AGR1403 – Lecture 7
Phosphorus

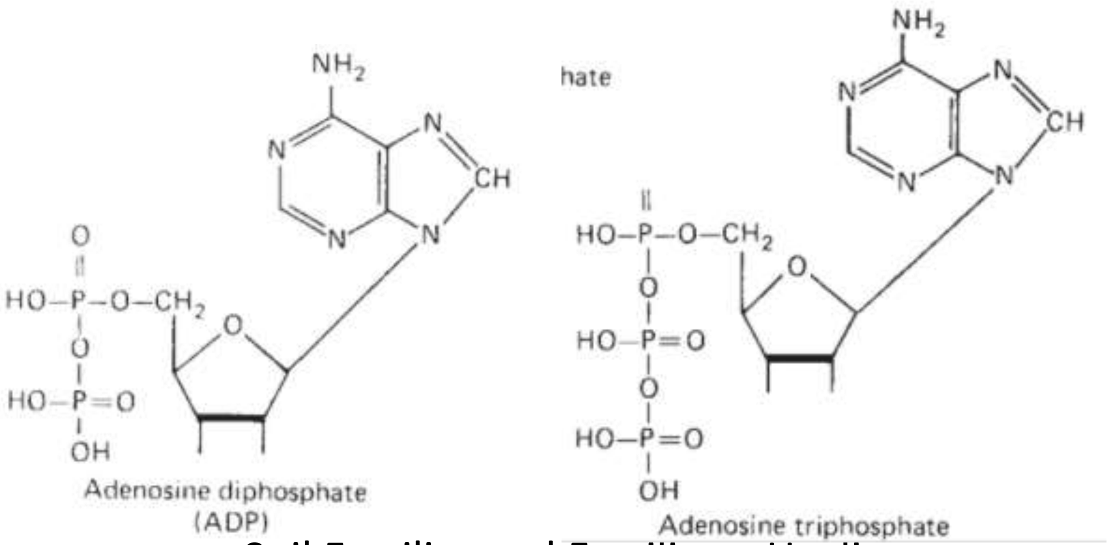
Learning Objectives

- By the end of the lesson you should be able to:
  - Discuss Phosphorus dependent plant functions
  - Identify deficiency symptoms of Phosphorus in plants
  - Explain the P cycle and plant available forms of phosphorus
  - Discuss Phosphorus sources and the P paradox

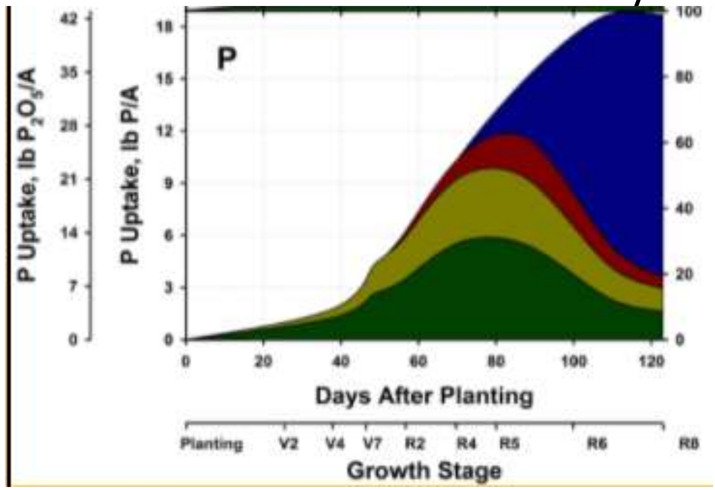
- Readings: Havlin pp 185 – 192; 200 - 217

Phosphorus Plant Functions

- Phosphorus in plants ranges 0.1 to 0.5%
- Major energy transfer and storage
  - ADP → ATP → ADP
- P is essential in DNA and RNA
- Cell membrane function and integrity
- Plant demands continuous during plant growth
  - Mobile in plants



