Tomato plant roots/ carboxymethyl cellulose (CMC) method for the removal and recovery of phosphate from agricultural wastewater

University of Windsor
Chemistry and Biochemistry

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University of Windsor

1. University of Windsor
2. Bruce Peninsula Biosphere Association

The goal of this project:

Reduce nutrient loadings from agricultural streams before it drains into rivers and lakes.

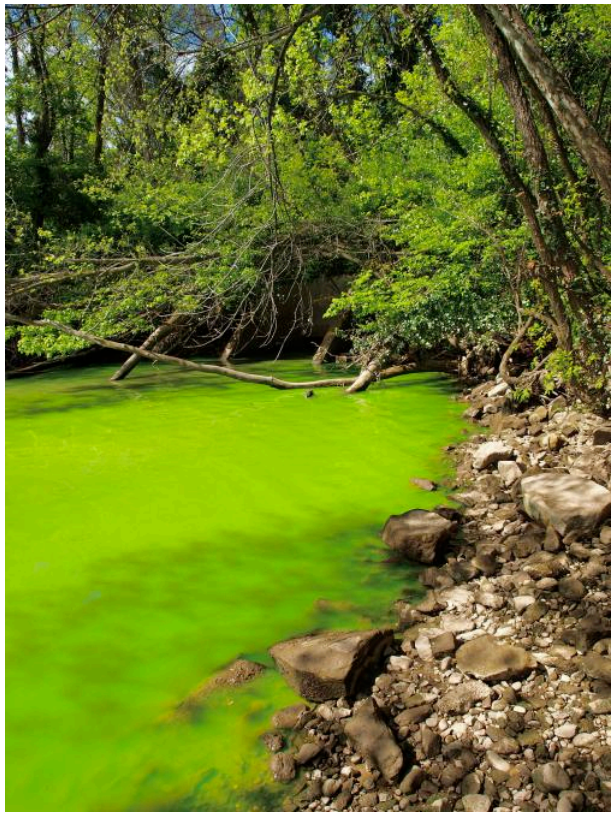
Accumulation in aquatic ecosystems leads to *eutrophication.*

Eutrophication

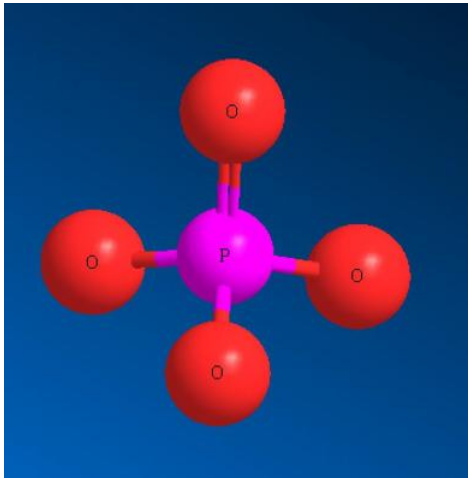
Eutrophication occurs when ecosystems accumulate too many nutrients

Aids the formation of harmful algal blooms

algal toxins> dead algae> bacteria> depletion of oxygen> kill of aquatic animals



Causes many, our focus = P



Phosphate is important in many aspects of biology

Therefore, it is used in fertilizers

Like crops, algae depends on phosphate for growth and development

Therefore, the accumulation of phosphate promotes algal growth

Phosphate Binders

Chitosan matrix with chelated iron

From shell fish exoskeleton

Phosphate Binders

Chitosan matrix with chelated iron

Drastic price increase

Leeching of iron to environment

Unstable: digested by microorganisms

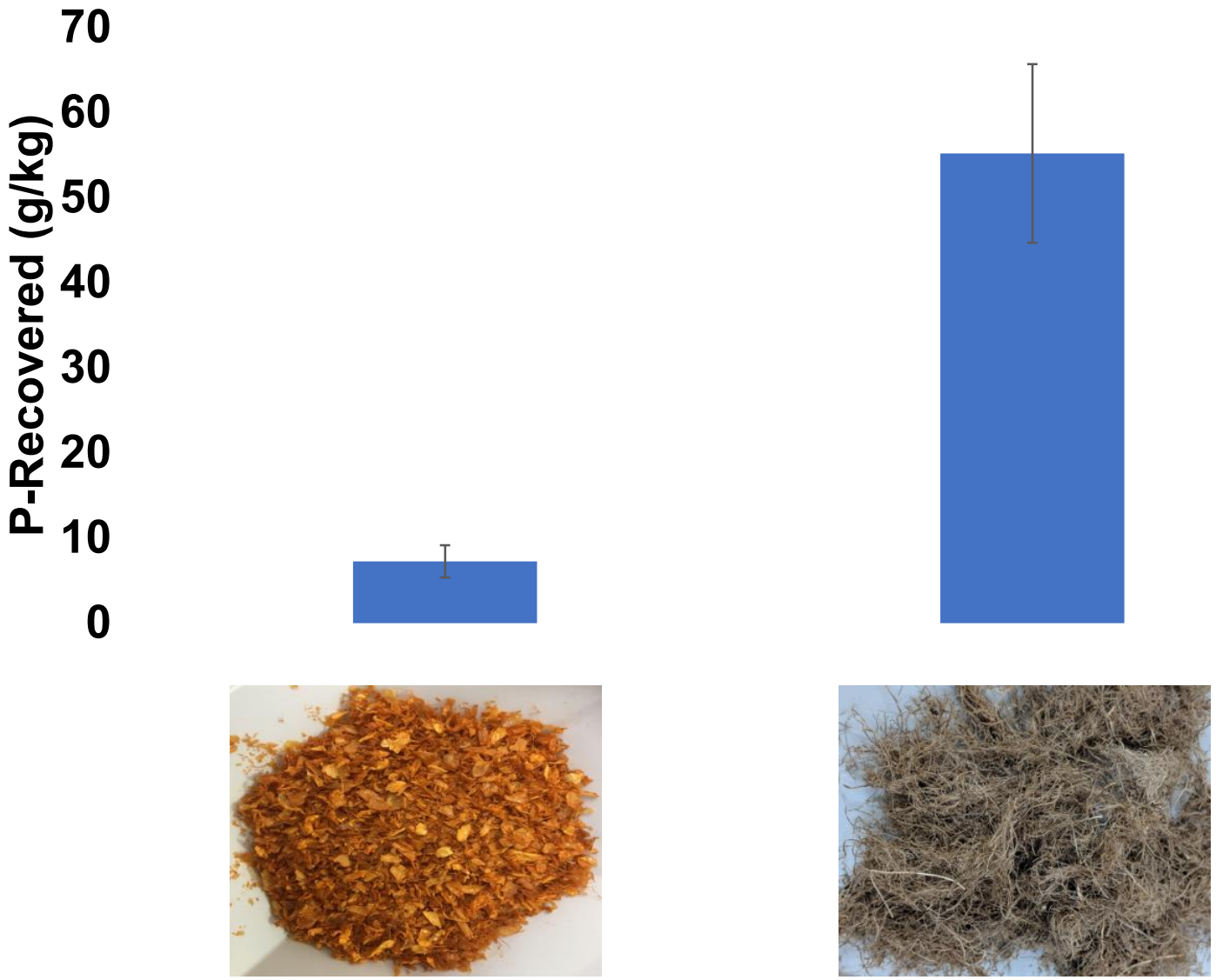
Phosphate Binders

Ideal binding matrix should;

1. Bind large quantities of phosphate
2. Inexpensive
3. Safe for the environment

Tomato plant roots

Binding Capacity



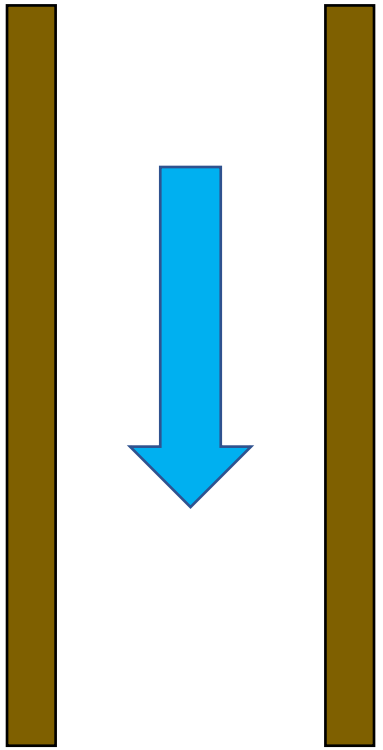
Phosphate Binders

Ideal binding matrix should;

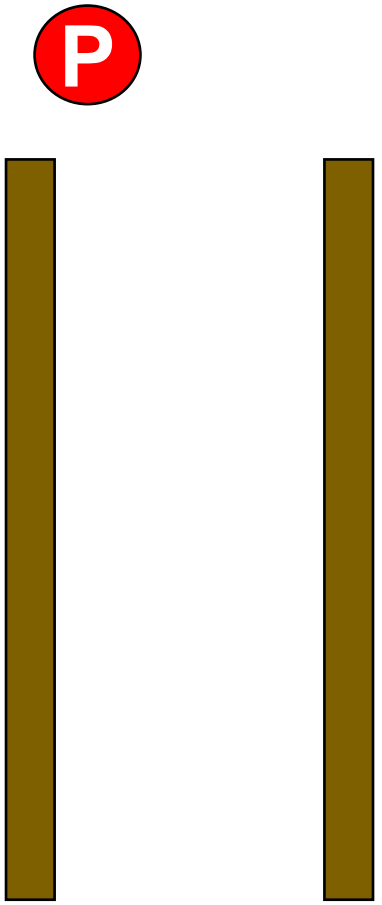
1. Bind large quantities of phosphate
2. Inexpensive
3. Safe for the environment

