bpia 2025 Annual Meeting

Big Data and Policy in Biologicals Discovery

Colin Todd PhD

APS Early Career Policy Intern

Presentation Overview

- Who is APS and what is the PPB?
- How I used microbiome data to identify novel yield-enhancing biologicals in grapevine
- Highlighting the value of national agricultural programs

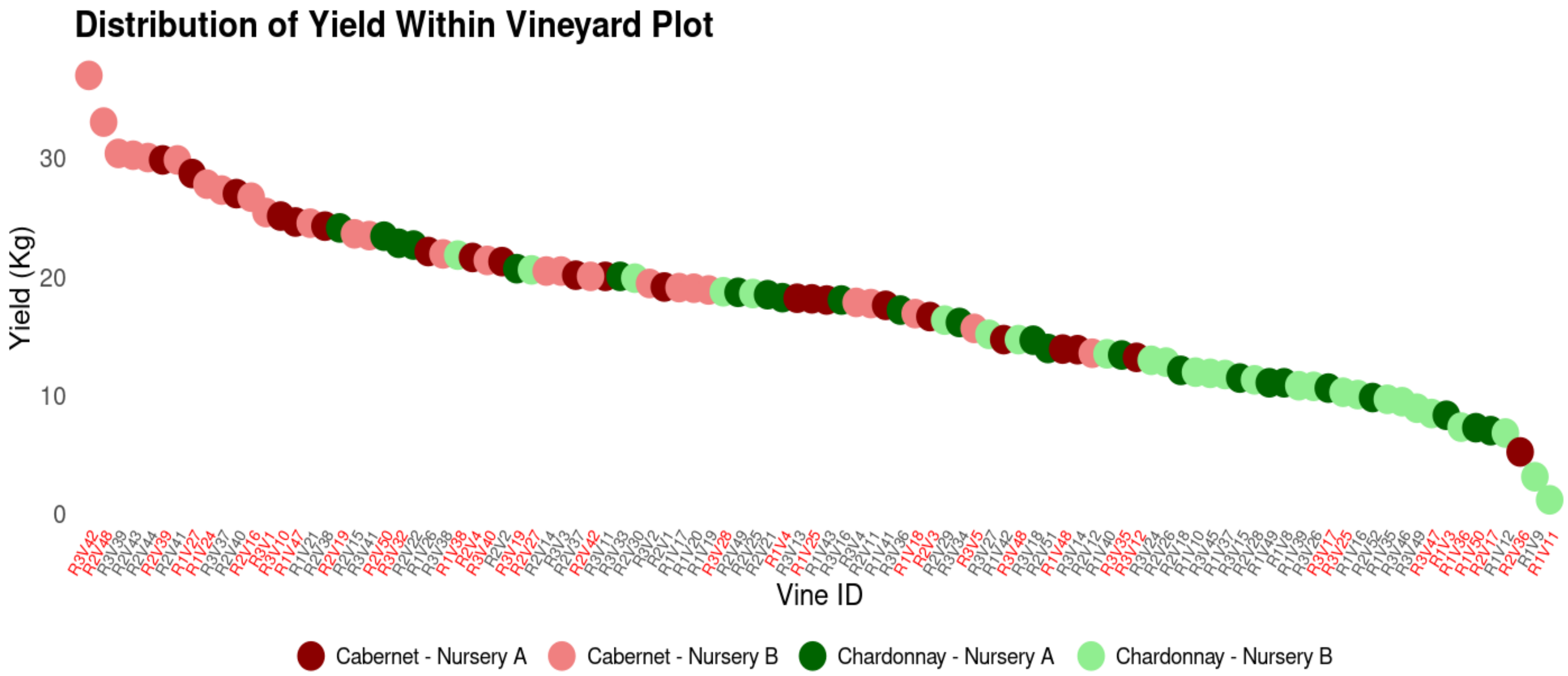
American Phytopathological Society and the Public Policy Board

- APS is a professional scientific organization representing over 4,500 scientists from academia, industry, and government
- The APS PPB provides scientific input directly to government agencies and legislative staff to advance the policy priorities of our society's members
- The National Plant Diagnostic Network (NPDN) is a congressionally funded program to support plant health and biosecurity
- How can NPDN be expanded to improve US agriculture productivity and strengthen US AgTech?

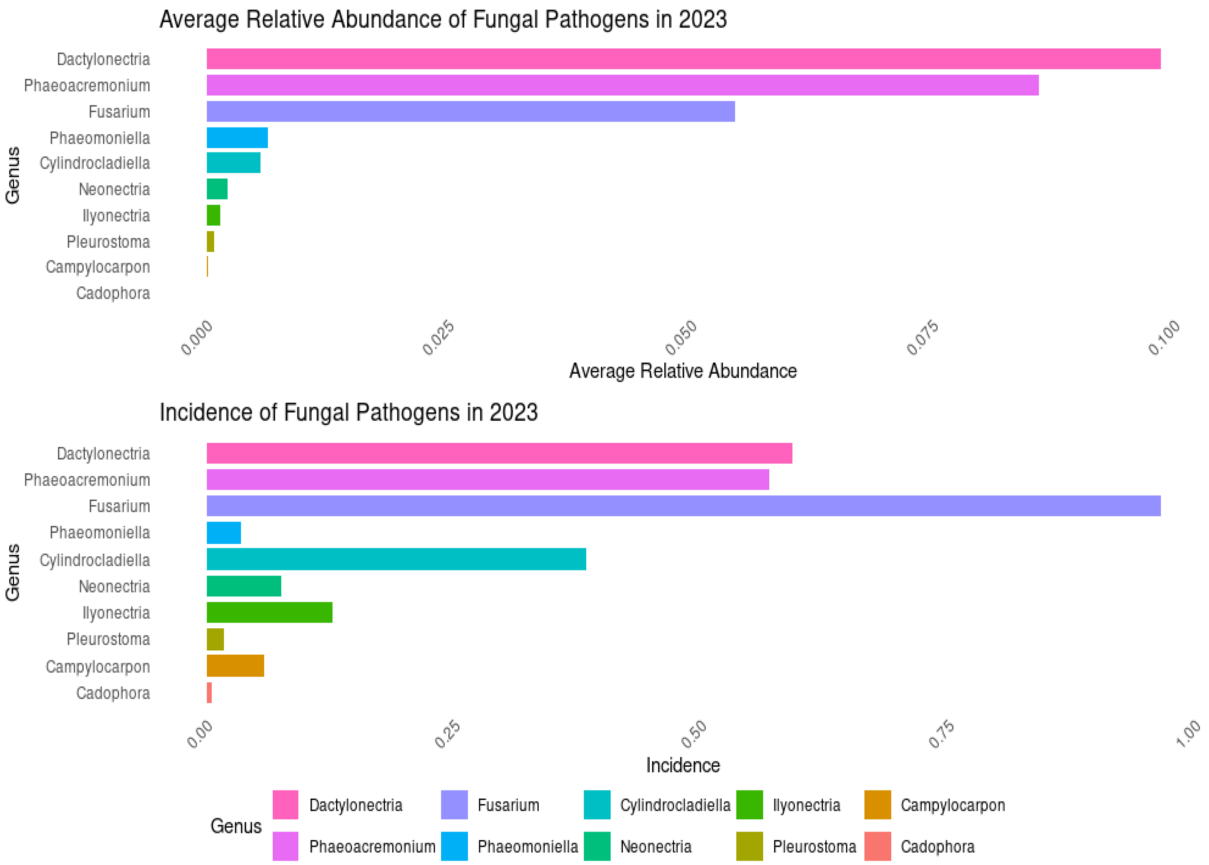
Using Microbiome Sequence Data to Identify High Impact Microbes

- Tracked grapevine performance and microbiome for three years in commercial vineyard
- Utilized statistical modelling to determine the microbes with the highest impact on yield
- Quantified the impact of these microbes on grapevine productivity and found 10 microbes contribute ~50% of yield variance
- Identified many microbes that were not yet associated with increased yield in grapevine that can be developed as biological products

Vine Genetics Explain Some, But Not All Yield Variance

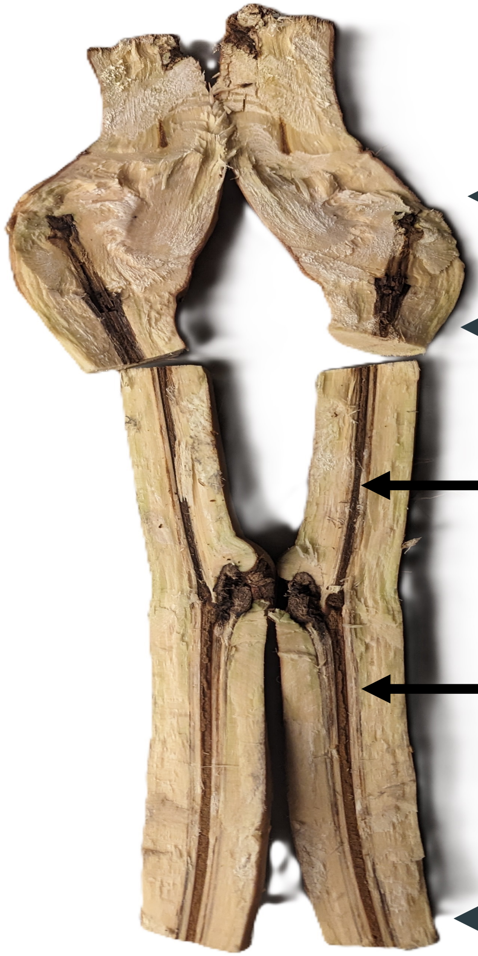


High Abundance of Pathogens but No Symptoms



Average Relative Abundance of Fungal Pathogens in 2023

Incidence of Fungal Pathogens in 2023



Above Graft Union

Below Graft Union

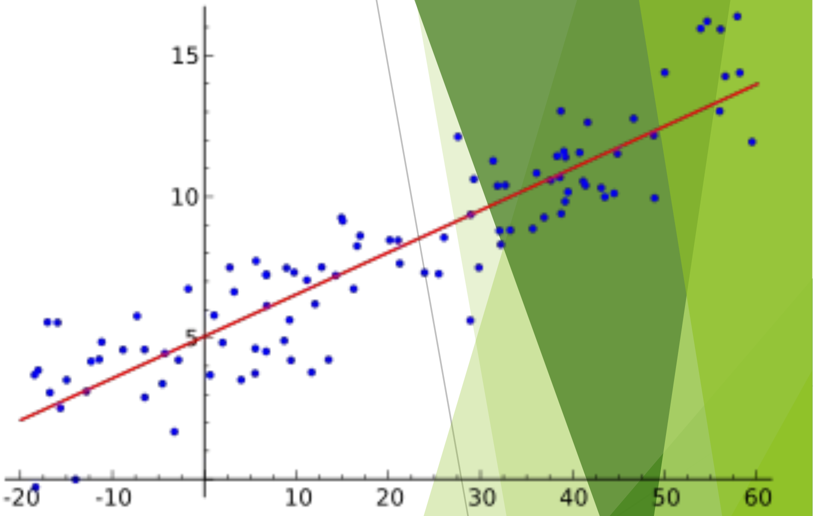
Discolored Pith (Normal)