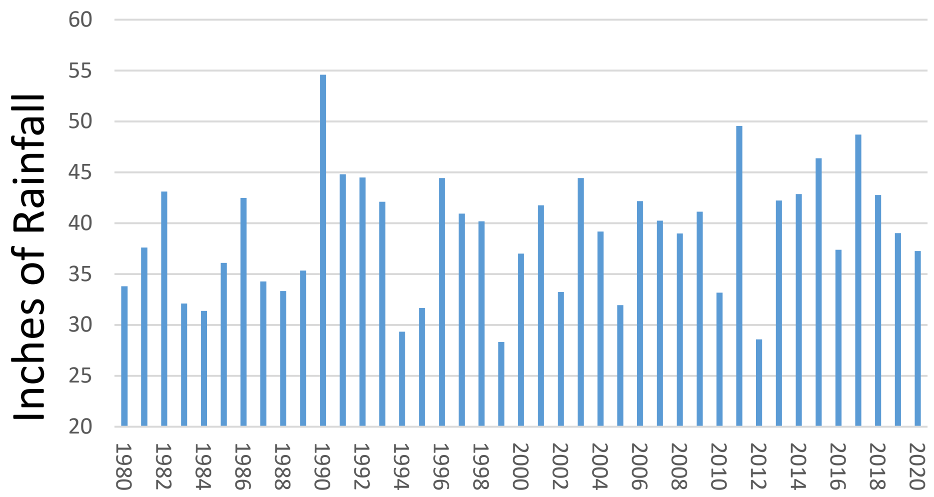
Soil Fertility and Fertilizers Havlin

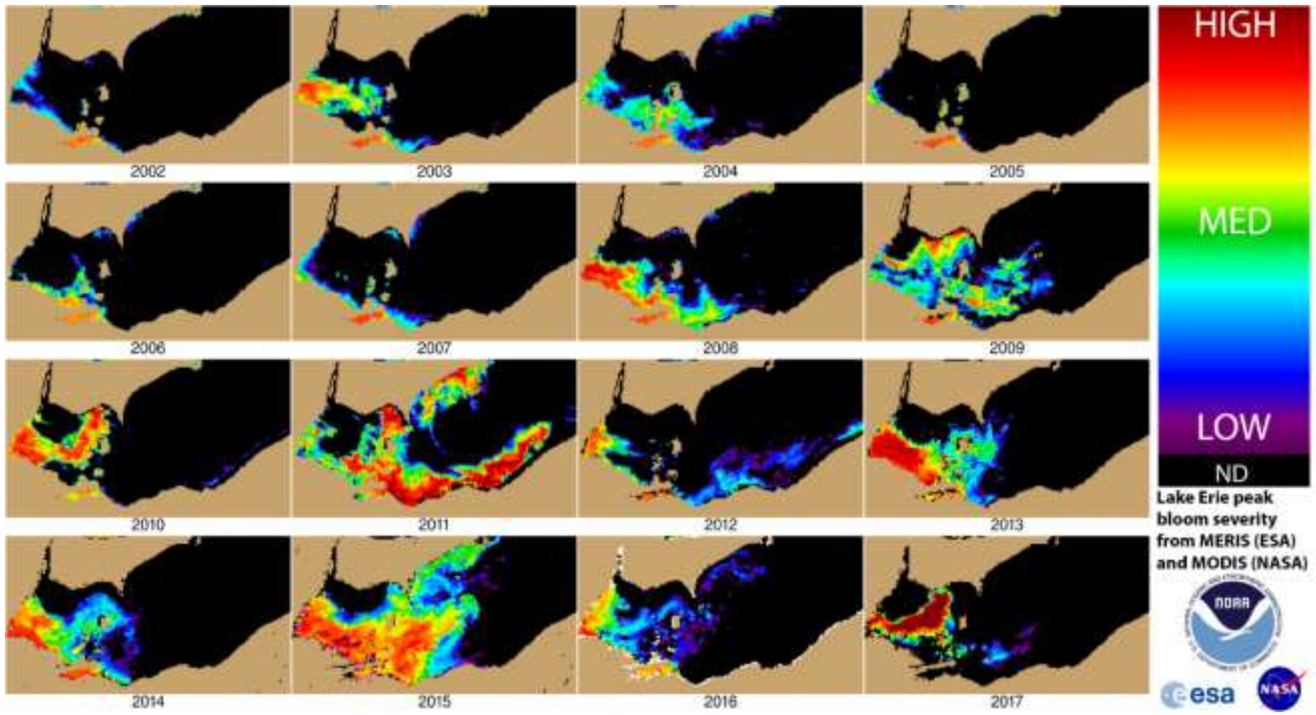


http://cropphysiology.cropsci.illinois.edu/soyuptake.html

Phosphorus Losses

- P strongly adsorbed to the soil
  - P Buildup like a bank
  - Most P lost by erosion
  - Some lost as dissolved reactive P
- Best Management Practices
  - Erosion, conservation tillage etc
  - Right rate, product, rate, time 4R
- More closely watched, why is algae only growing in the last decades?





https://crops.extension.iastate.edu/encyclopedia/why-manage-phosphorus

https://content.presspage.com/uploads/2170/1920_output-4x4-2002-2017-logos-revised-818546.png?10000

Nutrient Buildup in Lakes

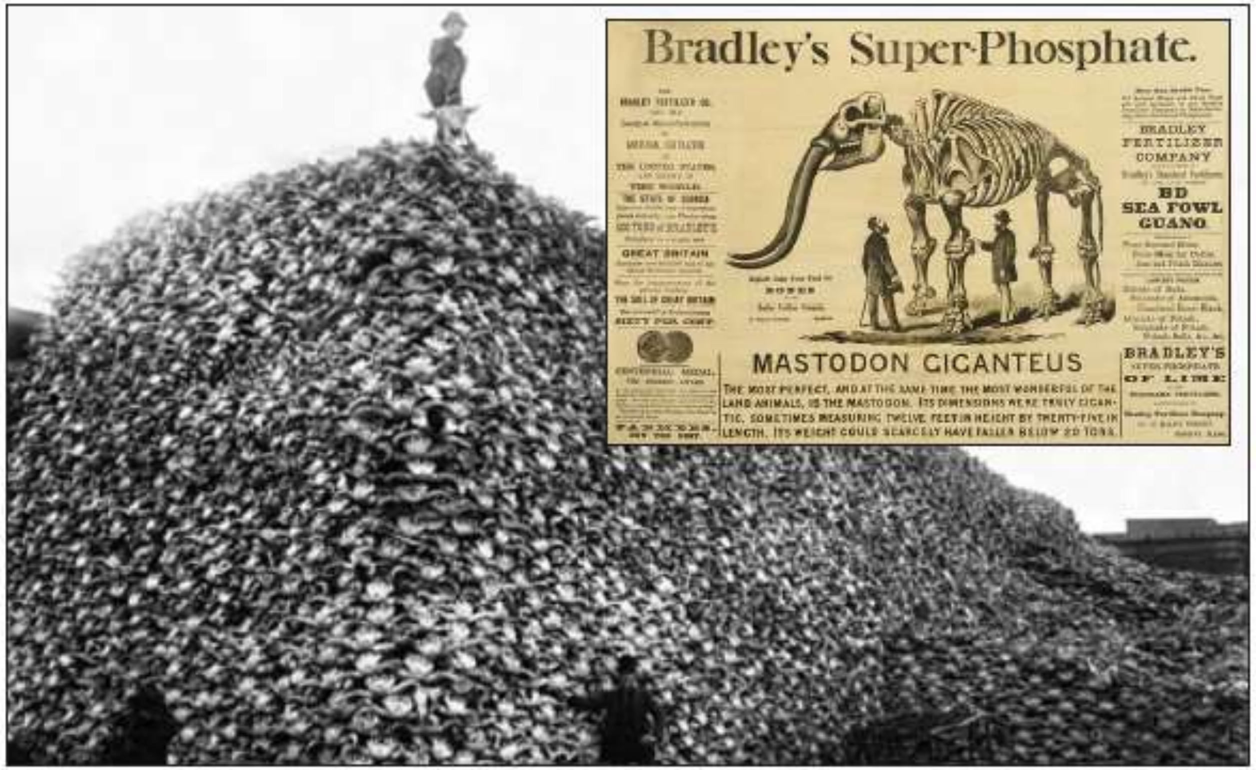
- Contributes to Harmful Algal Blooms – HAB
  - Algae grow out of control and produce toxins
- Nutrient runoff is related to HAB growth
- HAB have occurred for decades and are natural
  - But appear to be occurring more frequently

https://www.noaa.gov/what-is-harmful-algal-bloom

Initial Phosphorus Sources

- Bones were crushed and applied at rates of 1t/A or more
- Leibig noted that bones and P fertilizer was a valuable asset
- Manure and Peruvian Guano was a common source of P
- John Lawes pretreated bones with H2SO4 – superphosphate

$$2\ Ca_5F(PO_4)_3 \text{ phosphate rock} + 7\ H_2SO_4 \rightarrow$$
$$3\ Ca(H_2PO_4)_2 \text{ [superphosphate]} + 7\ CaSO_4 + 2\ HF$$



Large pile of bison skulls that will be ground into fertilizer in the U.S. around 1870 (left). Advertisement for Bradley Fertilizer Co. in 1881 (inset).

