Phosphorus Transformation in Soil

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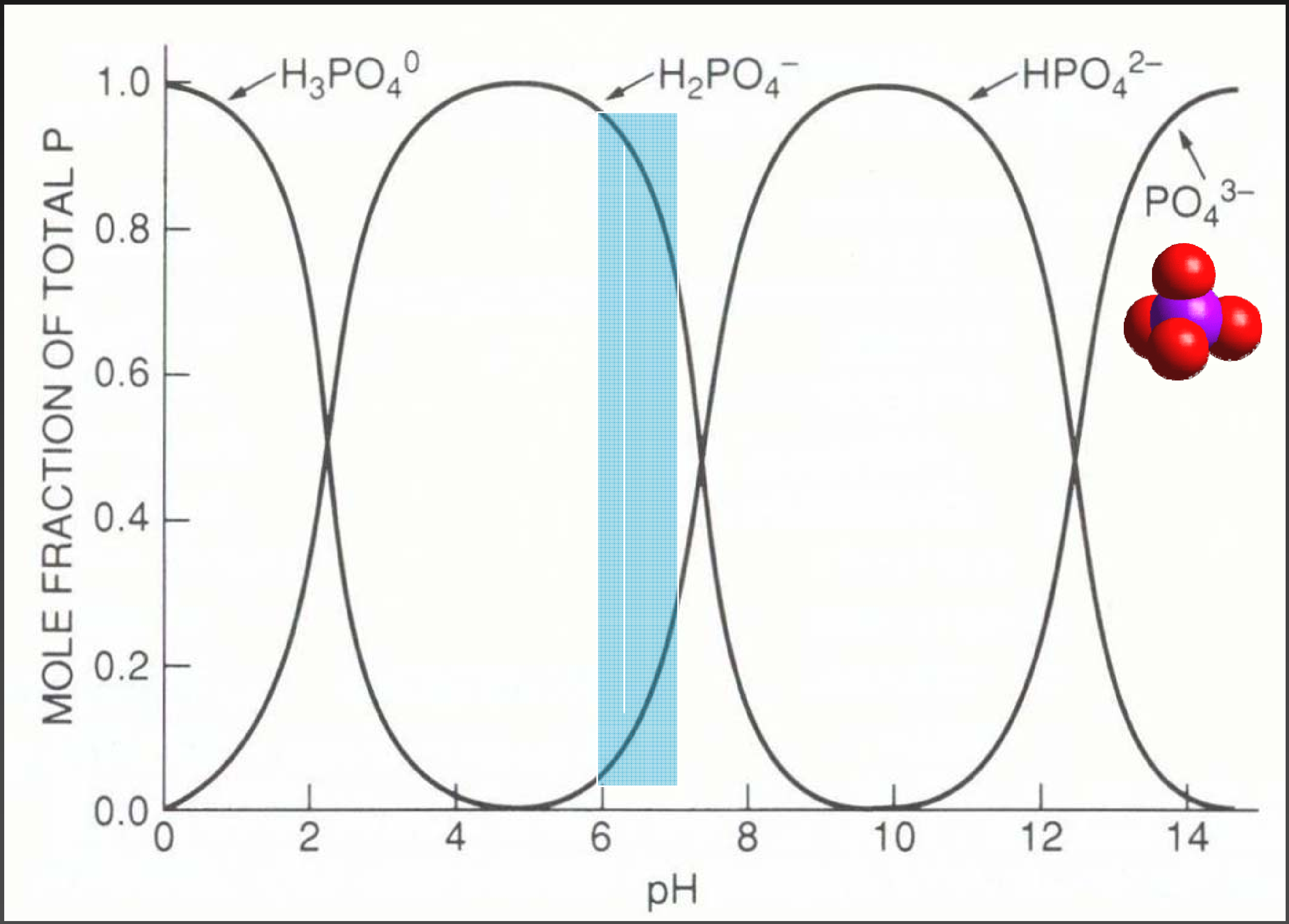
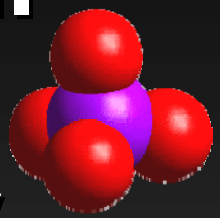
Dissociated anions of H_3PO_4 in water at various pH values