Probably

Tomato plant roots

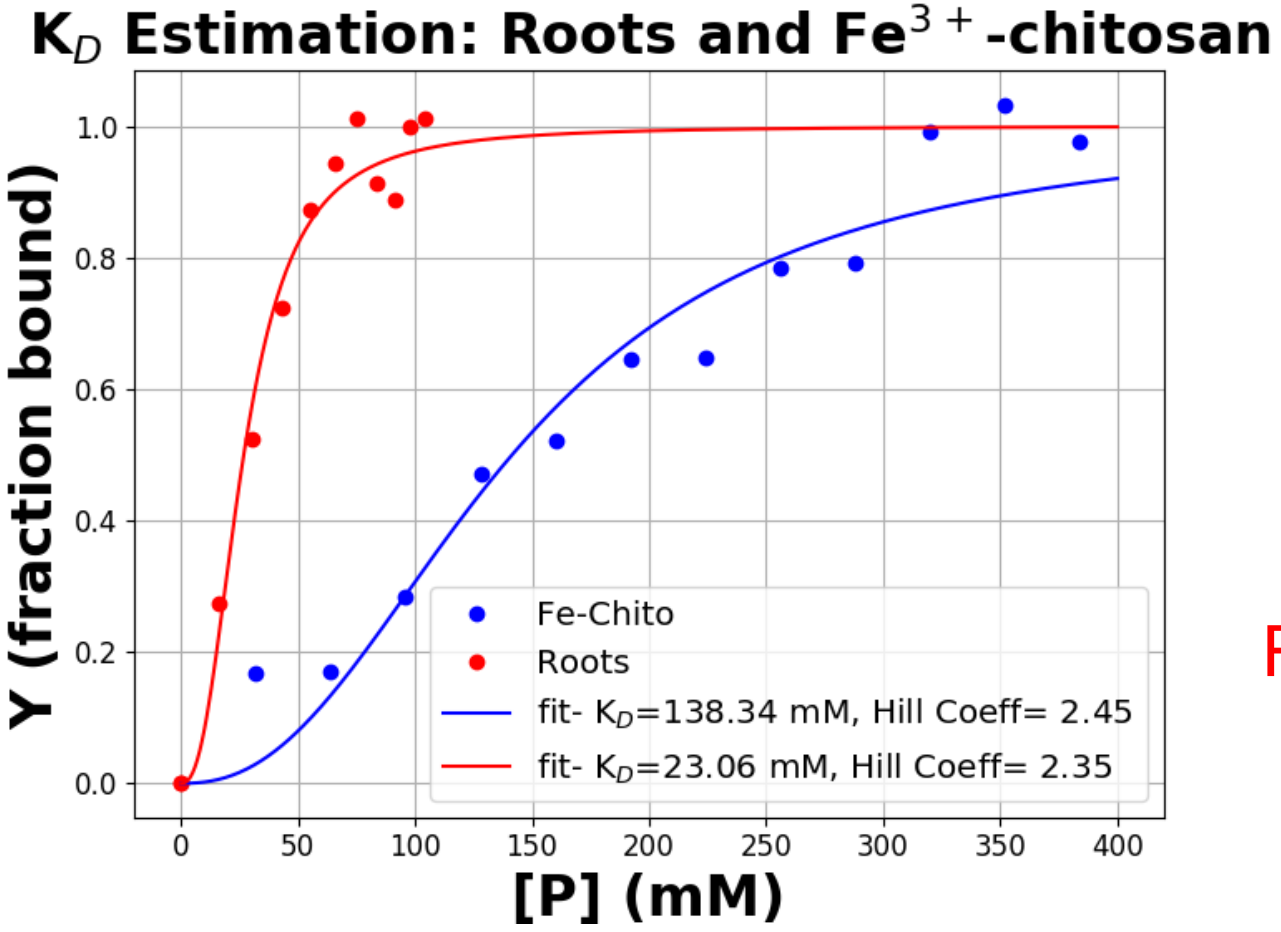


Plant Roots – Phosphate Binding Capacity: ~ 55 g/kg



Plant Roots – Phosphate Binding Capacity: ~ 55 g/kg

Tightness of Binding



$K_{D\ App}$

Iron-Chito: 138.3mM

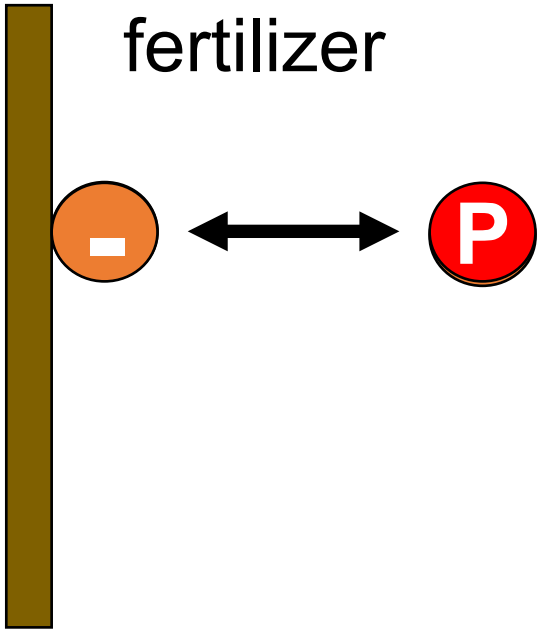
Roots: 23.1mM

Methods of P Recovery

Direct reapplication of P-saturated roots as fertilizer

Recovery and Regeneration of Binding Capacity

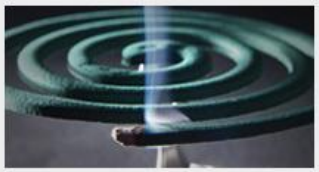
P replaced with counter anion – maybe liquid fertilizer



Typically, acid/base or conjugate salt

Carboxymethyl Cellulose (CMC)

