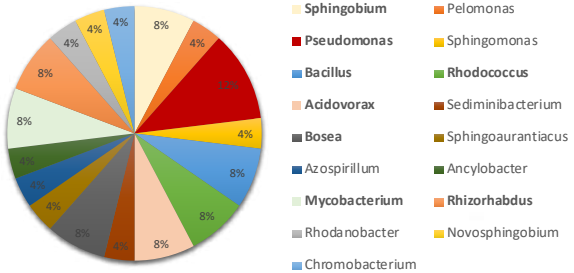


2 genera isolated in all NFT samples:

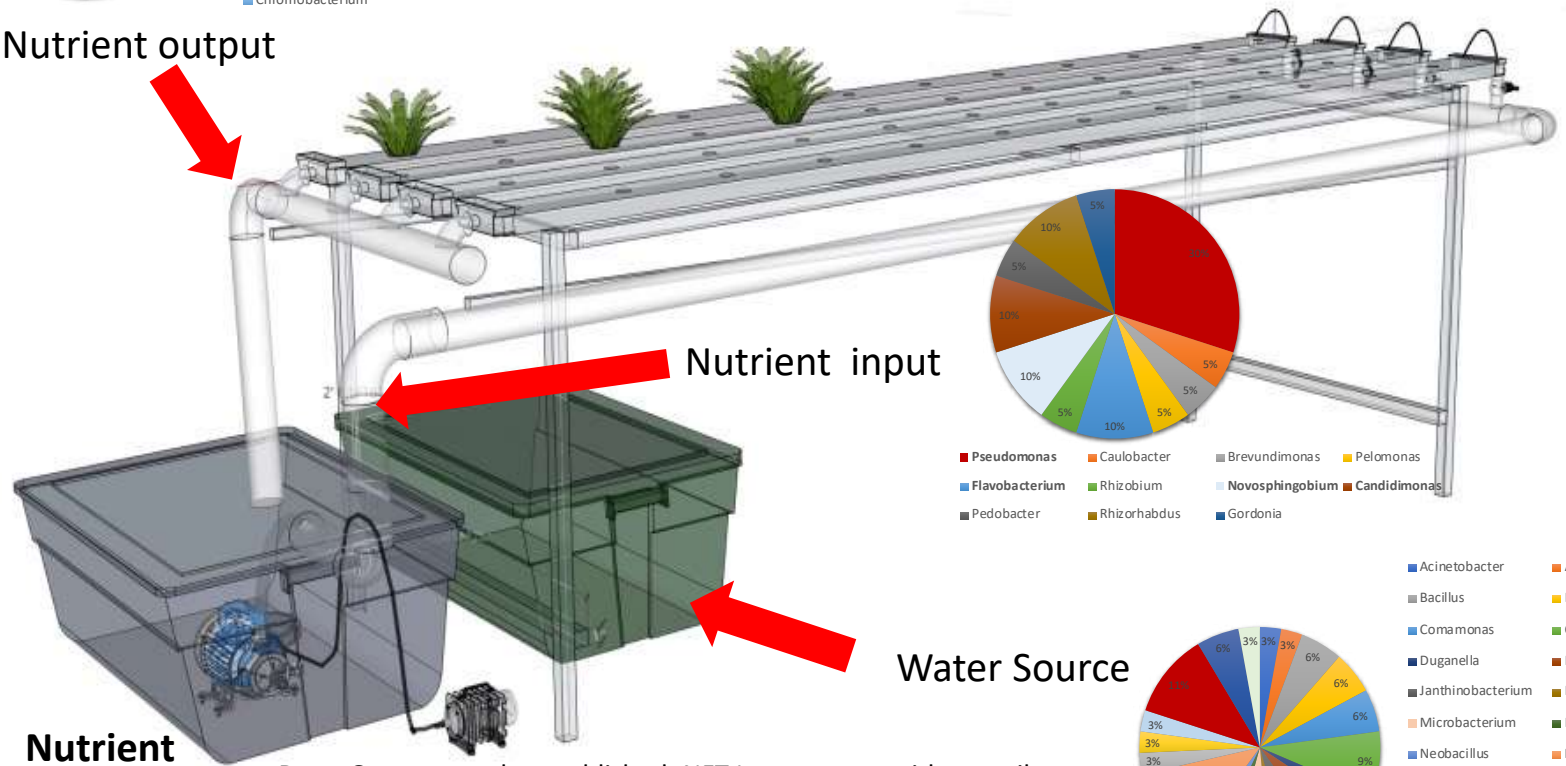


Guevara Guillen, *unpublished*

NFTs: Different bacterial genera isolated from different sampling locations (nutrient solution)