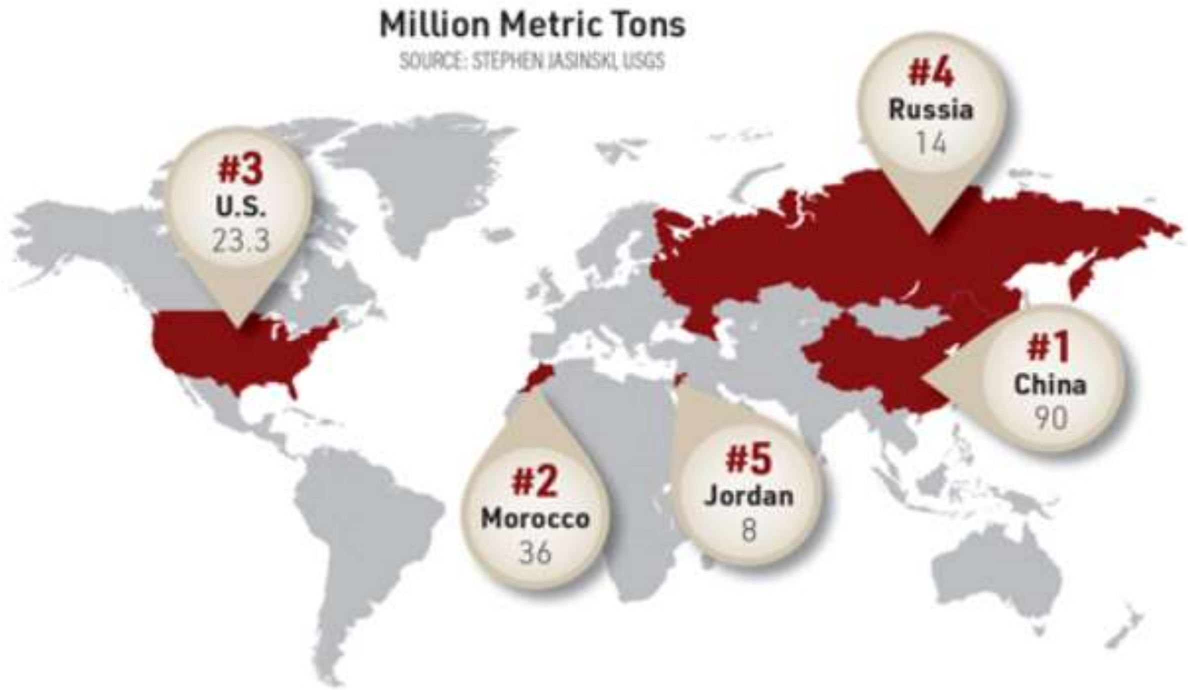
http://www.ipni.net/publication/bettercrops.nsf

Modern Phosphorus Production

- Phosphate rock was identified around the world
- England, 1847; Norway, 1851; France, 1856; USA, 1867; Tunisia, 1897, Morocco, 1921; Russia, 1930
- 72% Morocco, China, US, and Russia – 18% US

Phosphorus Paradox

- Phosphorus resources not widely distributed
  - FL, NC & Morocco current sources
  - China & Russia - uranium
- Mining is not eco-friendly



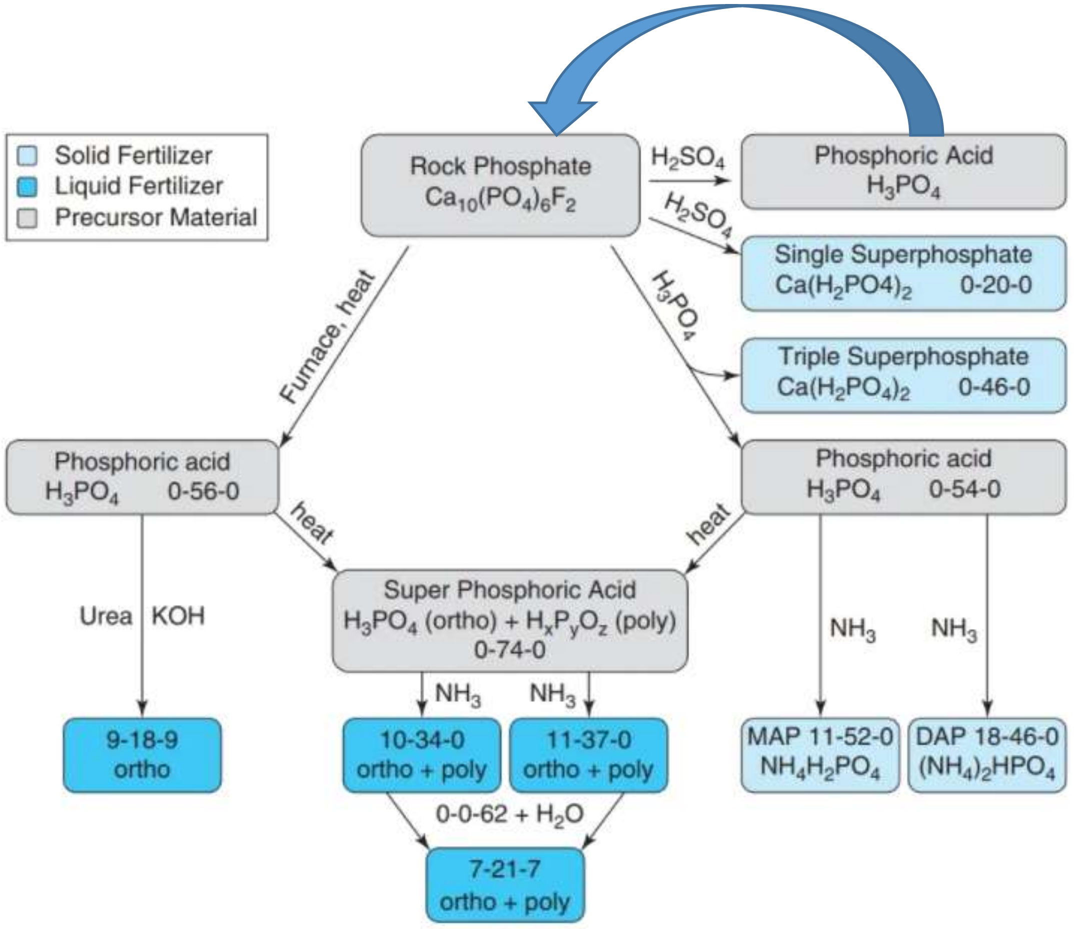
https://www.agweb.com/news/crops/crop-production/phosphorus-time-bomb-agriculture-myth-and-reality

