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BILL & MELINDA
GATES *foundation*

Pollution from fertilizer runoff



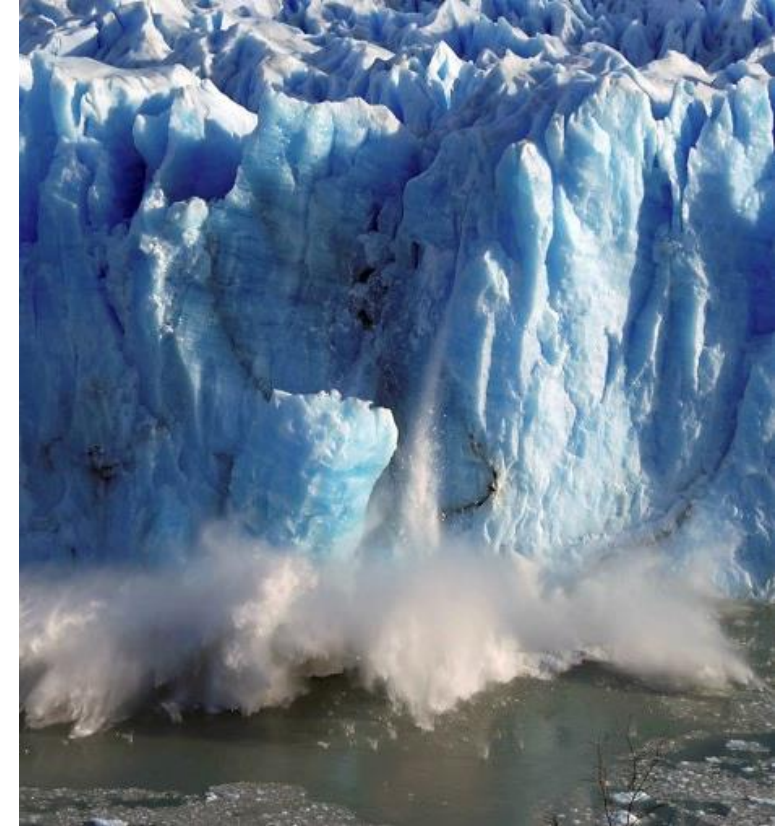
Source: NASA/Landsat/Phil Degginger/Alamy

Soil degradation



Source: Lynn Betts/USDA NRCS

Greenhouse gases and climate change



Source: Andres Forza / Reuters file

Modern day agriculture was not designed with sustainability in mind.

“Novel microbes and newly assembled syncoms to promote sustainable agriculture.”



Discovery



Colonization and persistence

Major take homes:

1. Noise in data can be frustrating but can also help us learn about microbial systems.
2. We can't just skip to the end. Investment in foundational science is required to realize the potential benefit from microbial solutions in agriculture.

Despite significant potential, these products don't work as well as they could/need to.

WHY?



* Can provide up to 25% of the plant's nitrogen needs.



Jeff Dangl (U. of North Carolina, Chapel Hill)

- SynComs developed based on associations with Arabidopsis



Daniel Schachtman (U. of Nebraska, Lincoln)

- Sorghum grown in Nebraska under nitrogen or water limited conditions

WHERE TO START?

- Can we translate findings from Arabidopsis into sorghum?

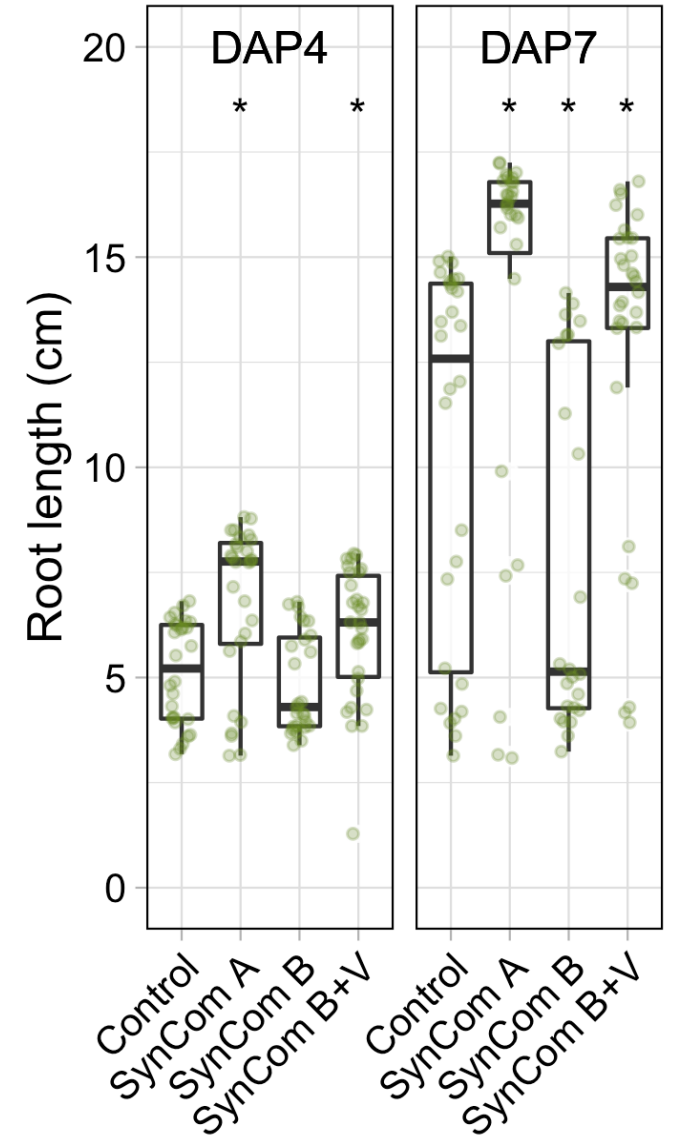
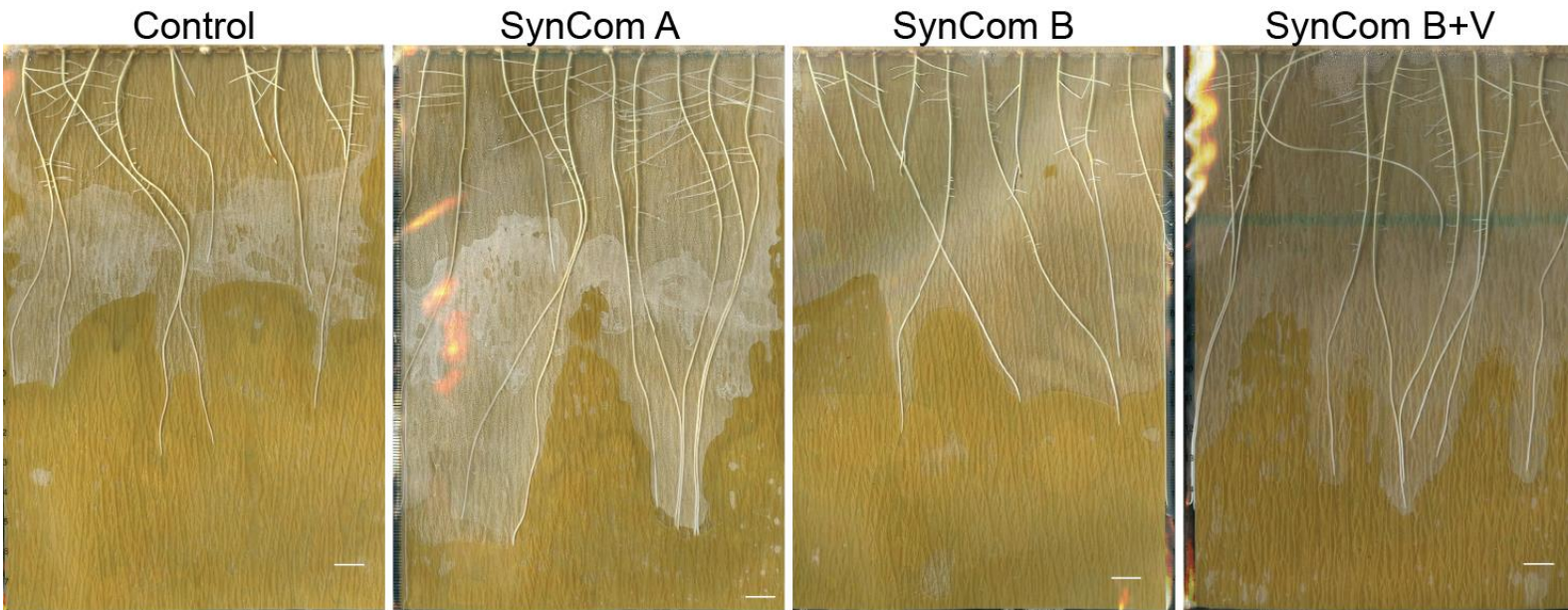
Article | [Published: 30 September 2020](#)