INDUSTRIAL GRADE CMC



FOOD GRADE CMC

TOOTHPASTE GRADE CMC

DETERGENT GRADE CMC

CERAMIC GRADE CMC

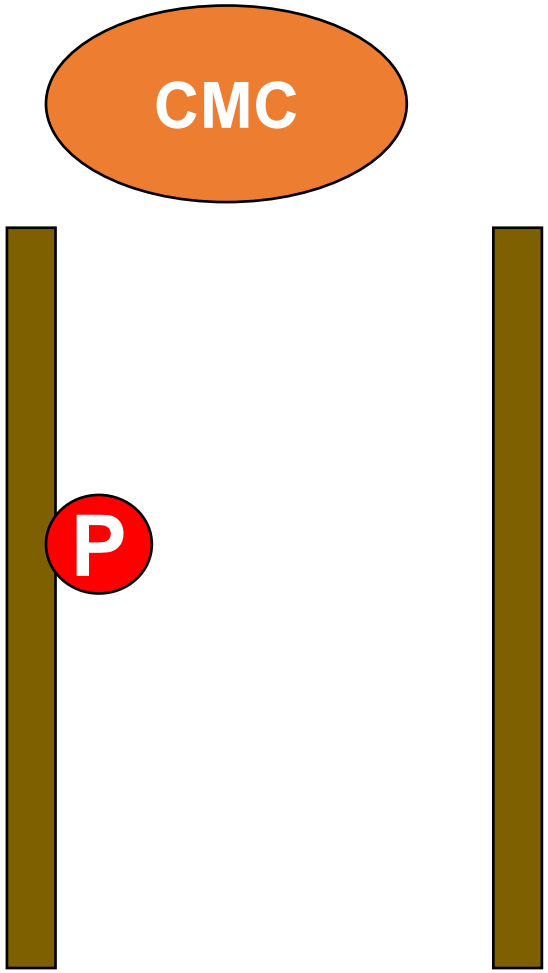
PAINTING GRADE CMC

MINING GRADE CMC

PAPER MAKING GRADE CMC

OIL DRILLING GRADE CMC

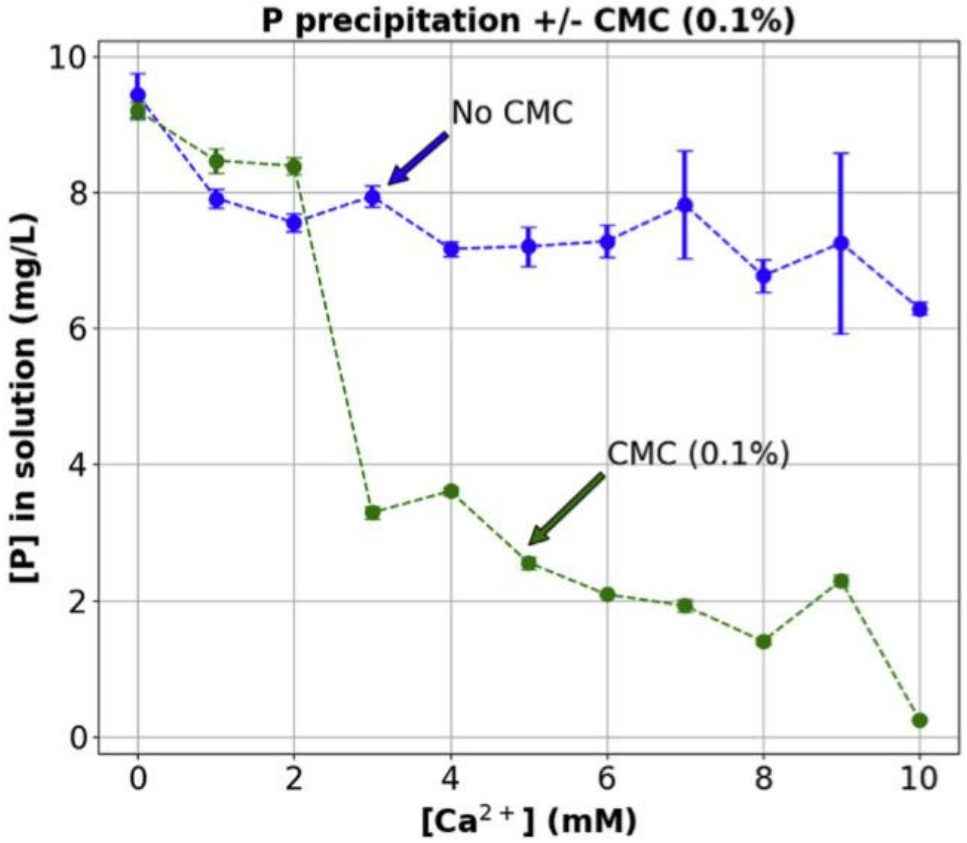
TEXTILE DYEING GRADE CMC



CMC displaces P

P can be collected and the root material reused

Precipitation of P as Calcium-Phosphate



CMC enhances calcium-phosphate precipitation

Less calcium to harvest P

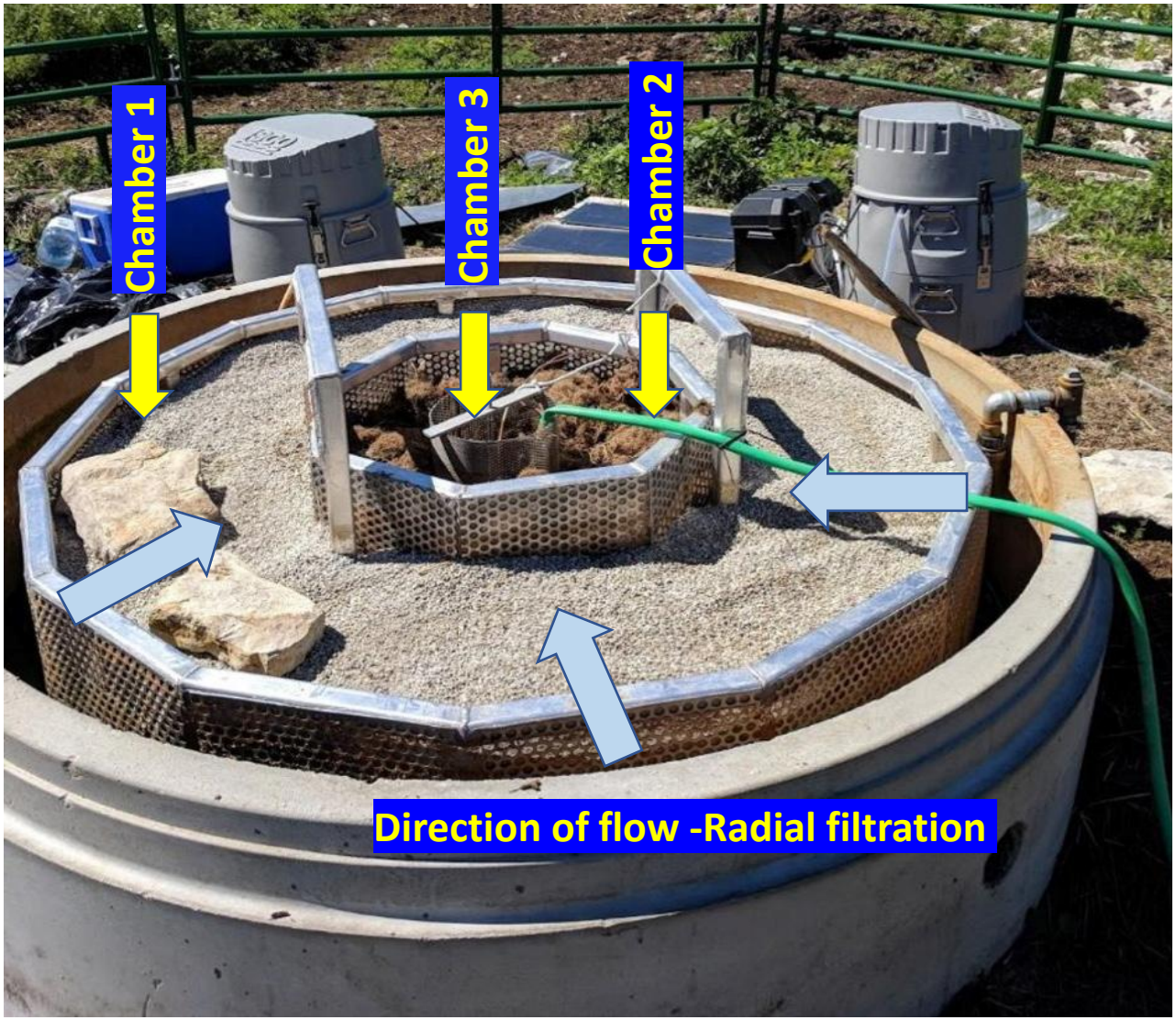
Lower cost

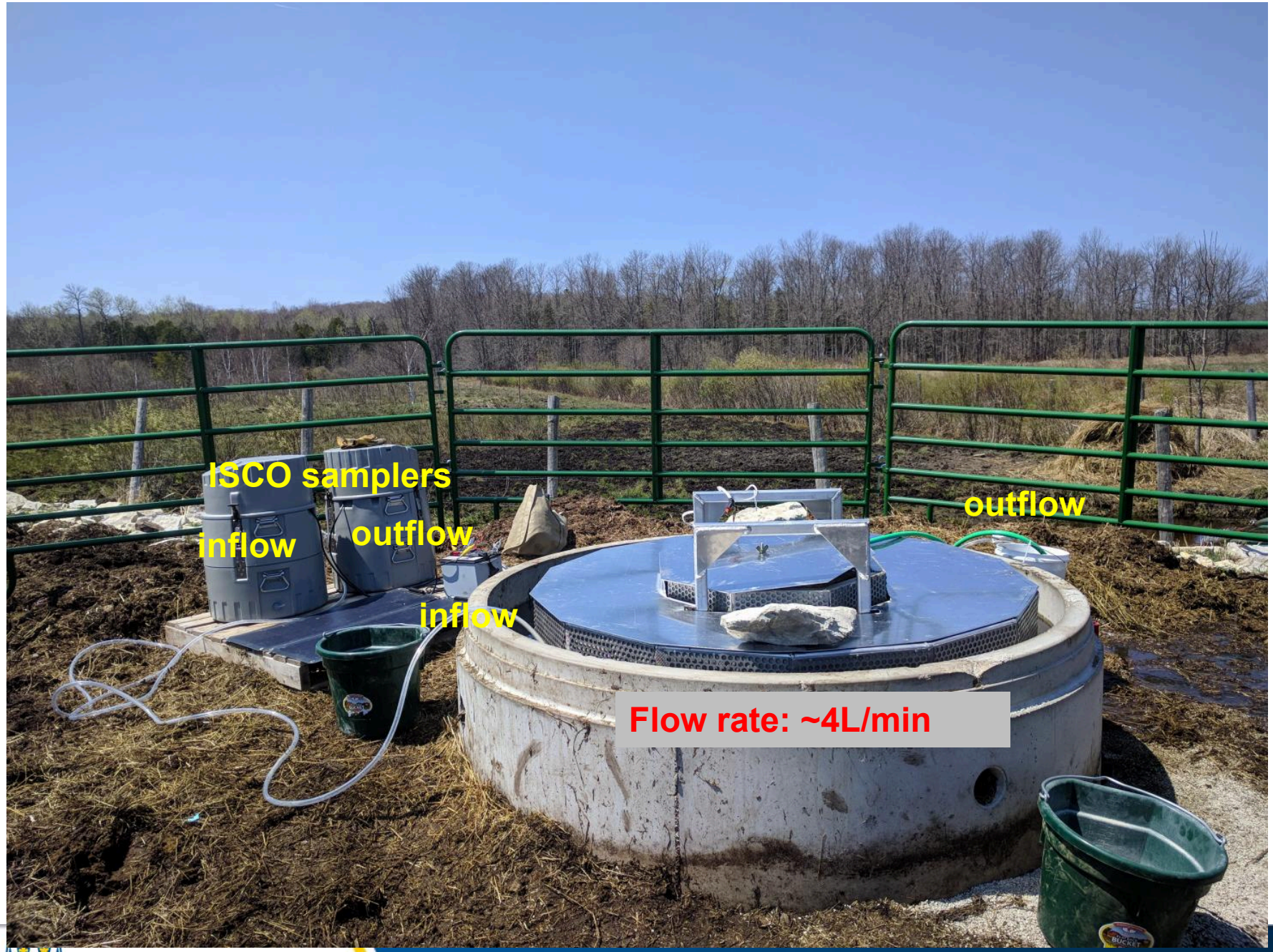
Increasing calcium (0-10mM)