Healthy Vascular Tissue

Crown

Statistical Modelling of Crop Traits Using Microbiome Data

- Microbial relative abundance is predictive of important crop traits[1,2,3]
- Studies have utilized various methods to identify predictive microbes
  - Differential Abundance, Indicator Species, Spearman Correlation, Random Forest, etc.
- Ultimately, microbial abundance is used in a regression model to predict traits of interest (yield, vigor, nutrient content)



Trait = (X * microbe A) + (Y * microbe B) + (Z * microbe C) + …

1. Yergeau et al. *FEMS Microbiol. Ecol.* 2019
2. Lutz et al. *Nat. Microbiol.* 2023
3. Song et al. *Nat. Microbiol.* 2025

Different Methods Identified Mostly Distinct Microbes

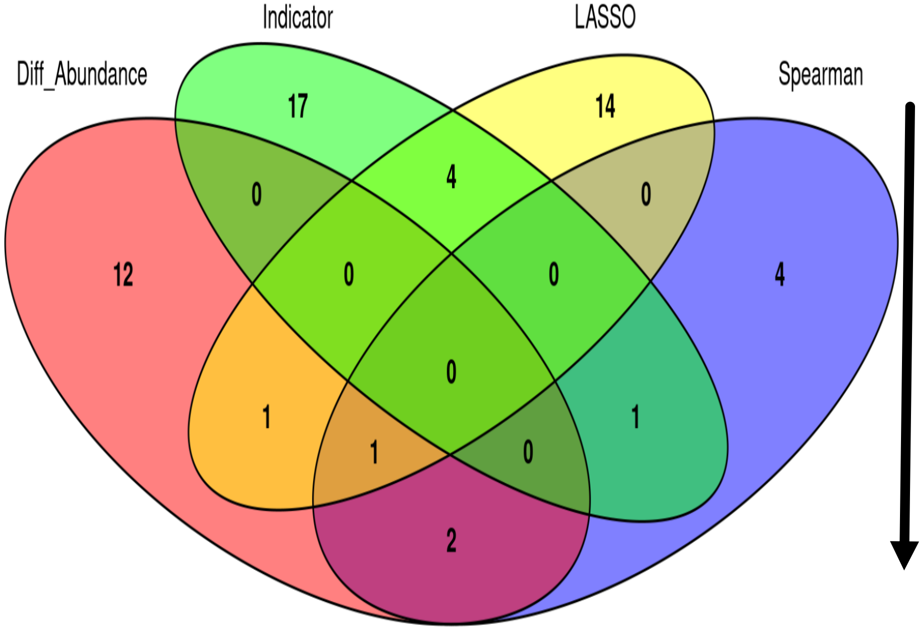
Differential Abundance – Statistically significant difference in abundance between groups.

Indicator Species – Analyzes both abundance and incidence between groups

LASSO – Regression method that identifies only high impact predictors of a variable

Spearman Correlation – Non-linear correlation of microbe abundance and yield

Random Forest Model – Used to rank importance of microbes' ability to predict yield



Random Forest Model

Multiple Linear Regression Model

Top 10 Most Impactful ASVs on Yield in Trunk and Roots

Trunk ASVs $R^2 = 49\%$

Taxa	Average Yield Contribution (Kg)	Ecological Niche
Pantoea	0.57	Biocontrol
Pseudactinotalea	0.38	Soil
Neoleptodontidium	0.29	Saprobe
Erwinia	0.15	Biocontrol
Phaeoacremonium	-0.63	Trunk Pathogen
Brachybacterium	-0.50	Rhizosphere
Nocardioides	-0.48	Biocontrol
Cystobasidium	-0.43	Biocontrol
Clonostachys	-0.40	Biocontrol
Blastococcus	-0.34	Rhizosphere

Root ASVs $R^2 = 58\%$

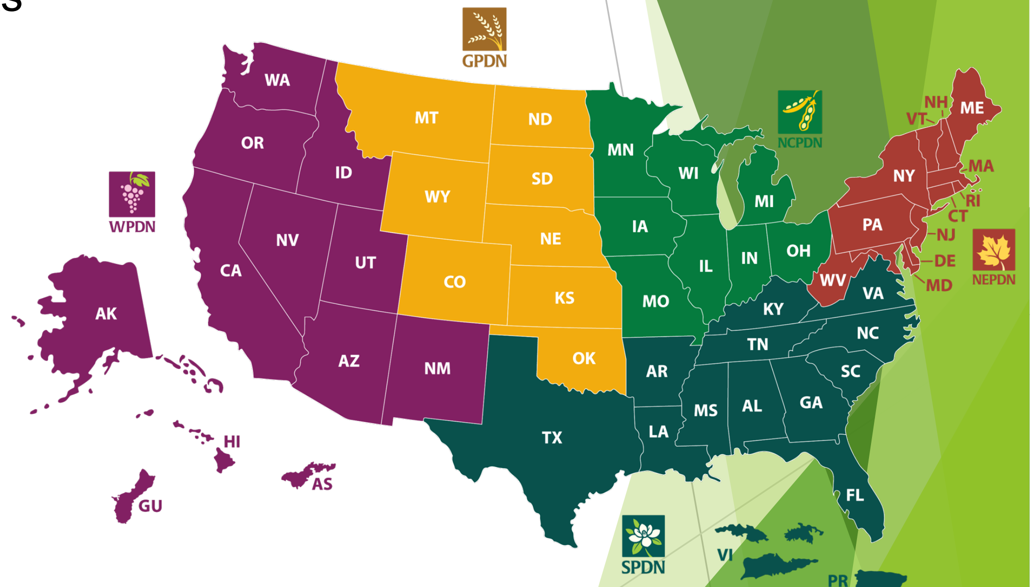
Taxa	Average Yield Contribution (Kg)	Ecological Niche
Devosia	1.38	PGPR
Phytohabitans	0.88	Root
Flavobacterium	0.83	PGPR
Klebsiella	0.58	PGPR
Rhizophagus	0.47	AMF
Rurimicrobium	0.44	Soil
Serratia	0.36	Biocontrol PGPR
Franconibacter	0.31	PGPB
Caulobacteraceae	-0.38	Grapevine Root
Hypocreales	-0.21	Plant Pathogen

How To Leverage This Approach At Larger Scale?

- Identifying beneficial biologicals can often involve screening large microbial libraries in greenhouse trials
- A sequence first approach integrated with phenotype data from the field may offer advantages
- Larger scale data collection would further help confirm the beneficial properties of potential biologicals
- Luckily, a national program collecting microbe and plant health data already exists…

National Plant Diagnostic Network and Big Data for Agriculture Security

- NPDN offers a pre-existing network of scientists collecting geographically diverse data of microbes impacting crop health
- This program remains underfunded although expansion could provide valuable data to industry
- Data privacy and external utilization requires careful considerations
- National database of geographically relevant high impact agriculture-associated microbes could improve biologicals discovery



Thank you!

Questions?

LinkedIn: linkedin.com/in/plant-doctor-todd/

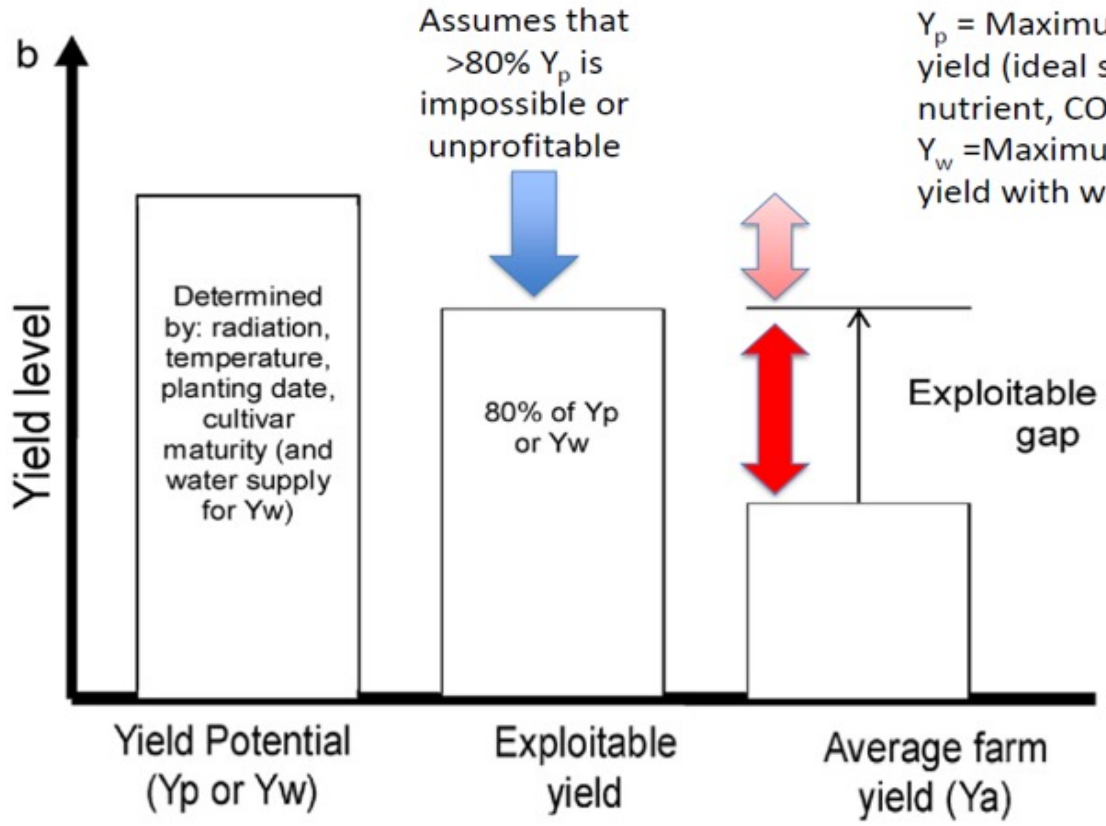
2025
Annual Meeting

What I want and need from a biostimulant… As a grower

Trying to make sense of a complicated topic

Zac Ellis
Sr. Director of Agronomy
Olam Food Ingredients

What do growers want more than anything?