A single bacterial genus maintains root growth in a complex microbiome

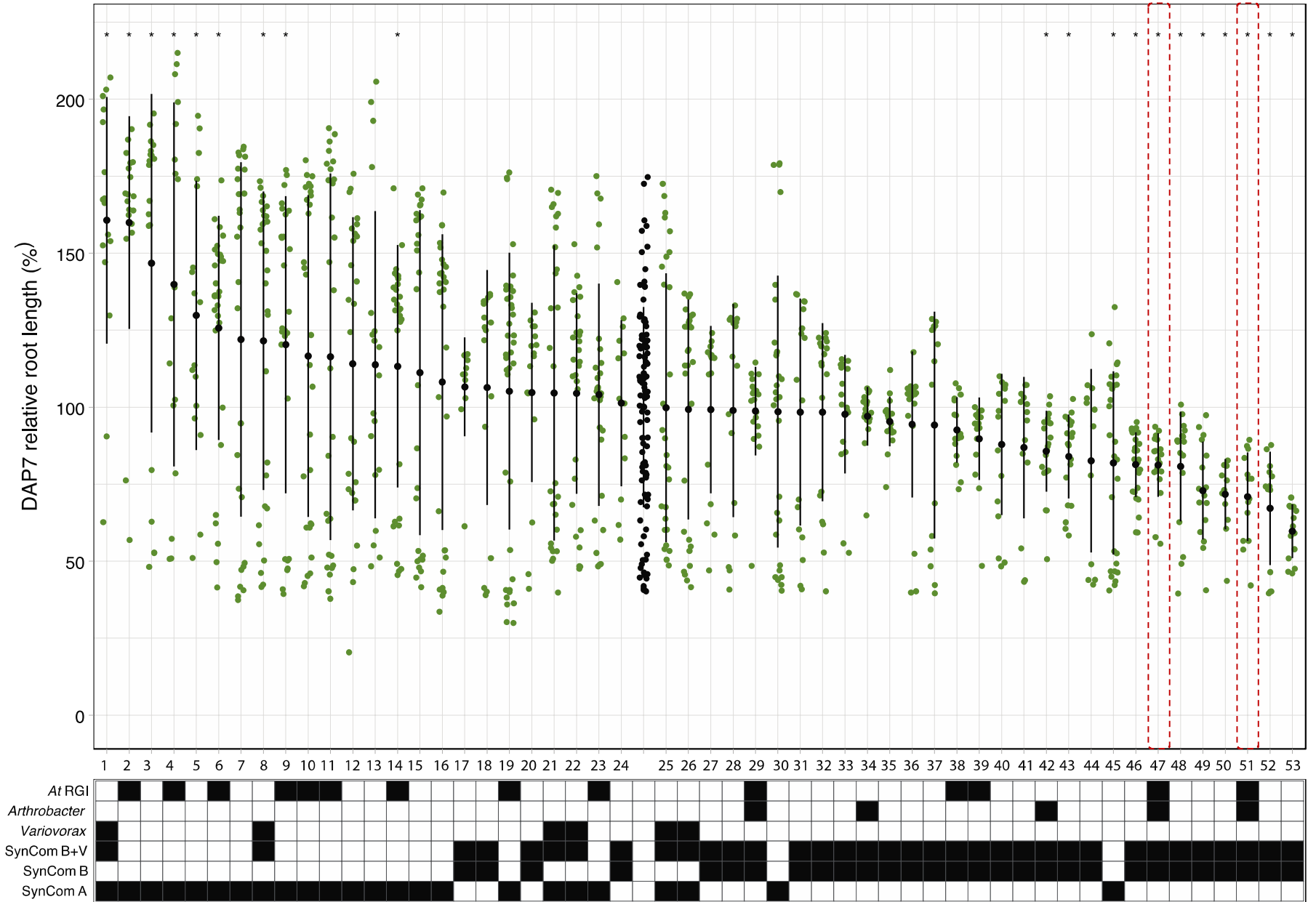
[Omri M. Finkel](#), [Isai Salas-González](#), [Gabriel Castrillo](#), [Jonathan M. Conway](#), [Theresa F. Law](#), [Paulo José Pereira Lima Teixeira](#), [Ellie D. Wilson](#), [Connor R. Fitzpatrick](#), [Corbin D. Jones](#) & [Jeffery L. Dangl](#) 

- Specific strains of bacteria, eg. *Arthrobacter*, induce a short root phenotype in Arabidopsis.
- *Variovorax* strains can block the short root phenotype through the degradation of auxin.

Sorghum seedling assay shows that strains of *Arthrobacter* induce a short root phenotype and that strains of *Variovorax* are protective.



1. Effects between Arabidopsis and Sorghum are similar, but not exactly the same.
2. Even in a super controlled system, so much noise!



WHY DO WE SEE SO MUCH NOISE?

Hypothesis: location of colonization might impact root phenotype.

Observation: Phenotype is dependent on location of colonization. Likely also dependent on the health of the seed.

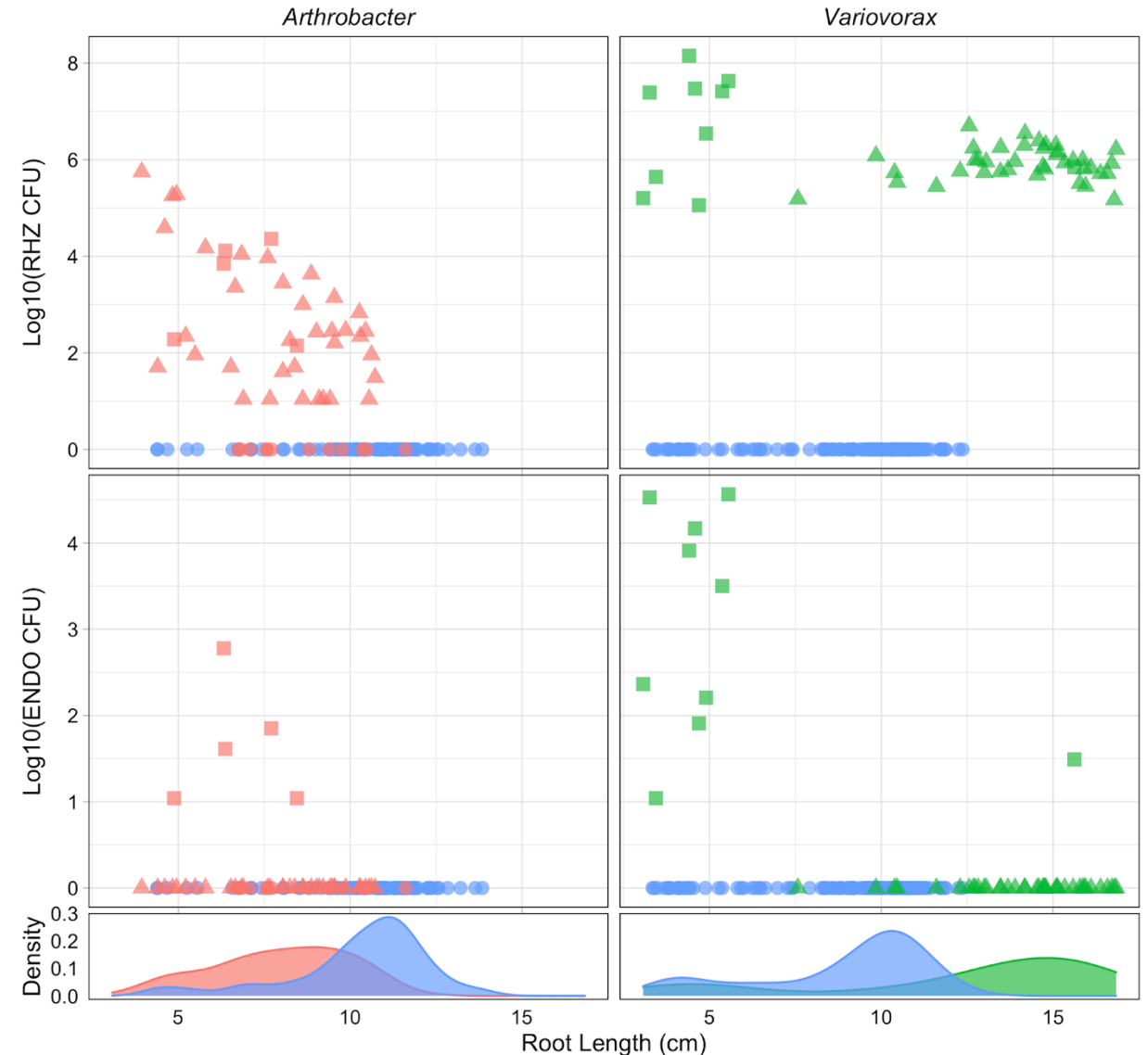


sample

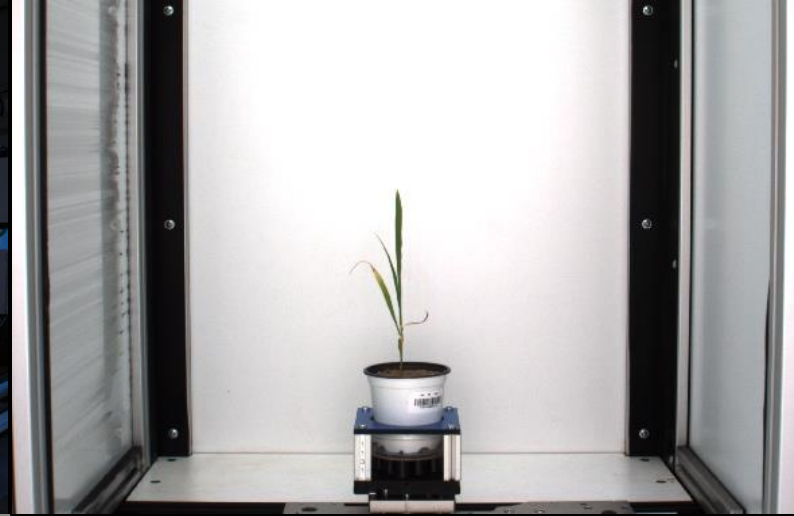
- CL28 *Arthrobacter*
- CL14 *Variovorax*
- Control

CFU

- RHZ_CFU = 0, ENDO_CFU = 0
- ▲ RHZ_CFU > 0, ENDO_CFU = 0
- RHZ_CFU > 0, ENDO_CFU > 0



Replication can help mitigate noise. Lemnatec phenotyper: 1,140 plants, weighed, watered and imaged every day.



ORIGINAL RESEARCH



High-throughput profiling and analysis of plant responses over time to abiotic stress

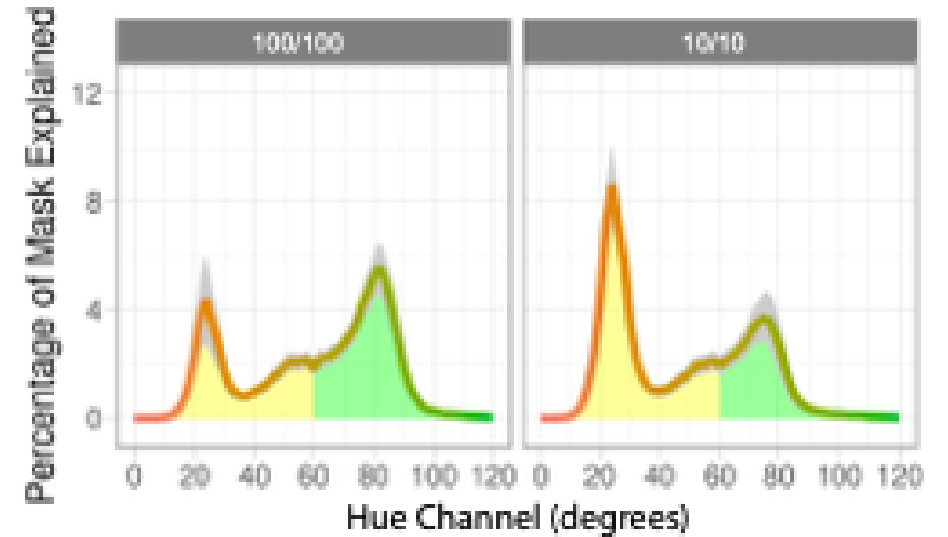
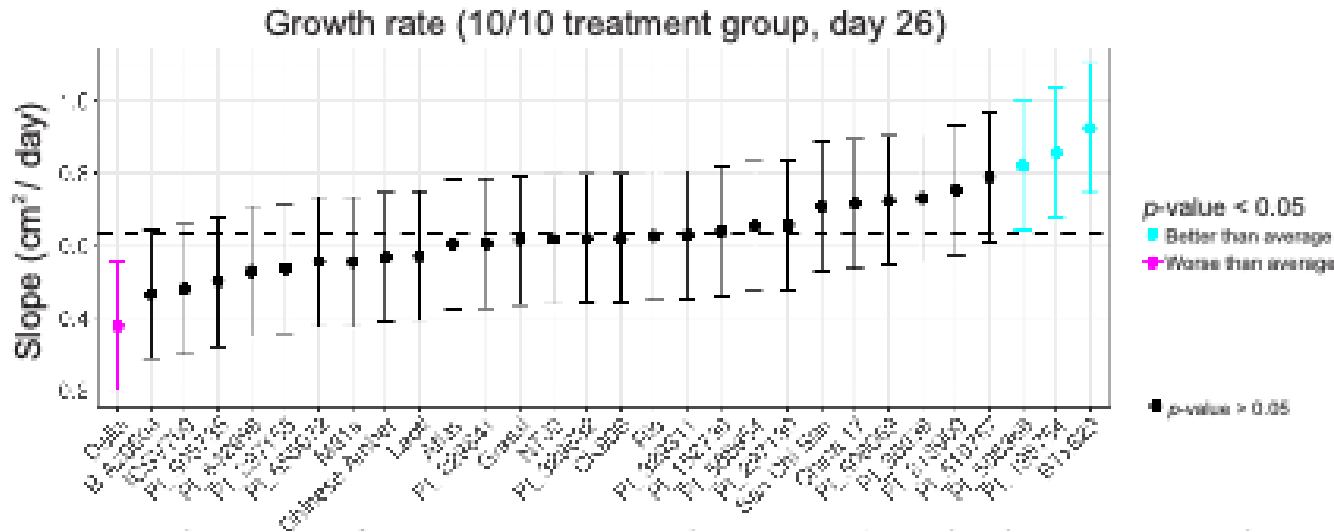
Kira M. Veley¹ | Jeffrey C. Berry¹ | Sarah J. Fentress¹ | Daniel P. Schachtman² | Ivan Baxter^{1,3} | Rebecca Bart¹