Lion's Head On Site Testing

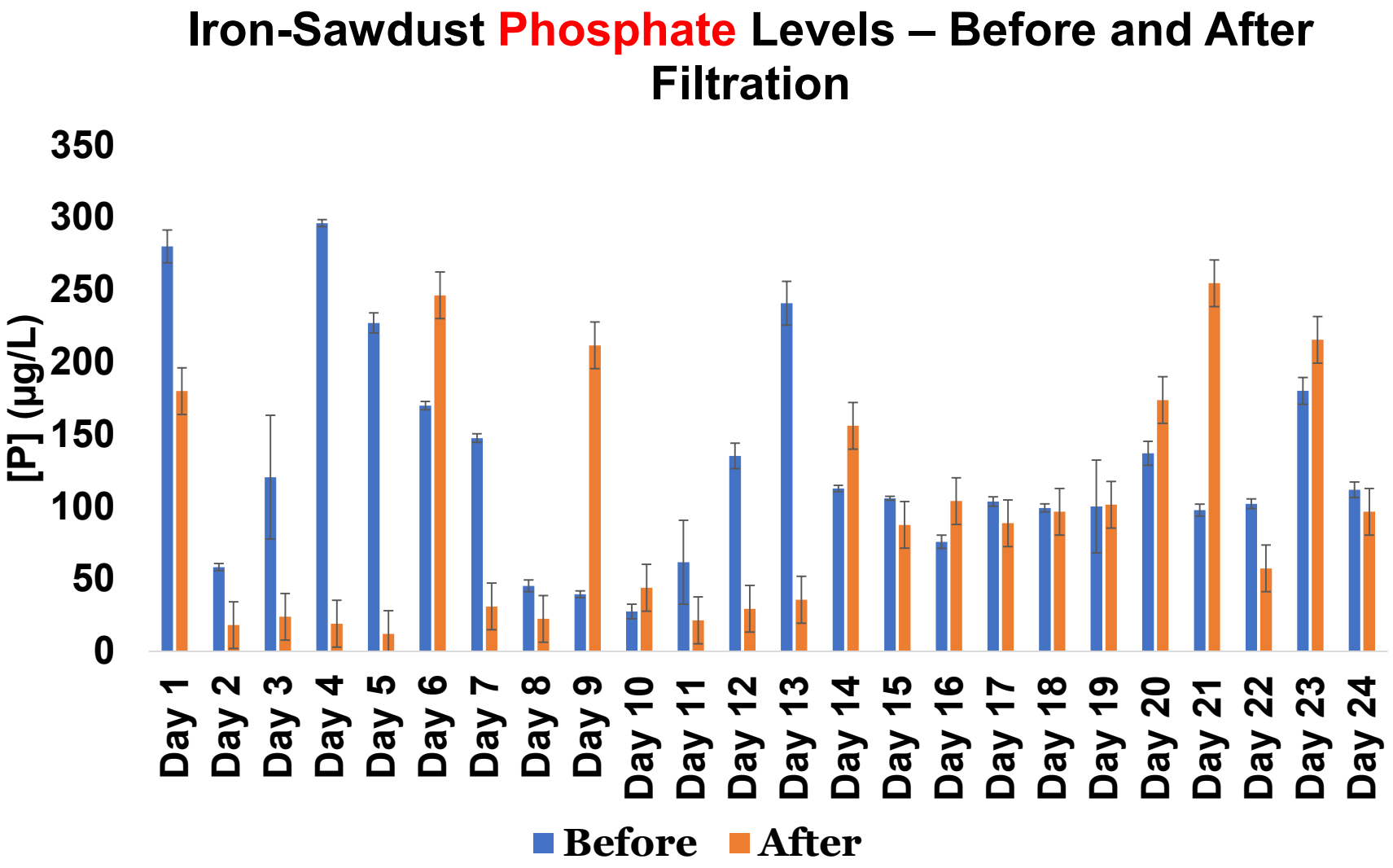

Lion’s Head On Site Testing
Water source on site contaminated with manure.
ISCO

Biofilter-Idea: Neils Munk**; Design**: Mutus; **Build**: UW Tech Support Centre



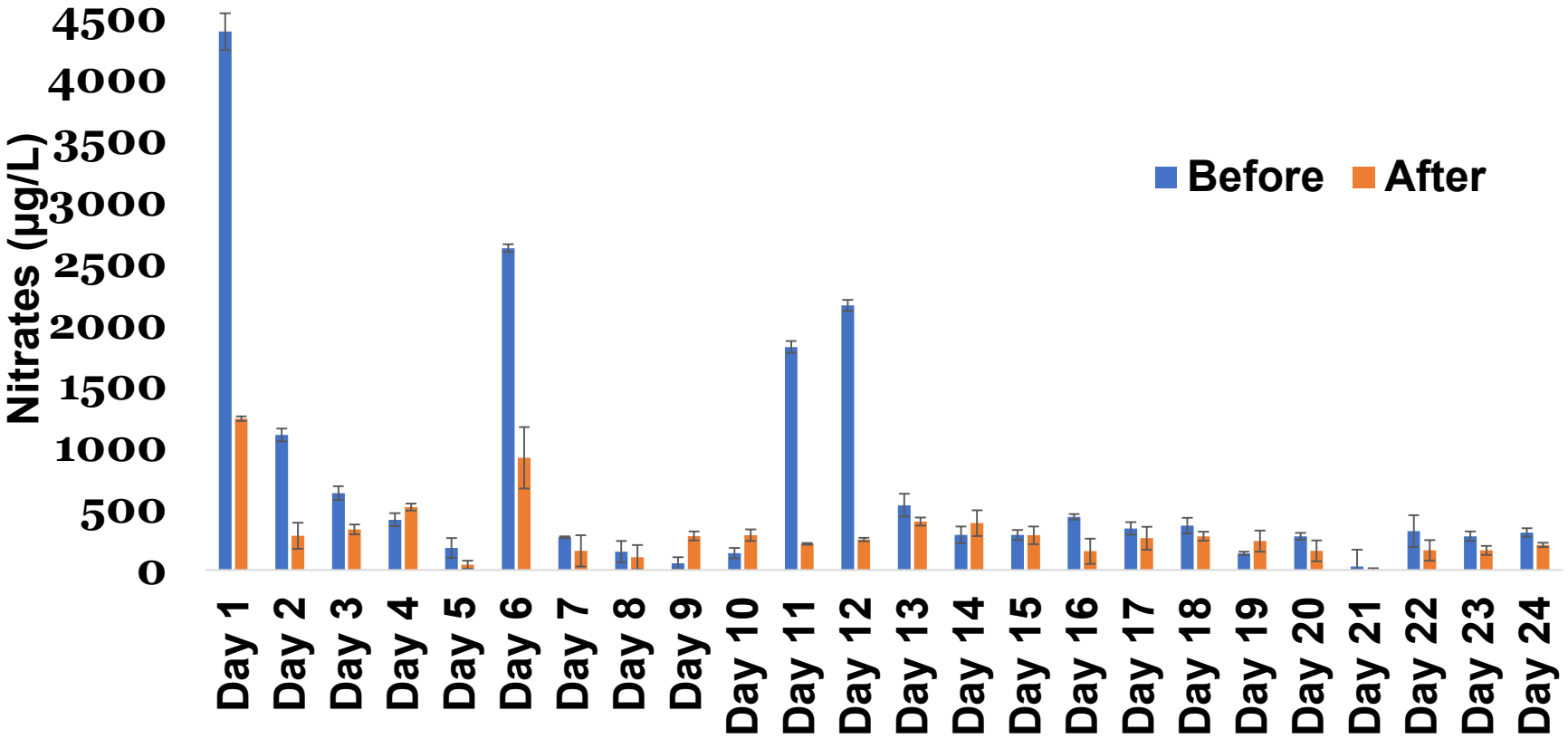

ISCO samplers
inflow
outflow
inflow
outflow
Flow rate: ~4L/min

Lion's Head On Site Testing



Lion's Head On Site Testing

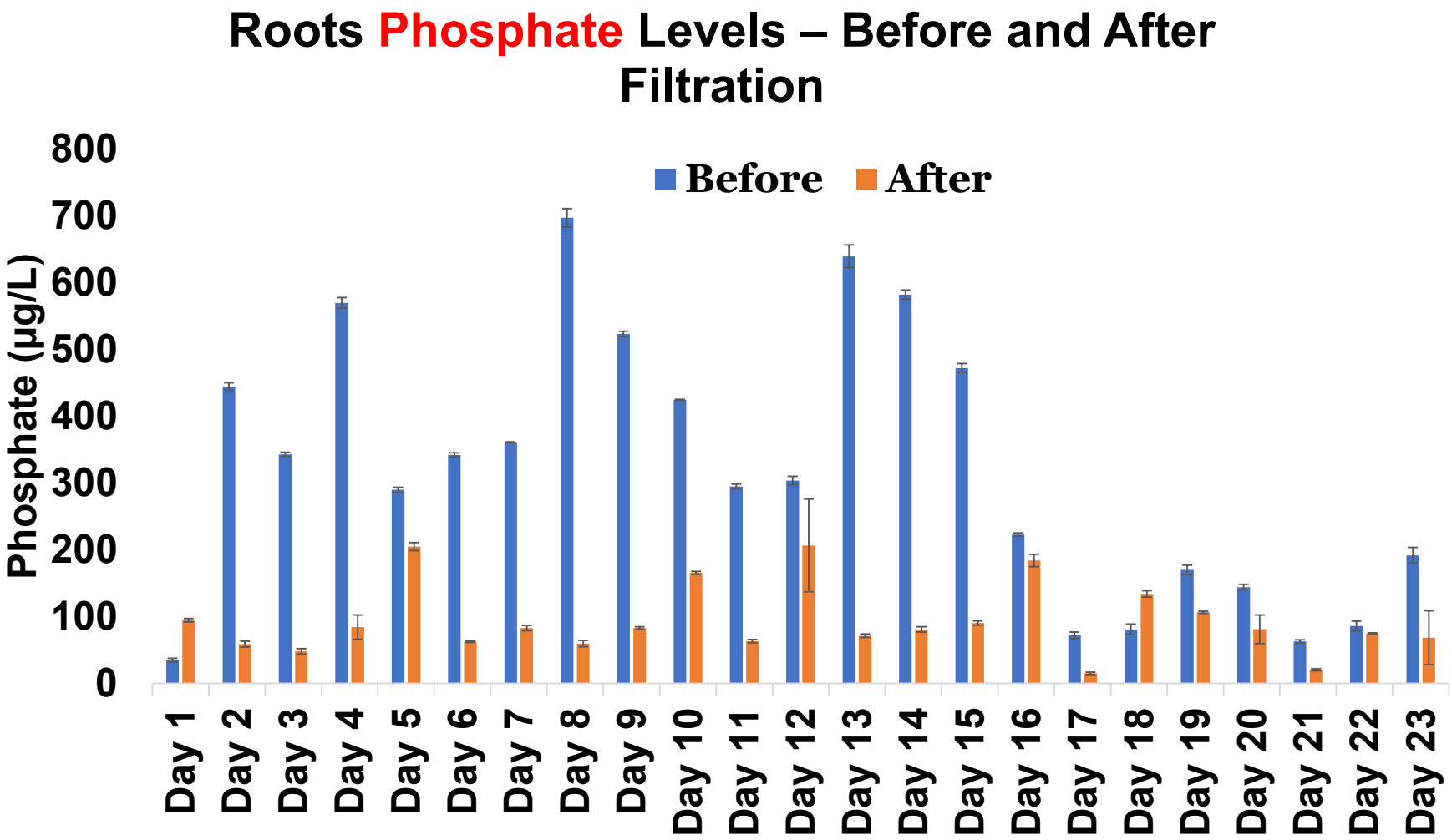
Iron-Sawdust Nitrate Levels – Before and After Filtration



Summary

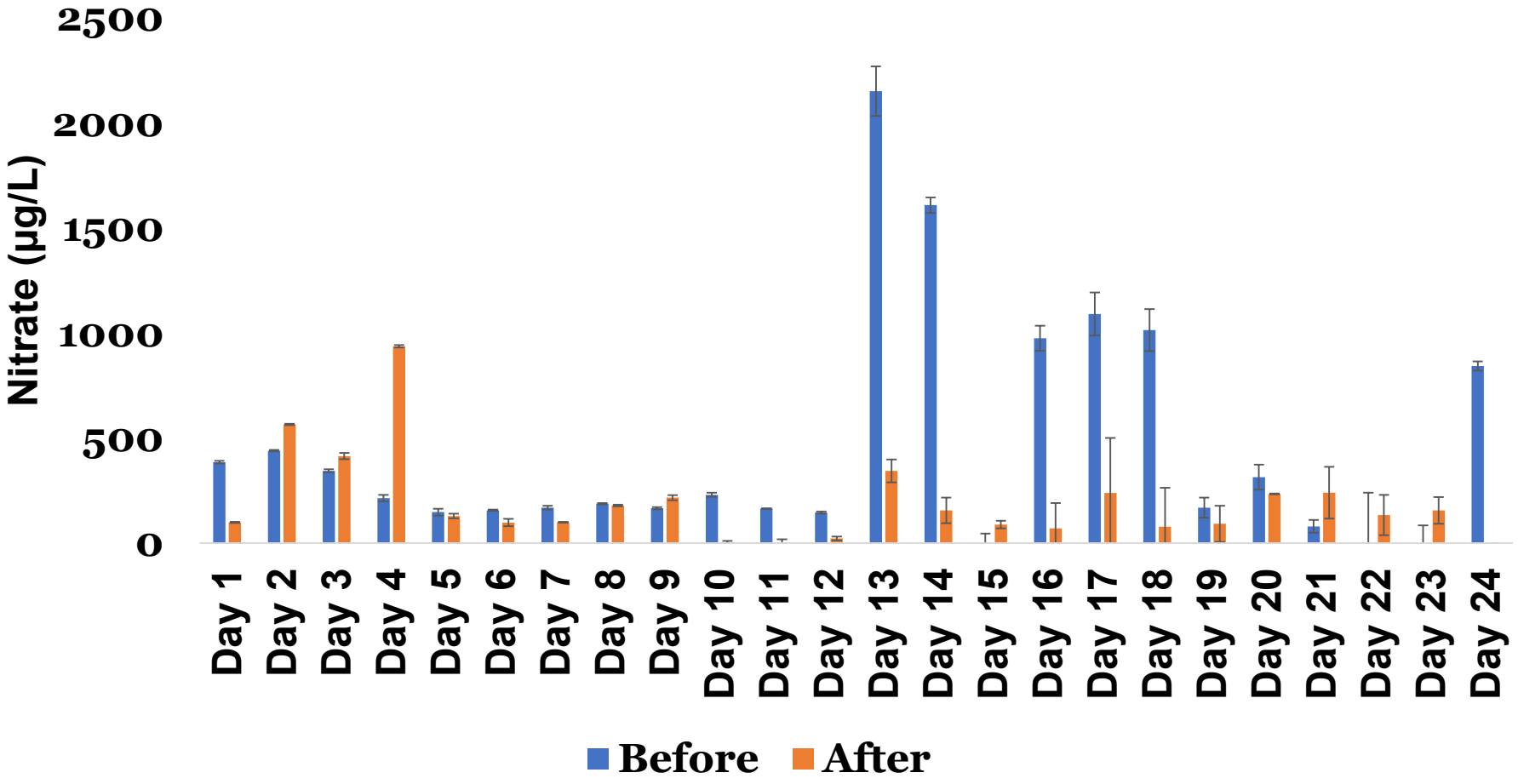
	Phosphate Removal (%)	Nitrate Removal (%)
Iron-Sawdust	26.2%	58.5%

Lion's Head On Site Testing



Lion's Head On Site Testing

Root Nitrate Levels – Before and After Filtration



Summary

	Phosphate Removal (%)	Nitrate Removal (%)
Iron-Sawdust	26.2%	58.5%
Plant Roots	70.8%	58.2%

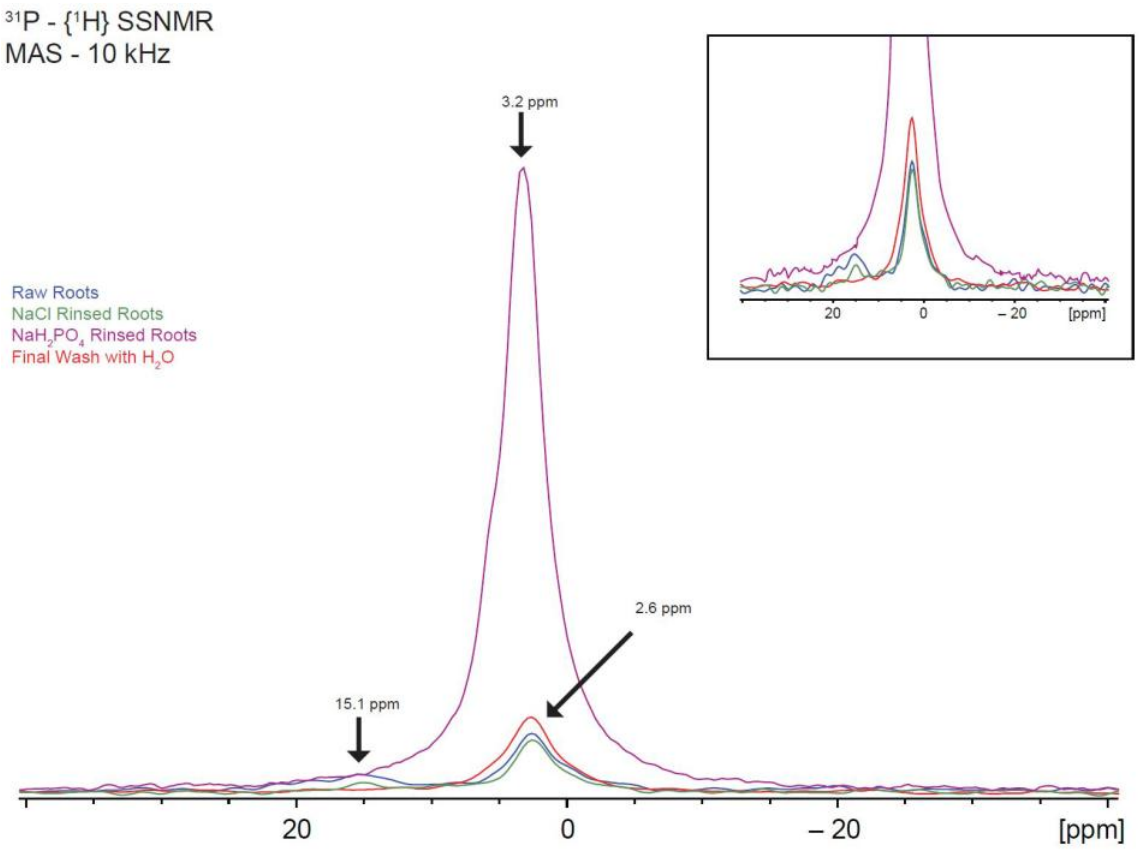
What in plant roots binds phosphate?