Assumes that >80% Y_p is impossible or unprofitable

Y_p = Maximum theoretical yield (ideal sunlight, temp, nutrient, CO_2)
Y_w =Maximum theoretical yield with water limitation

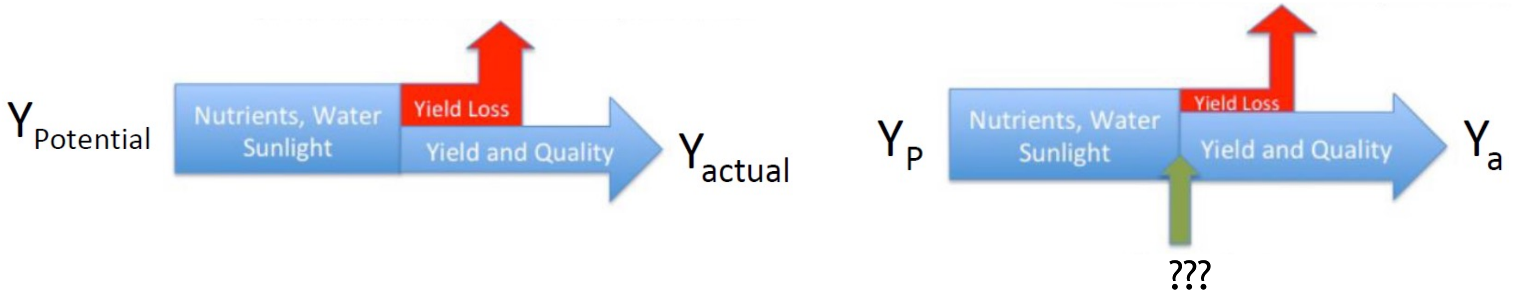
M.K. van Ittersum et al. / Field Crops Research 143 (2013) 4–17

How should we look at yield potential?

Plant Performance and Behavior (PPB) =

$$f\ (G, E, M, S)$$

where: (G) genetics, (E) environment, (M) management, (S) socioeconomic



- Understanding the Environment allows for effective Management.
- Yield losses from stress are a function of several components, rarely just one thing.
- Measures to mitigate or prevent stress requires timely integration into daily operations.

Brown and Saa, 2015 FIPS

What role do bio-stimulants have in commercial ag production?

Physiological Perspective

Stress Hypothesis

- Abiotic stress will inevitably happen, yield seldom reaches full potential.
    - A plant's response to stress is more effective.
    - Normal constraints to productivity are bypassed.

Microbiome Hypothesis

- Microbes modify plant stress response.
    - Plant microbiome is altered by introducing more microbes.
    - Beneficial effects of microbial metabolites may be copied.

Grower Perspective

Stress Hypothesis Dynamics

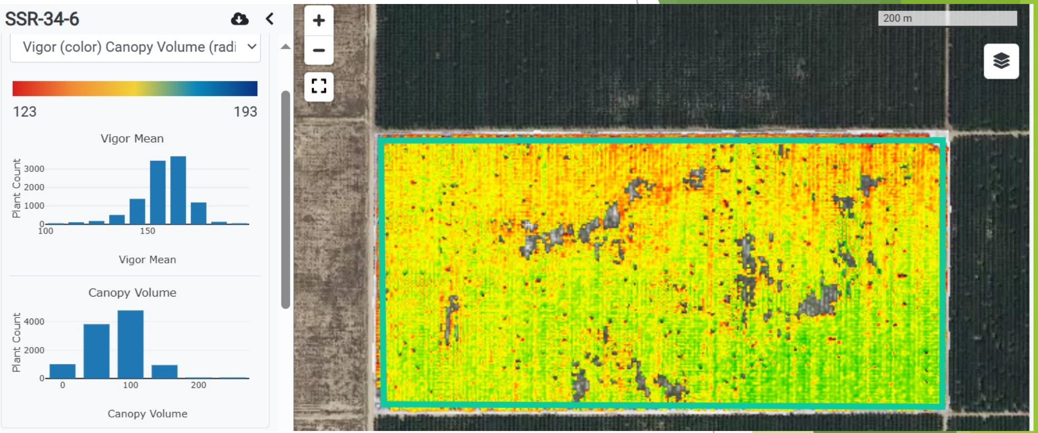
- Plants can benefit from biostimulants if they are under any kind of stress.
- Normal applications of ag chem must coincide with stress events.
- Drought and salinity stress is the biggest target.

Microbiome Hypothesis Dynamics

- Certain microorganisms can optimize soil health.
- Some products can 'feed' the soil microbiome, so the native populations are healthy.
- Application protocol, keeping the 'bugs' alive and integration current fertigation program are top of mind.

Plant Stress: How do we manage it?

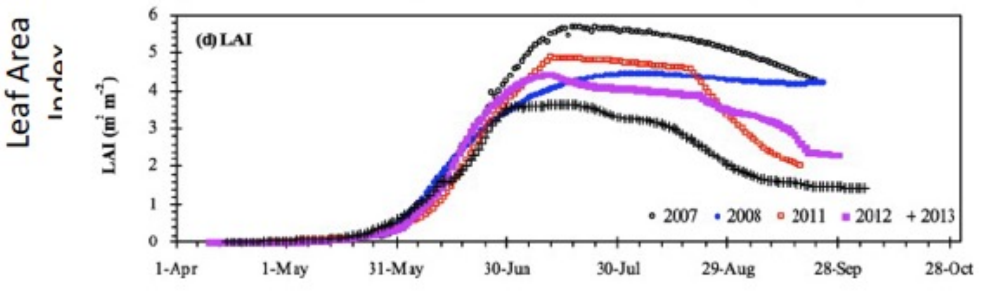
- **Considerations:**
  - What kind of stress? (Drought, salinity, heat, water, etc.)
  - When does the stress occur?
  - Where does the stress occur?
  - How do we apply to areas that are stressed and not to areas that are not?
  - How do we choose the right biostimulant?
  - How persistent is the biostimulant of choice?
  - **What happens if there is no stress??**