< BIOINFORMATICS AND GENOMICS

An automated, high-throughput method for standardizing image color profiles to improve image-based plant phenotyping

Bioinformatics tool | Bioinformatics | Plant Science

Jeffrey C. Berry, Noah Fahlgren, Alexandria A. Pokorny, Rebecca S. Bart, Kira M. Veley



Do we see similar effects of SynComs in a more complicated system?

PHENOTYPIC
METHODOLOGY:

Grow strains and resuspend
in relatively equal parts in
water.



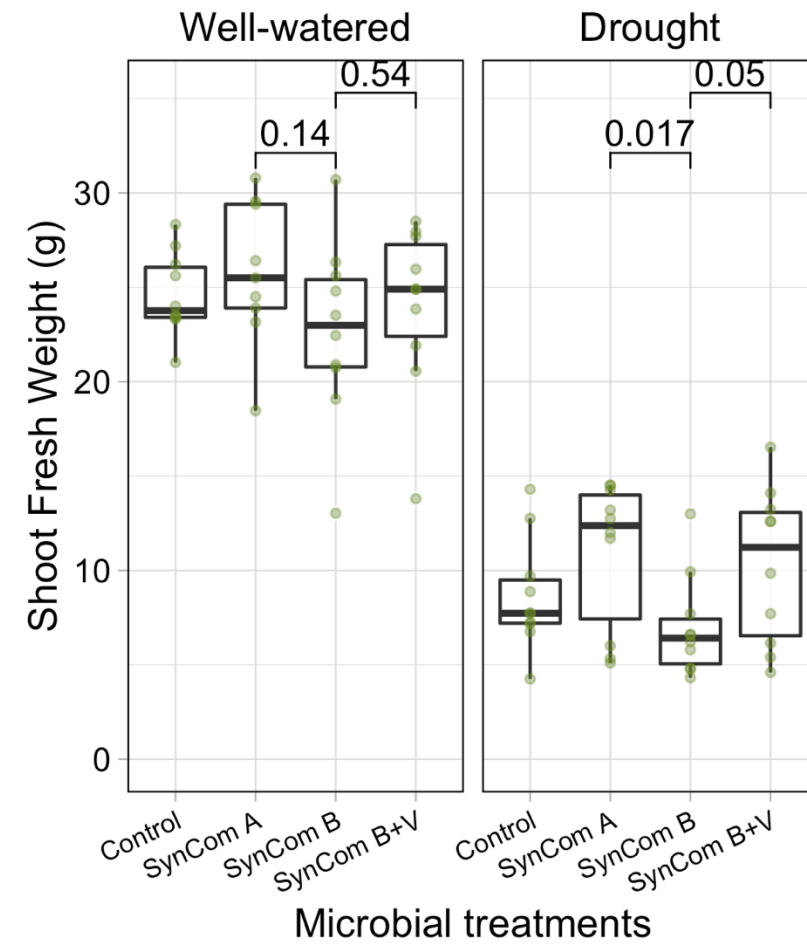
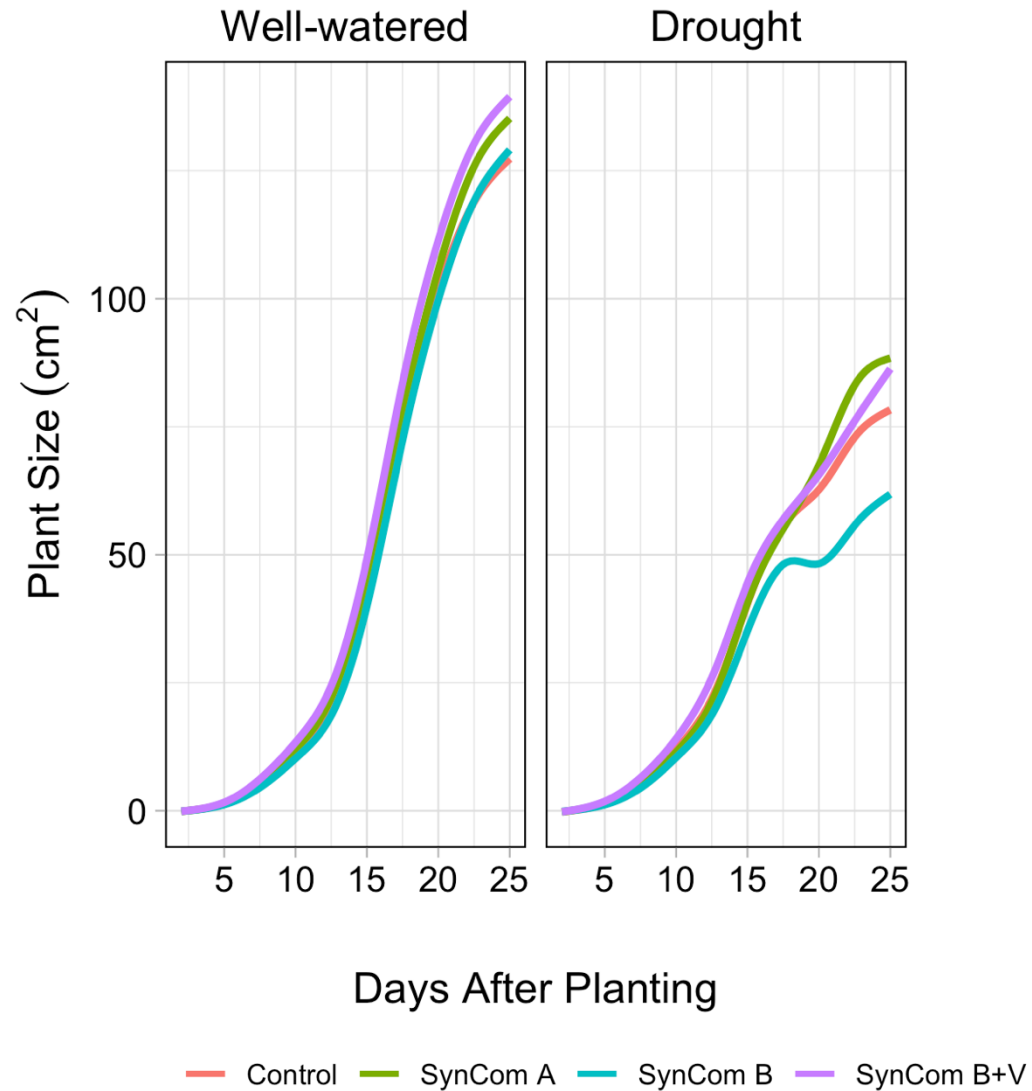
Sterilize seeds and
foam plugs and
allow germination
in presence of
microbes



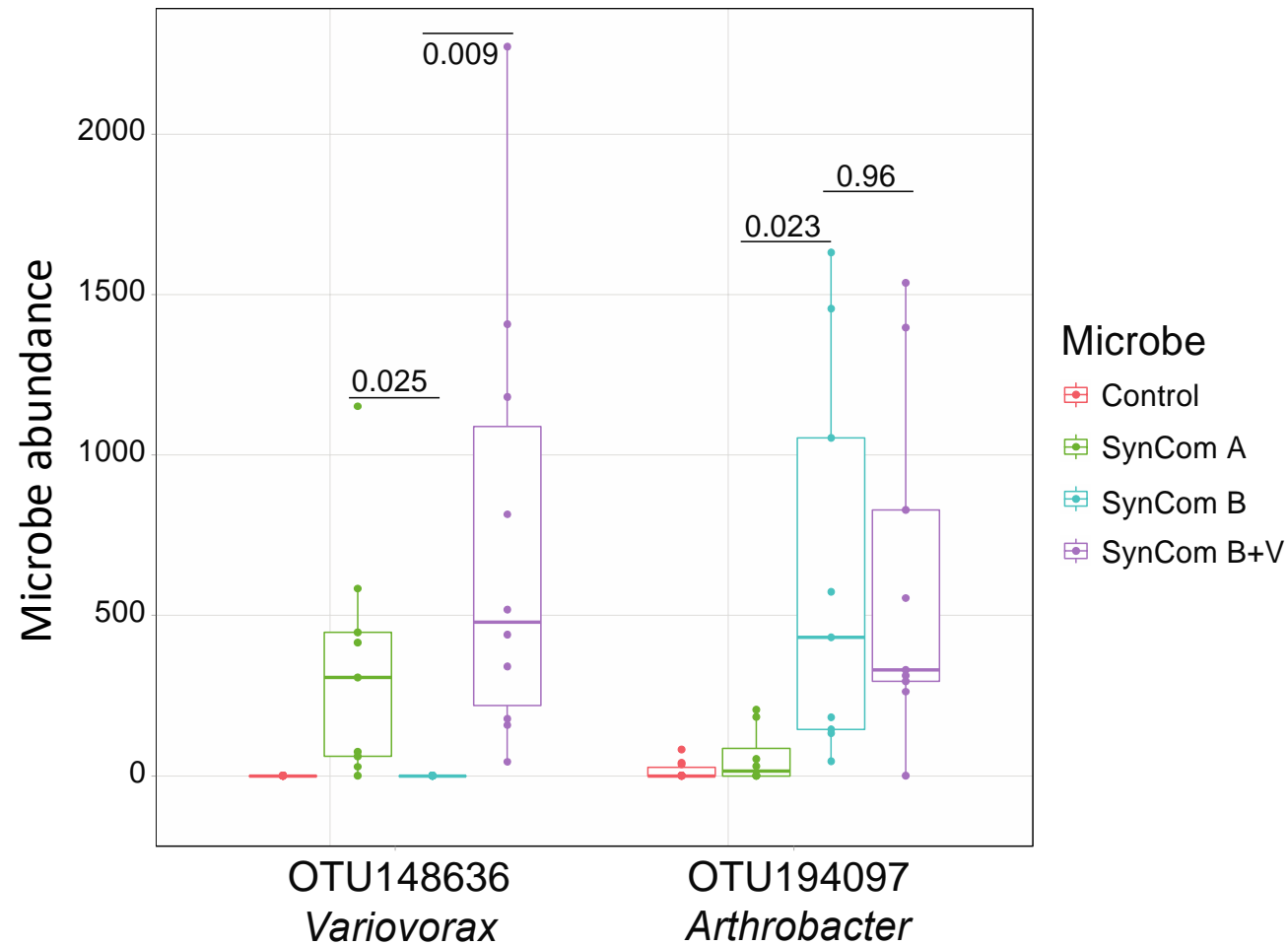
Transplant into tree pots
after germination