Nutrient output



Nutrient input

Water Source

Nutrient solution tank

Data: Guevara et al, unpublished; NFT Image: grow without soil

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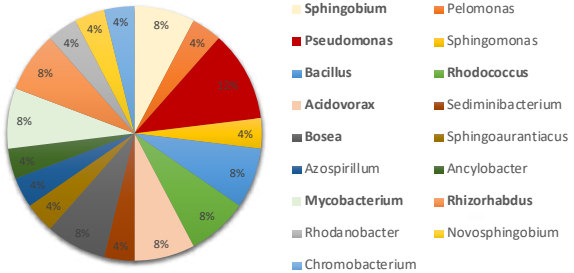
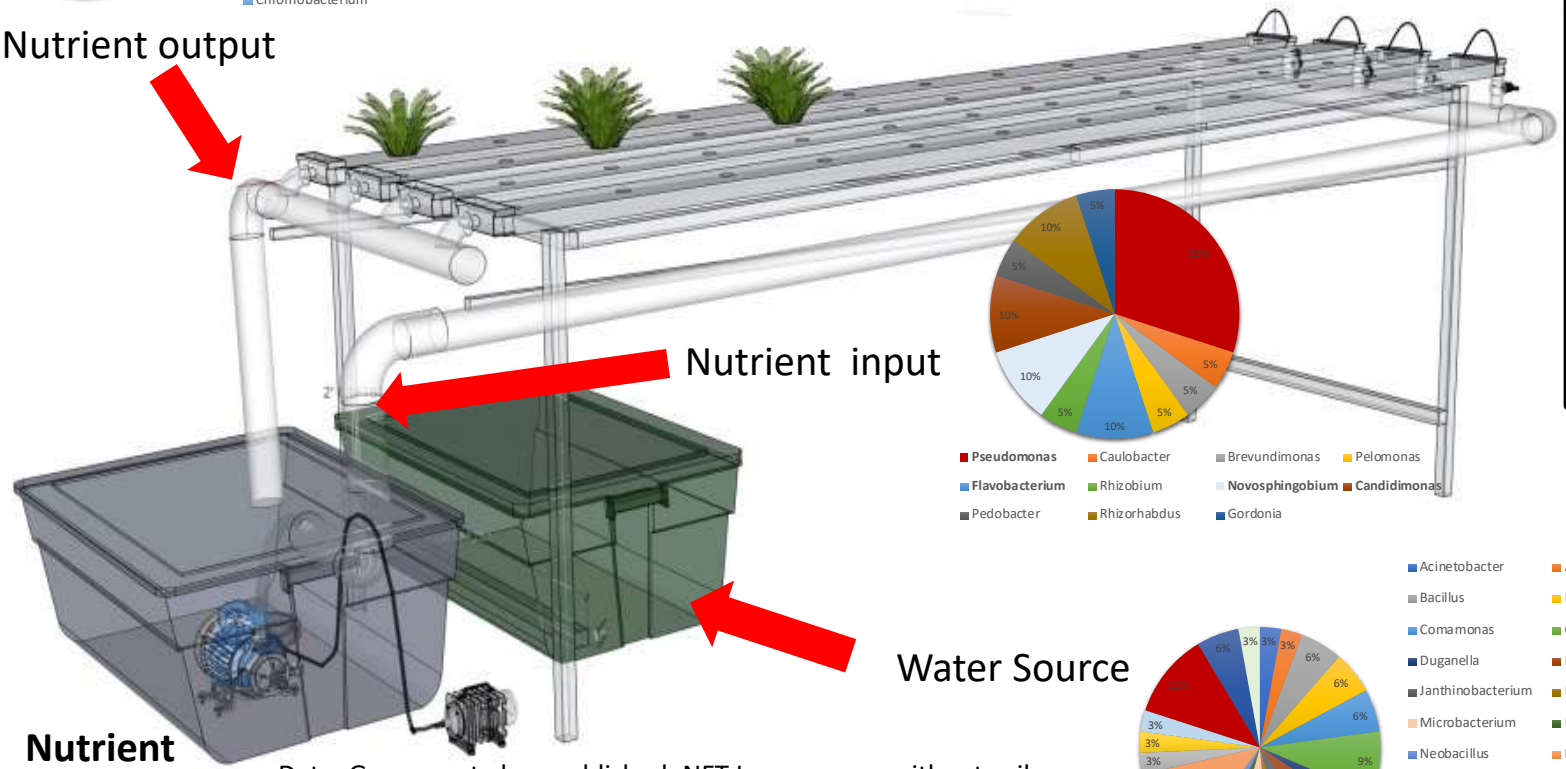


Nutrient output

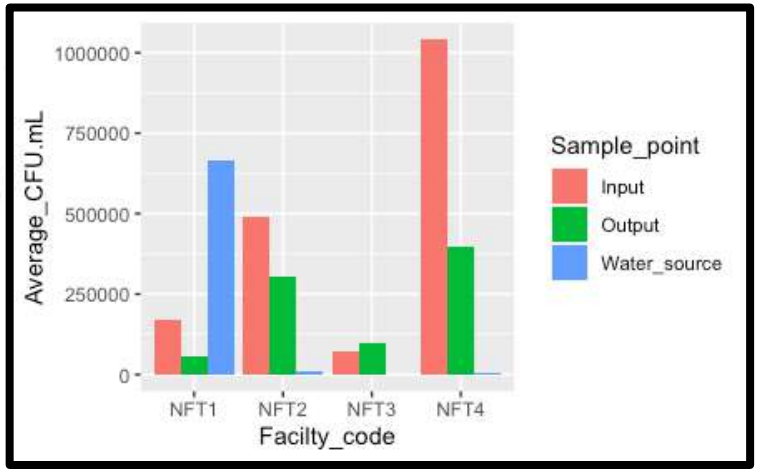


Nutrient input

Water Source

Nutrient solution tank

Differences in bacterial load across facilities



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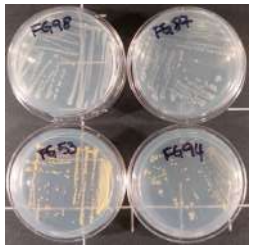

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CFAES

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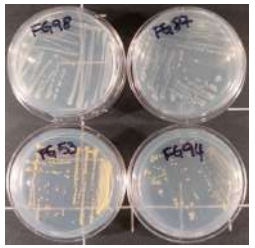

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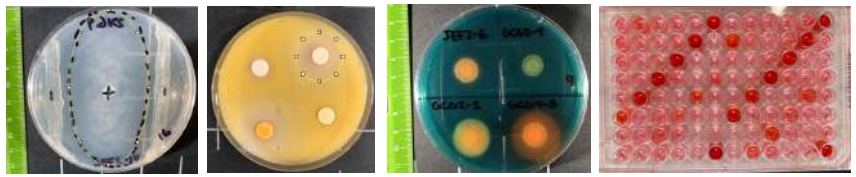
Next steps: a. Continue data analysis and modeling of bacterial and fungal community changes to system characteristics

b. Functional and genomic characterization of recovered isolates



Relevance to productivity?