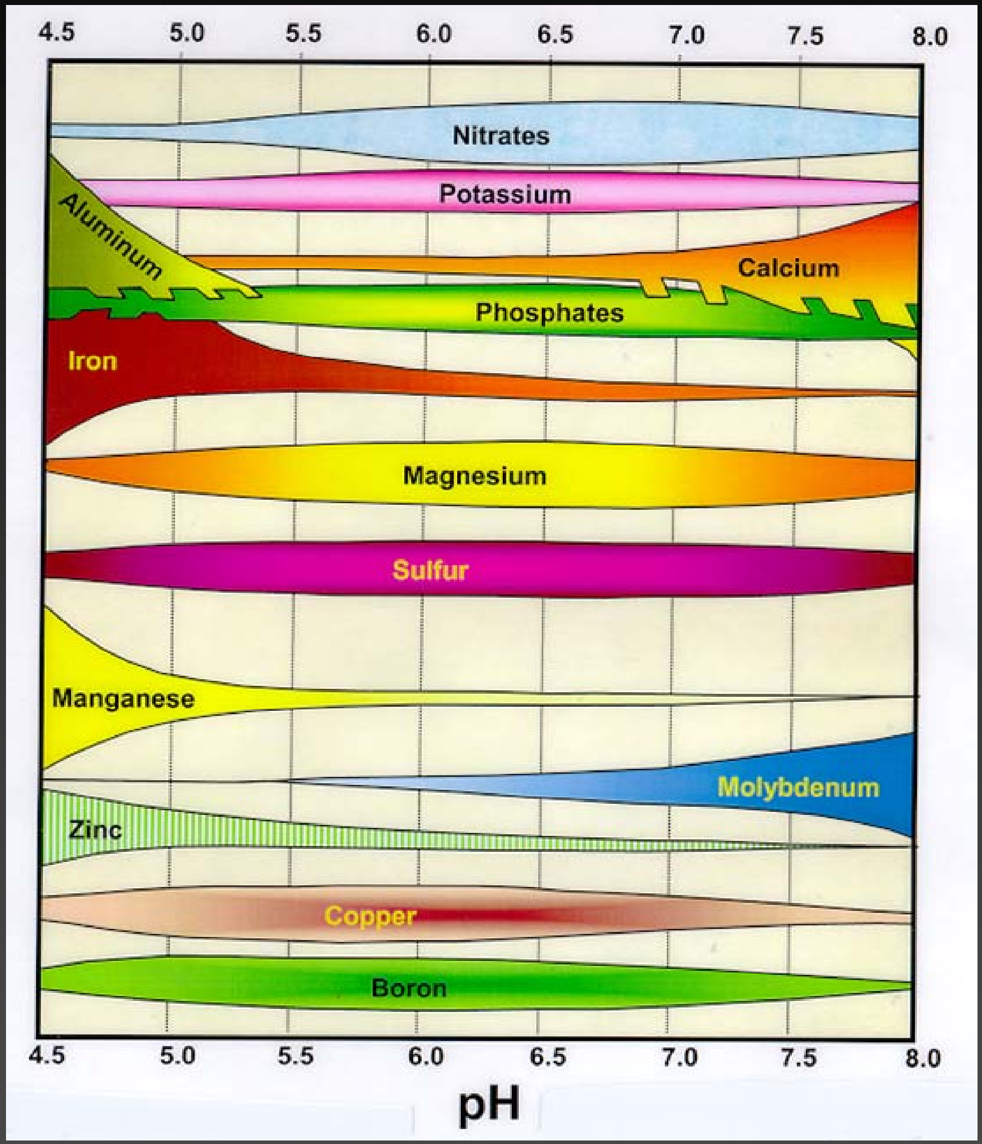


Effect of soil pH on P availability

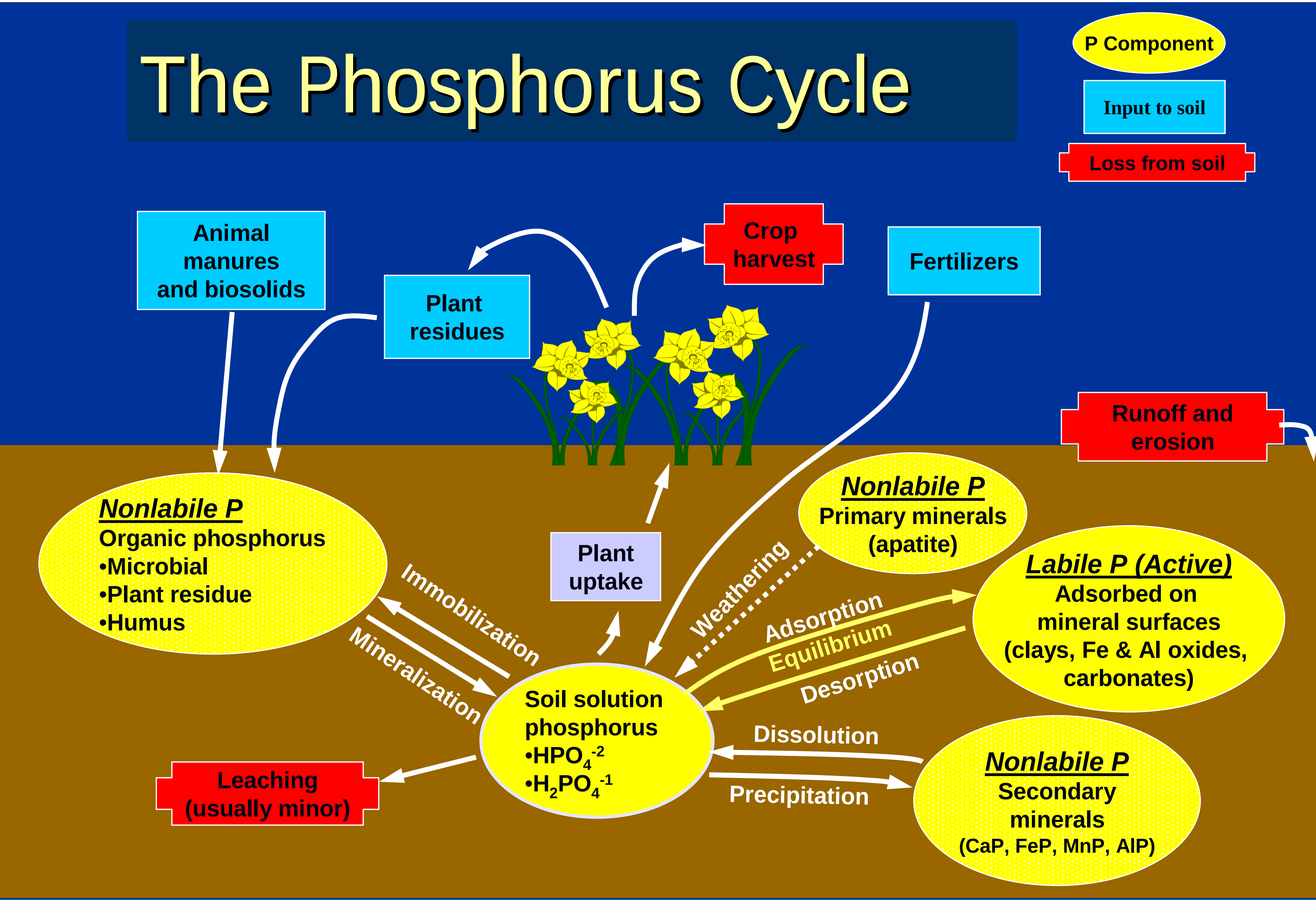


Soil pH affects plant availabile P:

- **Below pH 6.0, P becomes tightly bound with aluminum and iron oxides.**
- **Above pH 7.0, P becomes tightly bound with calcium.**



At pH 6.5, ~70% of solution P is $H_2PO_4^-$



The Phosphorus Cycle
P Component
Input to soil
Loss from soil
Animal manures and biosolids
Plant residues
Crop harvest
Fertilizers
Runoff and erosion
Nonlabile P
Organic phosphorus
•Microbial
•Plant residue
•Humus
Plant uptake
Immobilization
Mineralization
Weathering
Nonlabile P
Primary minerals (apatite)
Labile P (Active)
Adsorbed on mineral surfaces (clays, Fe & Al oxides, carbonates)
Adsorption
Equilibrium
Desorption
Soil solution phosphorus
•HPO4-2
•H2PO4-1
Dissolution
Precipitation
Nonlabile P
Secondary minerals
(CaP, FeP, MnP, AlP)
Leaching (usually minor)

Common P Minerals found in Soils
(listed in order of decreasing solubility)

Acidic Soils

- **Variscite - $AlPO_4.2H_2O$**
- **Strengite - $FePO_4.2H_2O$**

Neutral and Calcareous Soils

- ✓ **Dicalcium phosphate dihydrate (DCPD): $CaHPO_4.2H_2O$**
- ✓ **Dicalcium phosphate (DCP): $CaHPO_4$**
- x **Octacalcium phosphate (OCP): $Ca_4H(PO_4)_3$.2.5H2O**
- x **Tricalcium phosphate (TCP): $Ca_3(PO_4)_2$**
- x **Hydroxyapatite (HA): $Ca_5(PO4)_3OH$**
- x **Fluorapatite (FA): $Ca_5(PO_4)_3F$** ***(least soluble)***

P minerals in neutral and calcareous Soils:

✓Dicalcium phosphate dihydrate (DCPD)

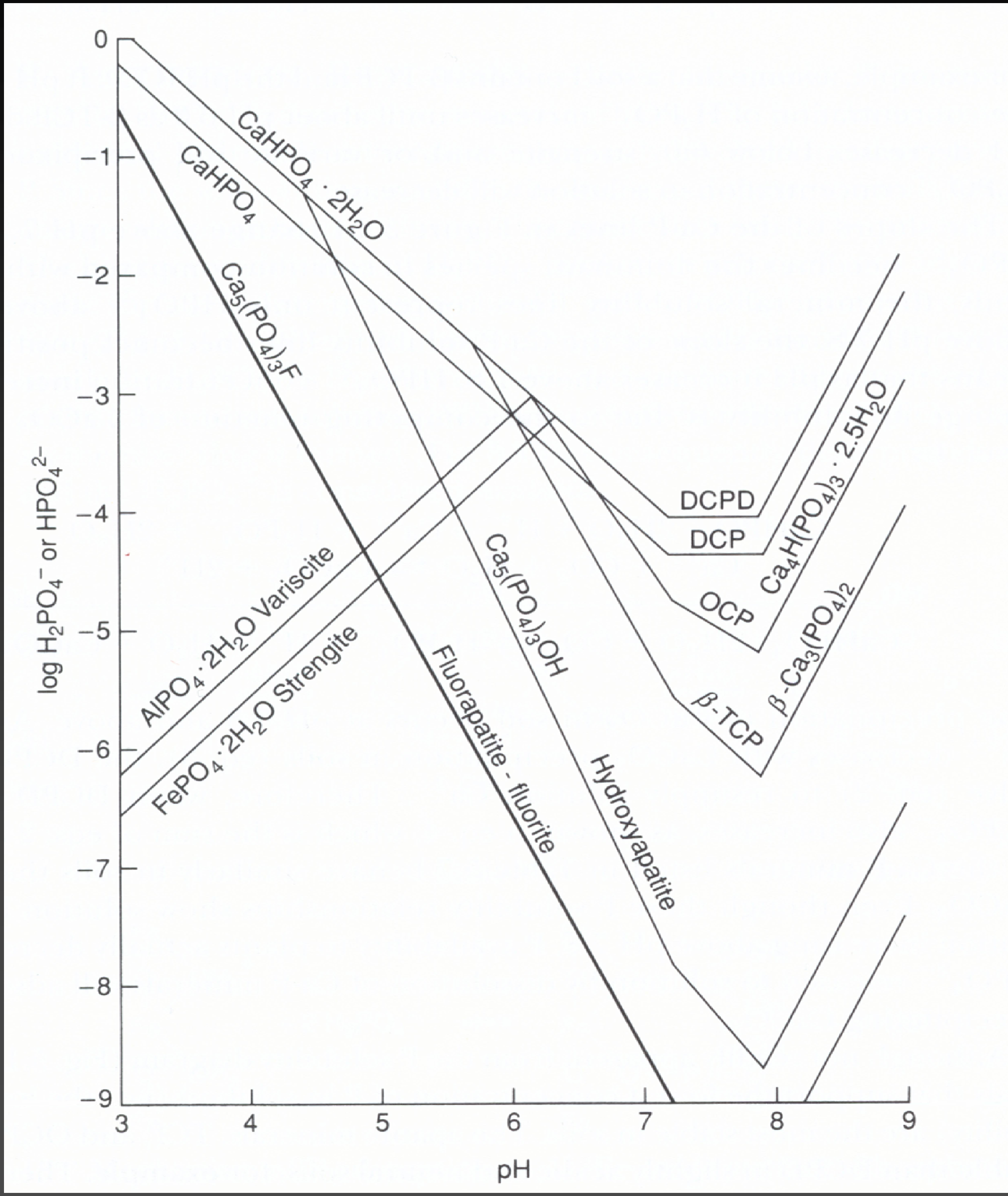
✓Dicalcium phosphate (DCP)

x Octacalcium phosphate (OCP)

x Tricalcium phosphate (TCP)

x Hydroxyapatite (HA)

x Fluorapatite (FA)