Variovorax strains can protect sorghum from drought stress, especially in the presence of *Arthrobacter*



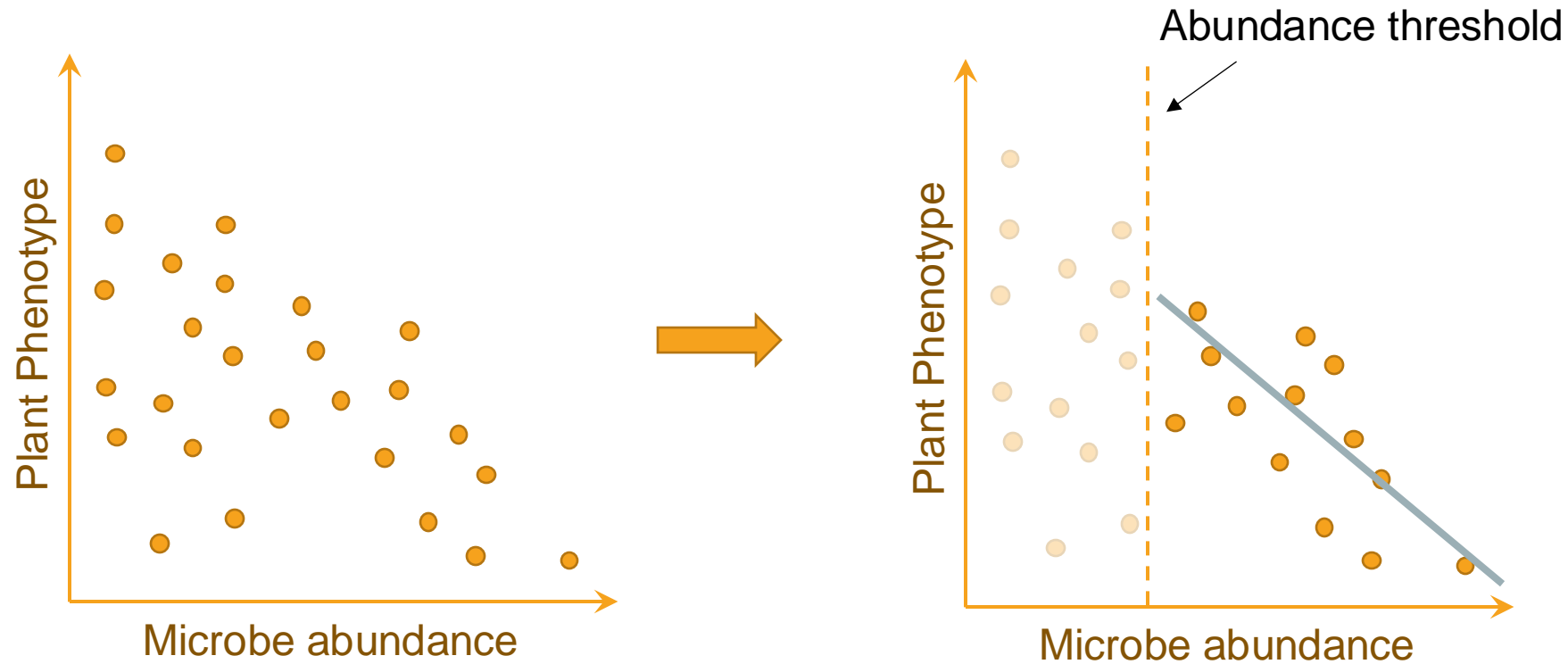
Colonization and persistence of *Variovorax* and *Arthrobacter* are inconsistent.



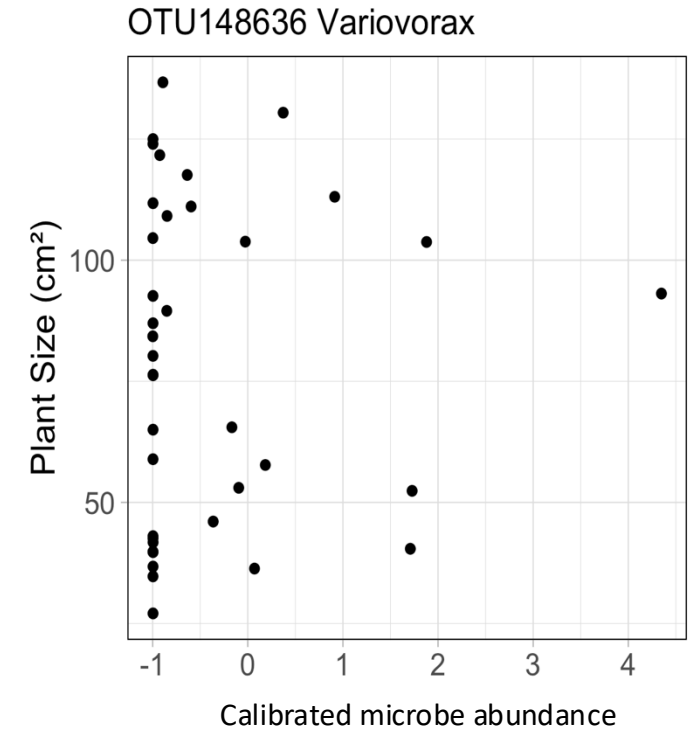
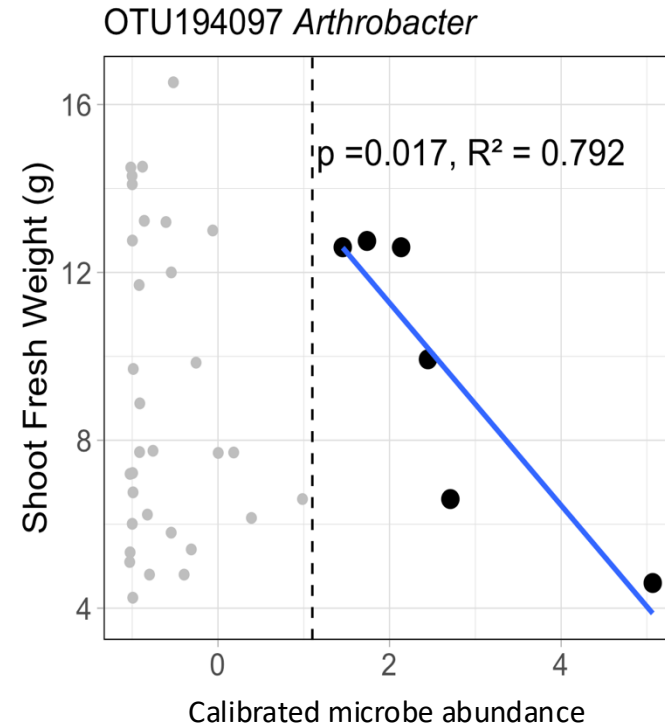
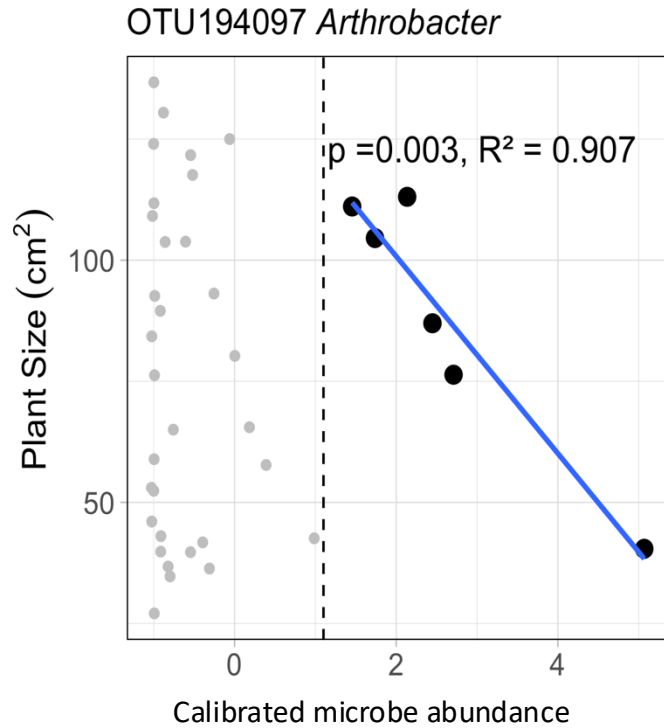
Colonization and persistence

Some microbes may only confer phenotype above a specific threshold abundance.

- Change-point models



For *Arthrobacter*, but not *Variovorax*, abundance correlates with plant phenotype.