In collaboration with Dr. Robert Schurko, Austin Peach and Michelle Quan

Used solid state nuclear magnetic resonance

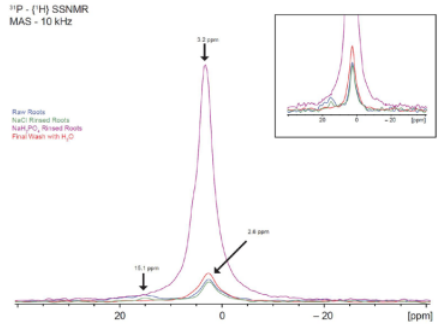
Probe the chemical environment of P atom

ssNMR of Plant Roots Throughout Binding-Elution Cycle

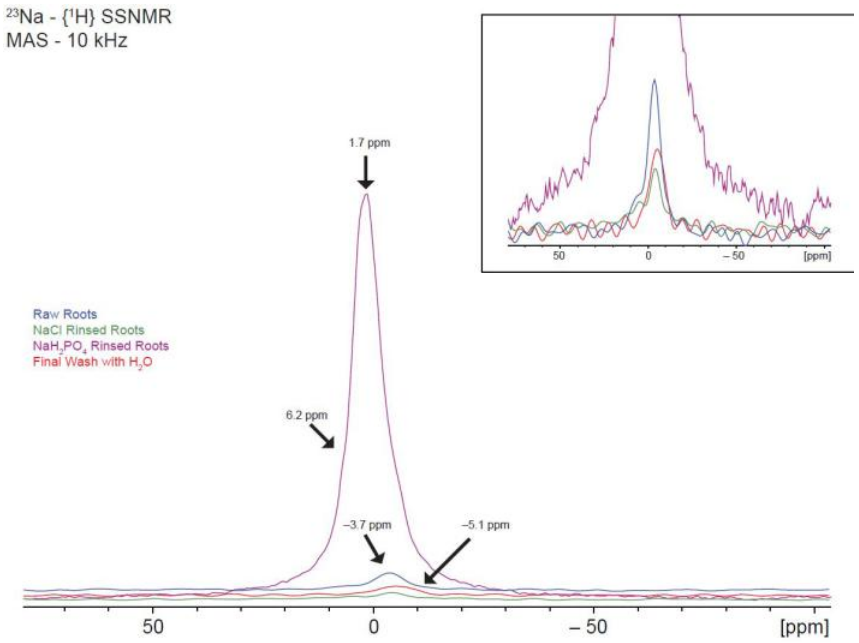


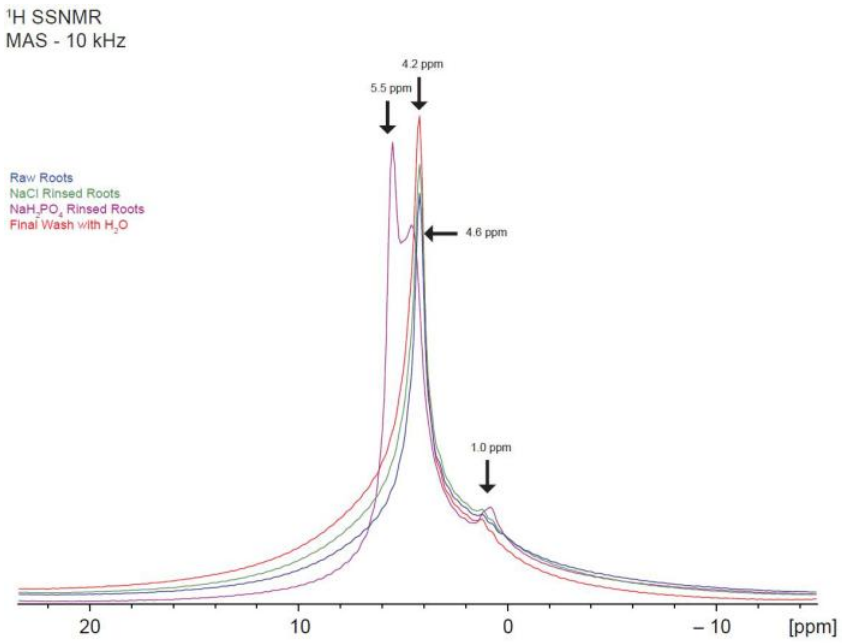
Demonstrates strong uptake and removal of phosphate throughout the binding-removal cycle

ssNMR of Plant Roots Throughout Binding-Elution Cycle

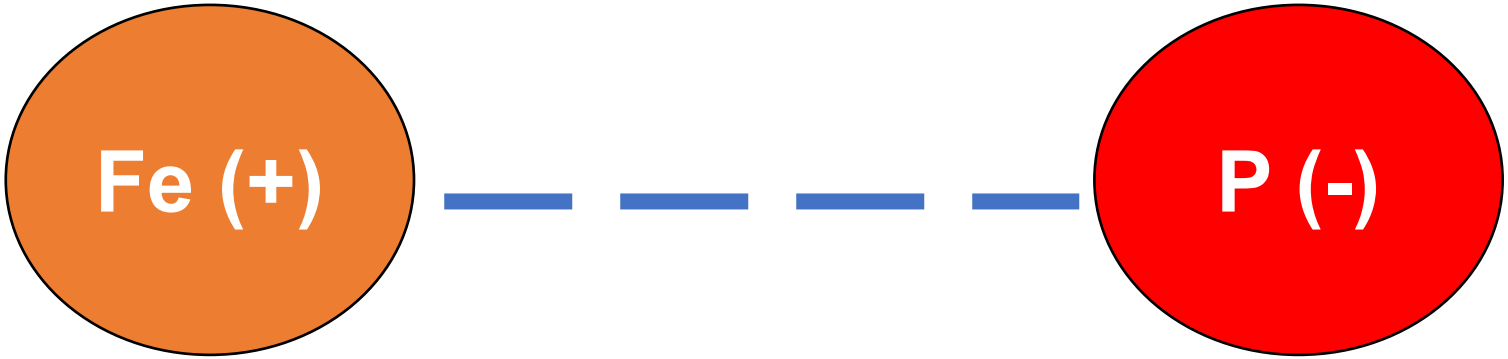


Not definitive on what binds P
Co-run Na and H atom NMR





Iron-chito – iron interacts with P

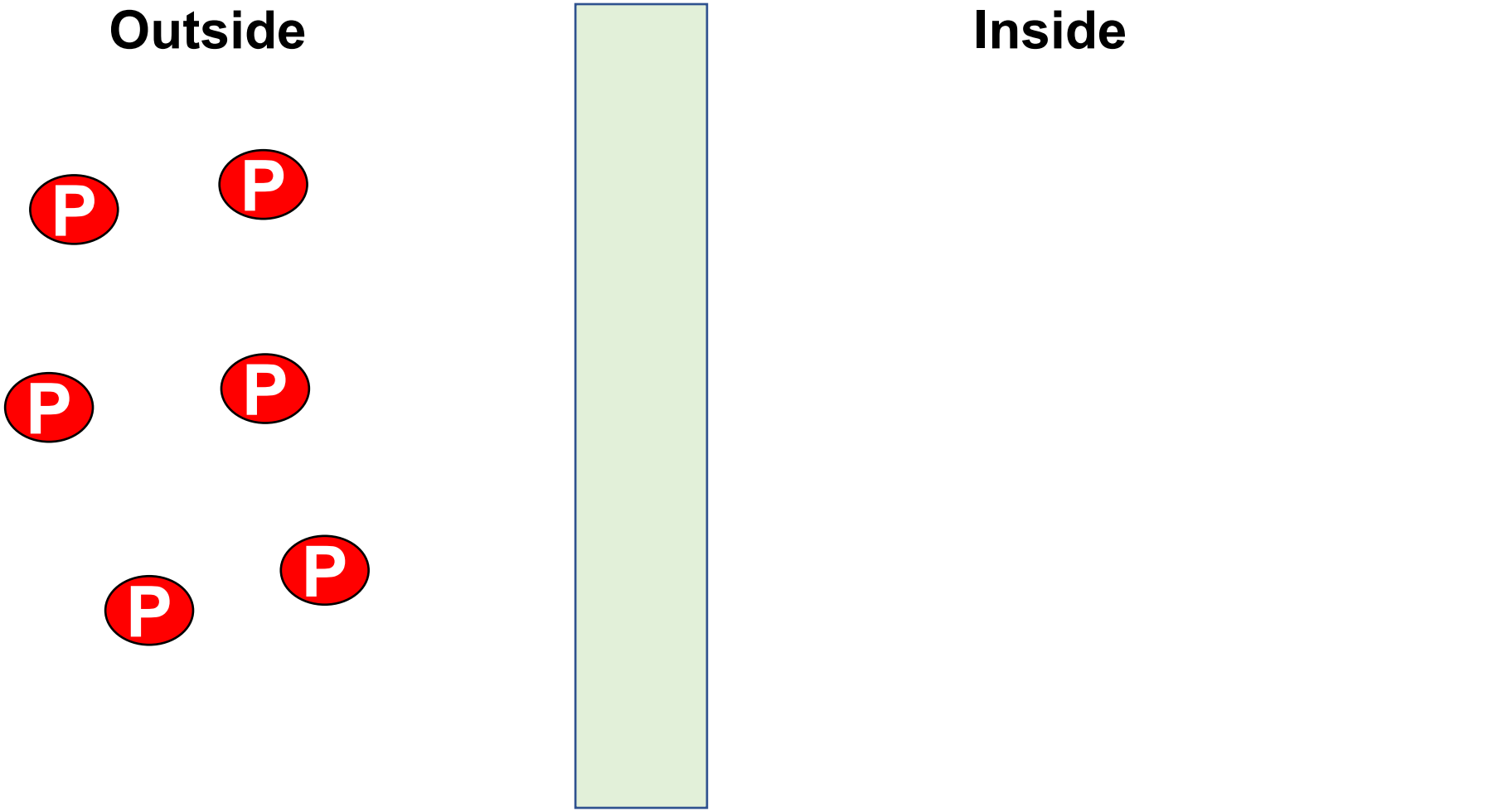


The NMR signal of metal – P interactions is distinct and not occurring in roots

NMR data suggests the formation of H-bond(s)