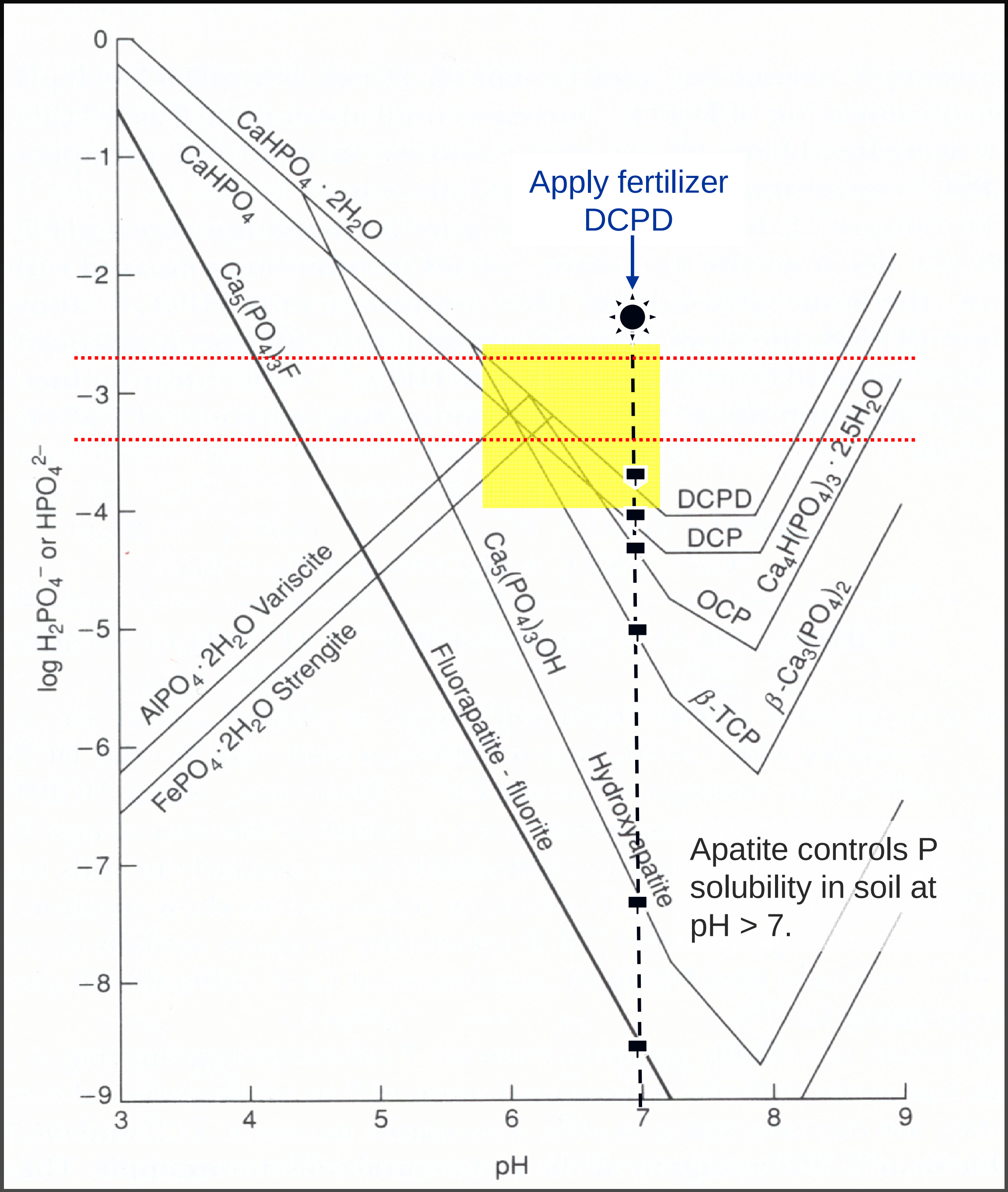
If DCPD is added to soil, then DCP will form first by dissolution of DCPD.

- **Then, DCP will dissolve and OCP/TCP will precipitate.**

- **Finally, OCP or TCP will "slowly" dissolve, hydroxyapatite will precipitate.**

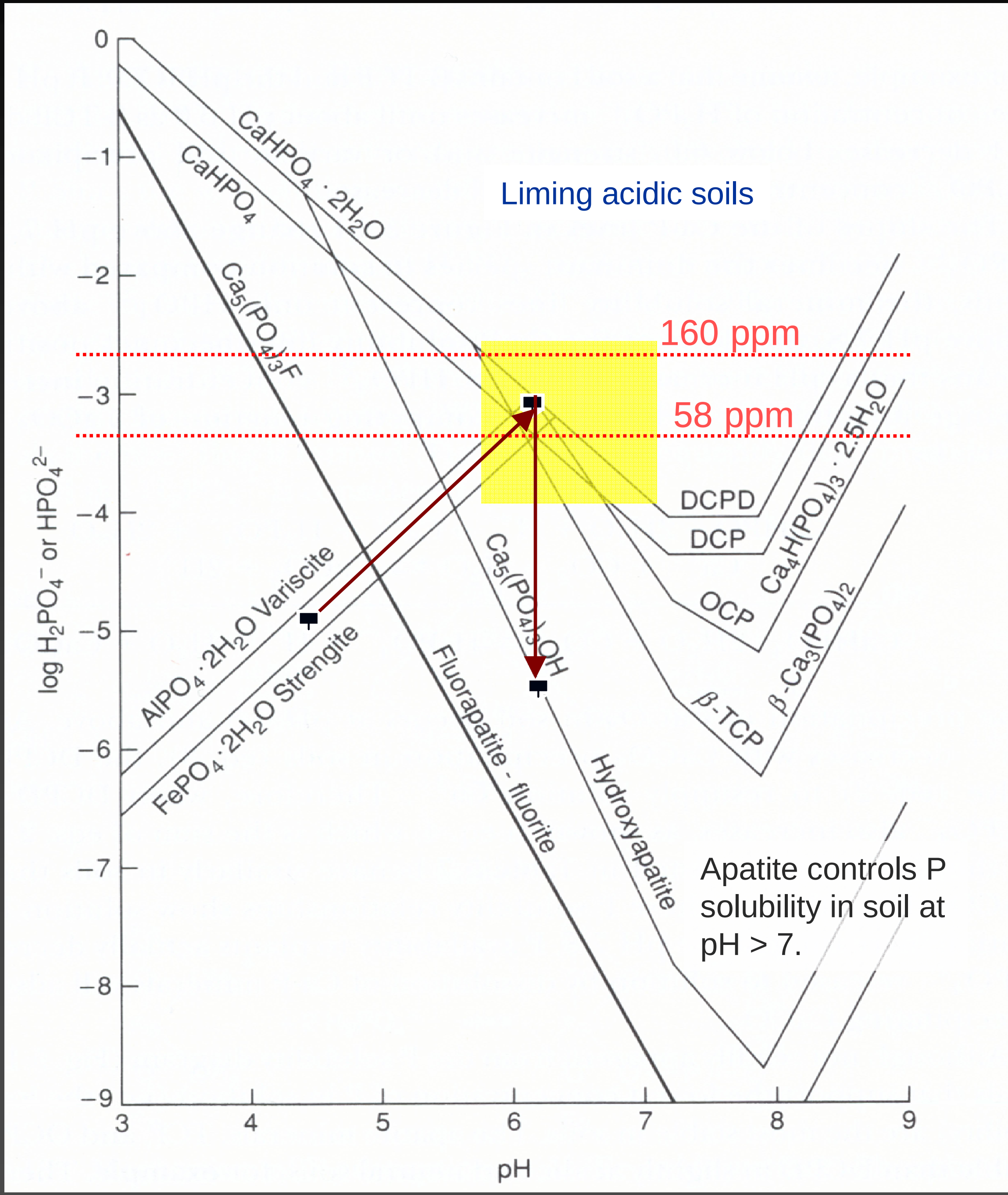
- ***Continual fertilizer application will maintain P supersaturation with respect to OCP or TCP.***

- ***Precipitation of P with Ca compounds and plant uptake could inhibit the formation of OCP or TCP.***



Adding lime to acid soils will increase the pH and will solubilize Fe and Al oxides. P will be released and become available to plant.

- **Depending on the soil pH and Ca compounds, hydroxyapatite will eventually precipitate.**



Movement and availability of phosphorus fertilizer applied through drip irrigation systems

OBJECTIVES

- Compare movement and availability of phosphorus fertilizers in soil.
- Demonstrate changes in soil phosphorus availability over time.
- Demonstrate pattern of phosphorus movement in soils relative to the drip tape.

METHODS

- Study was conducted near Mendota, California.
- P fertilizers were applied at 50 lbs P_2O_5 / ac:
  - *Phosphoric acid*
  - *NH_4-Polyphosphate*
  - *Actagro-P (Organically complexed, NH_4-P).*
- Fertilizers were applied through drip tape in ½ inch of water on July 23 and 24, 2006.
- Fertilizer treatments were arranged as a randomized block design with 4 replicates.

Treatment list

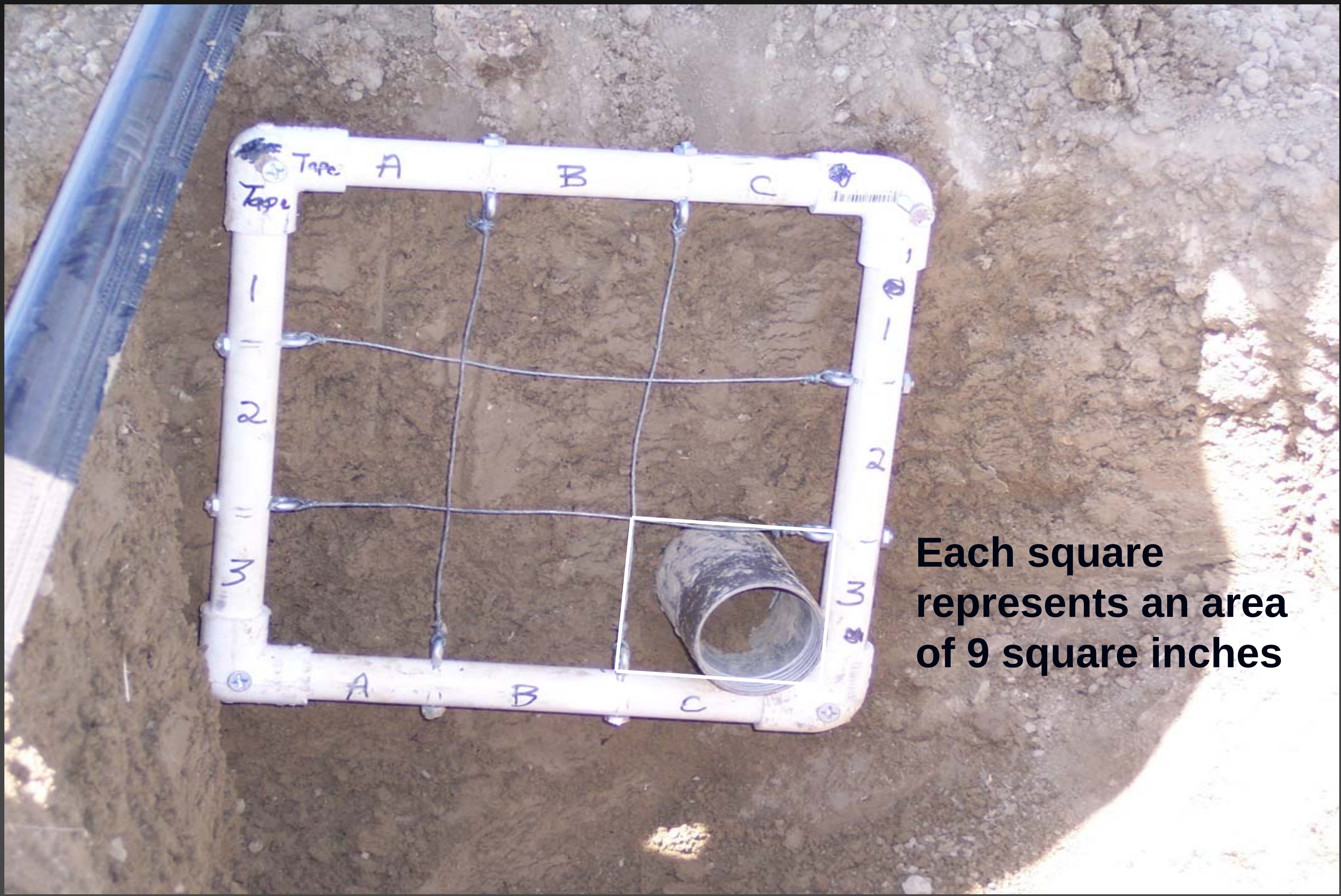
P fertilizer treatments	N lbs/ac	P lbs/ac
Phosphoric acid	0	21.8
Ammonium polyphosphate	7	21.8
Organically-complexed, reacted NH_4 phosphate	7	21.8
Untreated control (water)	0	0