This was the beginning of the 'hinge model' analysis and 'biology informed logic models'



Jeff Dangl (U. of North Carolina, Chapel Hill)

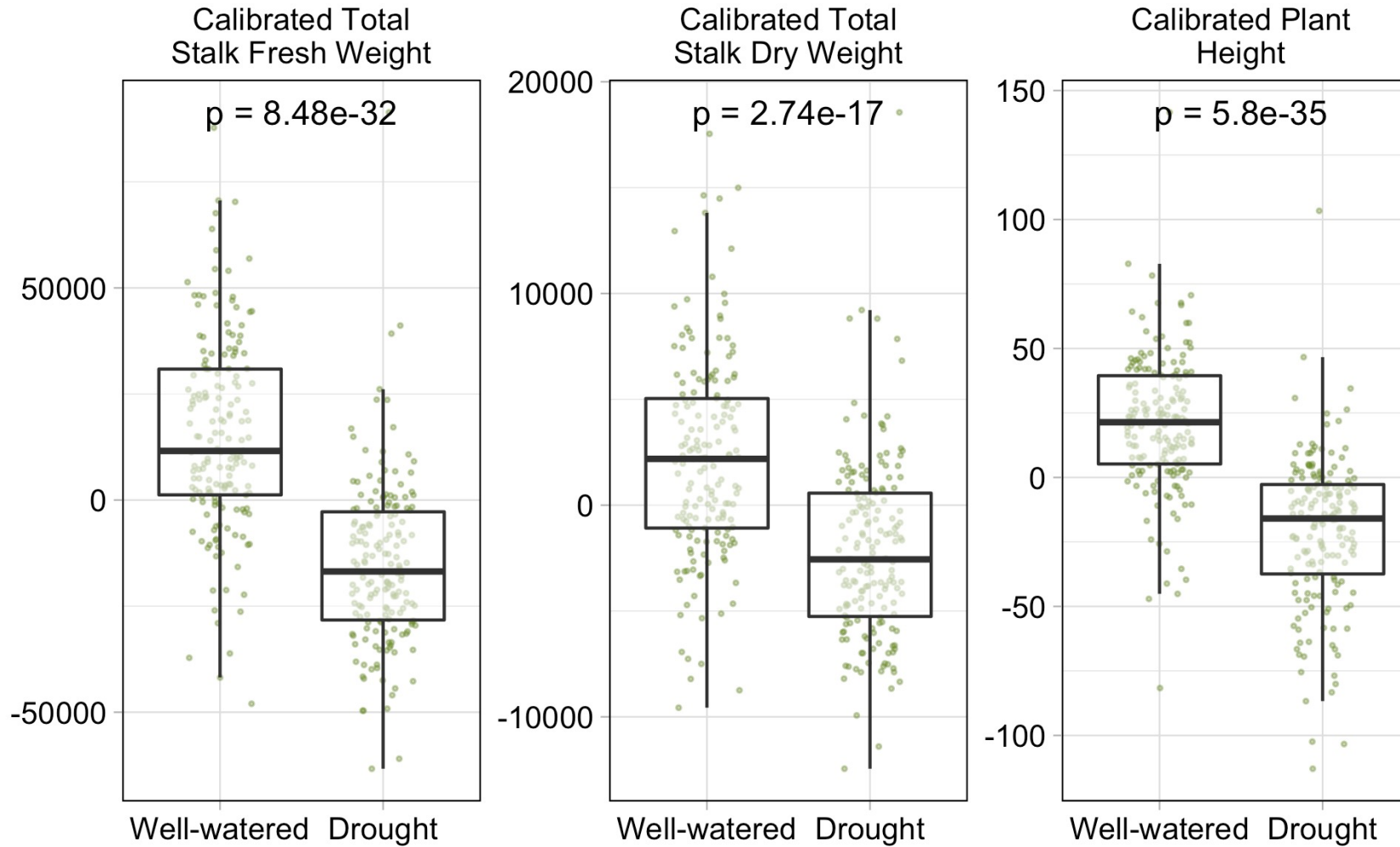
- SynComs developed based on associations with Arabidopsis



Daniel Schachtman (U. of Nebraska, Lincoln)

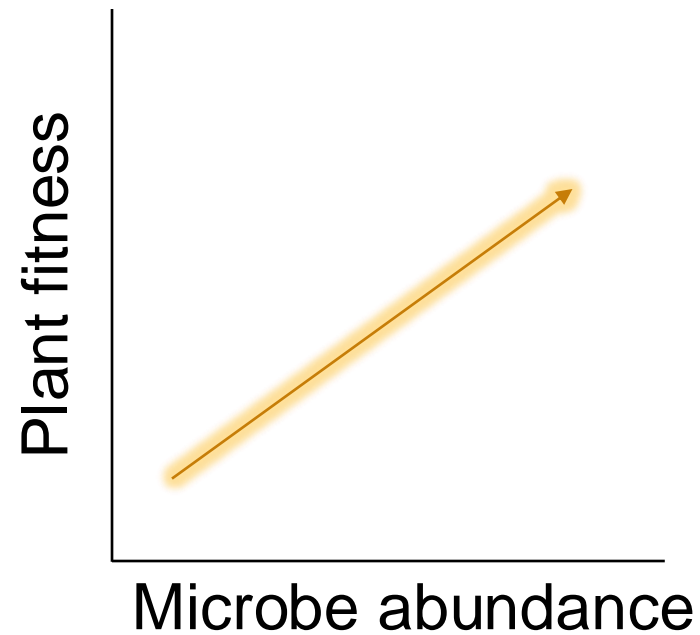
- Sorghum grown in Nebraska under nitrogen or water limited conditions

Field data is very noisy!



Can we use the hinge model method to identify new symbiotic associations and the causal organisms from field experiments?

Foundational hypothesis: symbiosis between plant and microbe can be observed as a positive correlation between plant fitness and microbe abundance.

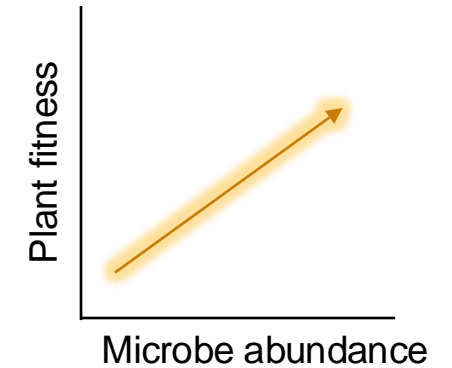
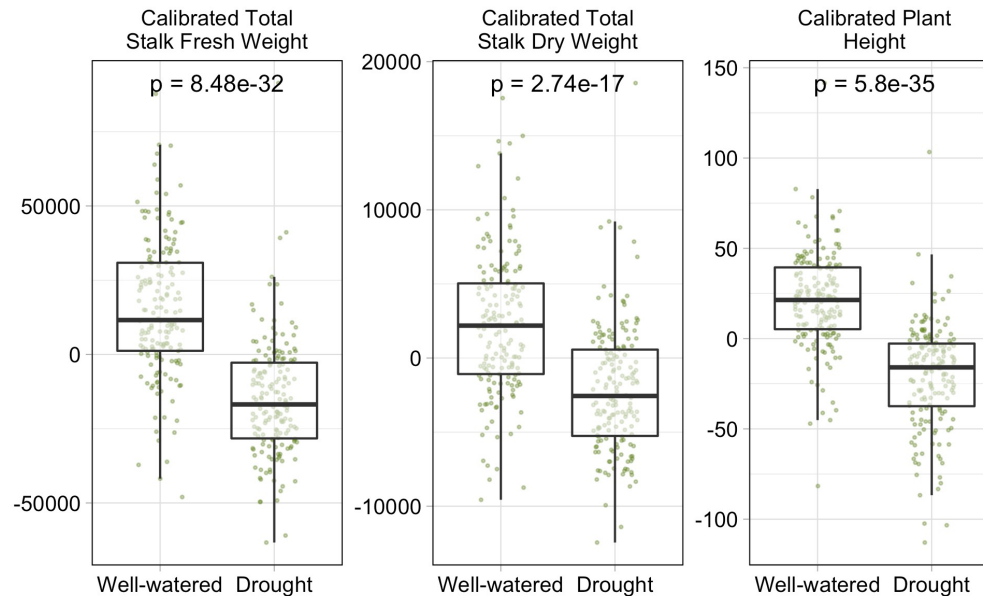
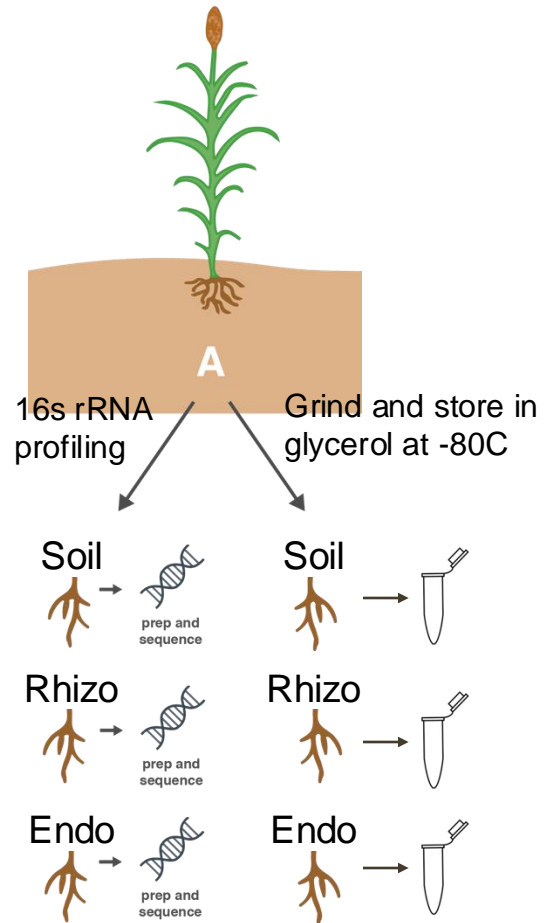


Can we discover new symbioses between plants and bacteria?

1. Sorghum plants were grown in the field under well-watered or drought conditions.

2. Diverse plant phenotypes quantified

3. Identify microbes whose abundance correlates with plant fitness.



*The first time we attempted this, we got no 'hits'

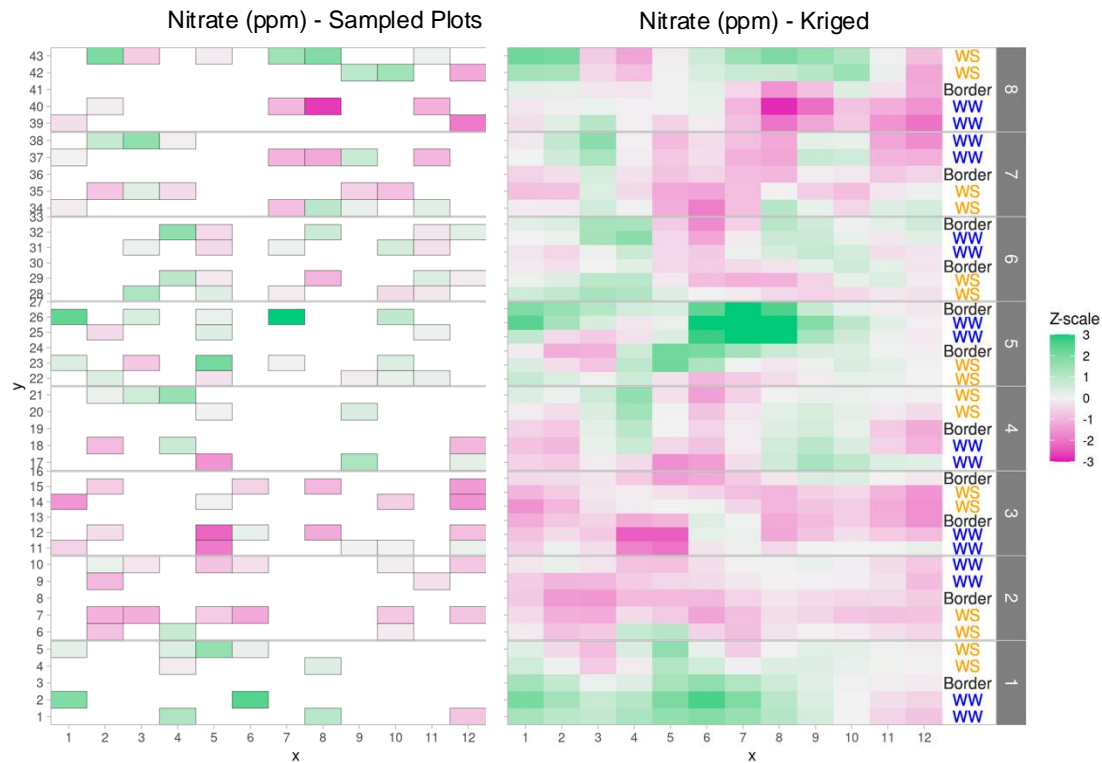
Daniel Schachtman, UNL
Susannah Tringe, JGI