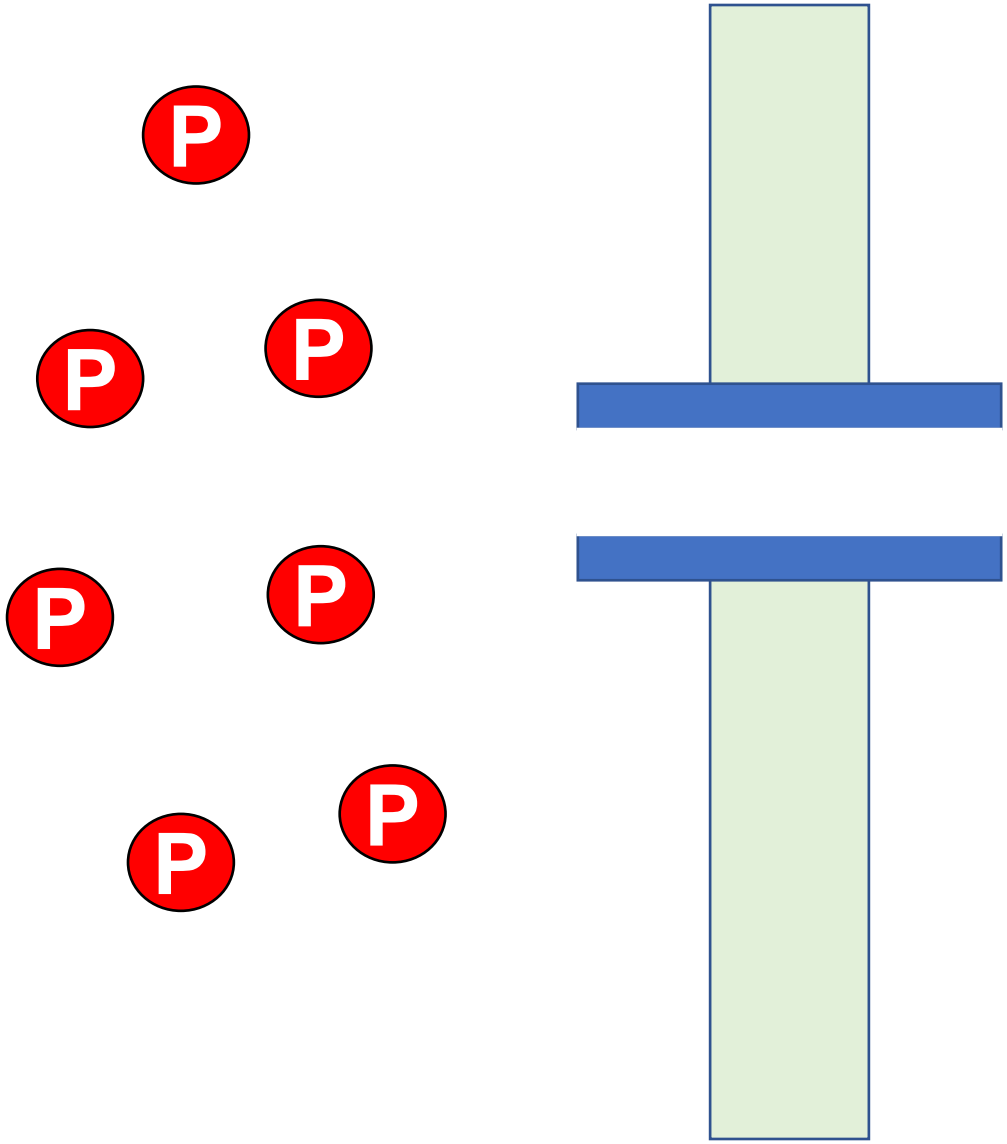
H-bonds suggest binding to a protein

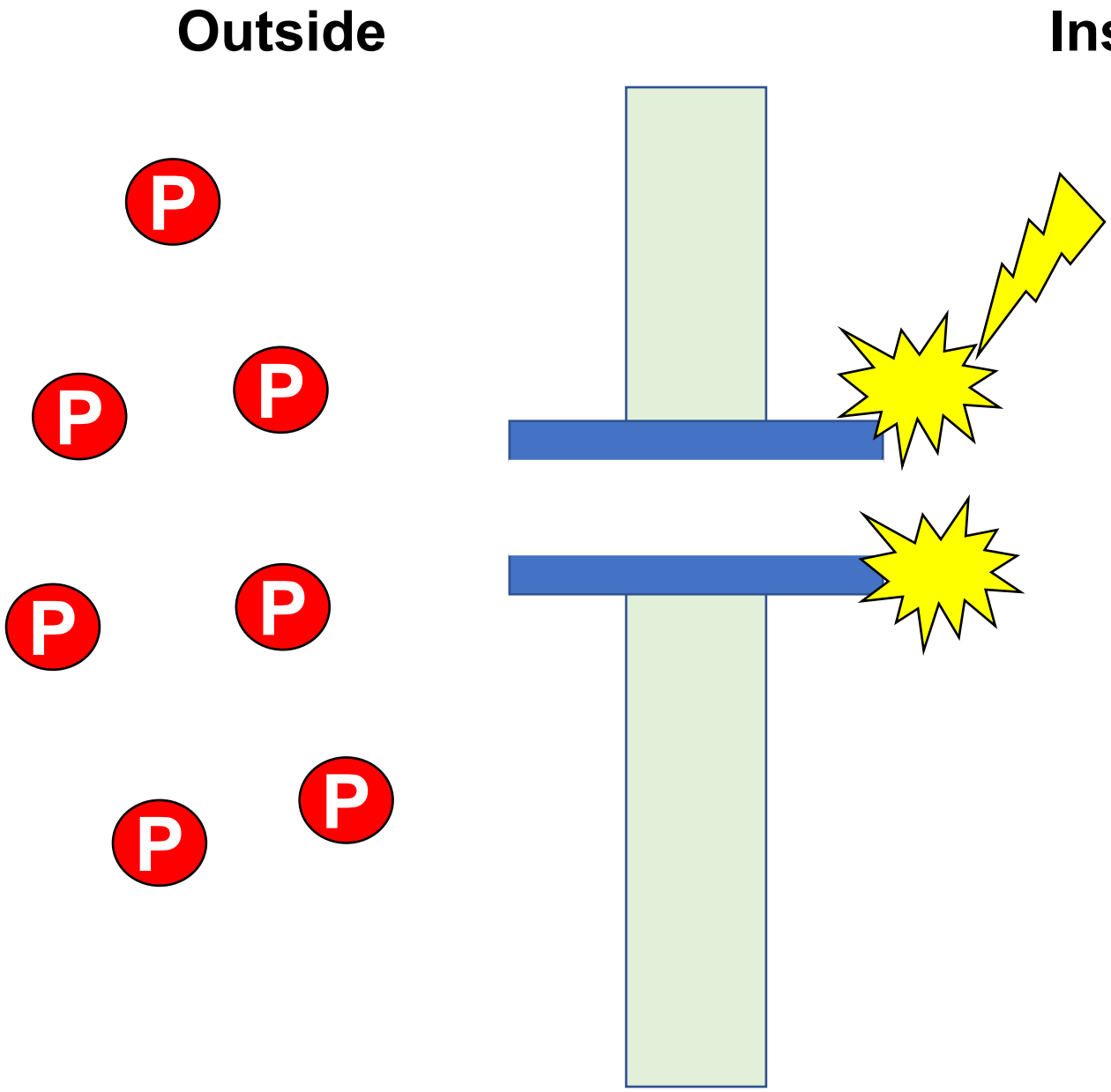
All organisms, including tomatoes have phosphate transporter proteins that internalize phosphate



Outside

Inside

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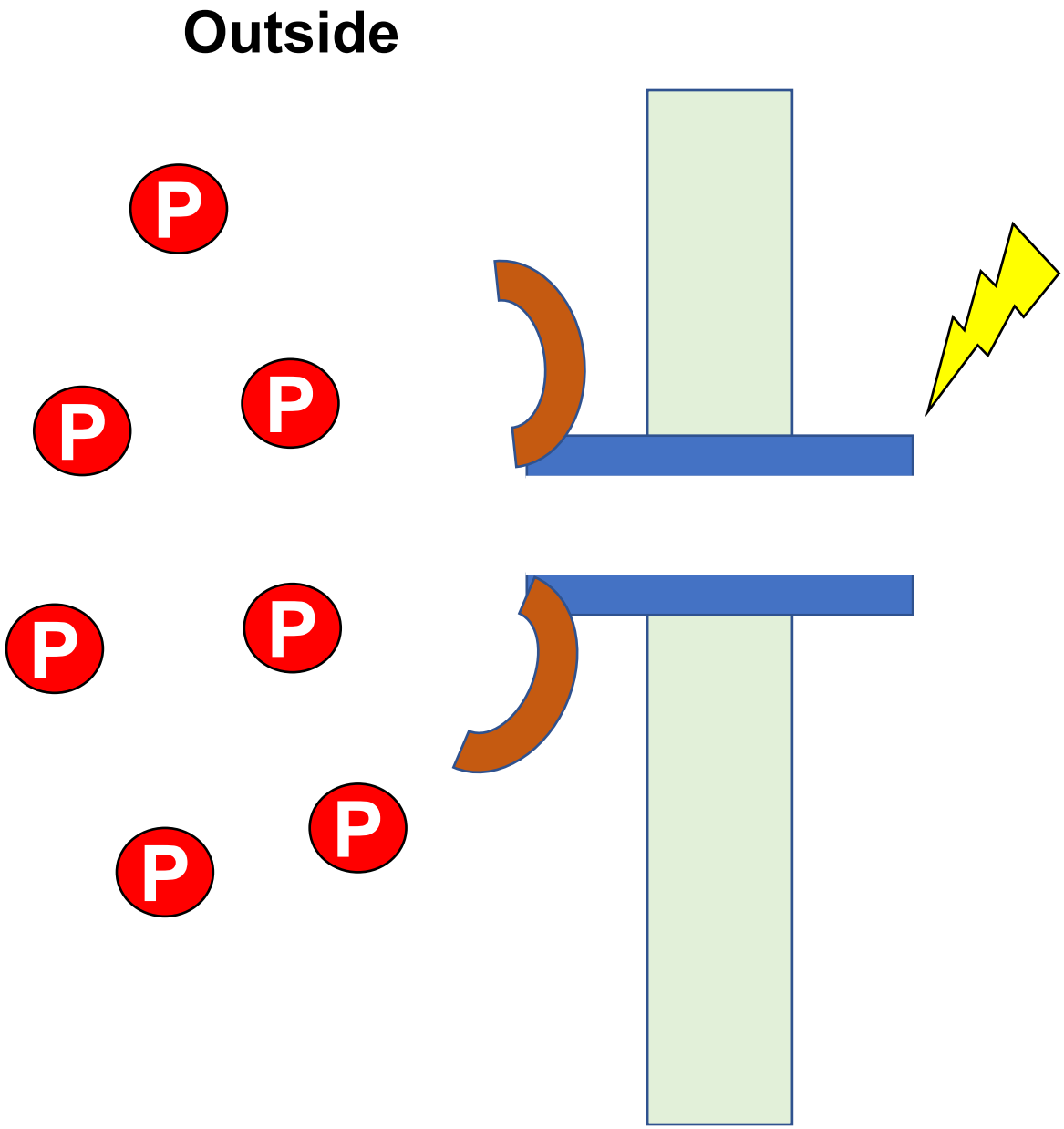
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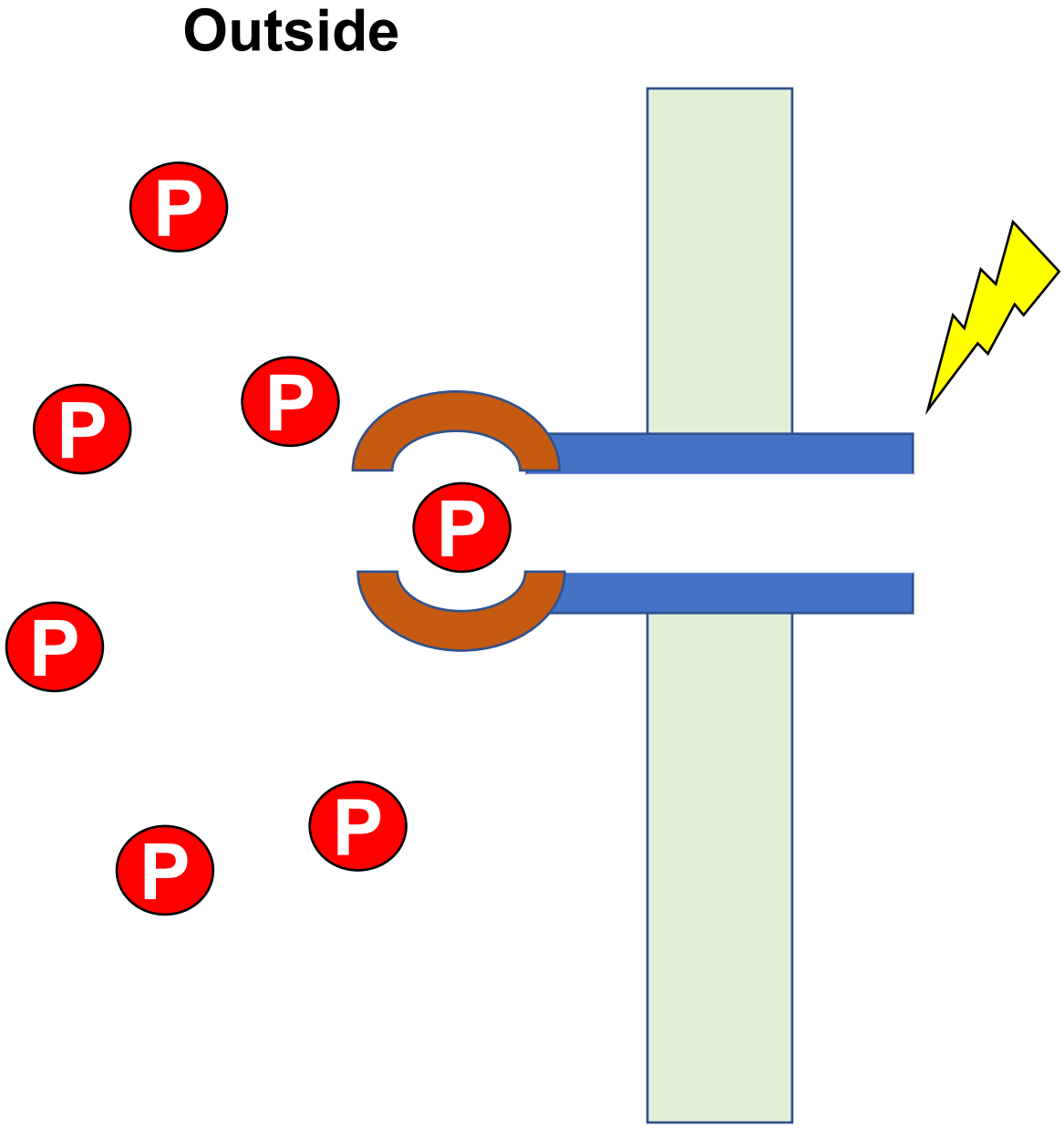
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Outside

