Phosphorus and Potassium Dynamics in Organic Production

Rob Mikkelsen

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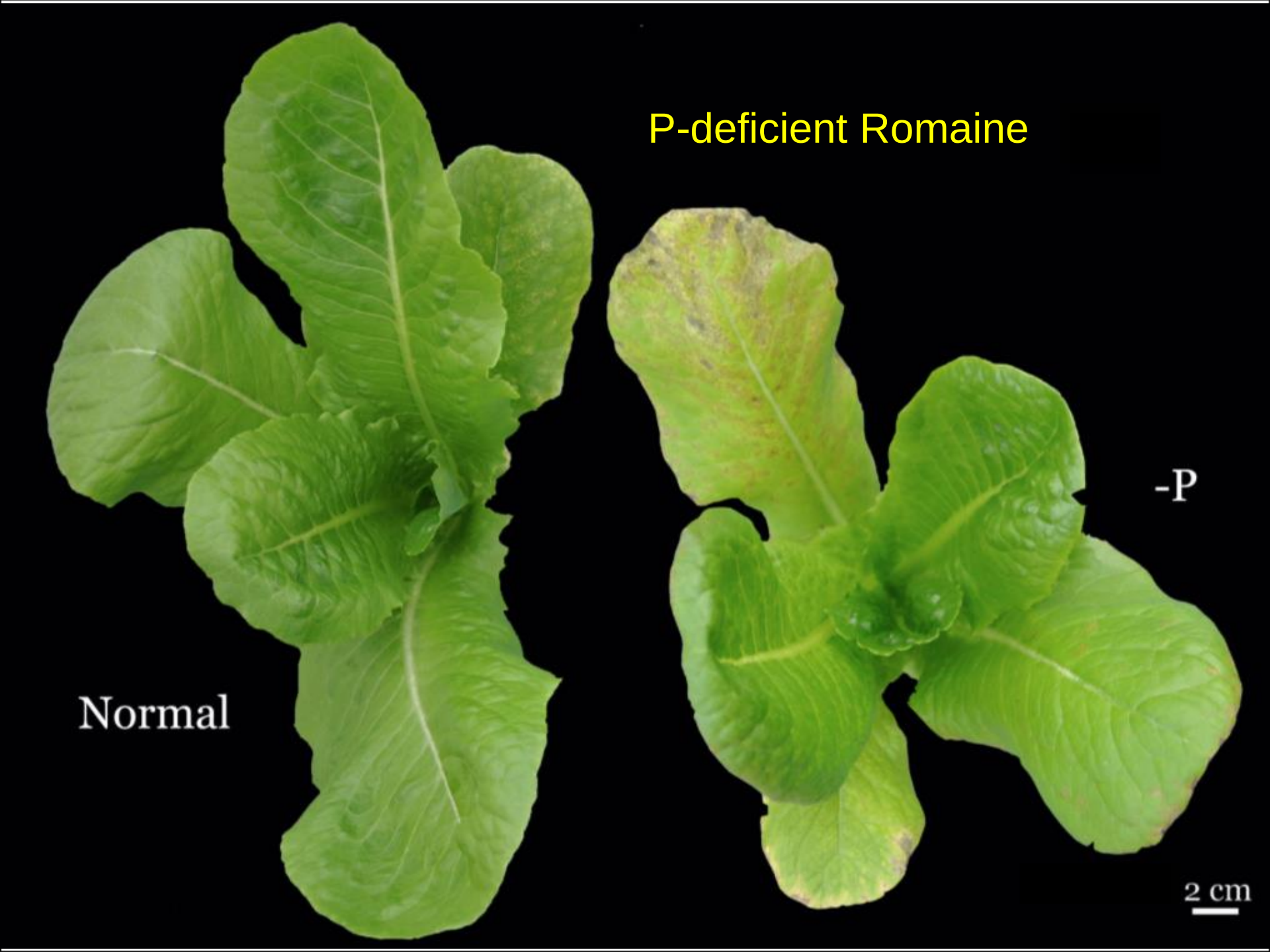
Phosphorus deficiency