What roles do microbial communities play in different compartments of a hydroponic systems?

CFAES

1. Microbiome dynamics in commercial hydroponic facilities
2. Factors that contribute to microbiome composition in lettuce hydroponics

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EC	Water source	pH
Type A: 1.8-2.2 Type B: 1.2-1.8 Type C: 1.5-2.2	8/10 city water 2/10 rainwater	5.4 – 6.1

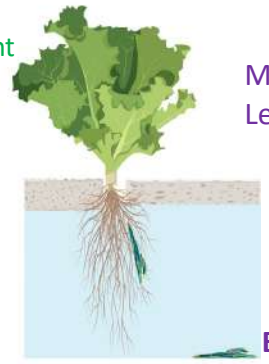
2. Factors that contribute to microbiome composition in lettuce hydroponics

EC	Water source	pH
1.2 1.8 2.5	City Rain Reverse osmosis City:RO City:RW	5 5.8 6.6

Chlorophyll content

Head biomass

Root biomass and length

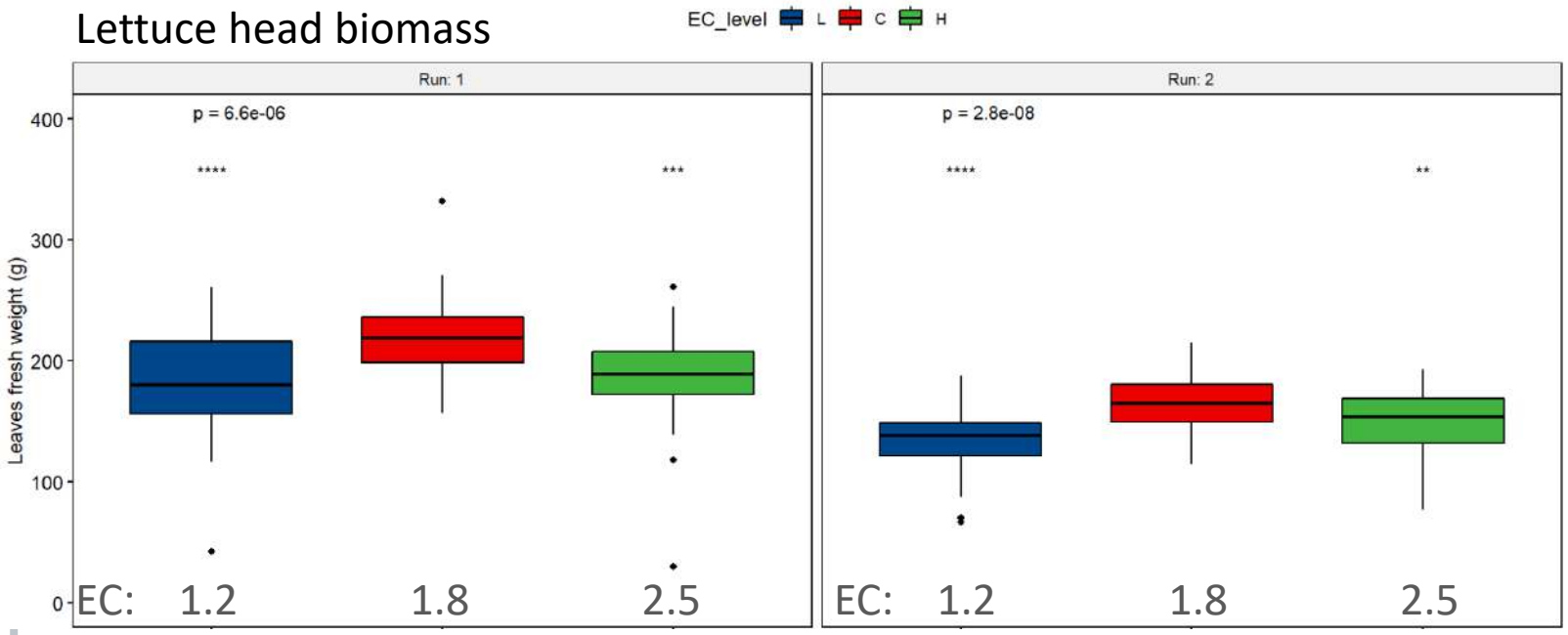


Microbial community samples:
Leaf, root, nutrient solution, rockwool

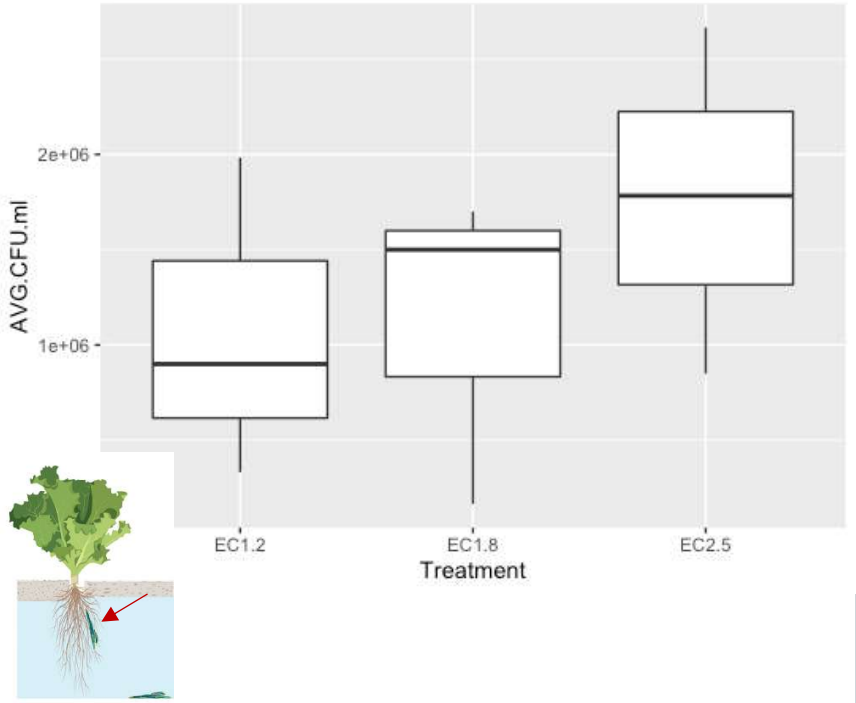
Biofilm accumulation (roots and other surfaces)

DWC: Nutrient solution EC influences head biomass and bacterial abundance on roots

Lettuce head biomass



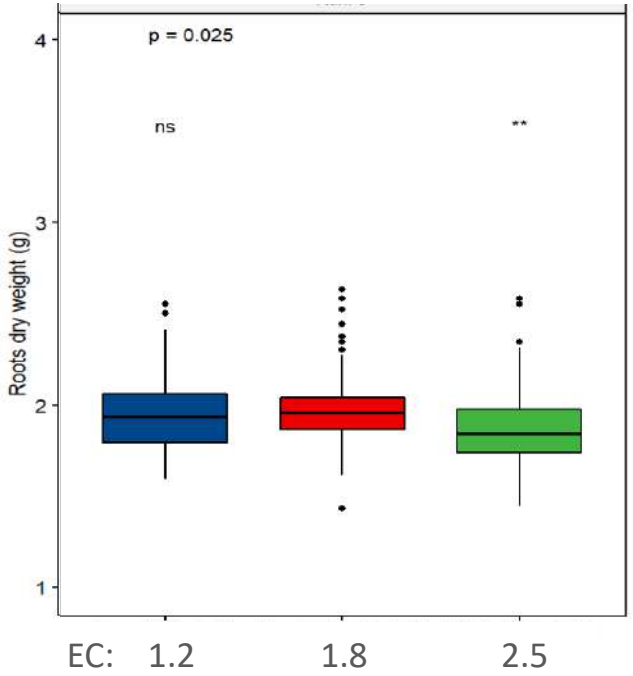
Bacterial counts on roots



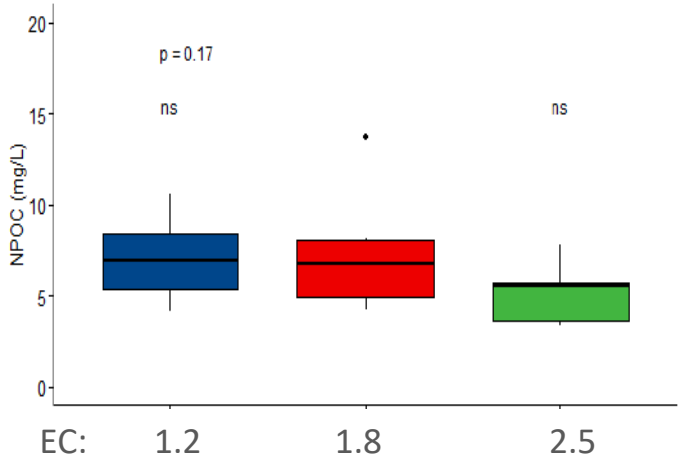
Guevara Guillen et al, *unpublished*

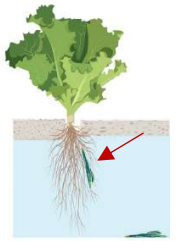
DWC: Nutrient solution EC influences head biomass and bacterial abundance on roots

Root biomass

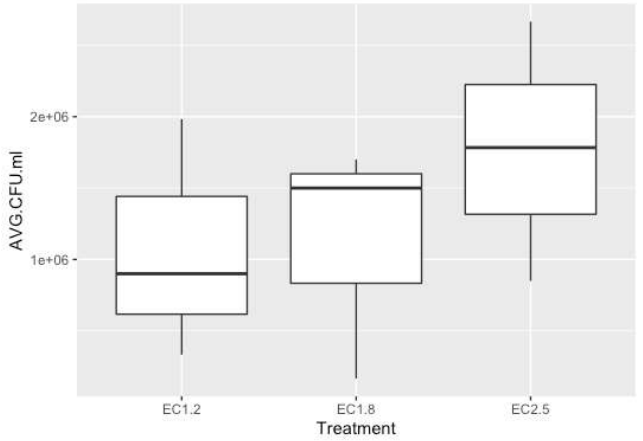


Organic carbon (nutrient solution)