Collecting soil samples

Soils were collected 2, 14, 28 and 42 days after the application.

Soils were collected along a 3x3 grid, at the depths of 0-3, 3-6 and 6-9 inches, and at the distances of 0-3, 3-6 and 6-9 inches from the drip line.

Soil sampling grid



Each square represents an area of 9 square inches

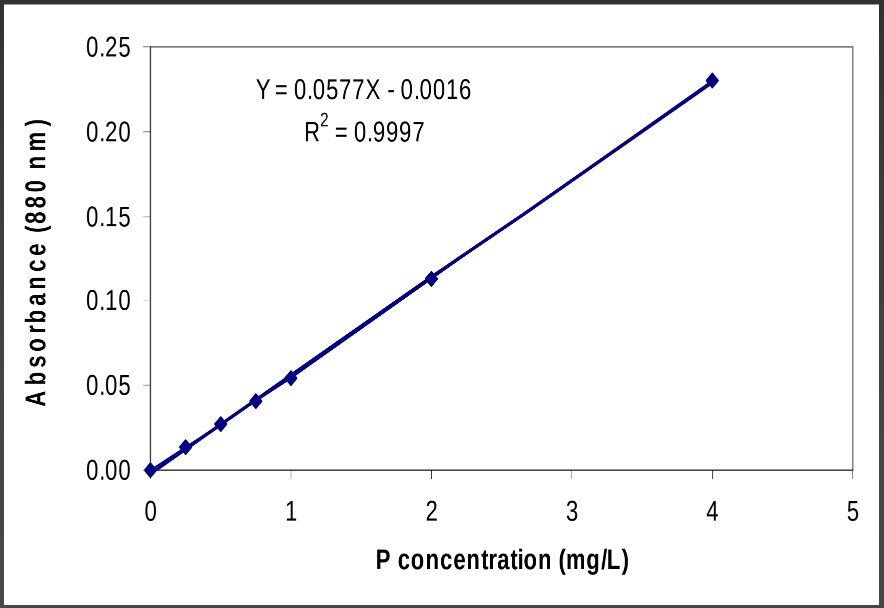
Soil P Extraction- *Fractionation Steps*

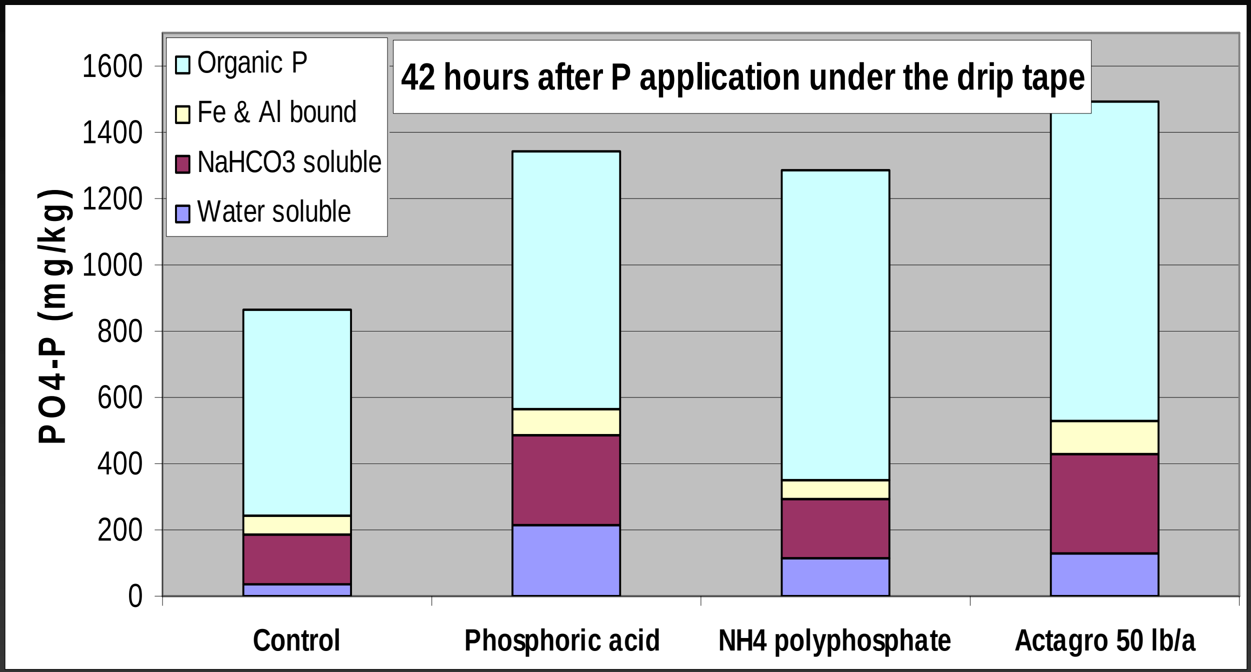
1. **Soluble P fraction**: H_2O soluble
2. **Adsorbed P and highly soluble Ca-P:**
   phosphates fraction (Plant available or Olsen-P):
   (0.27 M Na citrate + 0.11 M $NaHCO_3$ extract)
3. **Amorphous Fe & Al oxides fraction:**
   1 M NaOH extracts (cold)
4. **Organic P fraction:**
   1 M NaOH + digestion for 60 min
5. **Residual P**: 1M HCl extract
   (Kjehldal micro-digestion block)

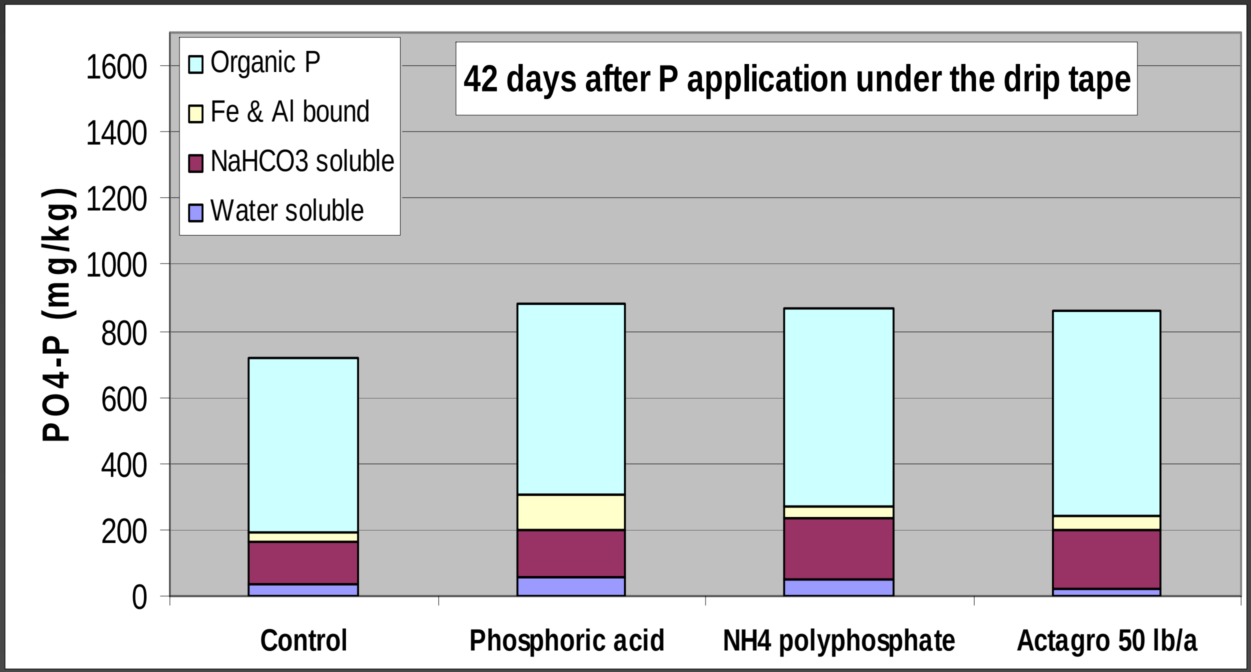
Soil : extractant ratio = 1 : 5

Soil P Analysis

<u>Ascorbic Acid method</u> for Ortho-Phosphate analysis and colorimetrical measurement (λ = 880 nm)