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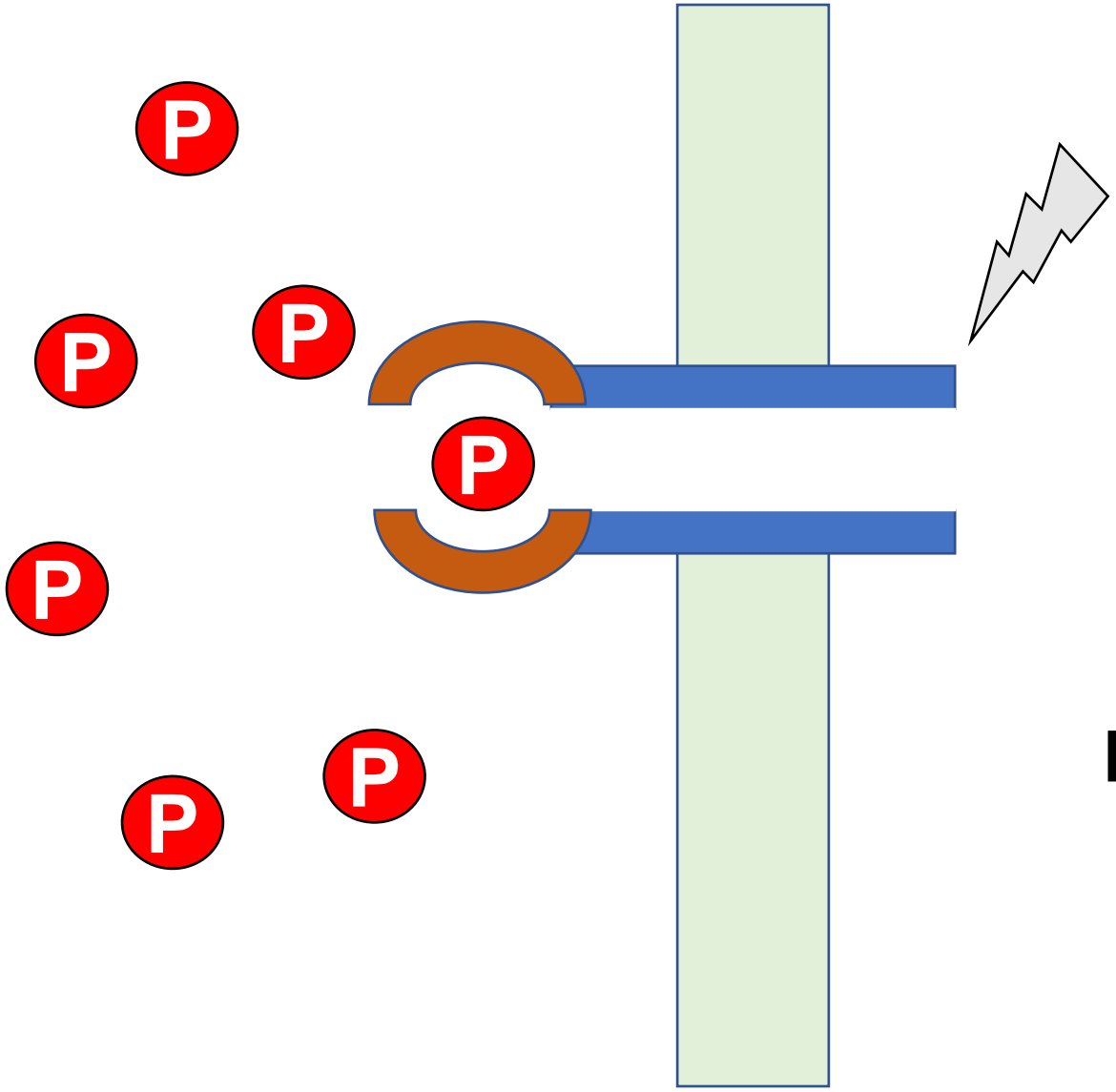
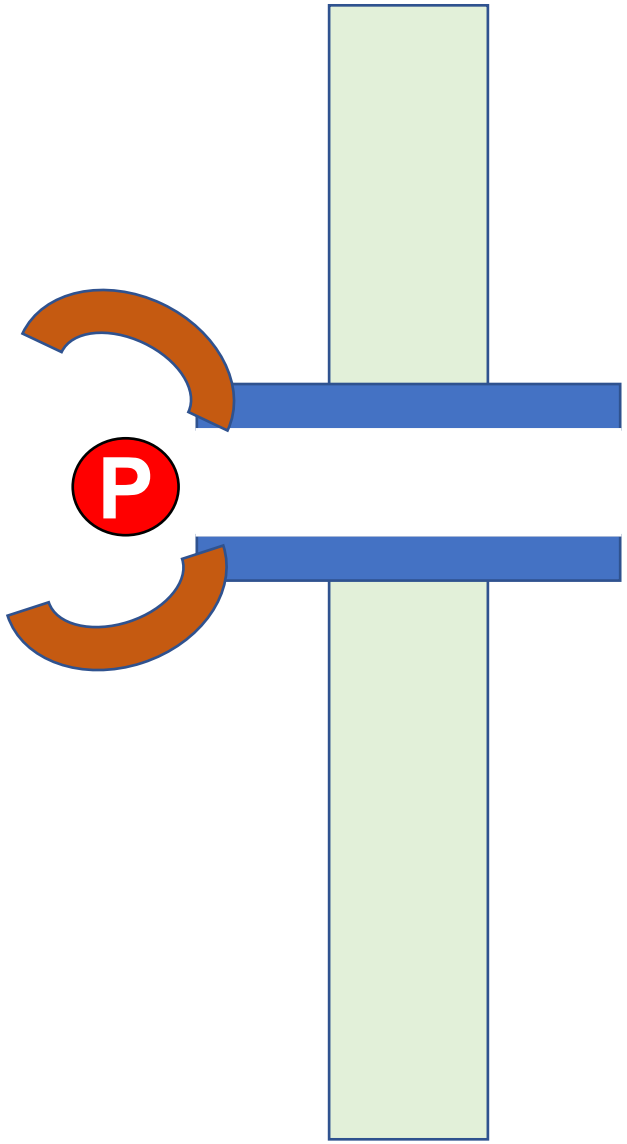