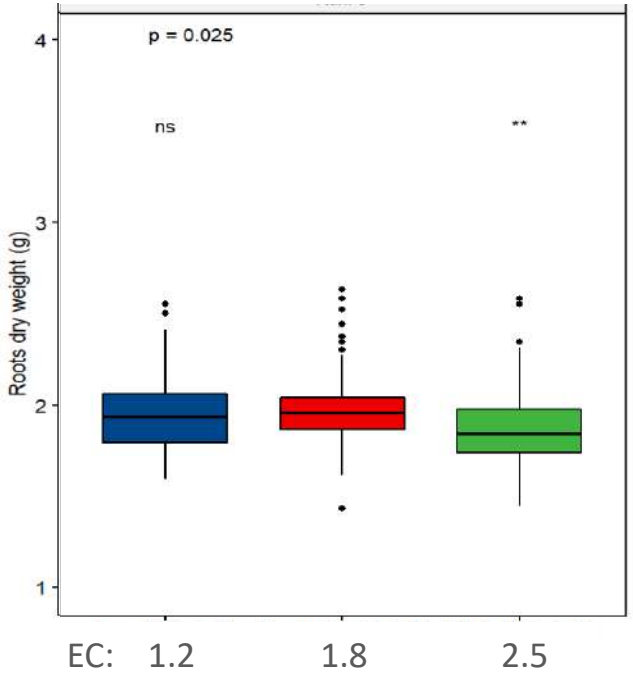
Bacterial counts on roots



Guevara Guillen et al, *unpublished*

DWC: Nutrient solution EC influences head biomass and bacterial abundance on roots

Root biomass



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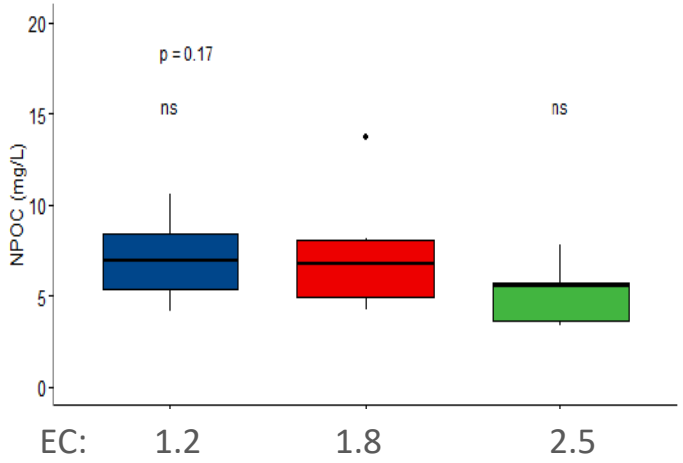
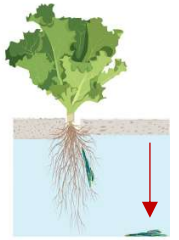
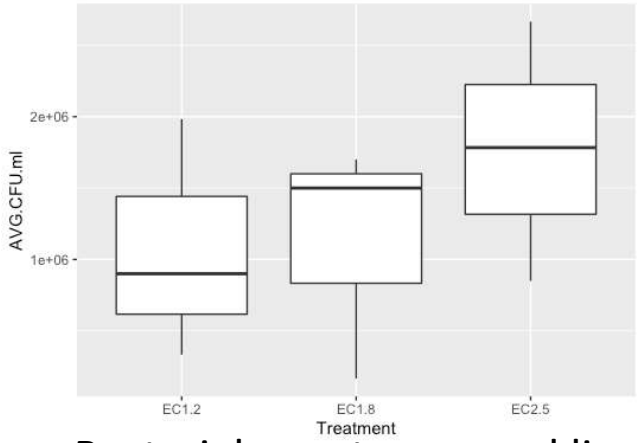
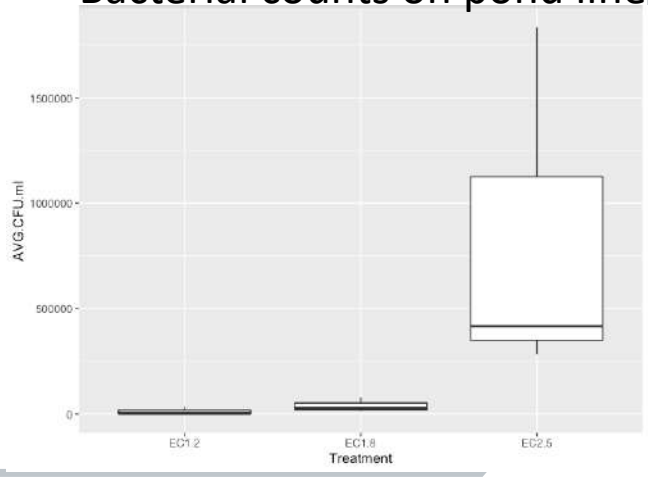