42 hours after P application under the drip tape
Organic P
Fe & Al bound
NaHCO3 soluble
Water soluble
PO4-P (mg/kg)
1600
1400
1200
1000
800
600
400
200
0
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a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Organic P
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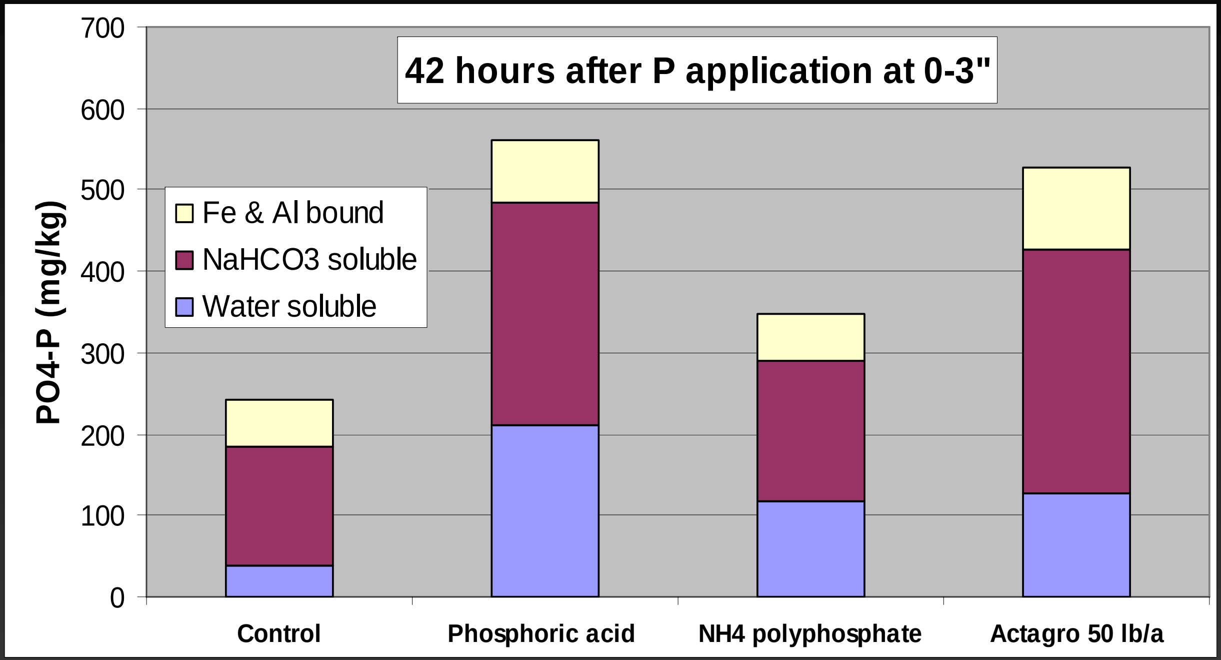
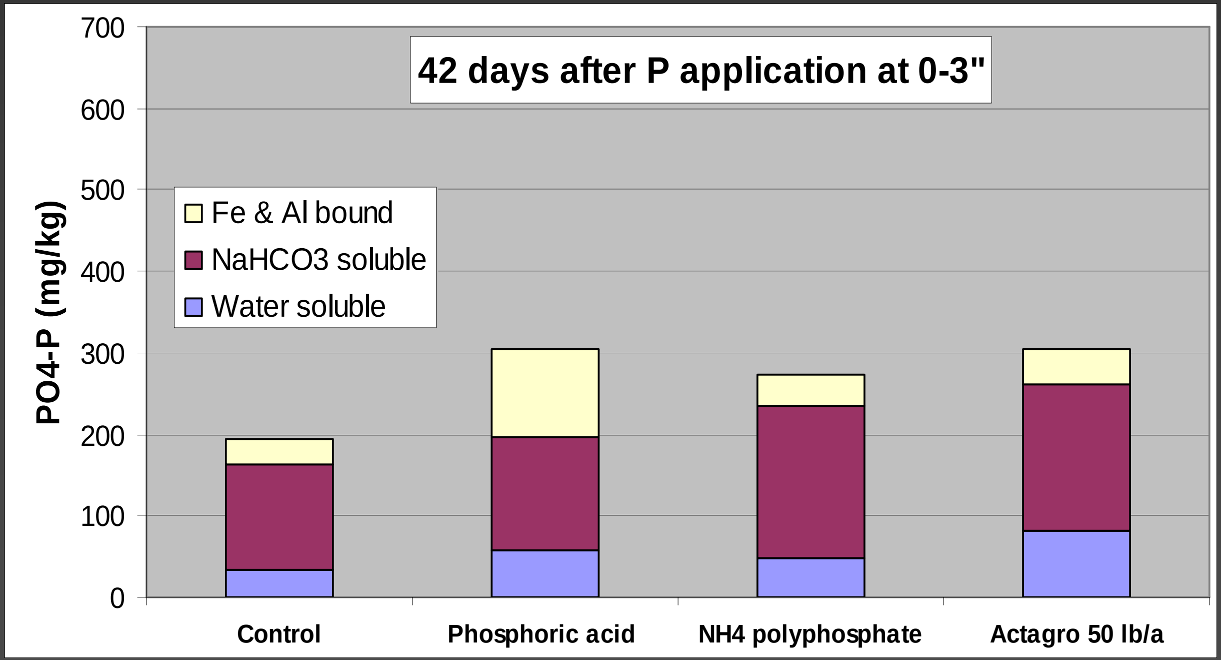
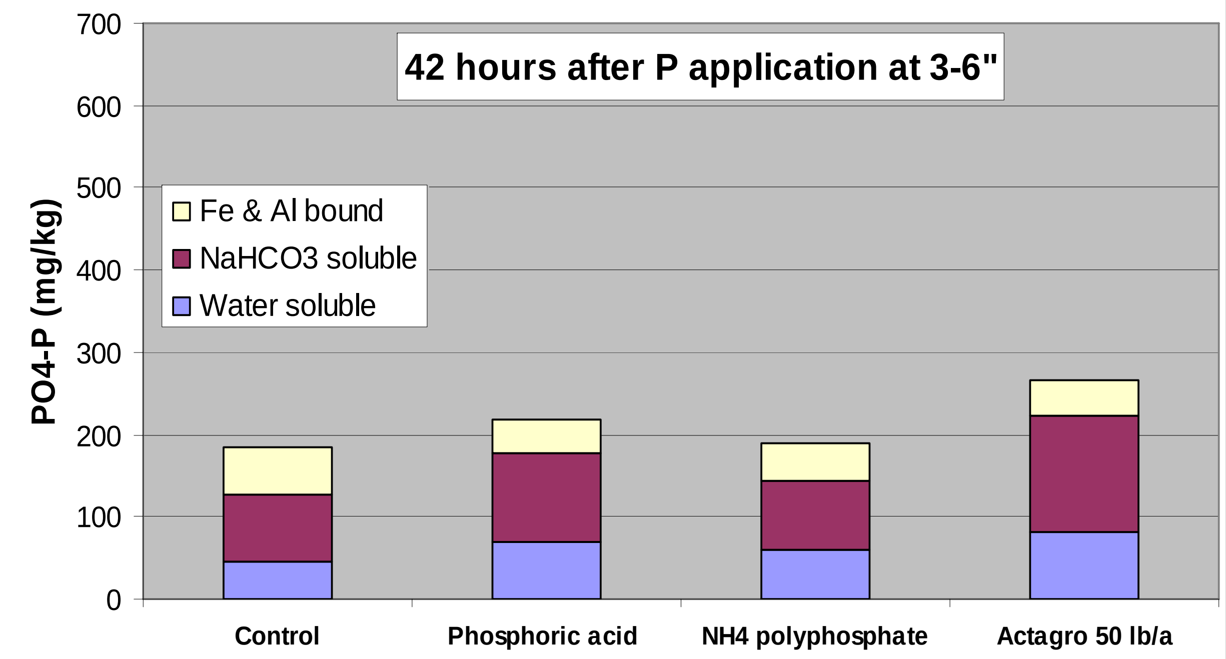
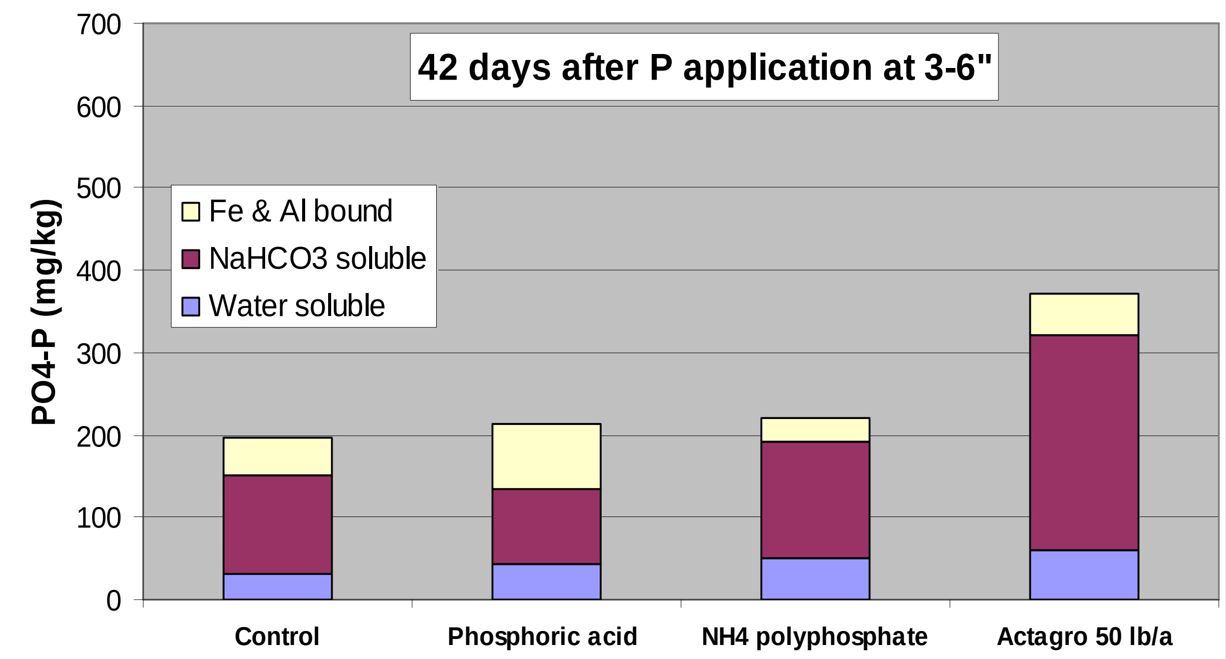