Method to account for (some) unintended experimental variation from field studies

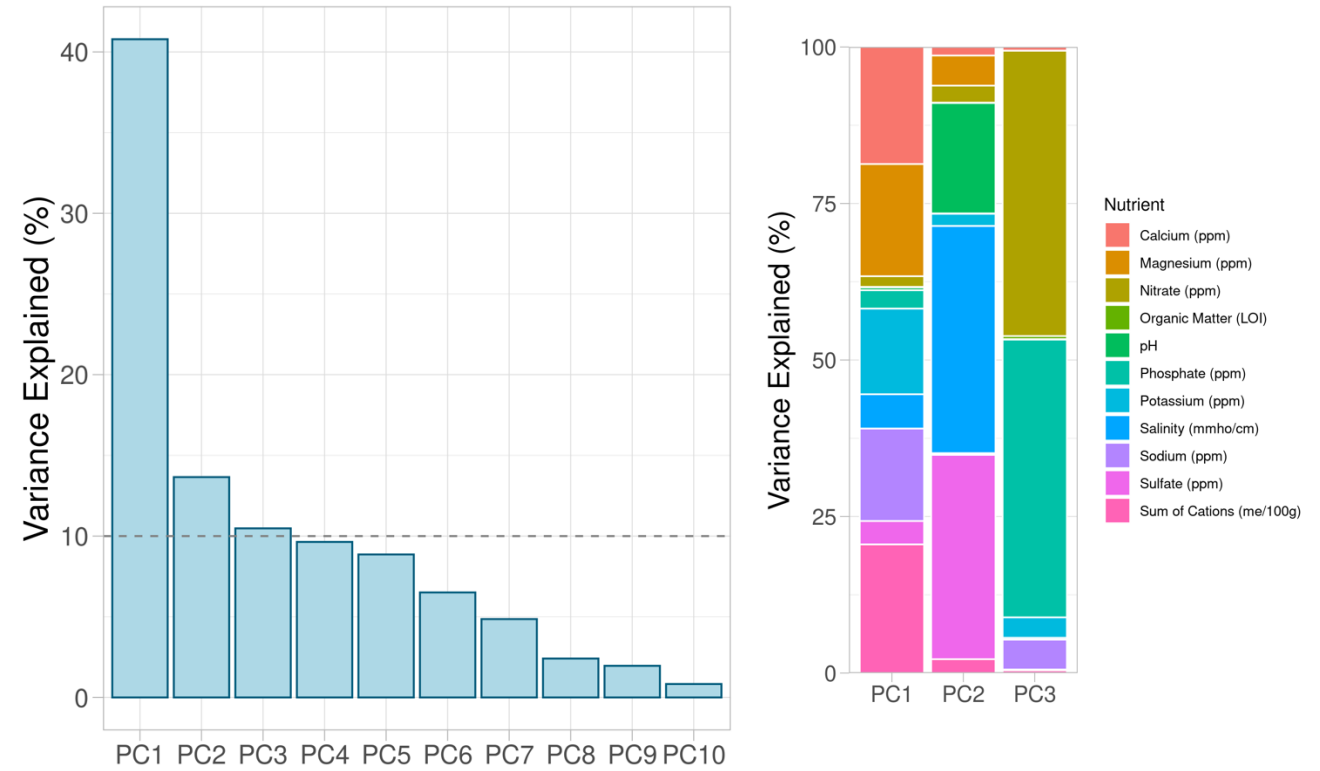


Jeff Berry
Peng Liu (Iowa)

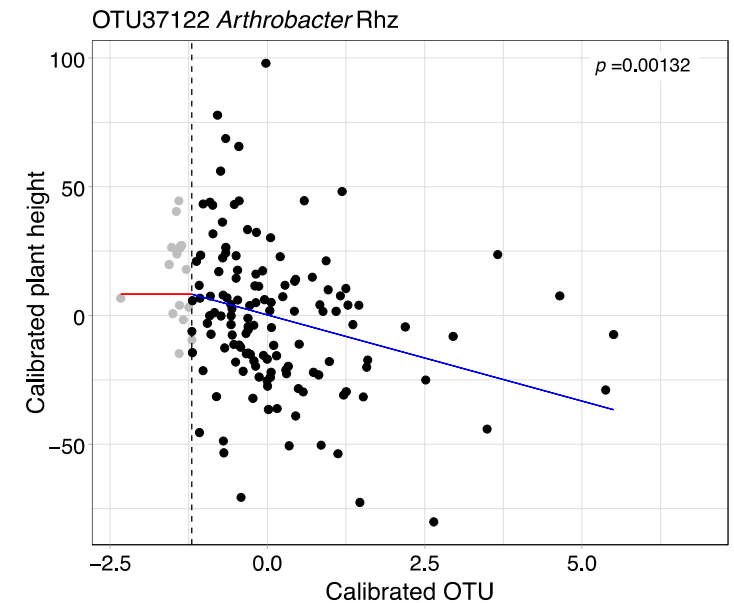
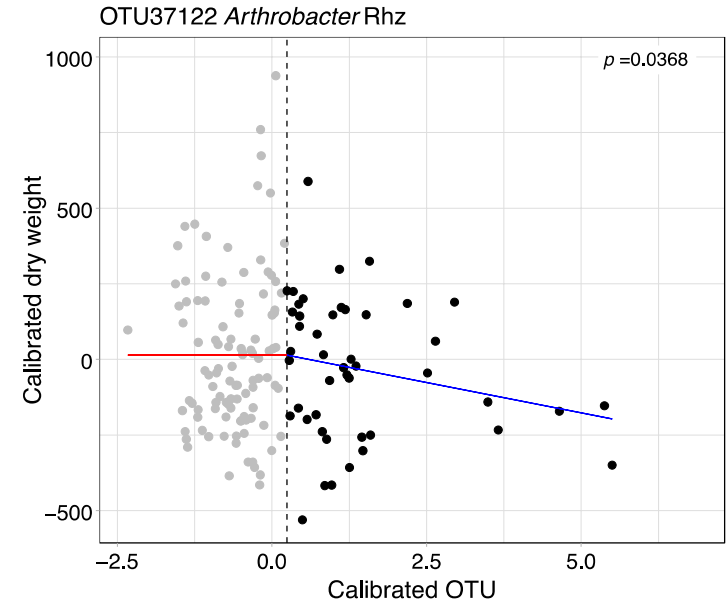
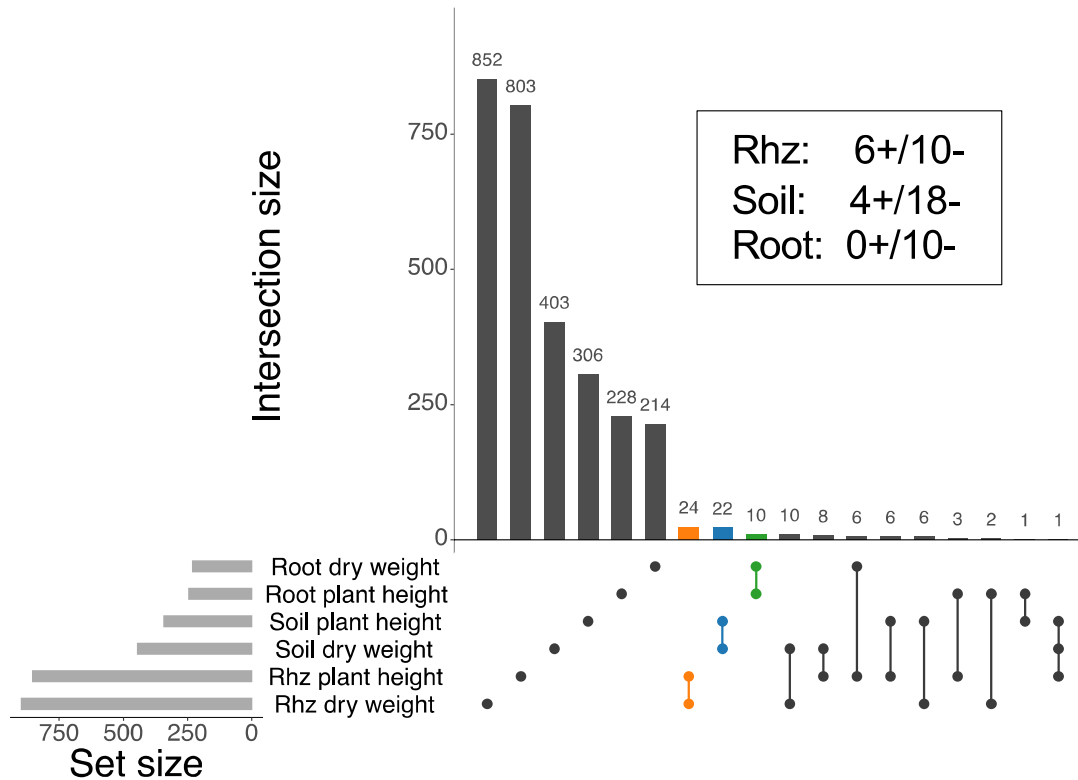
1) Measure soil properties & estimate missing values

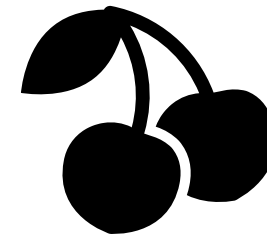


2) Dimension reduction through principal components



Accounting for variation in soil properties revealed new candidates for microbes that affect plant phenotypes.