Bacterial counts on roots



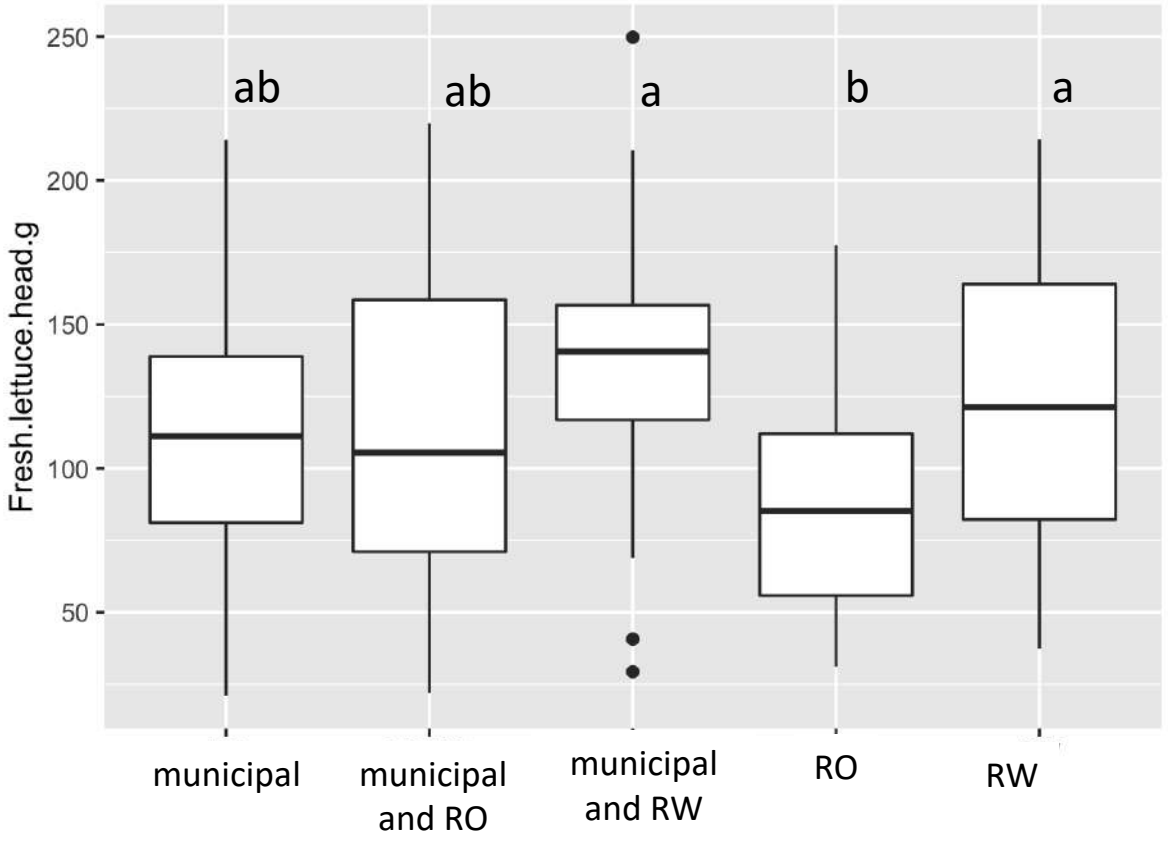
Bacterial counts on pond liner



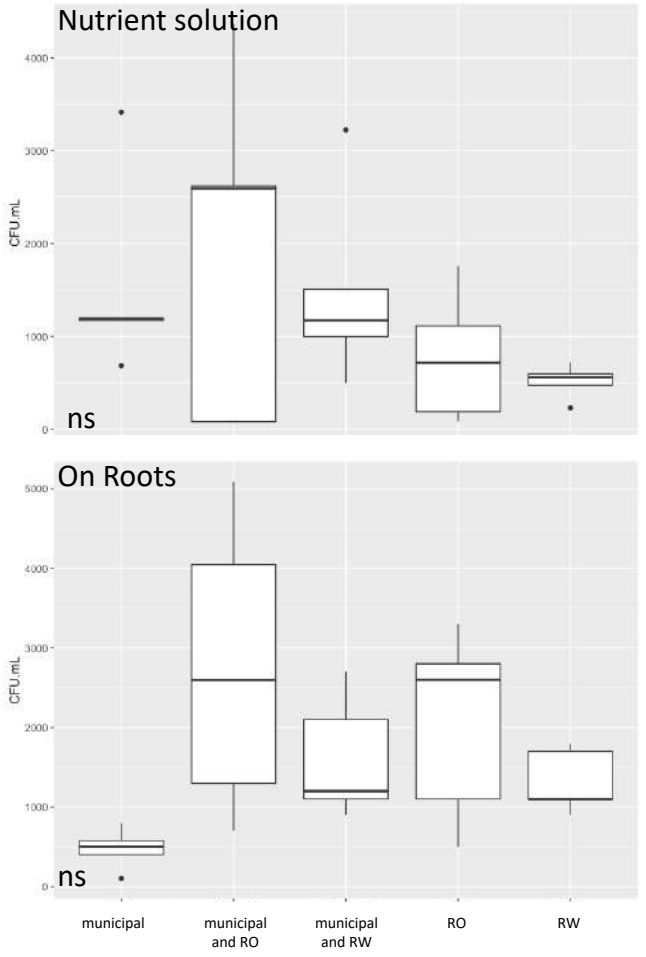
Guevara Guillen et al, *unpublished*

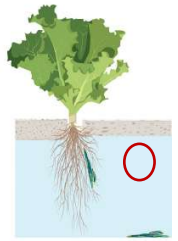
DWC: Water source could impact lettuce yield