Phosphorus Production

- Rock phosphate is not water soluble
- Treated with Sulfuric Acid or Heated
- Ortho phosphate – Single phosphorus (H2PO4) molecule
- Poly phosphate – salt of multiple phosphorus (H3PO4) molecules

$$\%P = \%P_2O_5 \times 0.43$$

$$\%P_2O_5 = \%P \times 2.29$$



Soil Fertility and Fertilizers Havlin

Phosphorus Deficiency

- Inhibits shoot growth – increase root to shoot ratio
    - Leaves become dark, dull blue-green to pale
    - Turning red to violet from sugar accumulation in leaves
    - Symptoms first appear on older leaves
    - New leaves look healthy but small
- Cool soils and compromised roots
    - Side wall compaction can compromise P uptake

https://www.cropnutrition.com/nutrient-management/phosphorus

https://plantscience.psu.edu/research/labs/roots/methods/methods-info/nutritional-disorders-displayed/phosphorus-deficiency

https://blog-crop-news.extension.umn.edu/2017/05/4-key-nutrient-deficiencies-to-scout.html

Phosphorus in the Soil

- Soil Phosphorus is relatively stable
  - Not very mobile in the soil
- P availability influenced by:
  - Soil pH, Organic Matter, and P placement
- pH 4 to 7 H2PO4 main form in soil
  - Plant available form if present in soil solution

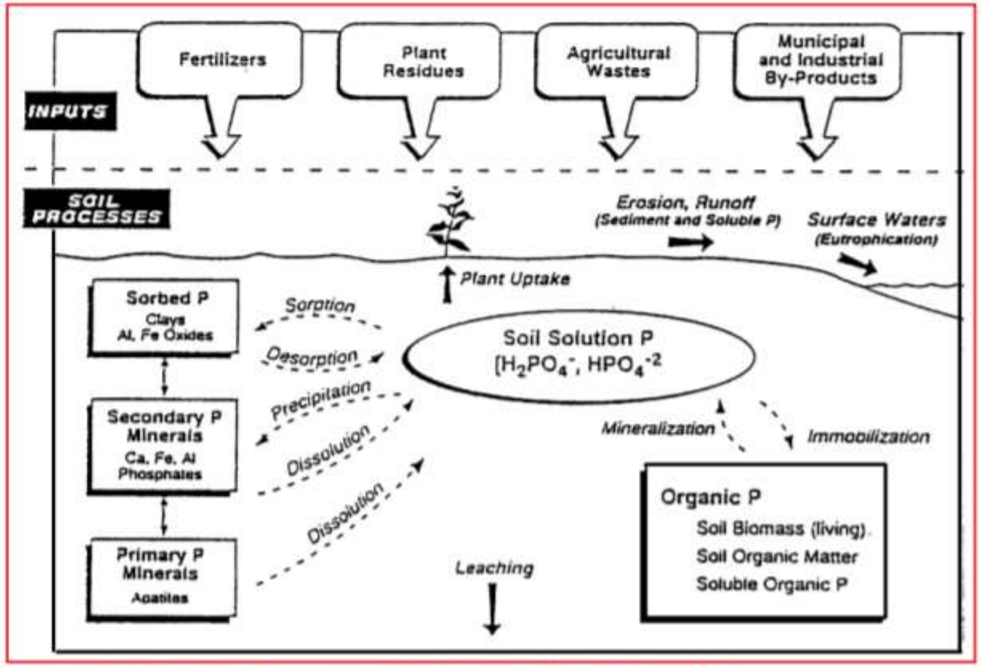
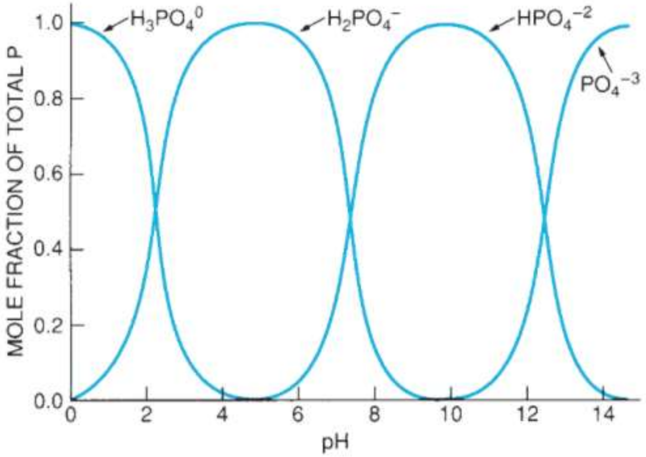


Figure 1. Soil phosphorus cycle (Pierzinski et al., 1994).

https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053254.pdf



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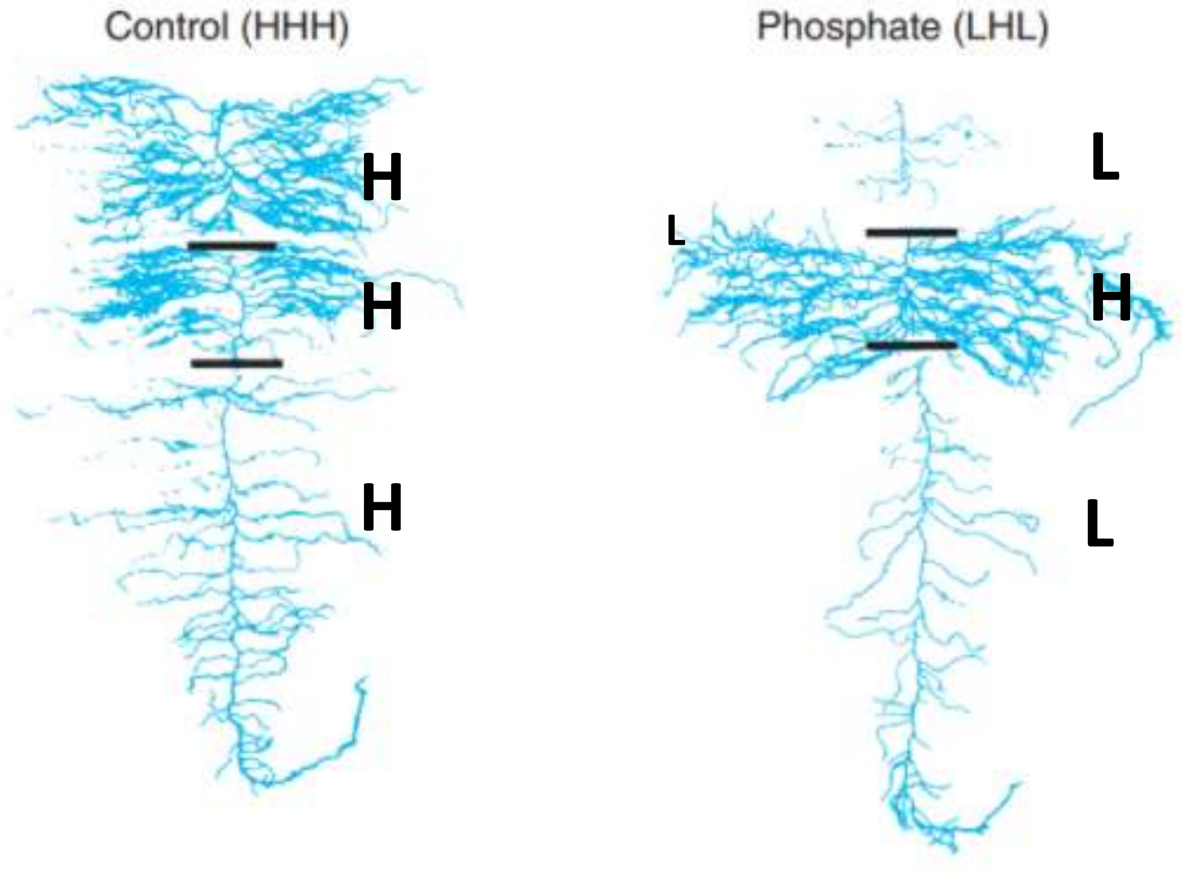
Nutrients and Root Growth