42 hours after P application at 0-3"
PO4-P (mg/kg)
700
600
500
400
300
200
100
0
Fe & Al bound
NaHCO3 soluble
Water soluble
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a

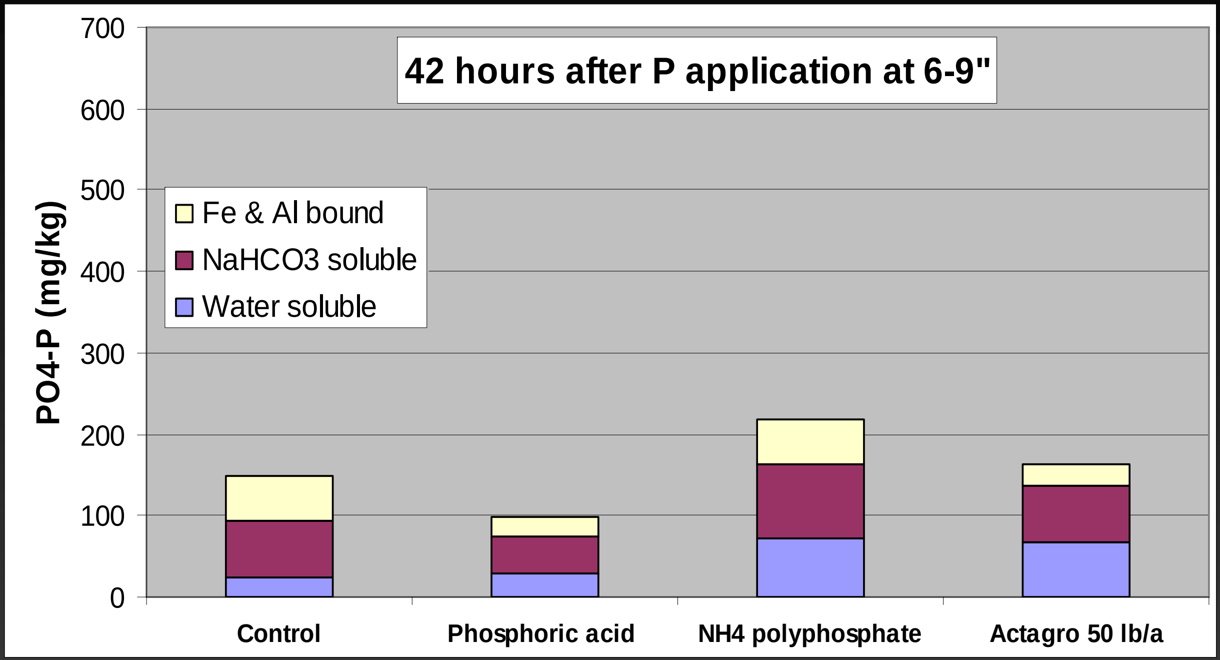

42 days after P application at 0-3"
PO4-P (mg/kg)
700
600
500
400
300
200
100
0
Fe & Al bound
NaHCO3 soluble
Water soluble
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a

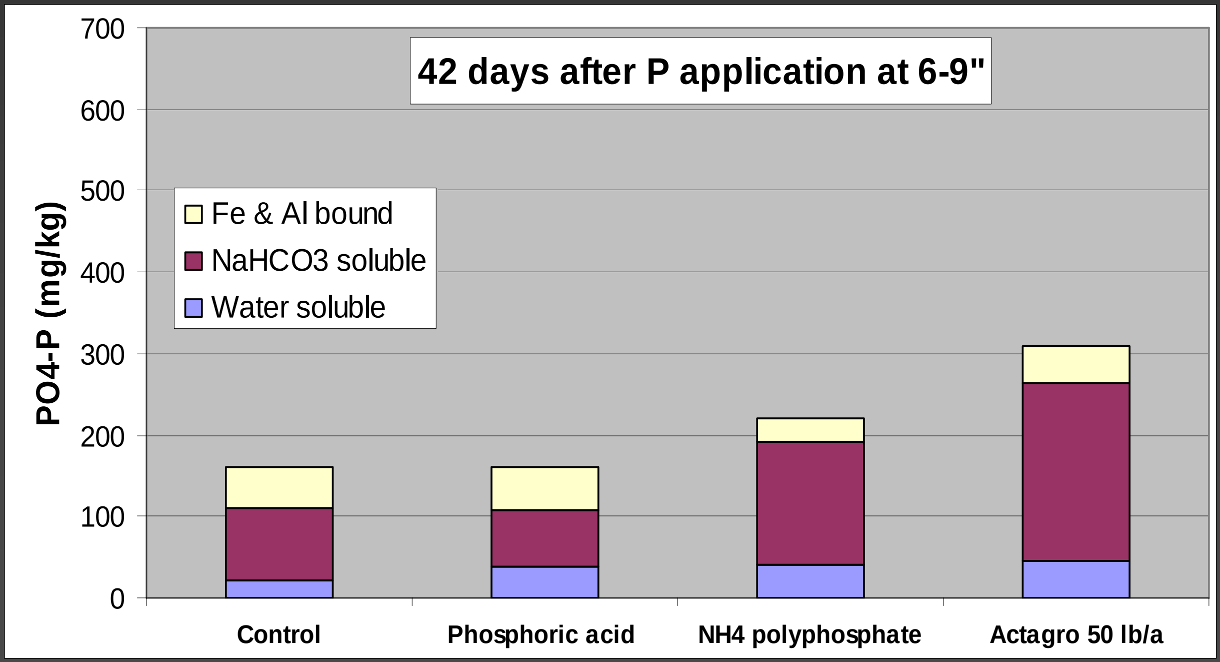


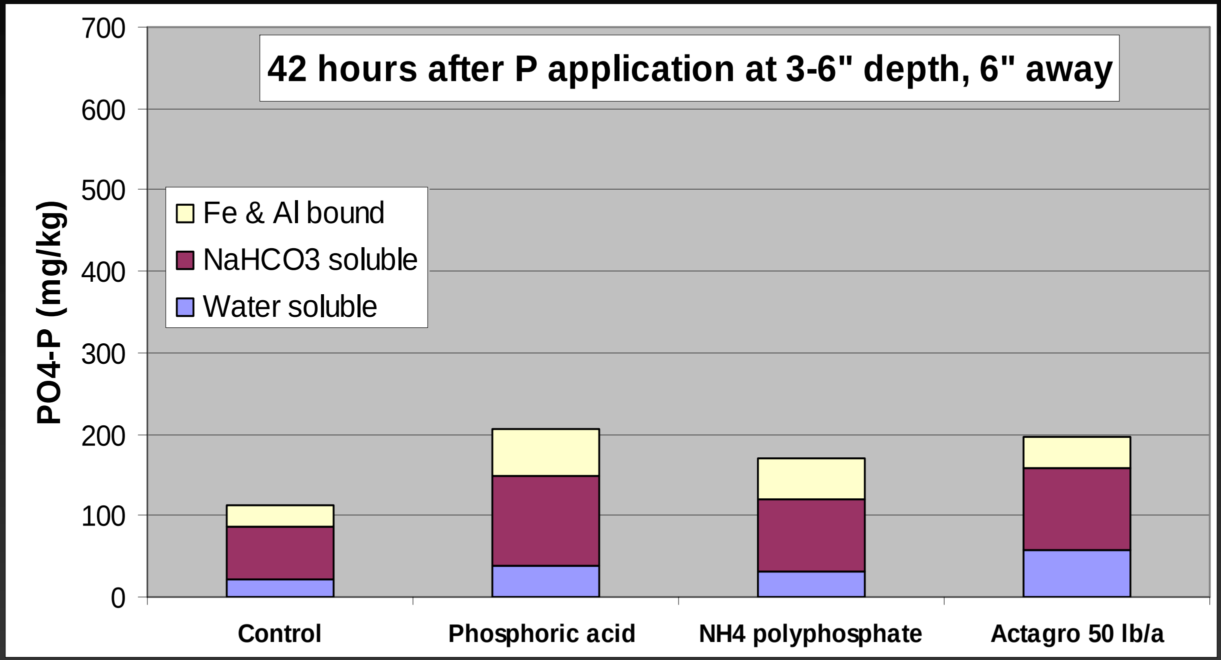
42 hours after P application at 3-6"
PO4-P (mg/kg)
0
100
200
300
400
500
600
700
Fe & Al bound
NaHCO3 soluble
Water soluble
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a