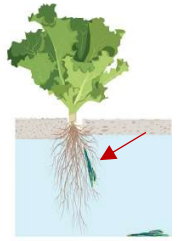
Lettuce head biomass



Bacterial counts

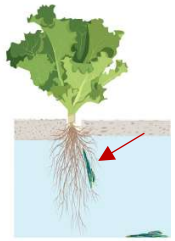


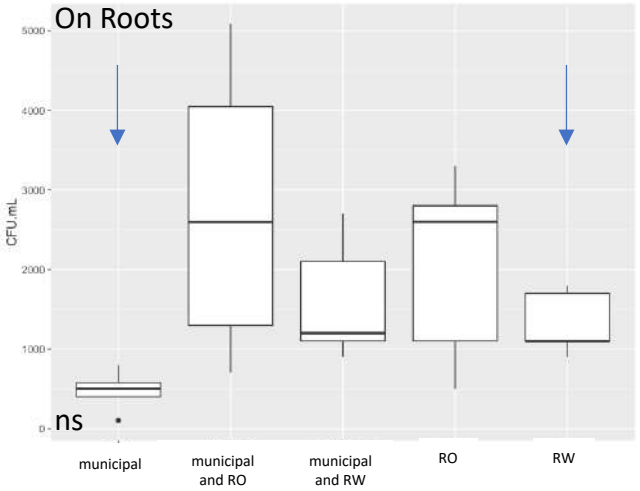


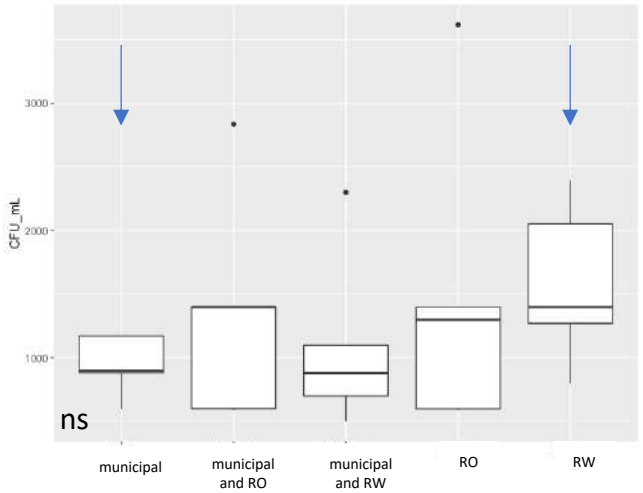


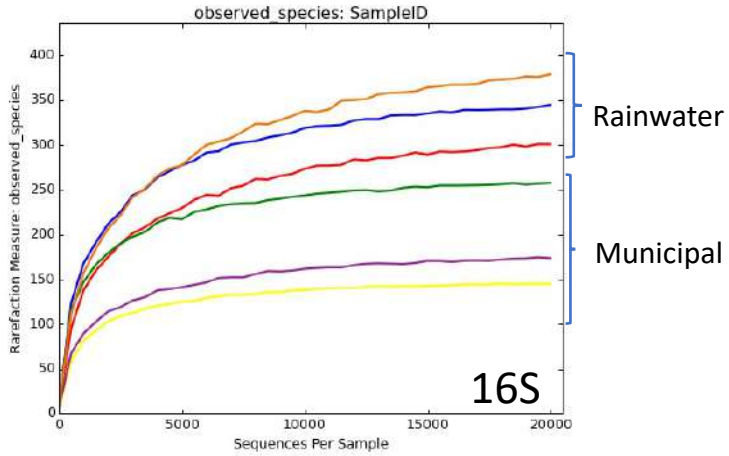
Garay et al, *unpublished*

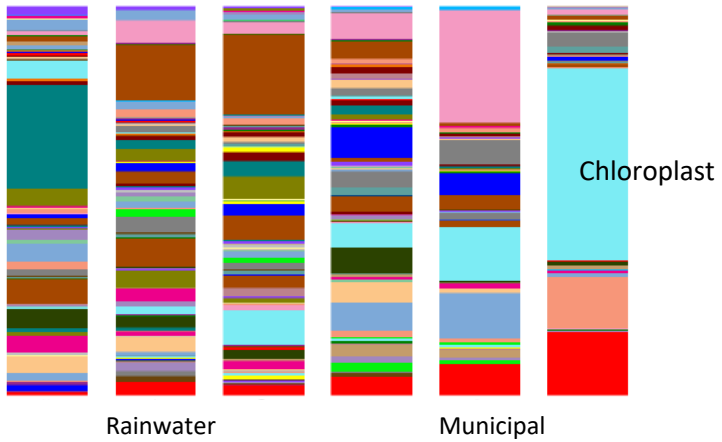
DWC: Water source influences bacterial diversity and composition of root epiphytes