- Stratified nutrient zones demonstrate root growth in regions of High and Low concentrations of Phosphorus
- Think about stratified soil texture differences
  - Water and nutrient flow between A and B horizons



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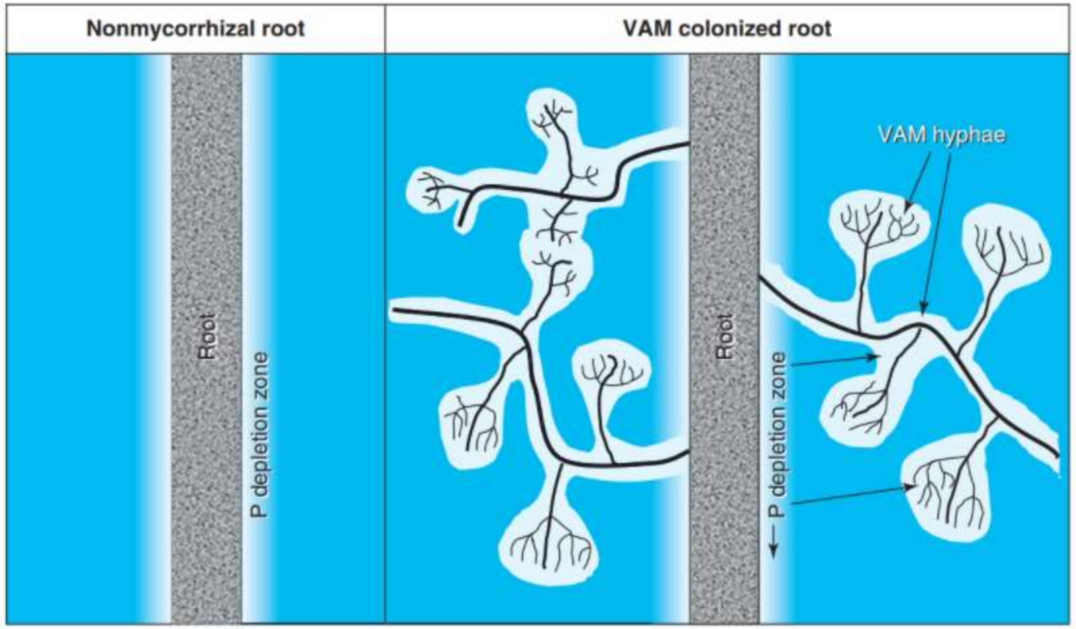
Non Mobile Soil Nutrients

- Nutrients near plant roots become depleted by plant uptake – Nutrient Depletion Zone
- Vesicular-arbuscular mycorrhiza VAM are Mycorrhizal Fungi extend root area and nutrient uptake
- Excessive N or P fertility can decrease Mycorrhizal Fungi



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Soil Phosphorus and Productivity

- Crop and productivity can influence Phosphorus demand
- Corn to move from 75% to 95% needs 3x ppm of P
- Soybean to move from 75% to 95% needs 8x ppm of P

Table 5-2
Estimated Soil Solution P Concentration Associated with 75 and 95% of Maximum Yield of Selected Crops

	Approximate Soil Solution P for Two Yield Levels	
Crop	*75% Maximum Yield*	*95% Maximum Yield*
	ppm	
Cassava	0.003	0.005
Peanuts	0.003	0.010
Corn	0.008	0.025
Wheat	0.009	0.028
Cabbage	0.012	0.040
Potatoes	0.020	0.180
Soybeans	0.025	0.200
Tomatoes	0.050	0.200
Head lettuce	0.100	0.300

Source: Fox, 1982, Better Crops Plant Food, *66:24.*

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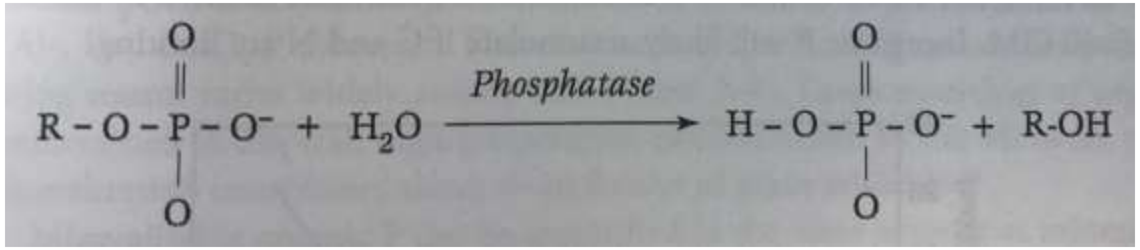
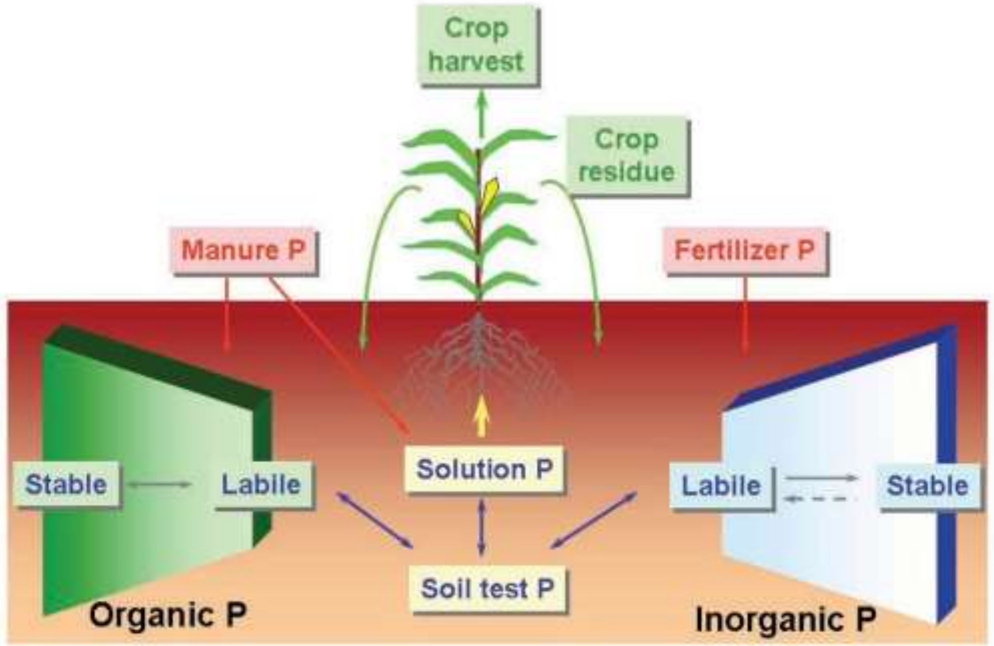
P Mineralization & Immobilization