SSR-34-6

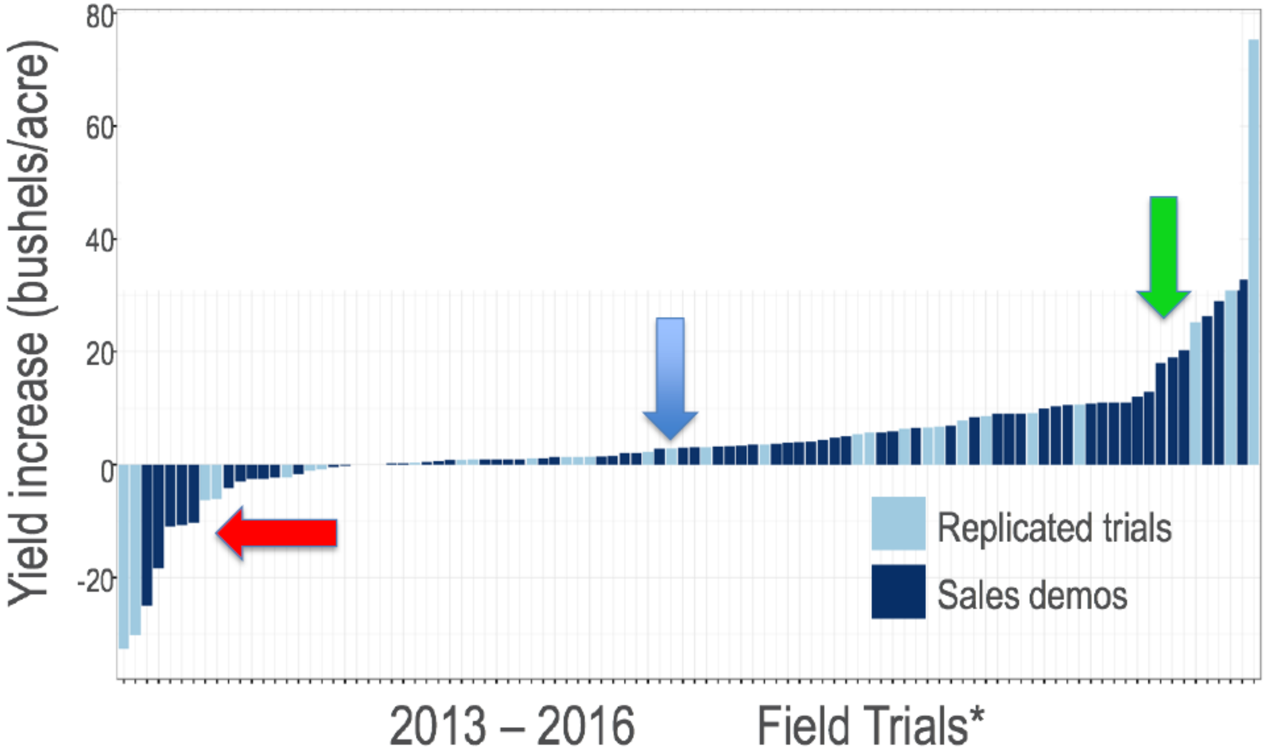
Vigor (color) Canopy Volume (radi

Spatial Variability in Environment

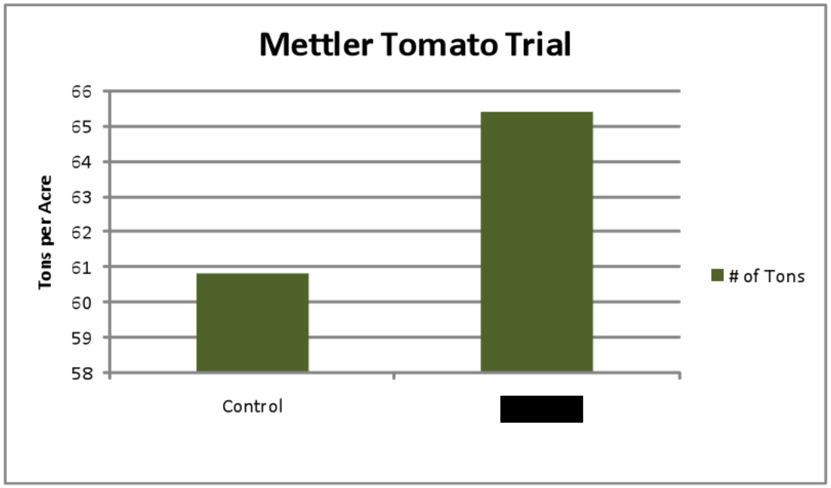


Seasonal Variability in Environment

Testing Biostimulants

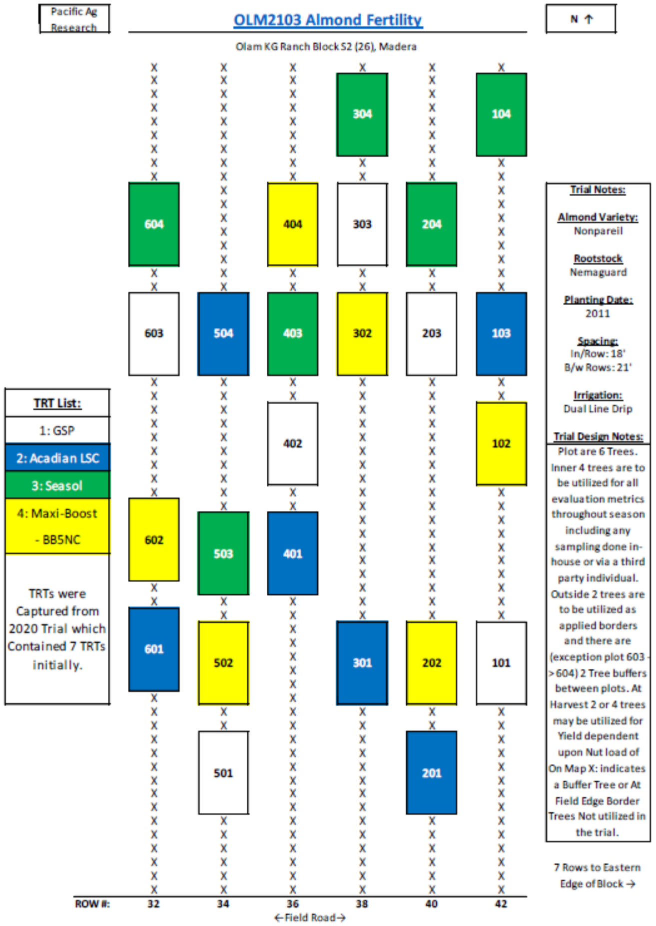


What does data normally look like from biostimulant products?



- The vast majority of ‘trial data’ for biostimulants (among other products) looks like this.
- No proper experimental design or statistical analysis.
- A lot of discussion of certain known mechanisms being involved, but very little evidence.

What SHOULD trial data look like?



TRT List:

- 1: GSP
- 2: Acadian LSC
- 3: Seasol
- 4: Maxi-Boost - BB5NC

TRTs were Captured from 2020 Trial which Contained 7 TRTs initially.

Trial Notes:

Almond Variety:
Nonpareil

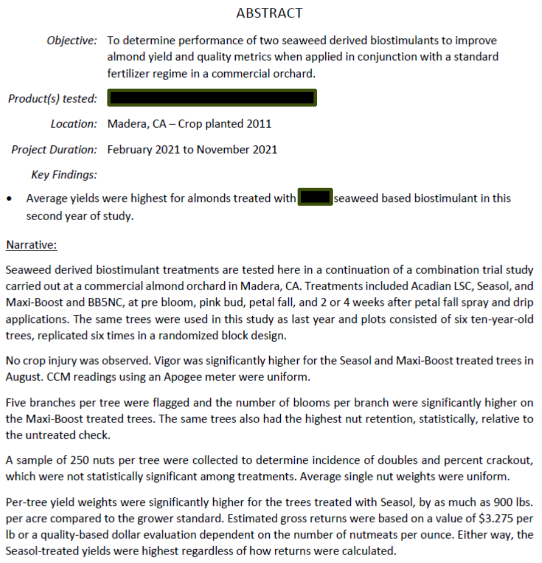
Rootstock
Nemaguard

Planting Date:
2011

Spacing:
In/Row: 18'
B/w Rows: 21'

Irrigation:
Dual Line Drip

Trial Design Notes:
Plot are 6 Trees. Inner 4 trees are to be utilized for all evaluation metrics throughout season including any sampling done in-house or via a third party individual. Outside 2 trees are to be utilized as applied borders and there are (exception plot 603->604) 2 Tree buffers between plots. At Harvest 2 or 4 trees may be utilized for Yield dependent upon Nut load of On Map X: indicates a Buffer Tree or At Field Edge Border Trees Not utilized in the trial.



ABSTRACT

Objective: To determine performance of two seaweed derived biostimulants to improve almond yield and quality metrics when applied in conjunction with a standard fertilizer regime in a commercial orchard.

Product(s) tested: [redacted]

Location: Madera, CA – Crop planted 2011

Project Duration: February 2021 to November 2021

Key Findings:

- Average yields were highest for almonds treated with [redacted] seaweed based biostimulant in this second year of study.

Narrative:

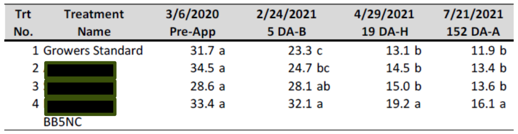
Seaweed derived biostimulant treatments are tested here in a continuation of a combination trial study carried out at a commercial almond orchard in Madera, CA. Treatments included Acadian LSC, Seasol, and Maxi-Boost and BB5NC, at pre bloom, pink bud, petal fall, and 2 or 4 weeks after petal fall spray and drip applications. The same trees were used in this study as last year and plots consisted of six ten-year-old trees, replicated six times in a randomized block design.

No crop injury was observed. Vigor was significantly higher for the Seasol and Maxi-Boost treated trees in August. CCM readings using an Apogee meter were uniform.

Five branches per tree were flagged and the number of blooms per branch were significantly higher on the Maxi-Boost treated trees. The same trees also had the highest nut retention, statistically, relative to the untreated check.

A sample of 250 nuts per tree were collected to determine incidence of doubles and percent crackout, which were not statistically significant among treatments. Average single nut weights were uniform.

Per-tree yield weights were significantly higher for the trees treated with Seasol, by as much as 900 lbs. per acre compared to the grower standard. Estimated gross returns were based on a value of $3.275 per lb or a quality-based dollar evaluation dependent on the number of nutmeats per ounce. Either way, the Seasol-treated yields were highest regardless of how returns were calculated.



Trt No.	Treatment Name	3/6/2020 Pre-App	2/24/2021 5 DA-B	4/29/2021 19 DA-H	7/21/2021 152 DA-A
1	Growers Standard	31.7 a	23.3 c	13.1 b	11.9 b
2	[redacted]	34.5 a	24.7 bc	14.5 b	13.4 b
3	[redacted]	28.6 a	28.1 ab	15.0 b	13.6 b
4	[redacted] BB5NC	33.4 a	32.1 a	19.2 a	16.1 a

[redacted]
[redacted]
[redacted]

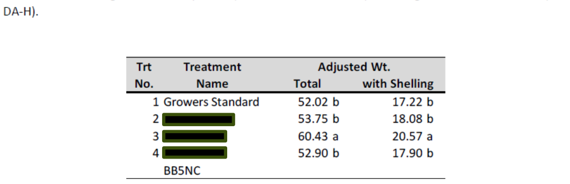


Table 8. Harvested Almond Evaluation: Moisture Adjusted Weight (kg, with and without Shelling). Estimated dried weight of almonds per tree, with and without shells, following harvest on October 28 (201 DA-H).

Trt No.	Treatment Name	Adjusted Wt. Total	Adjusted Wt. with Shelling
1	Growers Standard	52.02 b	17.22 b
2	[redacted]	53.75 b	18.08 b
3	[redacted]	60.43 a	20.57 a
4	[redacted] BB5NC	52.90 b	17.90 b

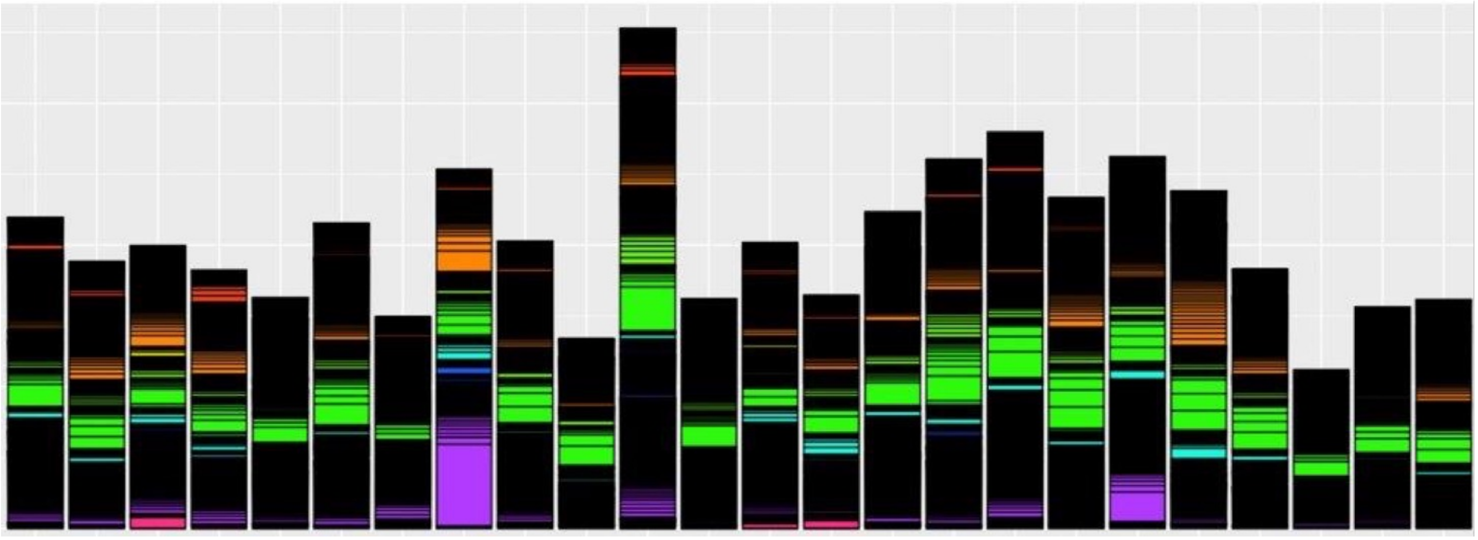
[redacted]
[redacted]
[redacted]

Best Management Practices and Experimental Approach

- Identify critical phenology and stress events that limit productivity
- Determine correct product to its corresponding physiological deficiency.
- Ascertain the ‘function’ of the biostimulant selected.
- Define the environmental and phenological drivers.
- Application of the material:
  - How does water treatment effect injection of the product?
- Understand how you will determine if it worked.
- ONLY USE PRODUCTS THAT HAVE BEEN EFFECTIVELY TESTED.