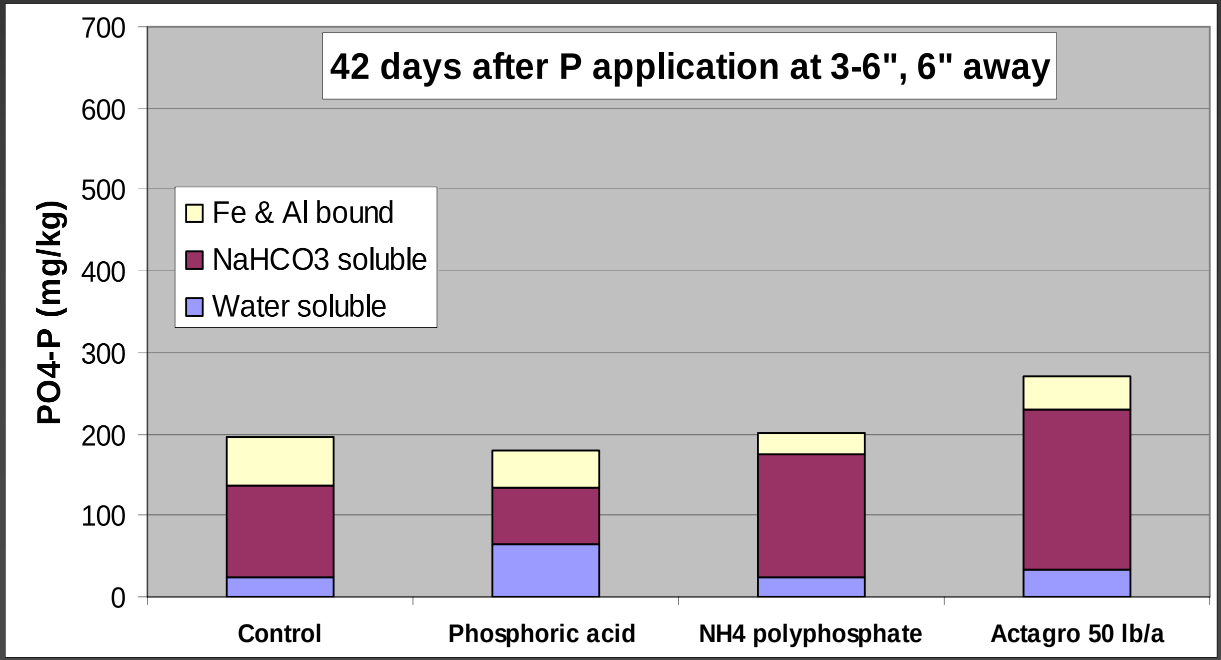


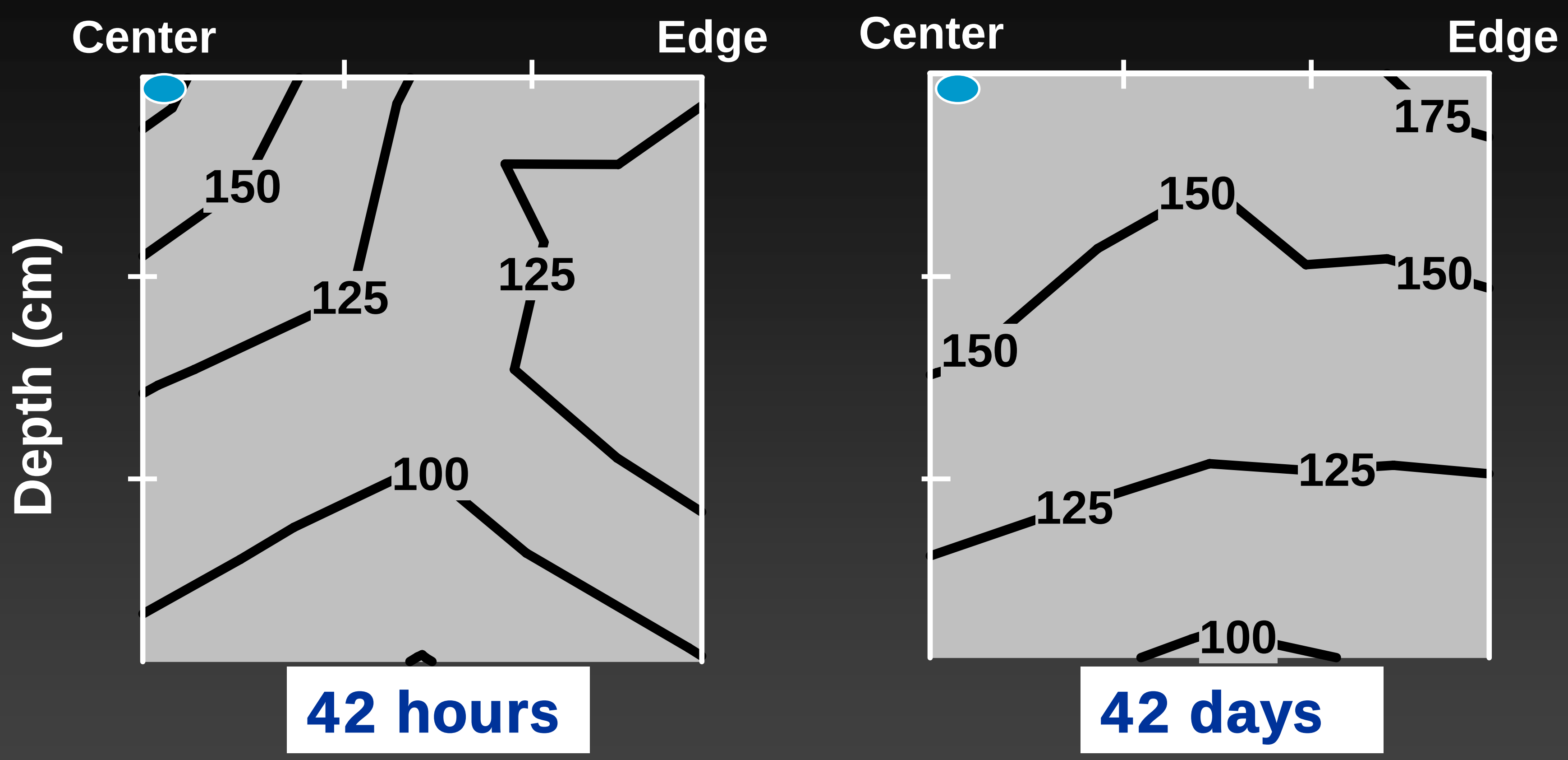
42 days after P application at 3-6"
PO4-P (mg/kg)
0
100
200
300
400
500
600
700
Fe & Al bound
NaHCO3 soluble
Water soluble
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a


42 hours after P application at 6-9"
PO4-P (mg/kg)
0
100
200
300
400
500
600
700
Fe & Al bound
NaHCO3 soluble
Water soluble
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a


42 days after P application at 6-9"
PO4-P (mg/kg)
0
100
200
300
400
500
600
700
Fe & Al bound
NaHCO3 soluble
Water soluble
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a

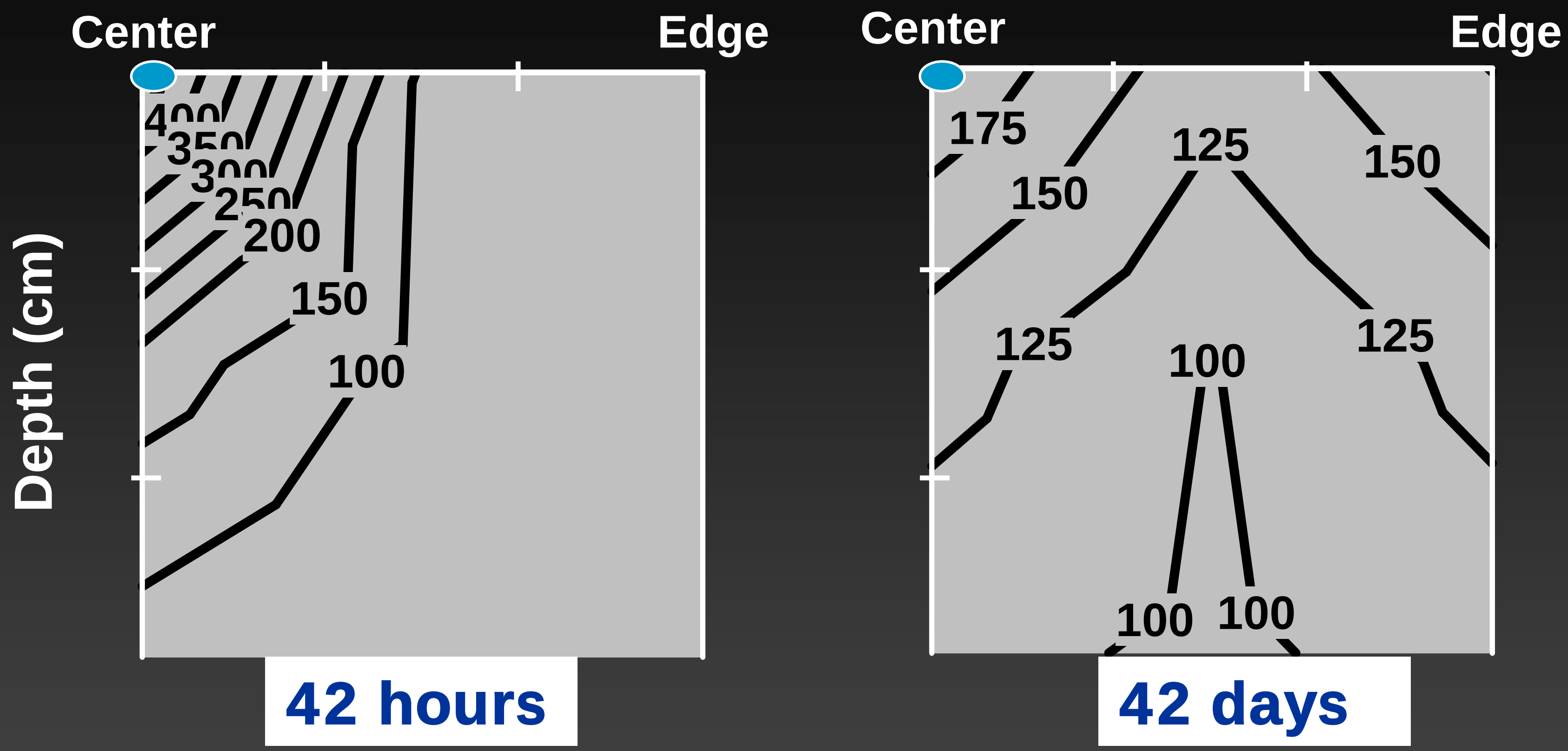

42 hours after P application at 3-6" depth, 6" away
PO4-P (mg/kg)
700
600
500
400
300
200
100
0
Fe & Al bound
NaHCO3 soluble
Water soluble
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a