- Both occur simultaneously in soils
- Plant and organic residues degraded making P available
- Soil texture, biology, P level etc. influence availability
- Phosphatase enzyme responsible for conversion



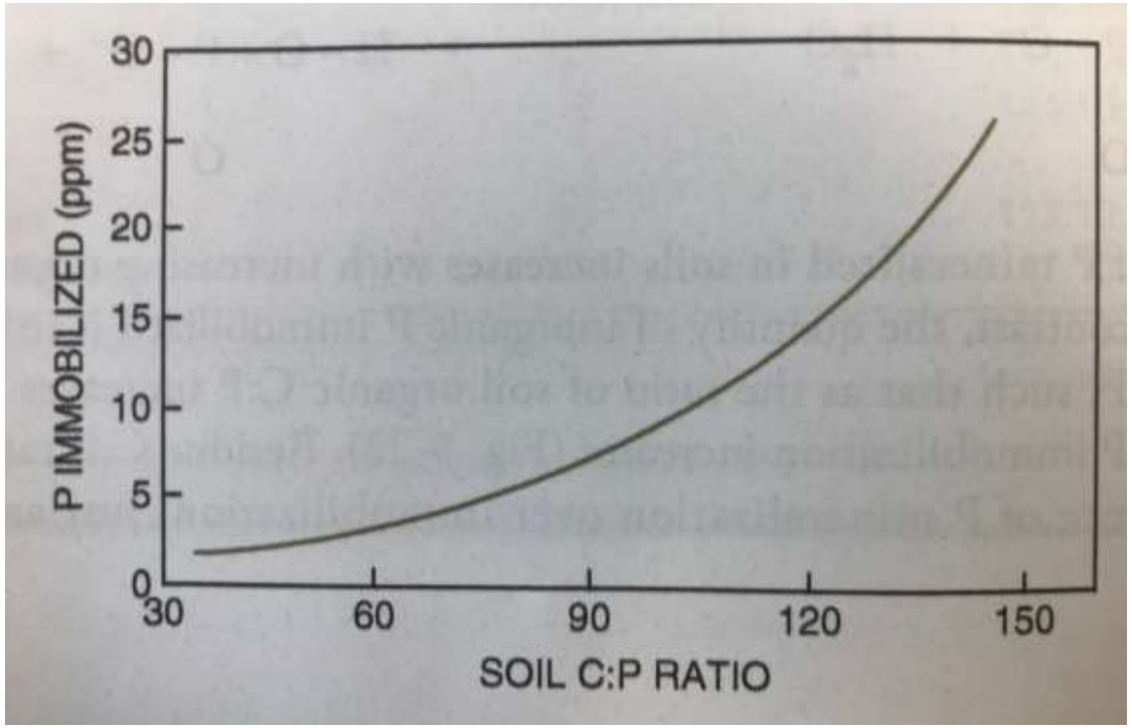


Modified from Figure 34-2 in the LPES Curriculum.

https://water.unl.edu/phosphorus-dynamics

Soil Carbon Content and P fixation

- Similar to N, Increasing soil carbon immobilizes more P
- Source and residue influences mineralization vs immobilization
- Soil moisture, pH, temperature, tillage all influence P cycle
- Increasing soil C, soil health, microbial activity all can change soil P availability



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Change in Soil P Over Time

- Blaine – Soil moderately deep, well drained soils that formed igneous rock, conglomerate, hard shale or sandstone
- Sutherland – Soil shallow hard pan well drained soils that formed in fan alluvium from mixed sources
- Bradwell – Soil Dark calcareous gravelly loam

TABLE 5-7
ORGANIC P LOSS WITH CULTIVATION IN THREE CANADIAN PRAIRIE SOILS

Soil Association	Native Prairie	60–70 Years of Cultivation	C or P Loss
	mg/g		— % —
Blaine Lake			
Organic C	48	33	32
Total P	0.82	0.72	12
Organic P	0.65	0.53	18
Inorganic P	0.18	0.20	
Sutherland			
Organic C	38	24	37
Total P	0.766	0.66	12
Organic P	0.50	0.41	17
Inorganic P	0.26	0.25	
Bradwell			
Organic C	32	17	46
Total P	0.75	0.53	29
Organic P	0.45	0.32	29
Inorganic P	0.30	0.21	29

Source: Tiessen et al., 1982, Agron. J., 74:831.

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P Dissolution over Time

- Estimate native soil P about 0.2 mg/g = 200 ppm
  - Ohio clay soil estimate 5-7 ppm
- Soil P diffusion mostly stays within 0.5” of granule