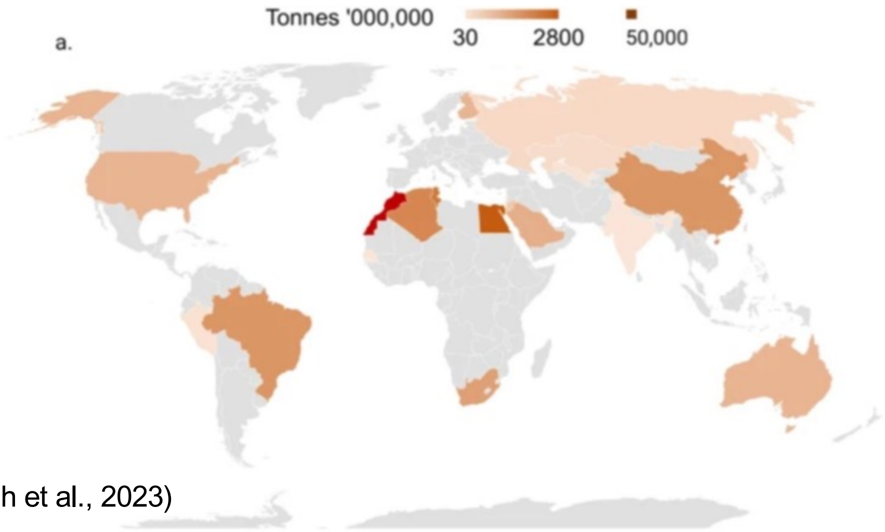
THANK YOU!

Phosphorus availability in agriculture and the role of phosphorous cycling microbial communities



Jenna Brouwer
David Lipson, Patrick H Brown
San Diego State University, University of California Davis

Fig. 2: Global rock phosphate reserves and mining.



(Walsh et al., 2023)

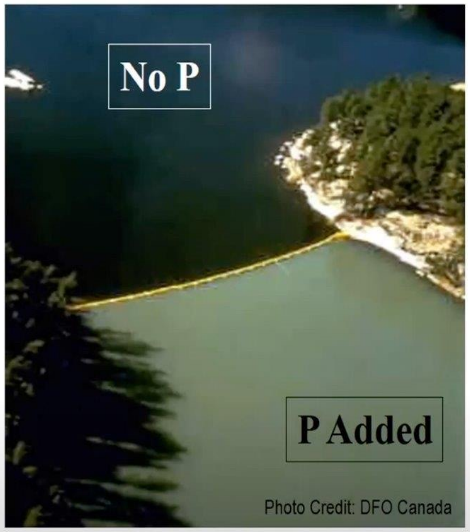


Photo Credit: DFO Canada

Lake 226, Experimental Lake Study, Ontario, 1973

- Phosphorus (P) is a critical nutrient for plant growth and development
  - Limited in most systems & a finite resource
- 10 billion by 2050- require an additional 500 million hectares of arable land converted (McDowell et al., 2025)

- 30-40% of operations overapply P fertilizers, yet only 25% applied P is incorporated into crop biomass
- 75% occluded or lost

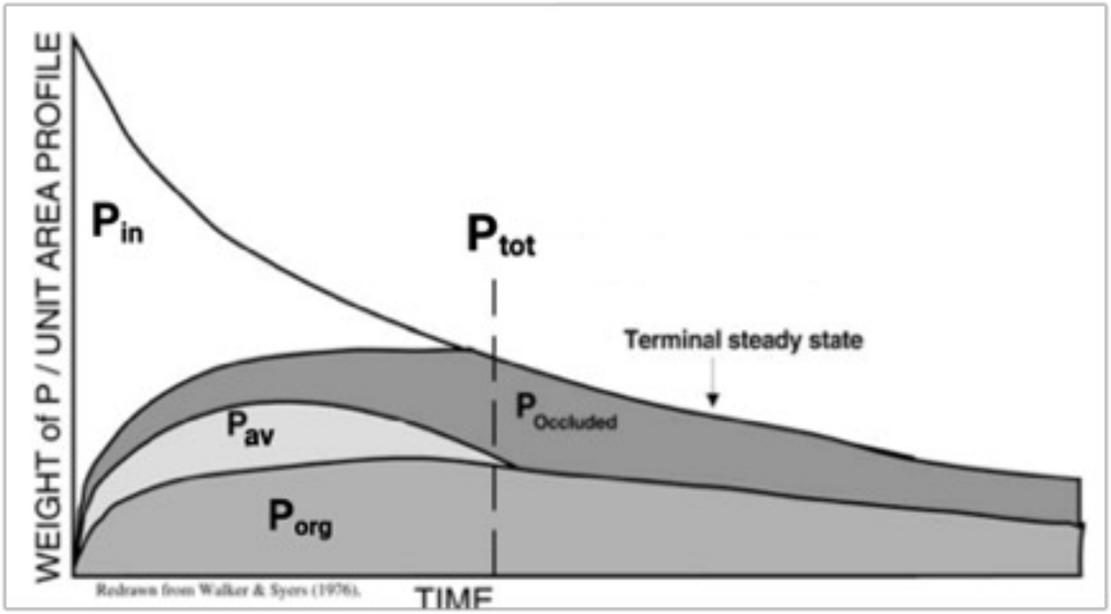


Figure 1. Adapted Walker-Seyer Model of phosphorous weathering over time. Describes the overall decrease of total phosphorous and the transformation of prevelant fractions as the Terminal Steady State is approached [1].

In system management of P

1. Applying phosphorus fertilizers only where they are needed

- Precision

2. Access existing soil phosphorus concentrations

- Pocc , Porg → Pav

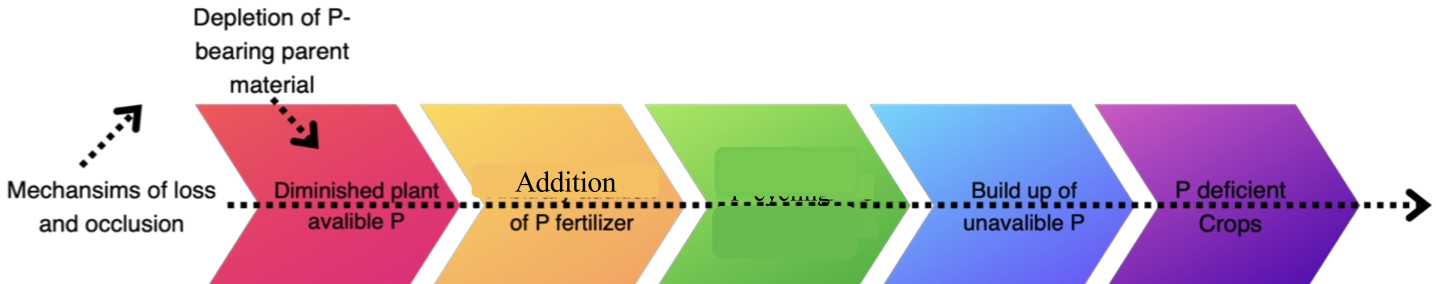
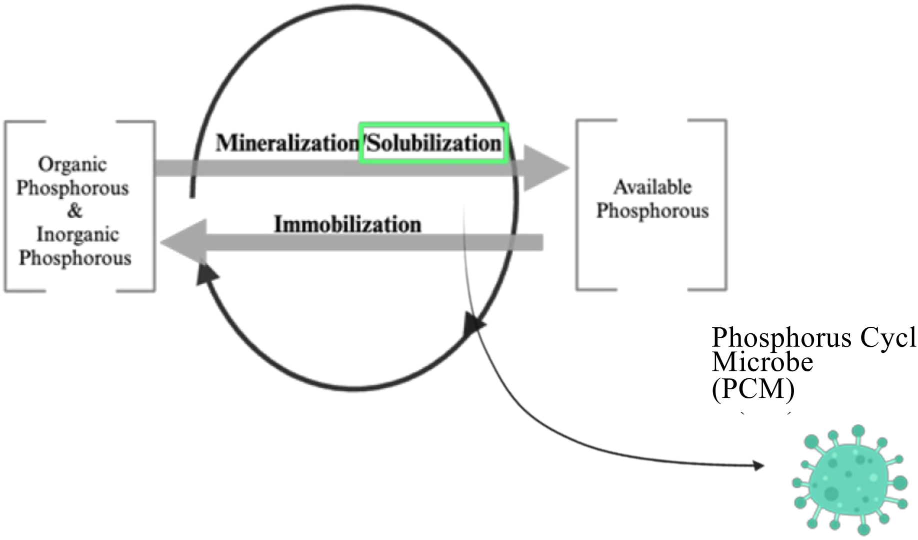


Figure 2.

(Lun et al., 2018; Drohan et al., 2019; Tkaczyk et al., 2020; Haygarth and Rufino, 2021;Biswas et al., 2021; Walsh et al., 2023; McDowell et al., 2025).