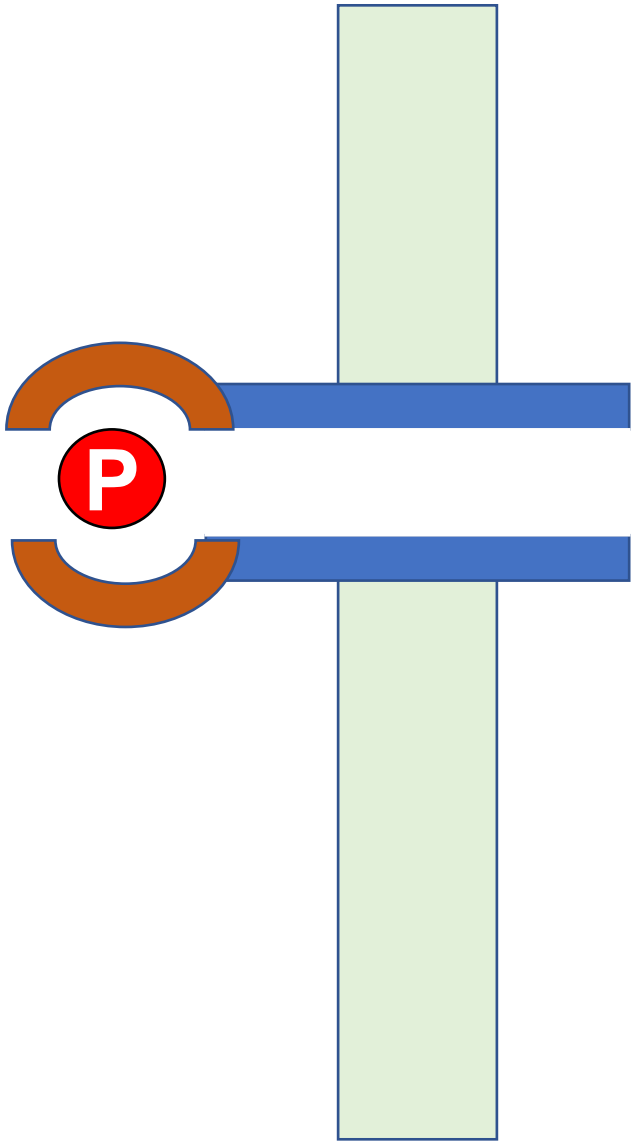
Our roots are dead

No energy available

But, the P binding protein works without energy

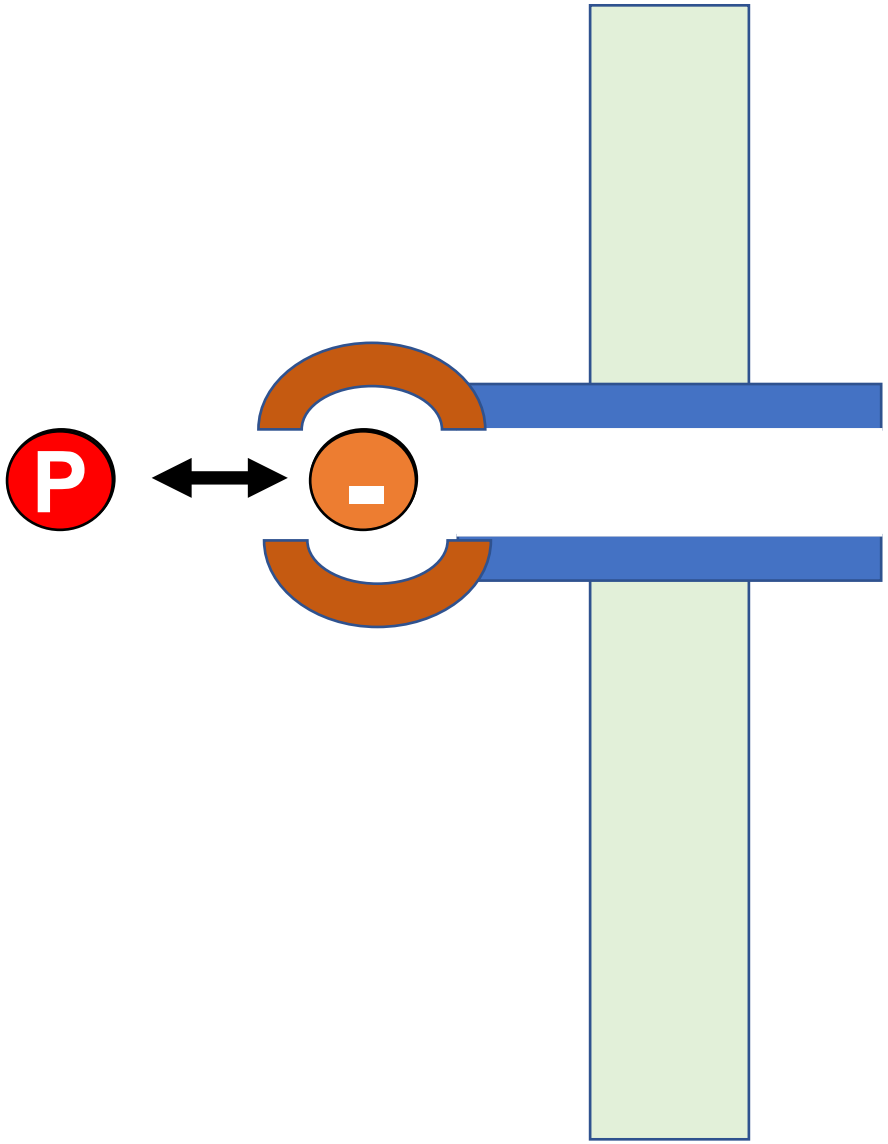


Phosphate binds



Phosphate binds

Induce release with counter anions (CMC or Cl)



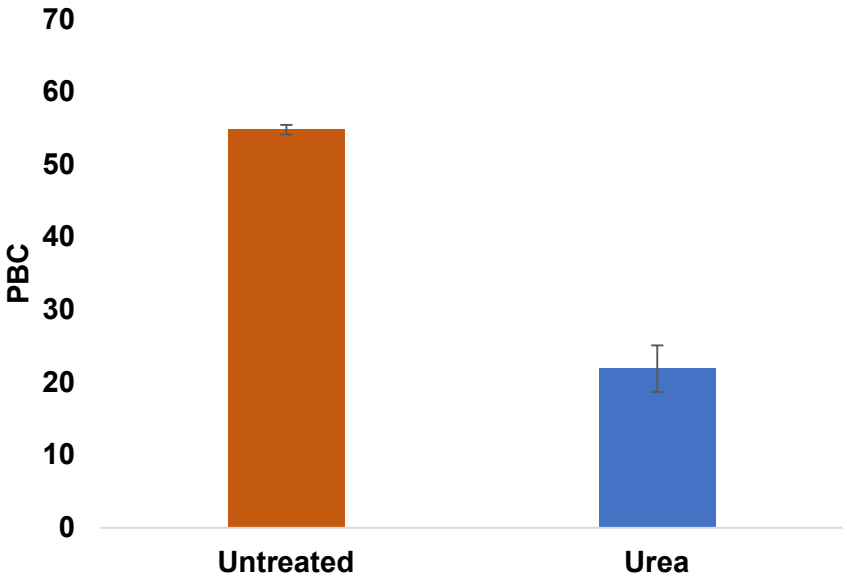
Phosphate binds

Induce release with counter anions (CMC or Cl)

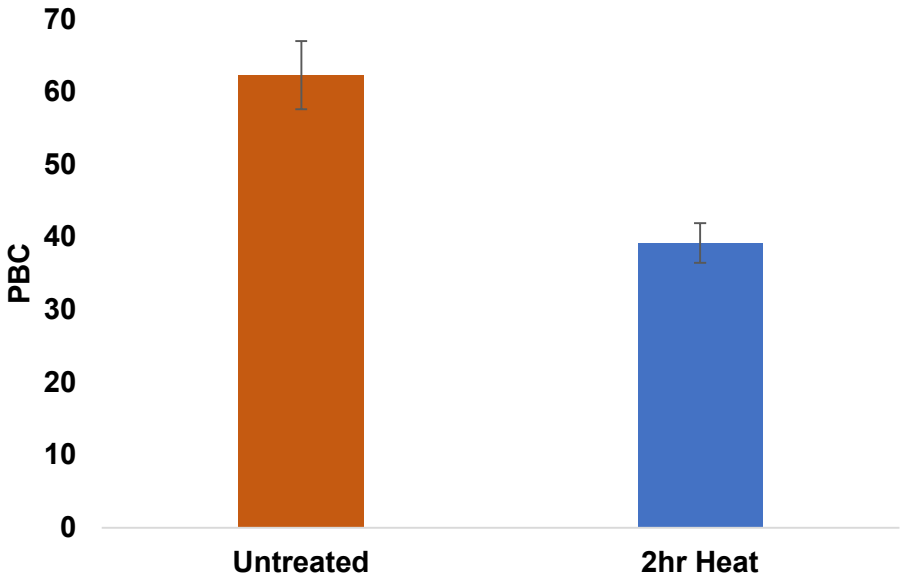
Repeat

Disrupt proteins with urea or heat treatment

6 M Urea



150 ° C



Current and Future Objectives

Phosphate transporter protein expression is regulated by phosphate in soil

Study the effect on phosphate treatment on later use of roots for remediation

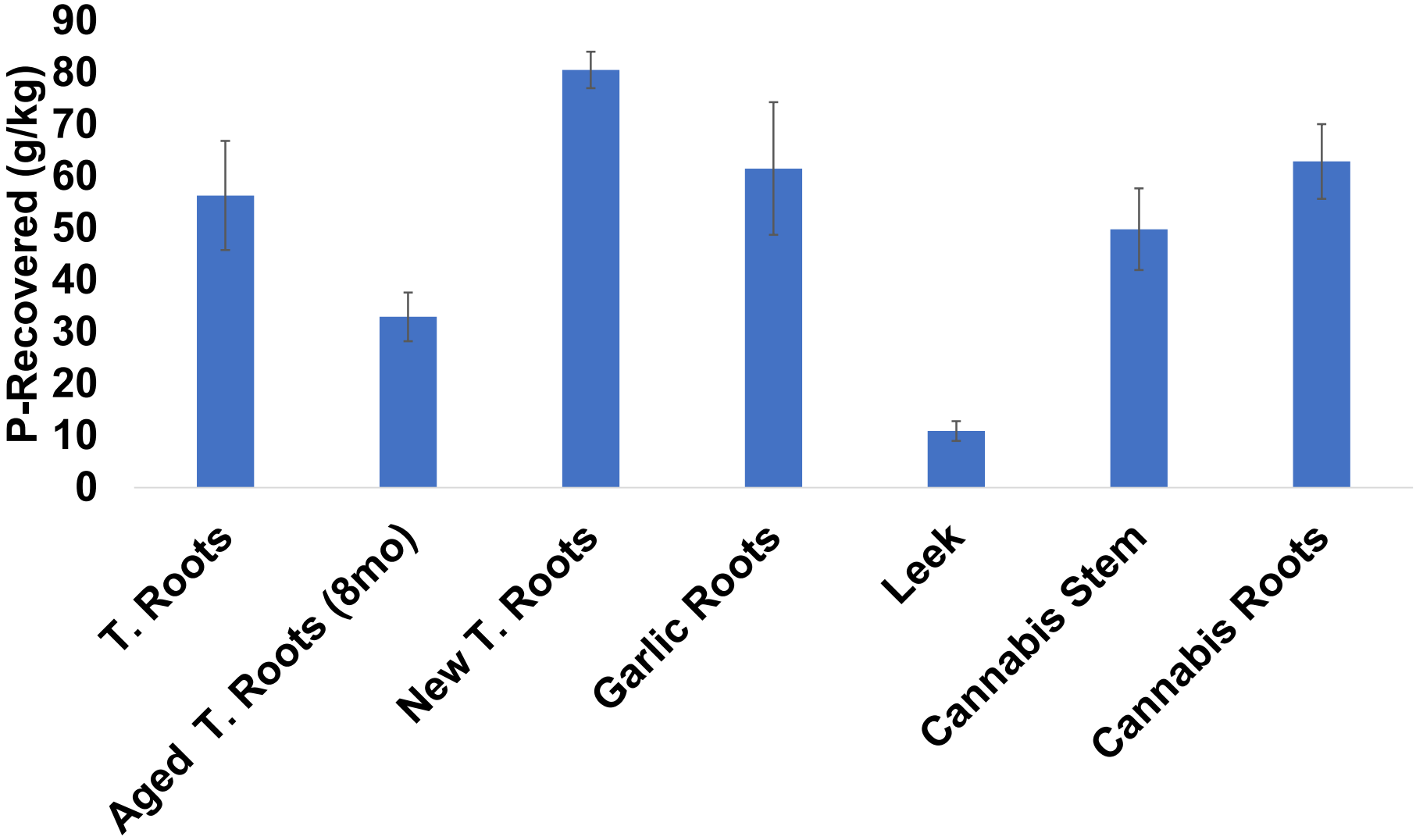
Working with Holy Names High School – STEM Academy (Ms Mary-Ellen Kavanaugh)

Current and Future Objectives

P and No P roots

Flow rates

Different Ages and Types of Plant Roots



Current and Future Objectives

Study different plant roots ie. cucumber

Study the degradation in binding capacity overtime

Acknowledgements:

WECO2 Parks: Matthew Posthumus, Sergey Postnikov

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Katherine McLeod, Amanda Stanger, Elizabeth Thorn and Neils Munk

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Thank you very much for listening
Questions?
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