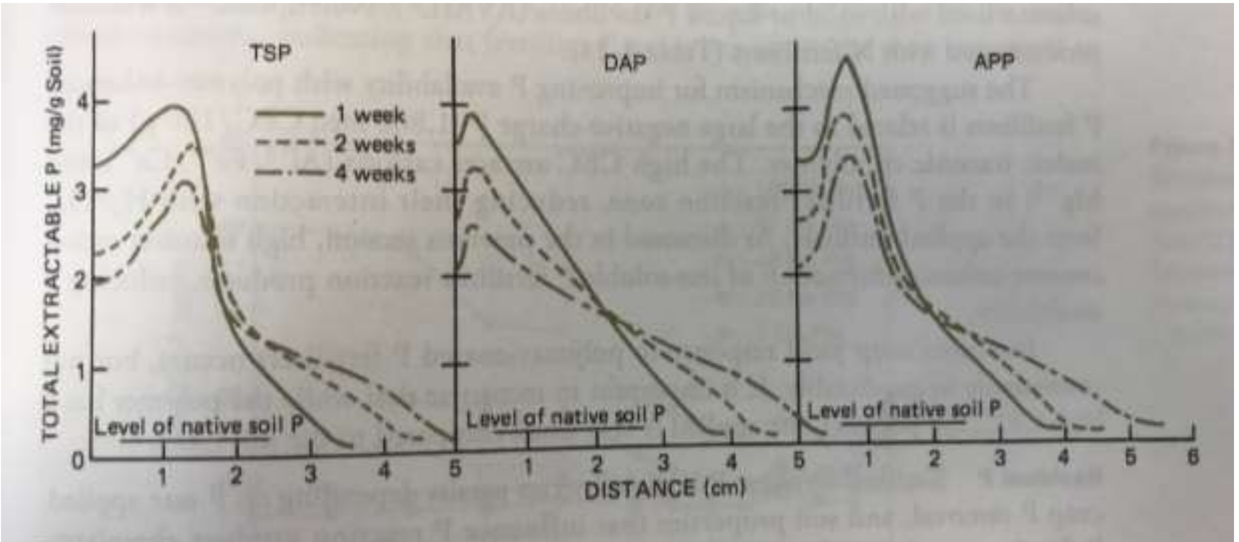
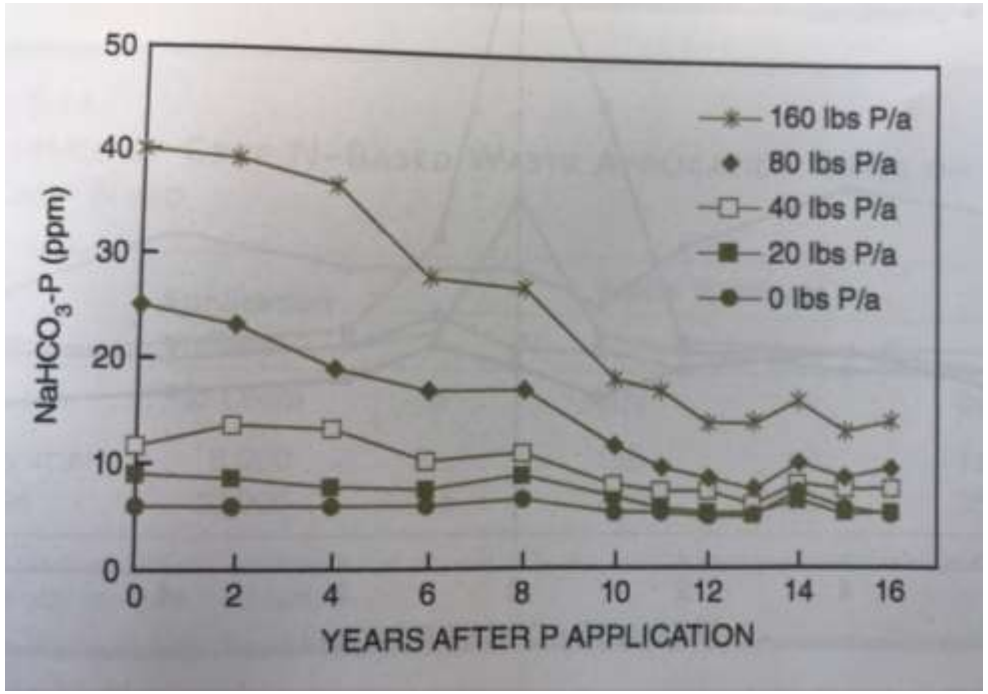


Figure 5-31
P diffusion away from TSP and DAP granules or an APP droplet in soil over 5 weeks.
(Khasawneh et al., 1974, Soil Sci. Soc. Am. J., 38:446.)

P Removal Over Time

- Single high P applications
- With higher P application P availability increases
- Higher application rates drop dramatically – continued higher rates of application needed to keep high levels



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Organic P Source

- Mixed analysis – if you want the N you get the other items along for the ride
- Manure is a good nitrogen source, but have to watch P level in the soil

Lab Number: 41724
Sample ID: BUILDING 1 2/3 FULL-ADJATCO
Manure Type: SWINE, LIQUID PIT (16)

Purchase Order: 003-6505
Date Sampled: 11/1/2021
Date Received: 1/3/2022
Date Reported: 1/5/2022
Page: 1 of 1

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal	First Year Availability Pounds Per 1,000 Gal
Moisture	%	99.14	8258	
Solids	%	0.86	72	
Nitrogen, Total Kjeldahl (TKN)	%	0.217	18.1	14.0*
Phosphorus (P)	%	0.018	3.5 (as P_2O_5)	3.5* (as P_2O_5)
Potassium (K)	%	0.128	12.8 (as K_2O)	12.8* (as K_2O)

TABLE 5-14
INFLUENCE OF CROP N–BASED WASTE APPLICATION RATES ON P APPLIED IN EXCESS OF CROP NEED

Source	Application Rate	Waste Nutrients				Crop Requirement[1]		Excess P Applied
		N		P		N	P	
	lb DM/a	*%*	*PAN*[1]	*%*	*lb/a*	— *lb/a* —		*lb/a*
Poultry litter	8,000	2	160	1.7	136	160	25	111
Biosolid	10,000	1.6	160	2.5	250	160	25	225

[1]PAN = plant available N represents the amount of N required by the crop. Waste rate determined by crop N needed. Crop P required based on 200 bu/a corn at ~0.2% P content.