Organic Phosphorous & Inorganic Phosphorous

Mineralization/Solubilization

Immobilization

Available Phosphorous

Phosphorus Cycling Microbe (PCM)

Halozone formation in vitro ✓

Isolation of strains with high solubilizing indices ✓

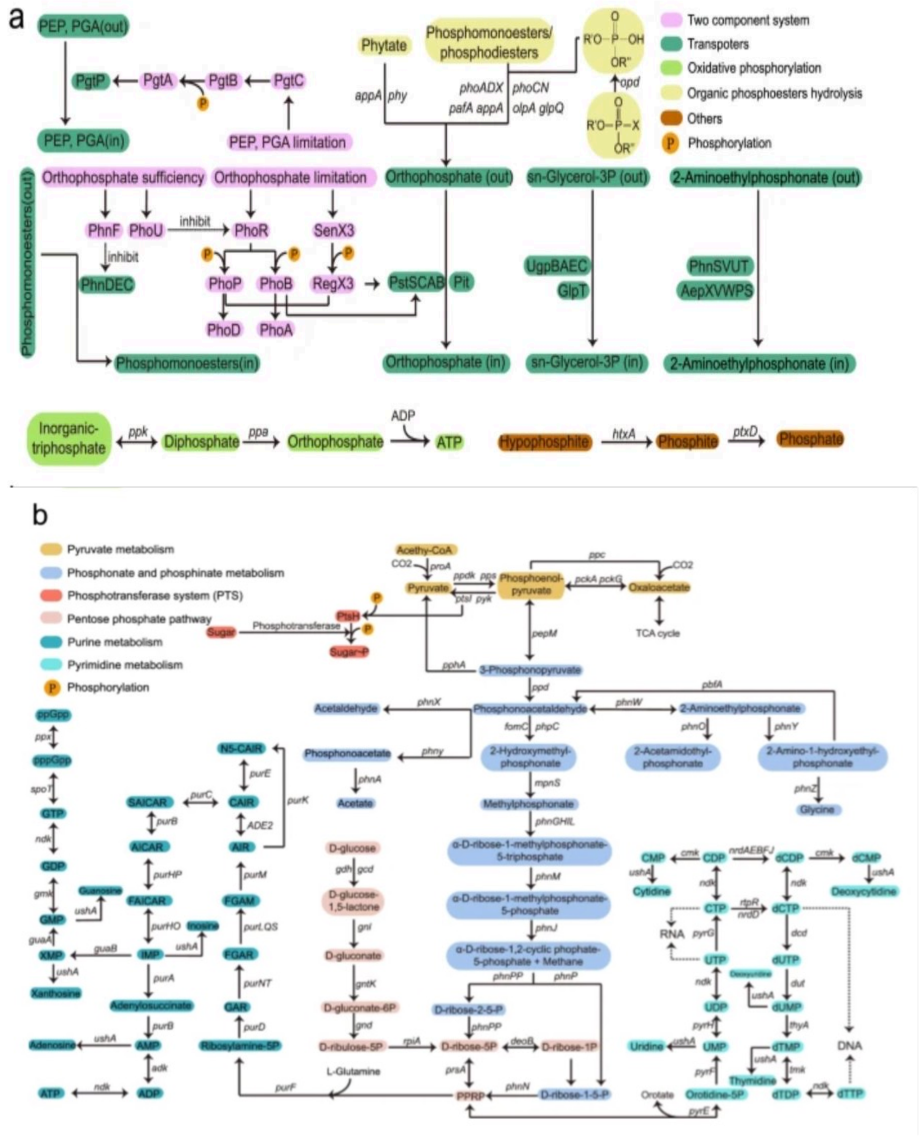
Genetic confirmation of solubilizing mechanisms ✓

Inoculation with model plant ✓

Successful greenhouse trials ✓

In field application ?

Zeng et al., 2022



Driving Questions

1. How is the full diversity of P-cycling genes related to the abundance of key phosphorus fractions?

2. How does the microbial community composition shift with P management

- Nonpareil and Wood Colony almond varieties
- Thirteen years old
- 308 trees/ha

Management

- Micro sprinkler
- 20 lbs/acre of 10-30-0 fertilizer annually in June.
- 2 quarts/acre of commercial biological amendment

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Pre-Amendment

-High root zone
-Low root zone

1. 20 lbs/acre of 10-30-0 fertilizer
2. 2 quarts/acre of commercial biological amendment

Post-Amendment

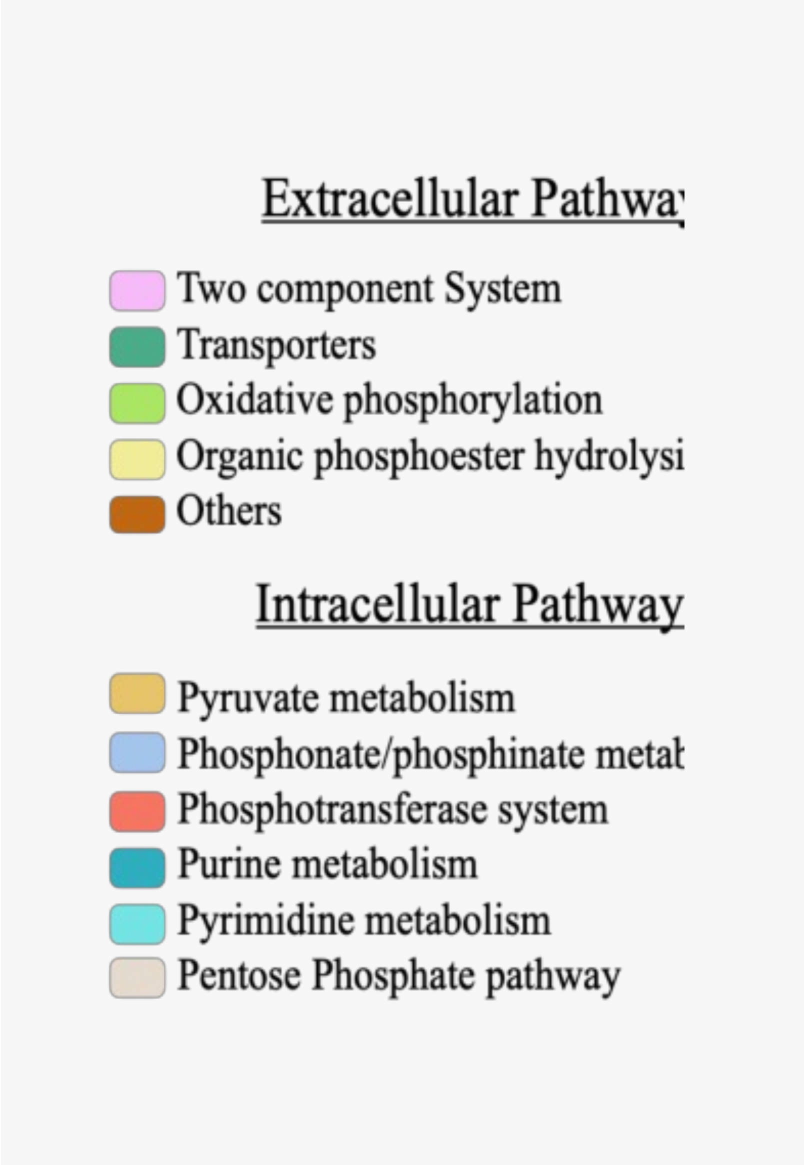
-High root zone

Step 1: Taxanomic and Functional annotation of metagenomic/amplicon libraries

- **Next-generation sequencing**
  - Functional analysis using the PCyC database (Zeng et al.,2022).
- **16S rRNA amplicon sequencing**
  - Community composition

Step 2: Extract representative P pools

- Total (Ptot)
- inorganic (Pin)
- organic (Porg)
- available (Pav)