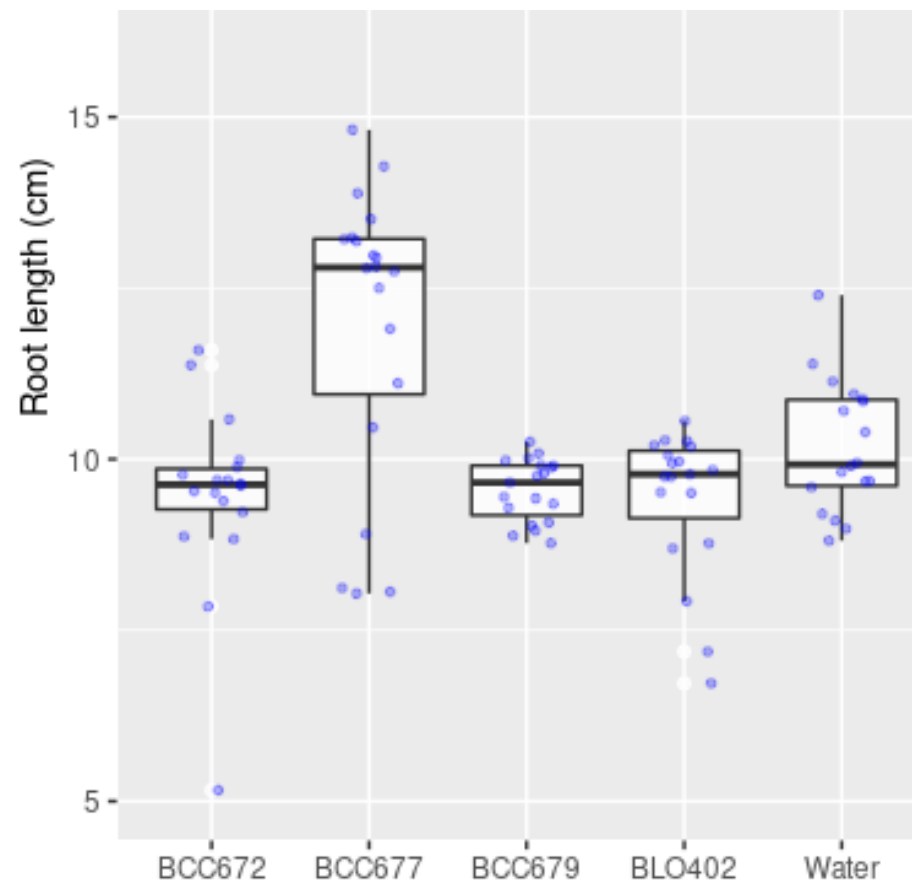
Newly isolated strain results in increased root growth.



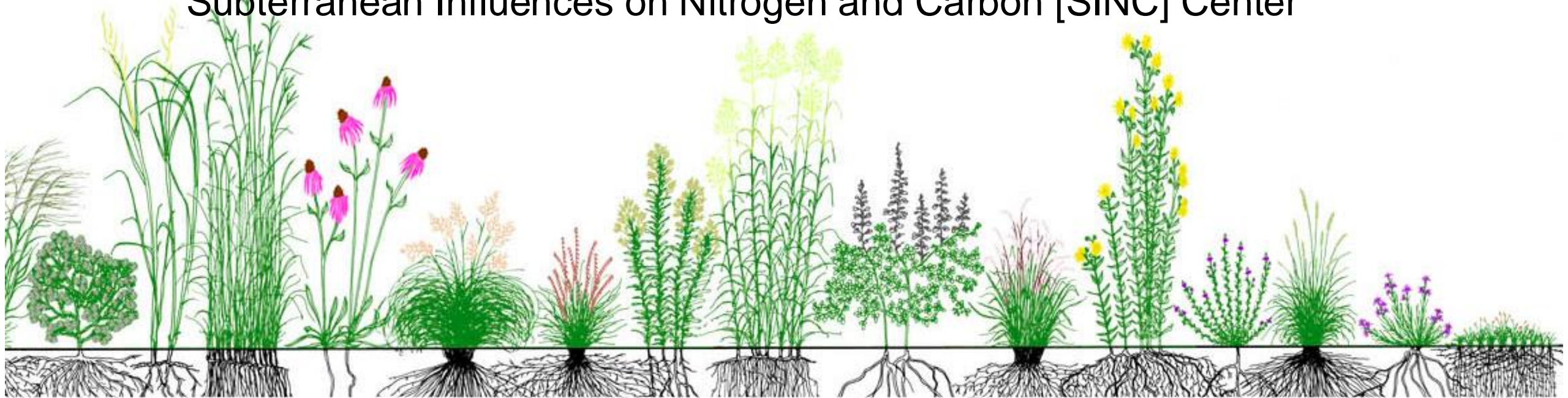
Control



BCC677



Subterranean Influences on Nitrogen and Carbon [SINC] Center



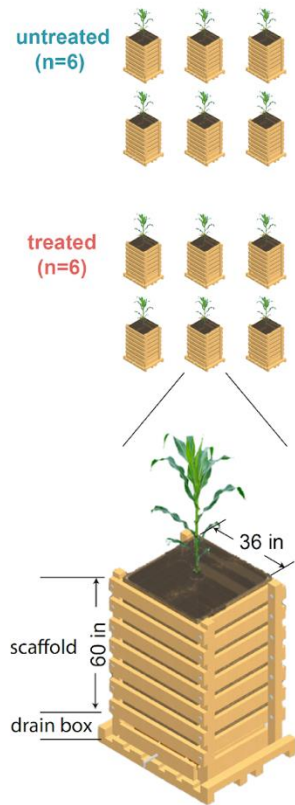
Overarching Center of Excellence concept:

The stated goal of the SINC center is to decrease or eliminate the need for chemical fertilizer while maintaining high plant yields. This will be accomplished by promoting beneficial interaction with microbes, optimized plant genetics and sustainable cropping systems.

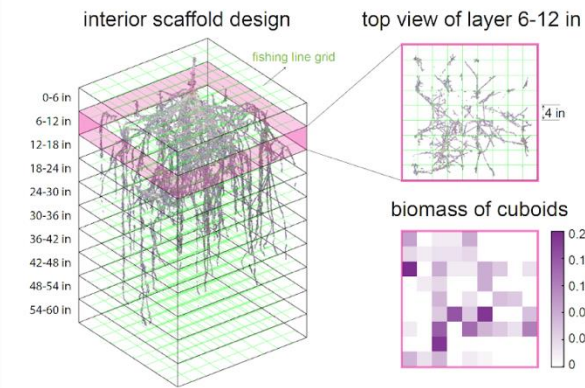
...with Doug Allen, Ivan Baxter, Armando Bravo and Chris Topp

Larger controlled environment systems may reveal additional sources of noise in microbiome data.

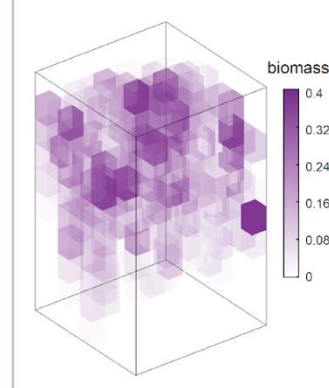
A Experiment design



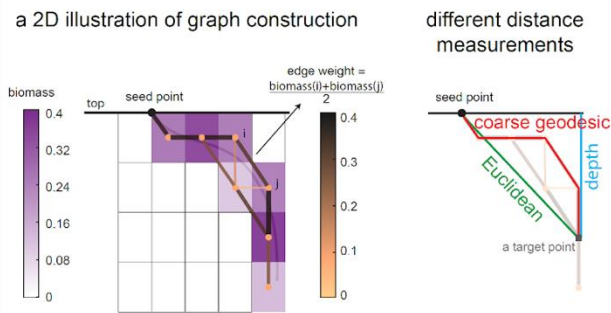
B Mesocosm scaffold system and manual biomass



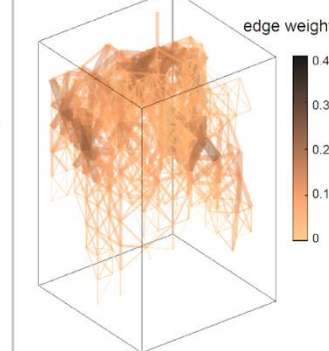
C 3D biomass visualization



D Graph construction and distance measurements

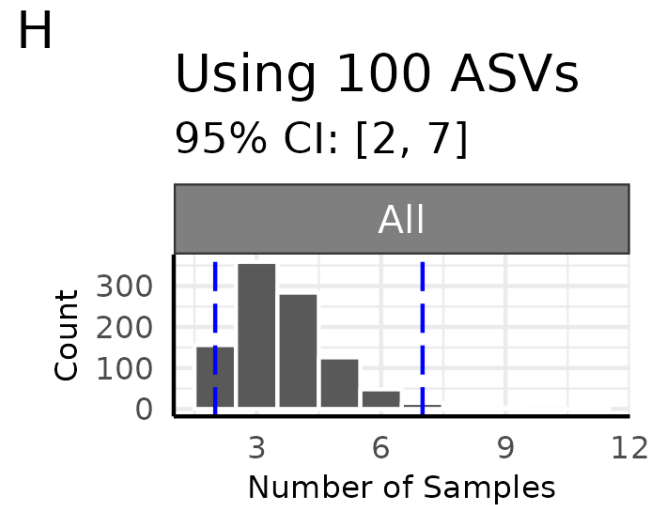
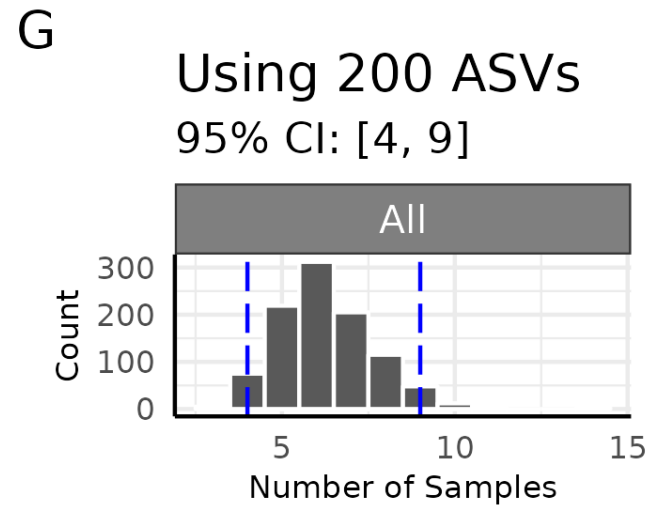
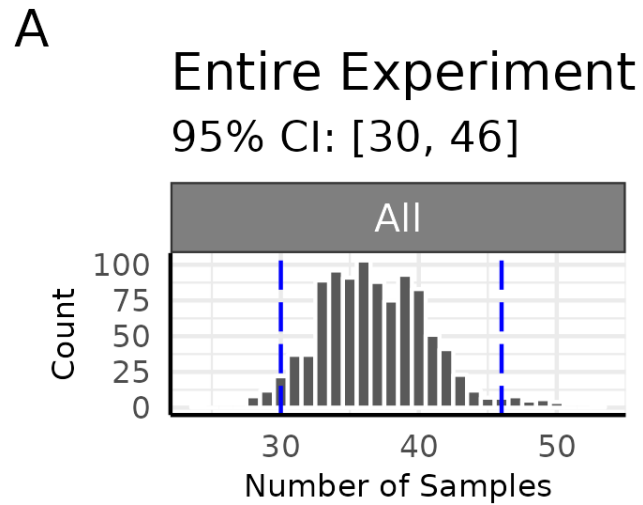


E 3D graph visualization



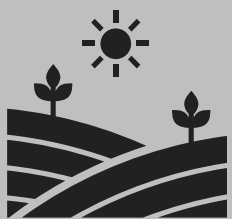
Is the root microbiome consistent across the root architectural system?