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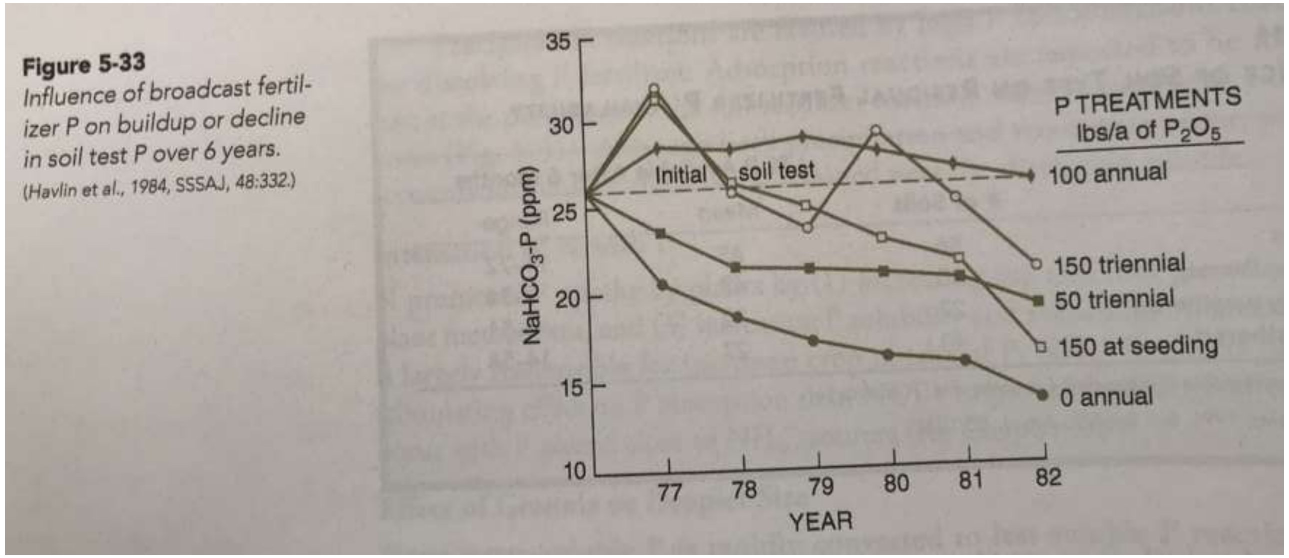
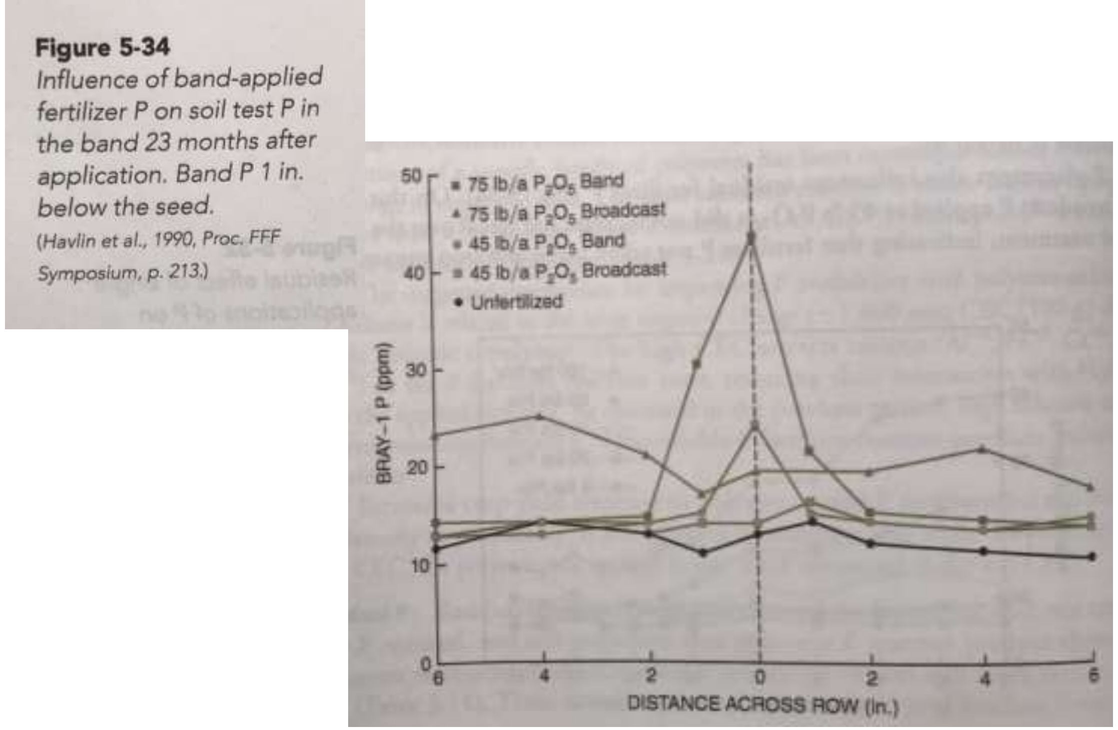
P Application Over Time

- 100 lbs/Ac P2O5 maintained level above 25 ppm (50 lbs/Ac)
- Zero applied P steady decline of P (25 to 15 ppm)
- 150 lbs/Ac every three years up and down
- 150 lbs/Ac at planting steady decline over six years
- 50 lbs/Ac every three years slow decline



P Placement at Planting

- Banding P2O5 at planting increases concentration close to the row – 75 and 45 lbs/Ac
- Broadcast Same rates spreads P across the soil



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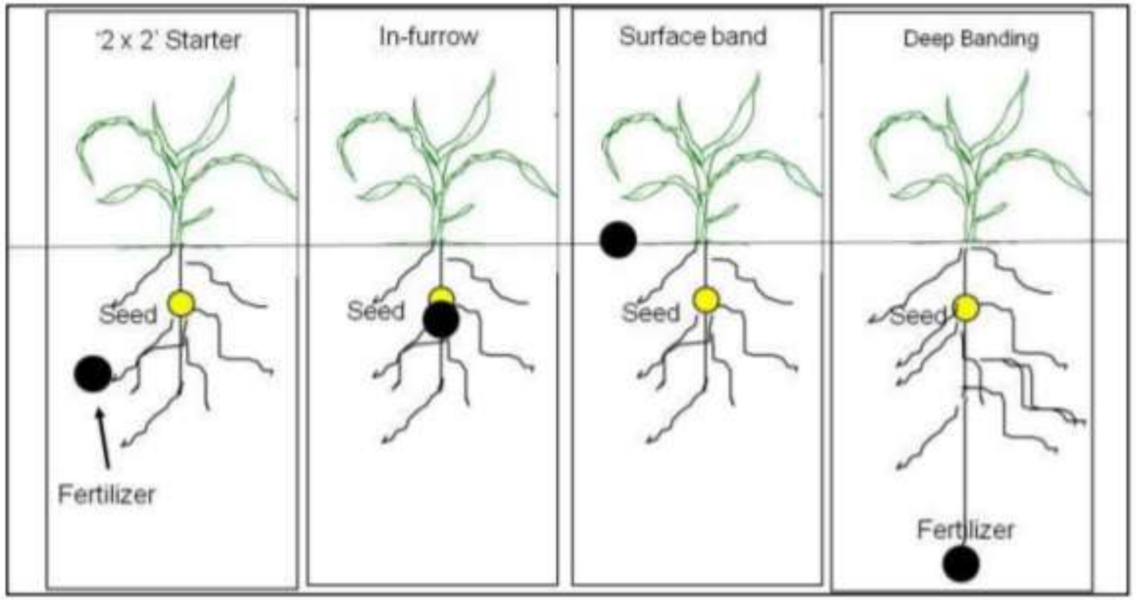
Phosphorus Applications

- P fertilizer may be broadcast on the soil surface (liquid or dry) or it can be placed in a concentrated band
- There may be advantages to banding, including
  - Early crop growth enhancement
  - Concentration of P to minimize soil contact and reaction
  - Placement in the root zone



https://www.ipni.net/ipniweb/portal.nsf/0/02d5d56d777313b2062577ce0069a3a8/$file/p%20fert%20tech%2011%2010%202010.pdf

Lesson Summary

- Phosphorus is essential for energy transfer in plant processes
- It is in finite supply, not widely distributed around the world
- Phosphate rock is not water soluble and has many impurities
- Phosphorus does not move well in the soil
- Phosphorus runoff misuses a finite resource and contributes towards harmful algal blooms