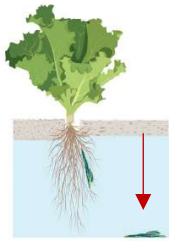




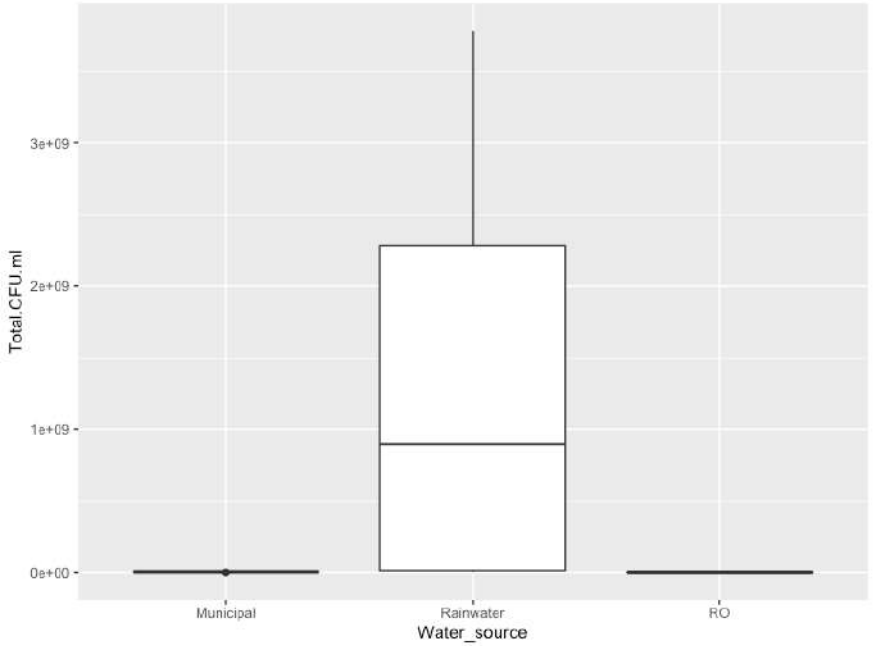
Rainwater	Municipal
Enterobacter	Pseudomonas ←
Novosphingobium ←	Unidentified
Asticcacaulis	Flavobacterium ←
Altererythrobacter	Chryseobacterium ←
Ensifer	Rhizobium ←
Pedobacter	Acidovorax ←
Pseudomonas ←	Pedobacter
Ferrunginibacter	Ferrungibacter
Rhodopseudomonas	Enterobacter
U_Chitinophagaceae ←	Asticcacaulis

Garay et al, *unpublished*

DWC: Water source influences abundance of culturable bacteria recovered from pond liner



Pond liner

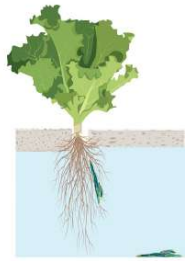


Garay et al, *unpublished*

2. Factors that contribute to microbiome composition in lettuce hydroponics

Nutrient solution characteristics influence both lettuce productivity and the recovery of culturable bacteria from roots, nutrient solution and surfaces

- Higher abundance of bacteria recovered from nutrient solution with the highest EC (2.5) and when prepared with rainwater
- The bacterial accumulation on the surface of the pond liner tend to mirror the patterns observed on roots



Next steps: a. Continue analysis (DNA-based) of bacterial communities across the different experiments

b. Functional and genomic characterization of isolates recovered from roots and pond liners across experiments

c. Biofilm characterization

Microbial community composition in leafy green hydroponics

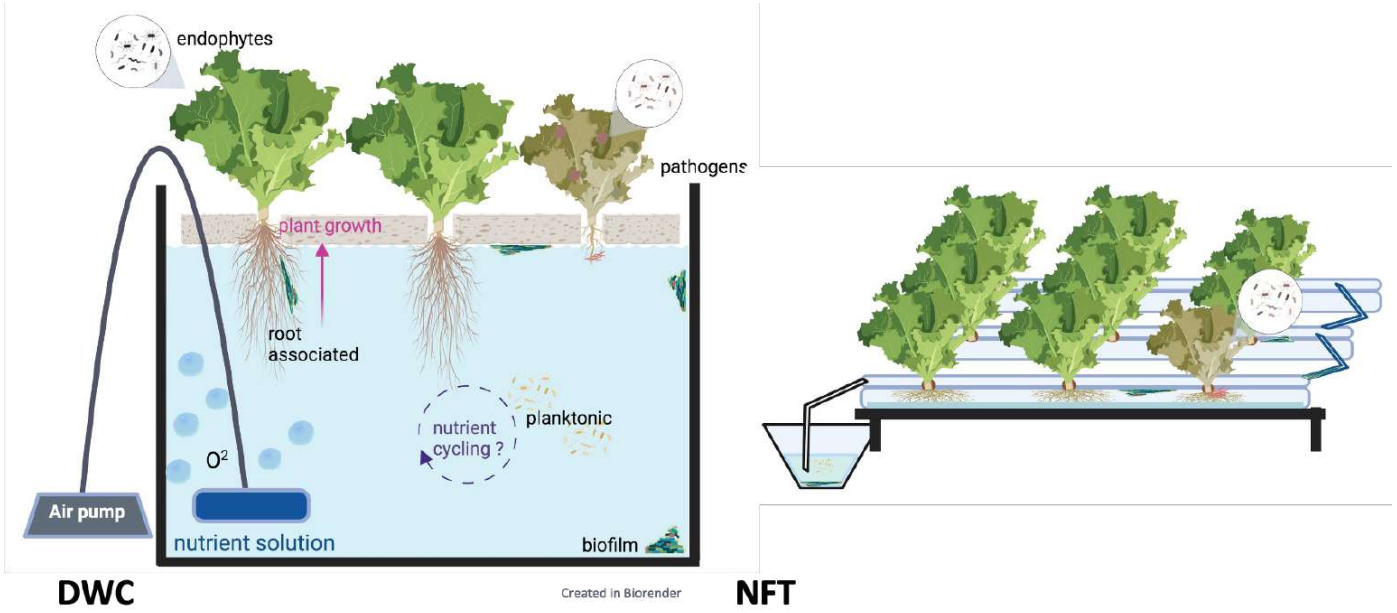
CFAES

- Sample type (bacterial habitat) drives community composition and diversity, with variability across facility/system design
- Microbial communities from nutrient solutions were less variable across facilities, compared to roots and leaves
- Nutrient solution manipulation affects bacterial communities from various surfaces
- Consistent groups of bacteria recovered from nutrient solution (amplicon metabarcoding and culturing) across facilities and greenhouse experiments

Future work:

- Functional characterization of individual isolates and determining potential adaptations to unique environment characteristics
- Characterization of biofilms and their roles in productivity

Questions?



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benitezponce.1@osu.edu
@msbenitezponce