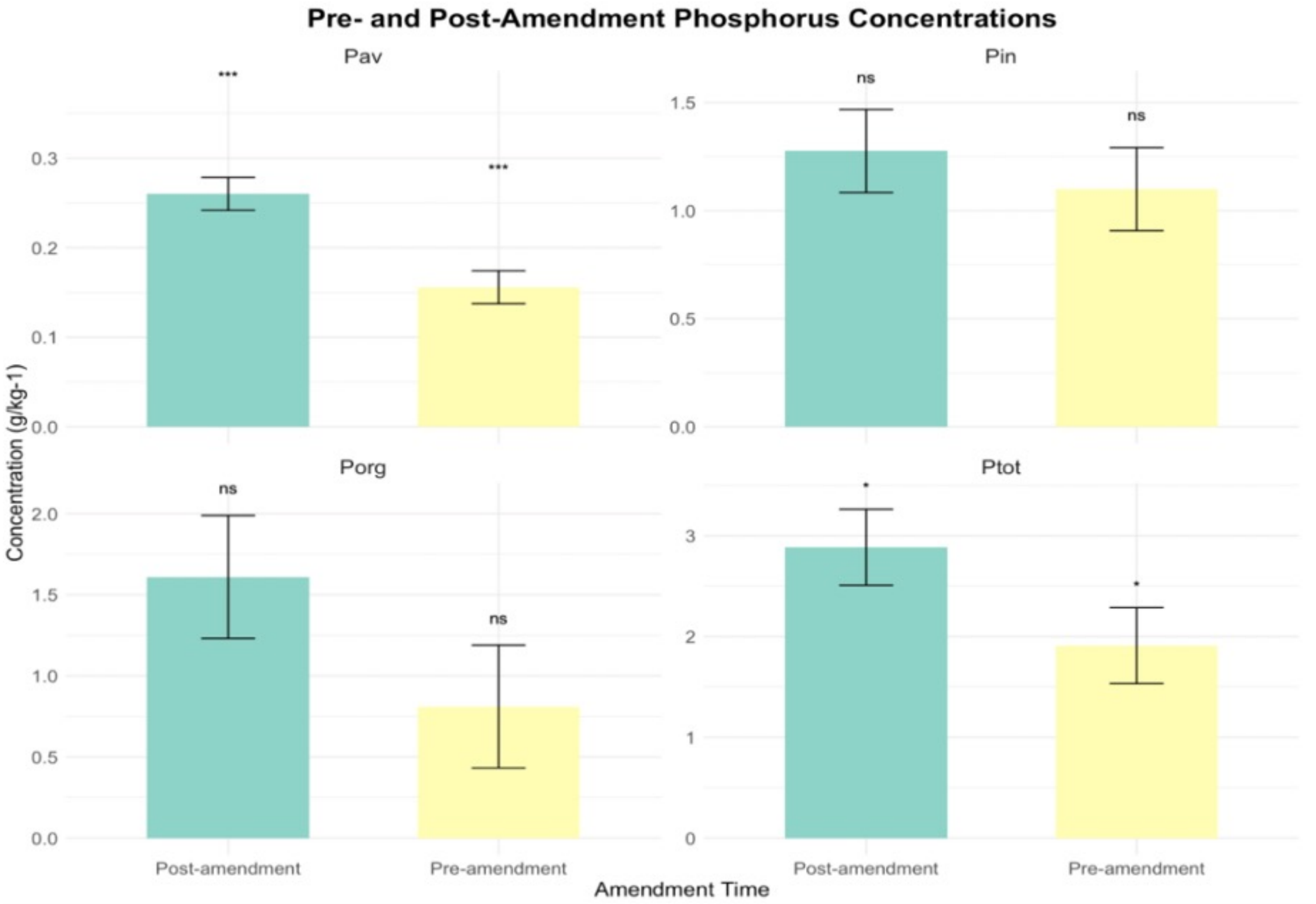


Extracellular Pathwa

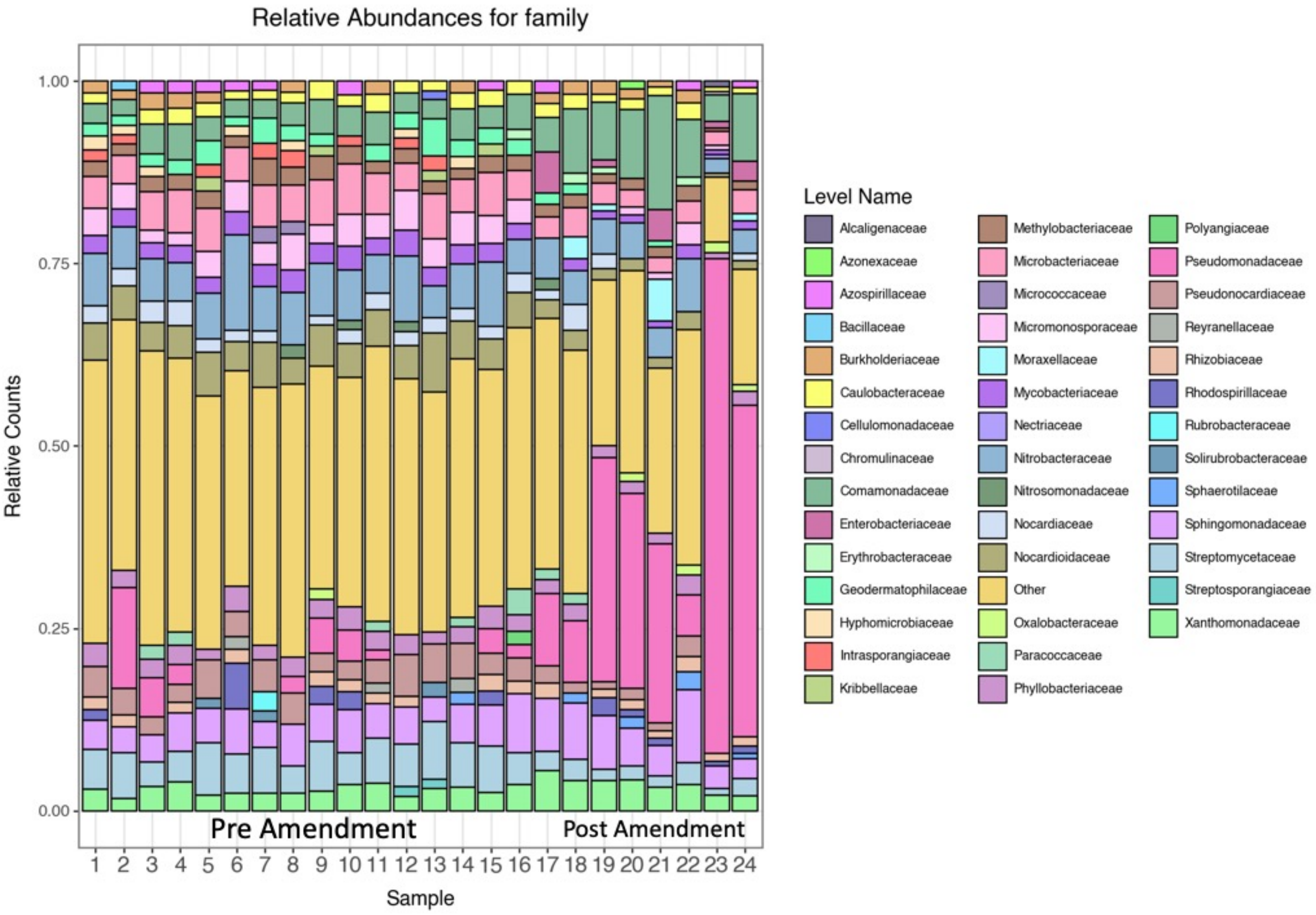
- 🟪 Two component System
- 🟩 Transporters
- 🟩 Oxidative phosphorylation
- 🟨 Organic phosphoester hydrolysi
- 🟧 Others

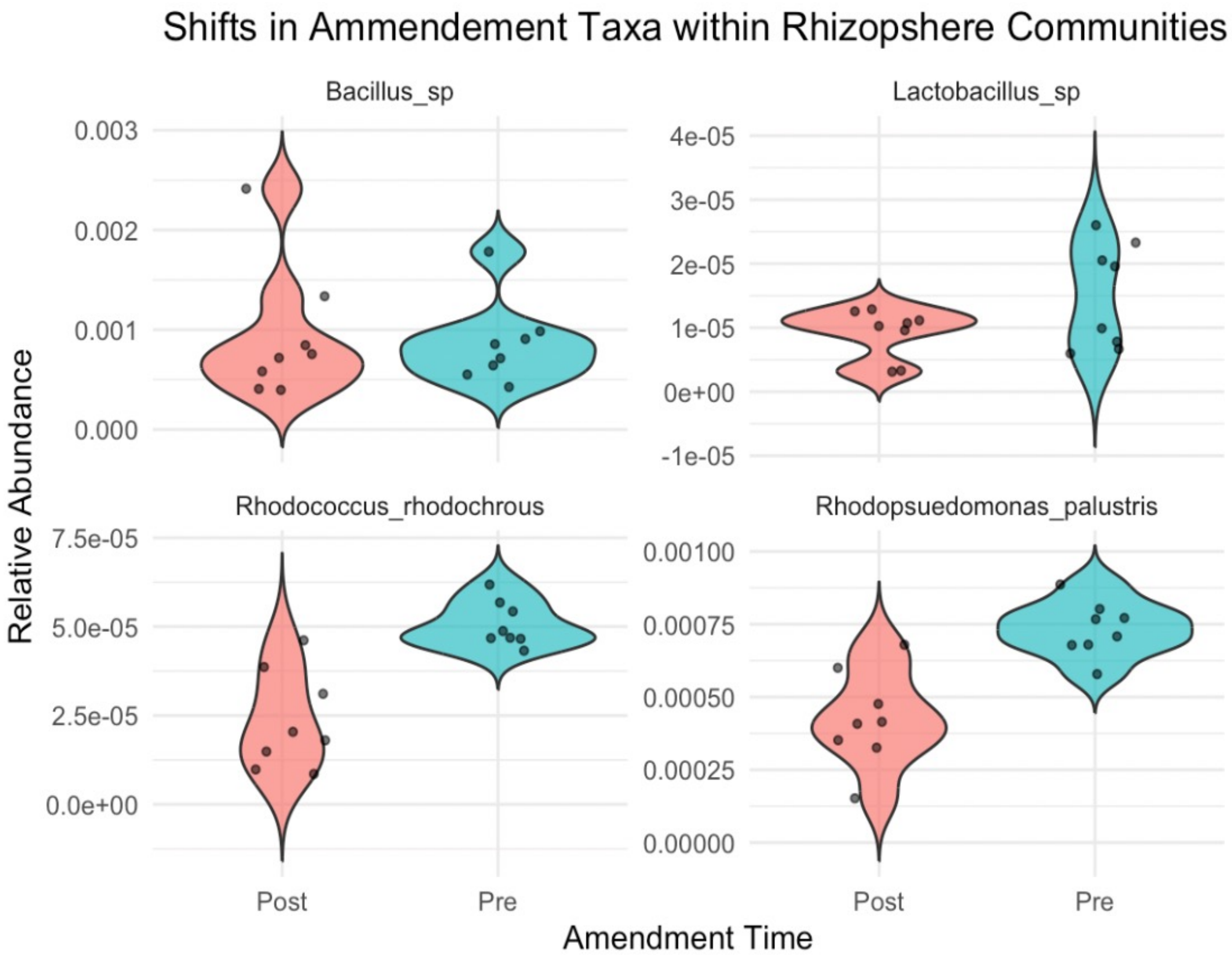
Intracellular Pathway

- 🟨 Pyruvate metabolism
- 🟦 Phosphonate/phosphinate metab
- 🟥 Phosphotransferase system
- 🟦 Purine metabolism
- 🟦 Pyrimidine metabolism
- ⬜ Pentose Phosphate pathway



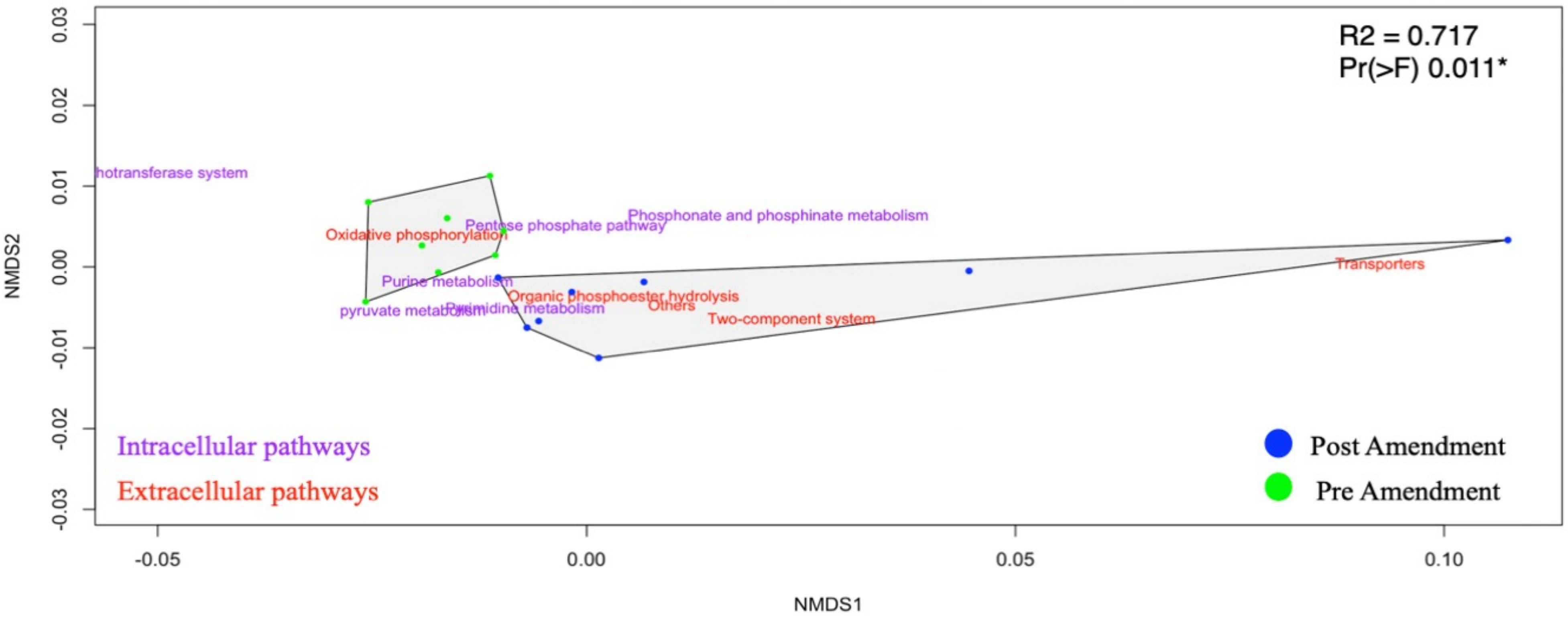
* $p < 0.05$, **$p < 0.01$, and *** $p < 0.001$