42 days after P application at 3-6", 6" away
PO4-P (mg/kg)
700
600
500
400
300
200
100
0
Fe & Al bound
NaHCO3 soluble
Water soluble
Control
Phosphoric acid
NH4 polyphosphate
Actagro 50 lb/a



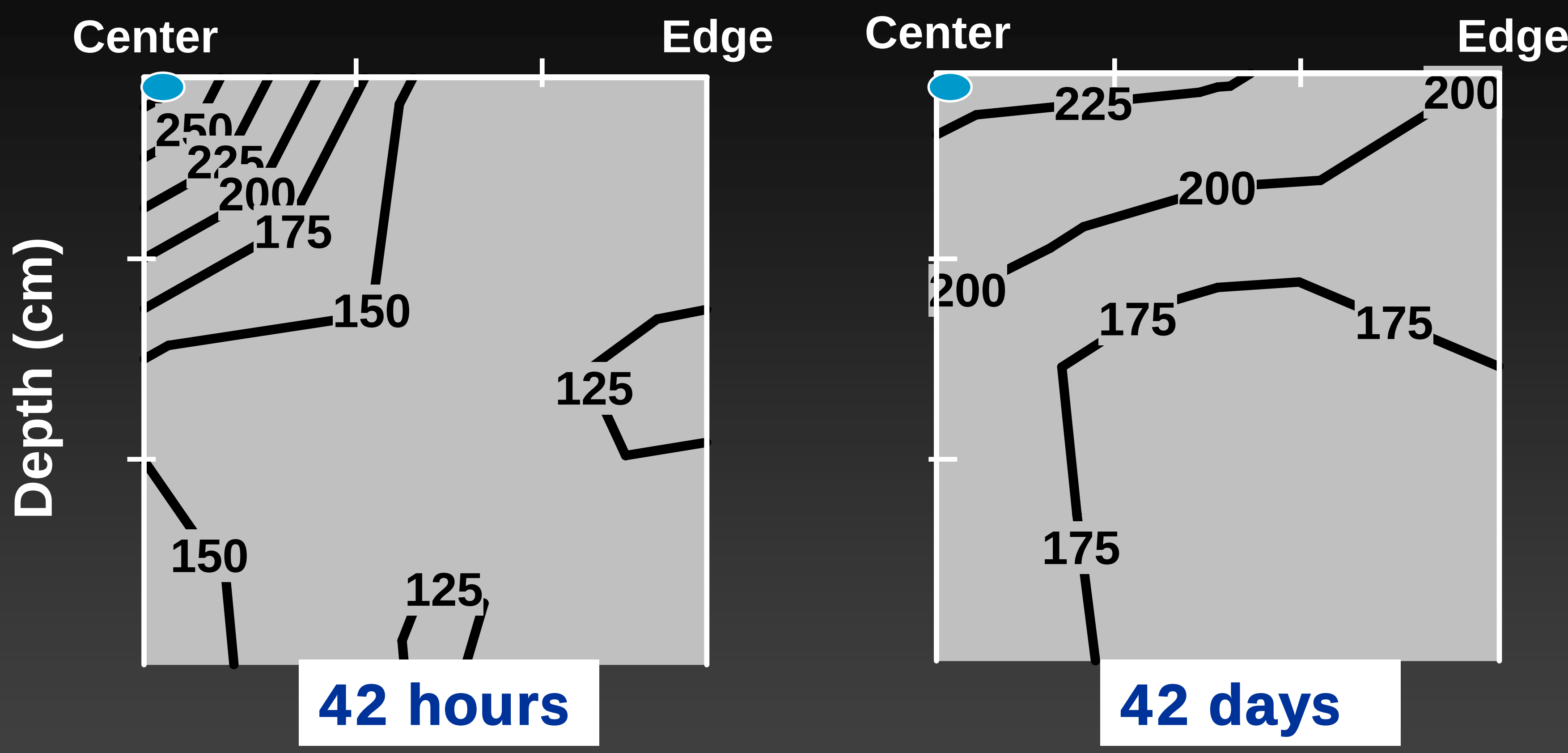
Distribution of PO_4-P at 42 hours and 42 days in the <u>untreated</u> "control" plots.

Irrigation water was applied twice a week.



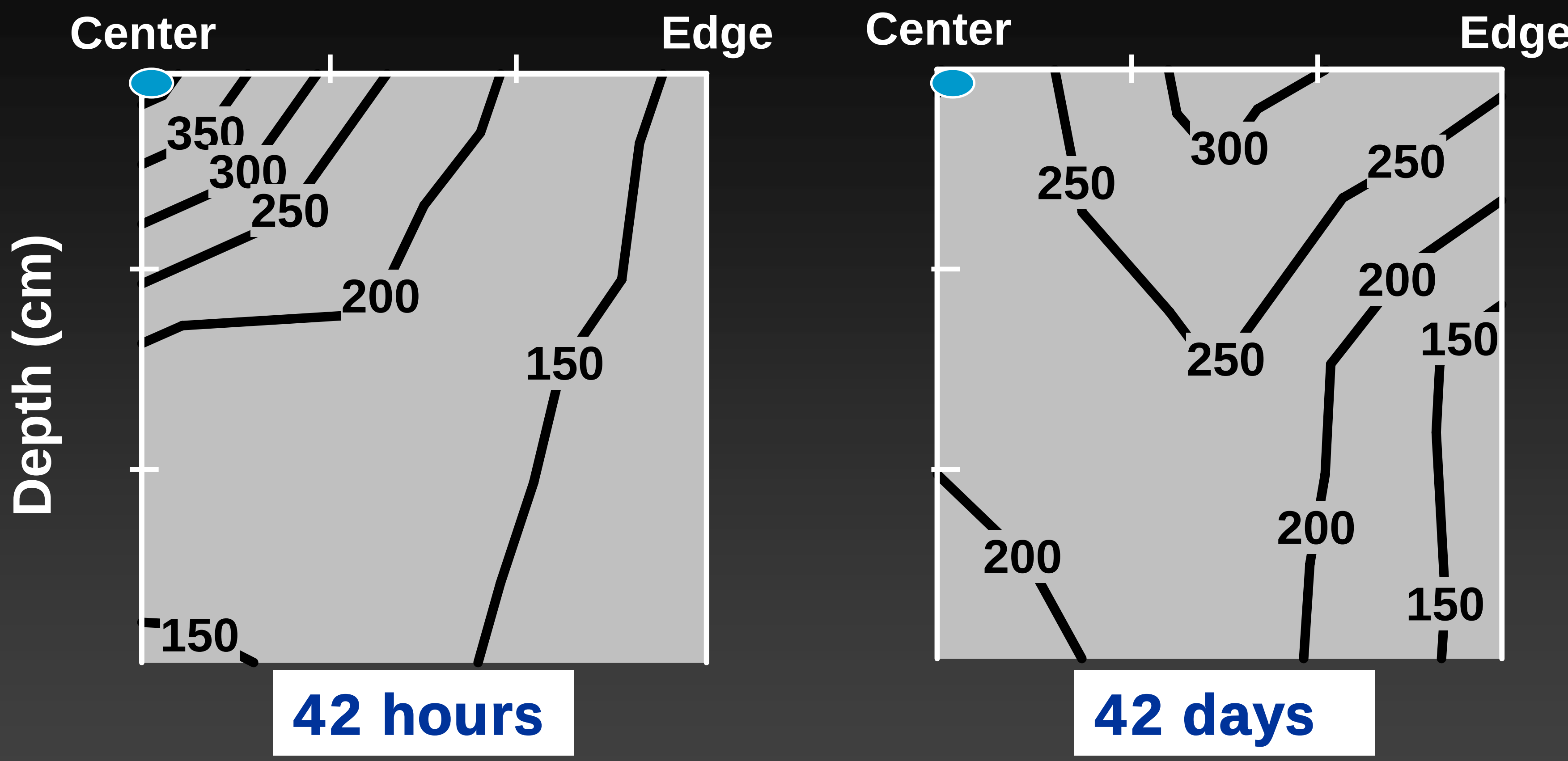
Distribution of PO_4-P 42 hours and 42 days after application of Phosphoric acid in 1" of water.

Irrigation water was applied twice a week.



Distribution of PO_4-P 42 hours and 42 days after application of <u>NH_4-Polyphosphate</u> in 1" of water.

Irrigation water was applied twice a week.



Distribution of PO_4-P 42 hours and 42 days after application of 50 lbs P_2O_5 of <u>ActaGro-P</u> formulation in 1" of water.

Irrigation water was applied twice a week.

Summary

- Drip-applied P fertilizers can move 3 to 4 inches from the irrigation tape.
- Organically-complexed, reacted NH_4-P fertilizer (ActaGro-P) moved twice the distance of phosphoric acid or NH_4 polyphosphate.
- Phosphoric acid “seems” to react with soil constituents (clay, org. matter, carbonates) and possibly precipitates as insoluble P compounds.
- Org.-complexed P fertilizer does not “seem” to react readily with soil constituents.
- Plant-available P after 42 days was in the order:

  ActaGro-P > NH_4 polyphosphate > phosphoric acid.

Thank you very much

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