If not, how many root samples do you need to sample, to capture the microbial diversity across the root architectural system?

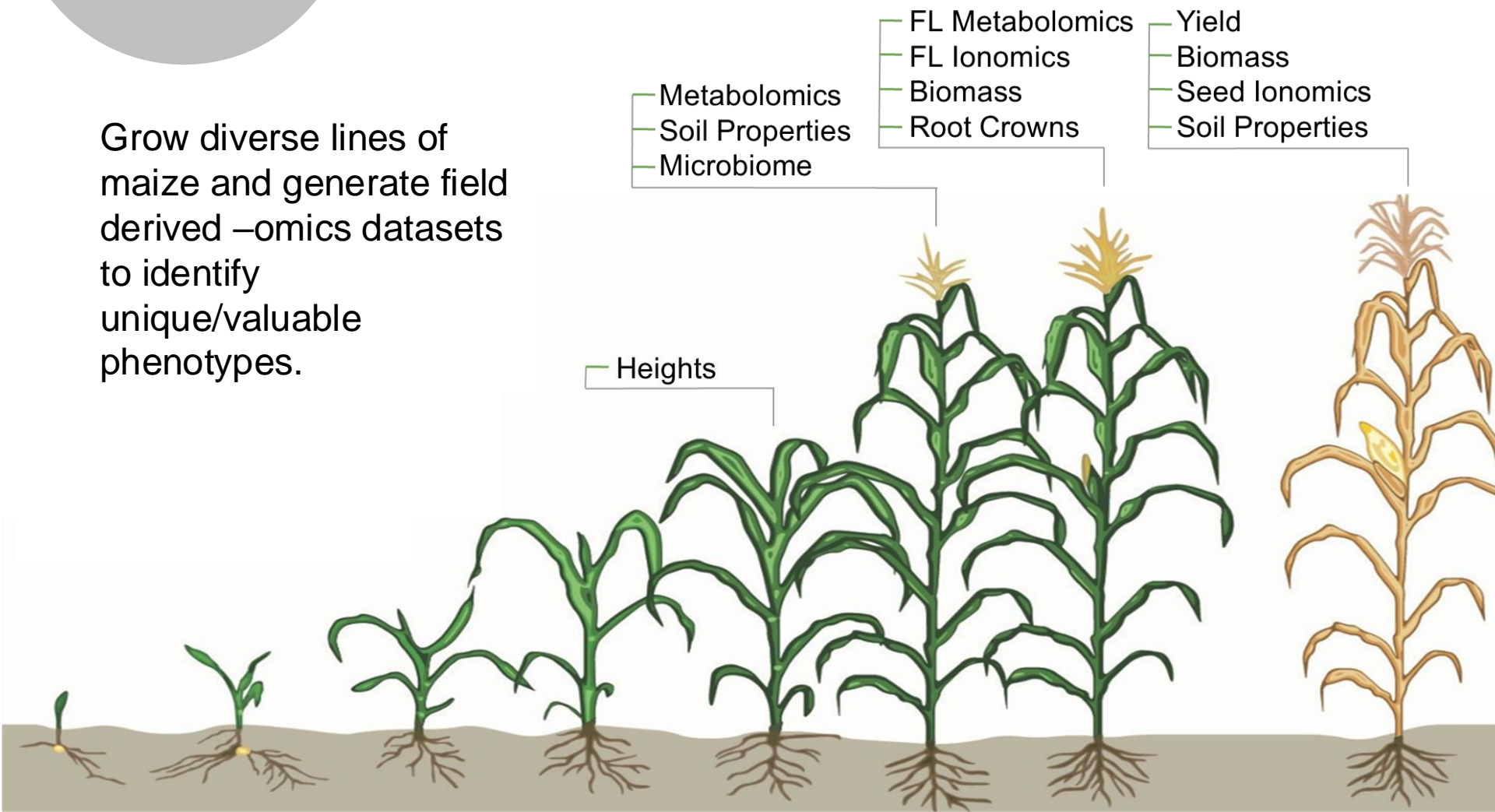


Diverse microbiomes exist across a mature root architecture and this likely contributes to additional noise.

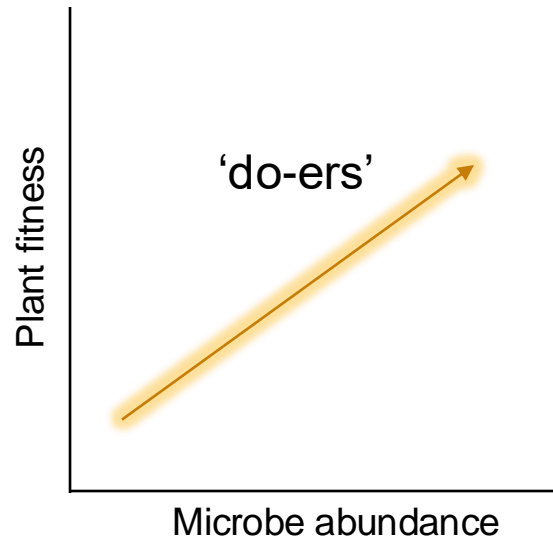
NOVEL PLANT TRAITS THAT GOVERN NITROGEN USE EFFICIENCY AND/OR CULTIVATING A HEALTHY MICROBIOME.



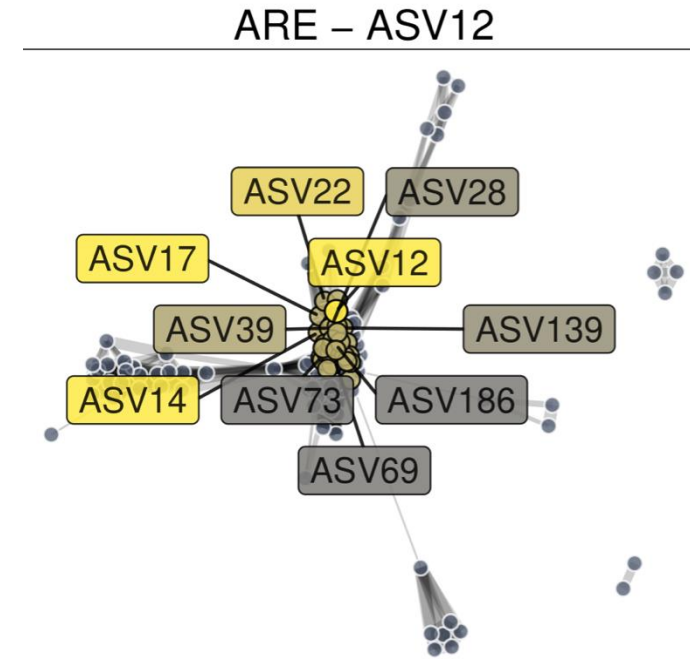
Grow diverse lines of maize and generate field derived –omics datasets to identify unique/valuable phenotypes.



Biology Informed Logic Models

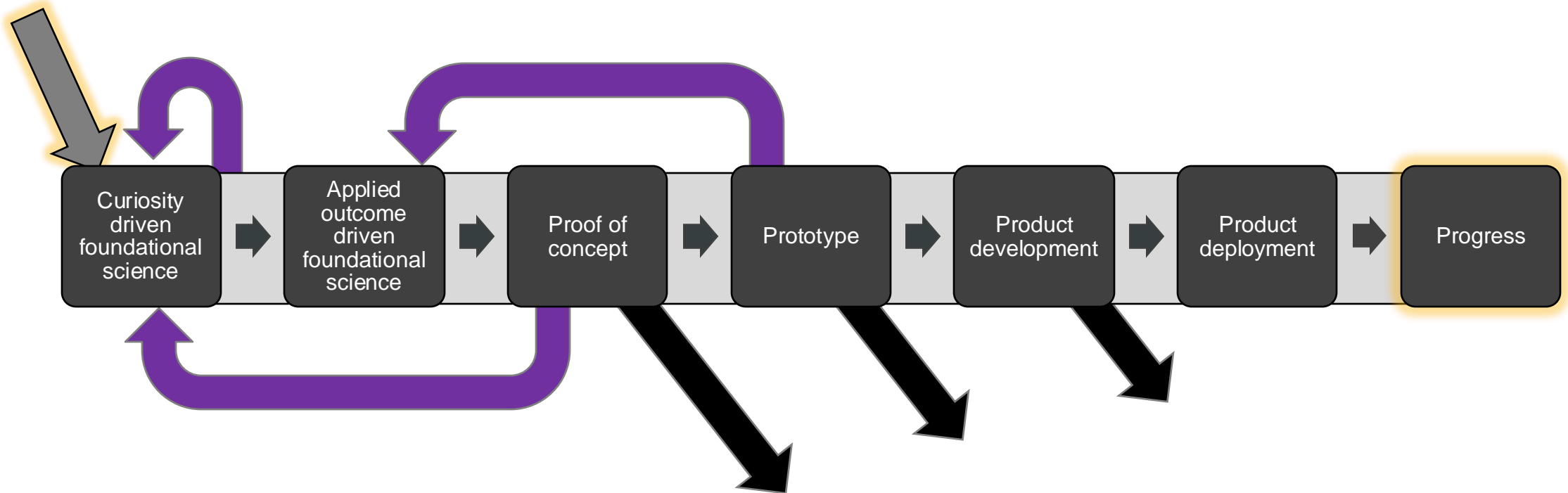


Symbiosis between plant and microbe can be observed as a positive correlation between plant fitness and microbe abundance.



Co-occurrence can be used as an indicator of candidate 'helpers'. These patterns may help in assembly of SynComs.

PIPELINE TO PROGRESS



Foundational work fuels the pipeline.
Projects sometimes exit the pipeline for good reasons.

“Novel microbes and newly assembled syncoms to promote sustainable agriculture.”



Discovery



Colonization and persistence

Major take homes:

1. Noise in data can be frustrating but can also help us learn about microbial systems.
2. We can't just skip to the end. Investment in foundational science is required to realize the potential benefit from microbial solutions in agriculture.

Questions?