Relative Abundances for family
Relative Counts
1.00
0.75
0.50
0.25
0.00
Pre Amendment
Post Amendment
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Sample
Level Name
Alcaligenaceae
Azonexaceae
Azospirillaceae
Bacillaceae
Burkholderiaceae
Caulobacteraceae
Cellulomonadaceae
Chromulinaceae
Comamonadaceae
Enterobacteriaceae
Erythrobacteraceae
Geodermatophilaceae
Hyphomicrobiaceae
Intrasporangiaceae
Kribbellaceae
Methylobacteriaceae
Microbacteriaceae
Micrococcaceae
Micromonosporaceae
Moraxellaceae
Mycobacteriaceae
Nectriaceae
Nitrobacteraceae
Nitrosomonadaceae
Nocardiaceae
Nocardioidaceae
Other
Oxalobacteraceae
Paracoccaceae
Phyllobacteriaceae
Polyangiaceae
Pseudomonadaceae
Pseudonocardiaceae
Reyranellaceae
Rhizobiaceae
Rhodospirillaceae
Rubrobacteraceae
Solirubrobacteraceae
Sphaerotilaceae
Sphingomonadaceae
Streptomycetaceae
Streptosporangiaceae
Xanthomonadaceae



Strains in Biological amendment at 2.26x10^3 CFU/ml

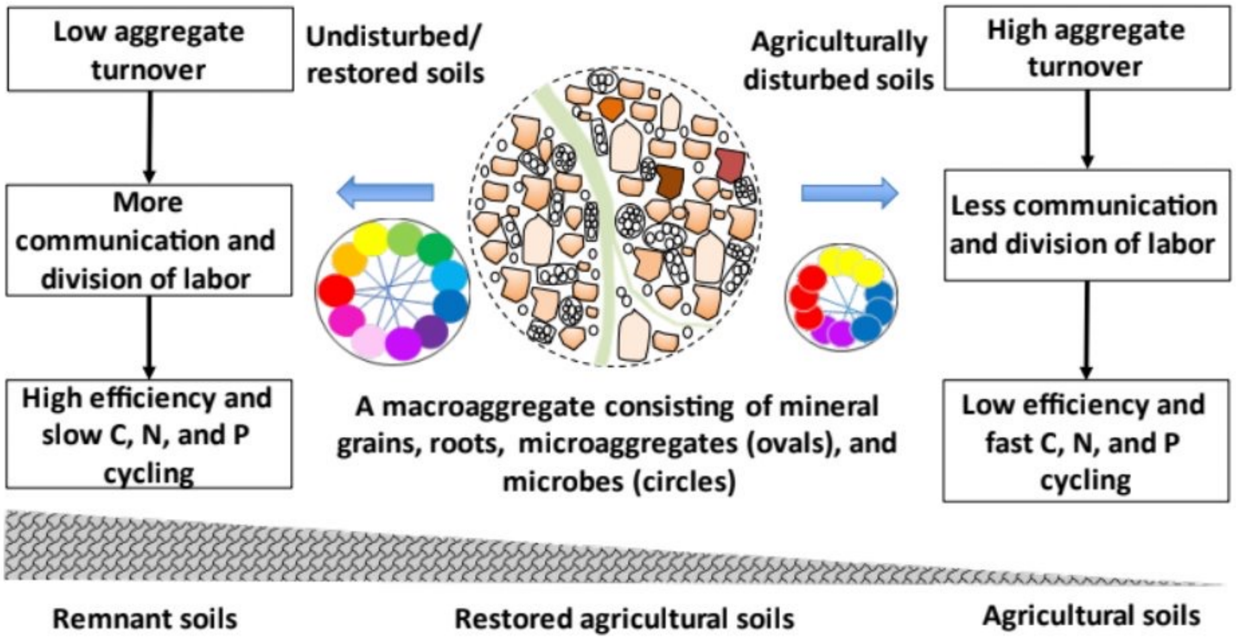
i. Bacillus megatarium….
ii. Bacillus brevis….
iii. Bacillus licheniformis….
iv. Lactobacillus plantarum….
v. Rhodopseudomonas palustris….
vi. Rhodococcus rhodochrous ….



- Bray distance NMDS using vegan package in R v4.4.3
- Permutational multivariate analysis of variance (PERMANOVA) Adonis package
- 72% (R2) of the distance can be explained by the combination effects of Amendment time , Pin, and Pav , and tree

Conclusions and Next Steps

- P-cycling pathways shift with P availability
  - Intracellular recycling -> extracellular turnover
  - Mean-resident-time hypothesis
- In the given sampling time frame, PCM in biological amendment do not establish
  - Nutrient strategist



Low aggregate turnover

More communication and division of labor

High efficiency and slow C, N, and P cycling

Undisturbed/ restored soils

Agriculturally disturbed soils

High aggregate turnover

Less communication and division of labor

Low efficiency and fast C, N, and P cycling

A macroaggregate consisting of mineral grains, roots, microaggregates (ovals), and microbes (circles)

Remnant soils

Restored agricultural soils

Agricultural soils

Figure 2*.* *We hypothesize that communities within stable (low turnover) aggregates have more capacity for communication and division of labor, leading to higher efficiency and slower decomposition of organic matter. Stable aggregate communities will have larger niche space (larger color wheel), less species overlap, more diverse OM-degrading genes (many colors), and stronger network connections among species (solid blue lines).*

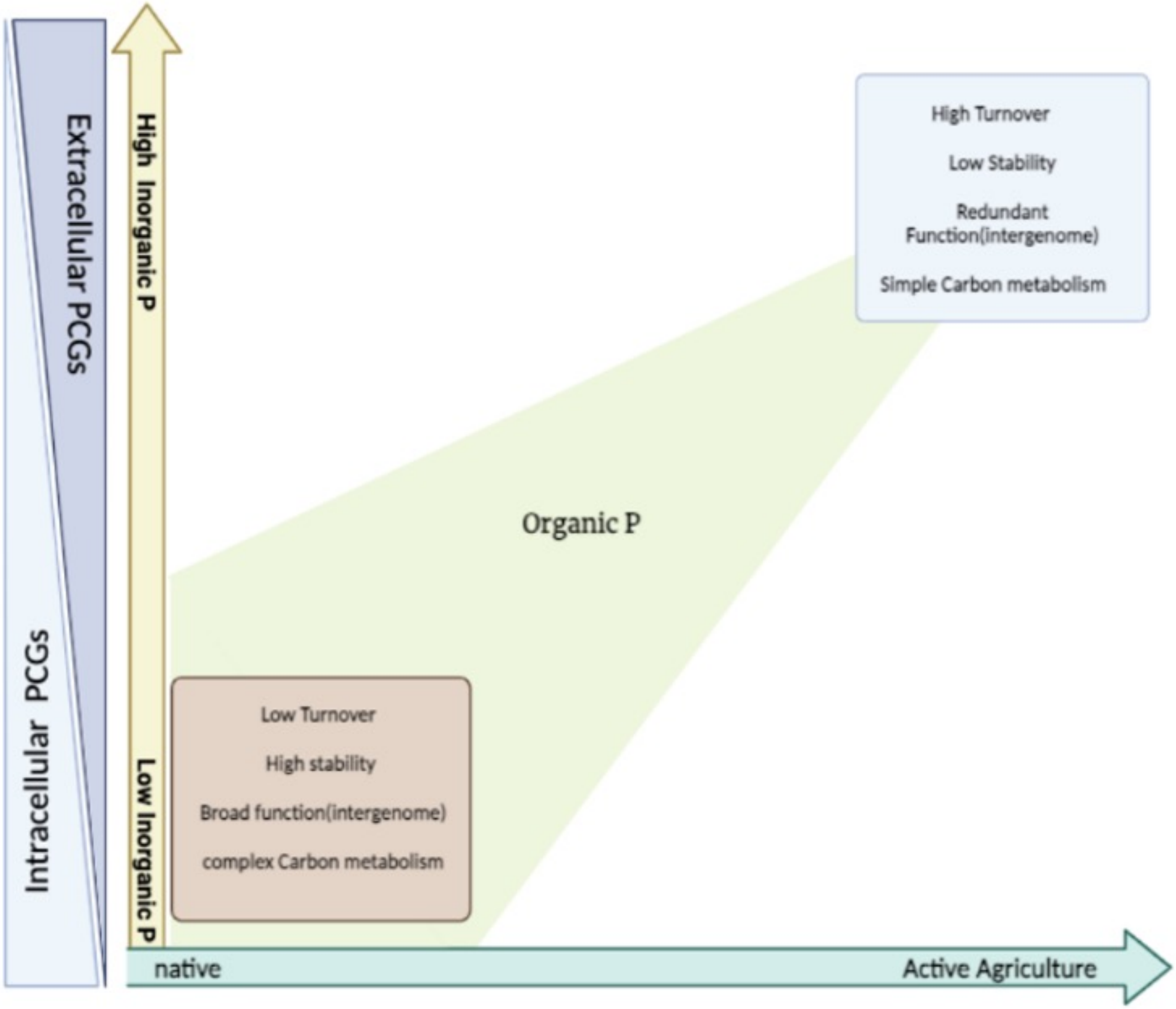
Aknowledgements

A special thanks to:

- The Patrick H Brown Lab at the University of California Davis
- The Lipson Lab at San Diego State Unviresty
- To Biomemakers and Tracegenomics for their support in analyses

WESTWIND
FARMS

USDA nextgen


Extracellular PCGs
Intracellular PCGs
High Inorganic P
Low Inorganic P
High Turnover
Low Stability
Redundant Function(intergenome)
Simple Carbon metabolism
Organic P
Low Turnover
High stability
Broad function(intergenome)
complex Carbon metabolism
native
Active Agriculture