P-deficient butter lettuce


P-deficient butter lettuce

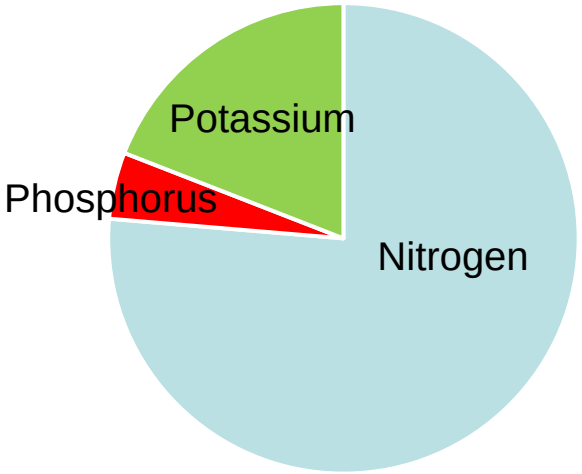

P-deficient Romaine
Normal
-P
2 cm

P-deficient broccoli

The Essential Role of Phosphorus

- Plants get 14 essential nutrients from the soil
  - Some are taken up in greater quantities, but all are just as essential

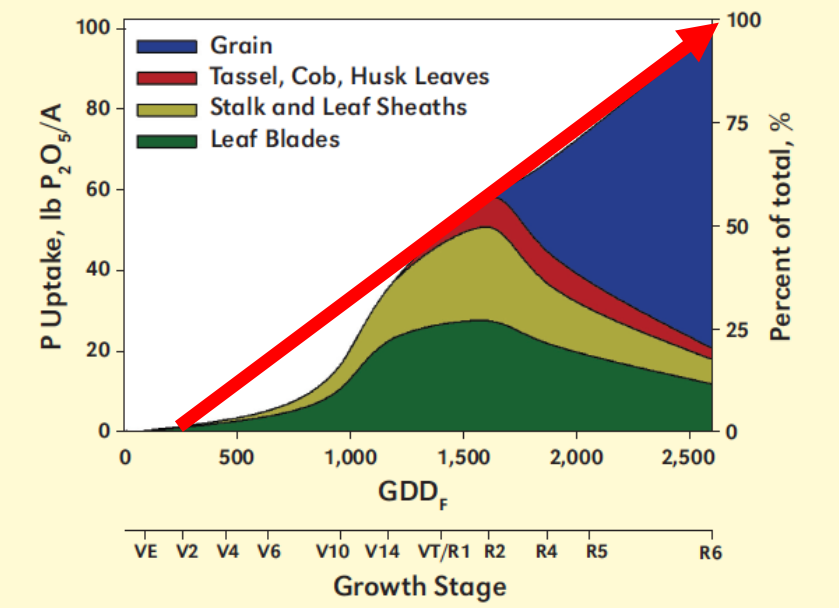
Of the three “primary” plant nutrients, the amount of phosphorus uptake is lowest, following nitrogen and potassium



The Essential Role of Phosphorus

- Plants get 14 essential nutrients from the soil
  - Some are taken up in greater quantities, but all are just as essential

- A constant supply of P needed through the growing season (corn example)



Bender, R.R. et a;. 2013 Better Crops. 97 (1):7-10

Not enough phosphorus? Symptoms

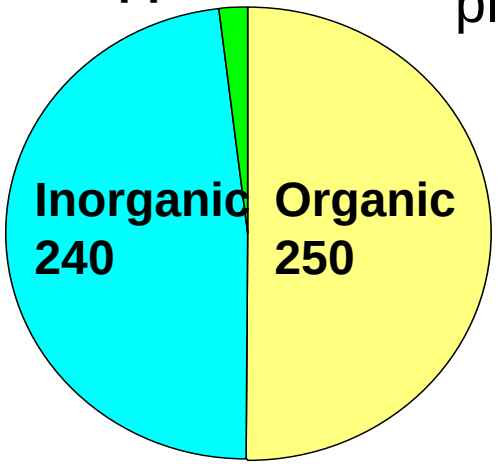
- Purple leaves (?)
- Stunted plants
- Distorted leaf shape
- Reduced tillering, fewer heads
- Reduced root mass
- Delayed maturity
- Reduced yield

"Not all purple plants are phosphorus deficient, and not all phosphorus deficient plants turn purple."

The Colors in Phosphorus Deficient Plants. 2016. Better Crops. 100 (1):14-16.

General forms of soil phosphorus

example:
Soil test P
of 5-30 ppm



Less than 5% of total soil P is immediately plant available

Phosphorus taken up by plants as:

- Primary orthophosphate ion

$$H_2PO_4^-$$

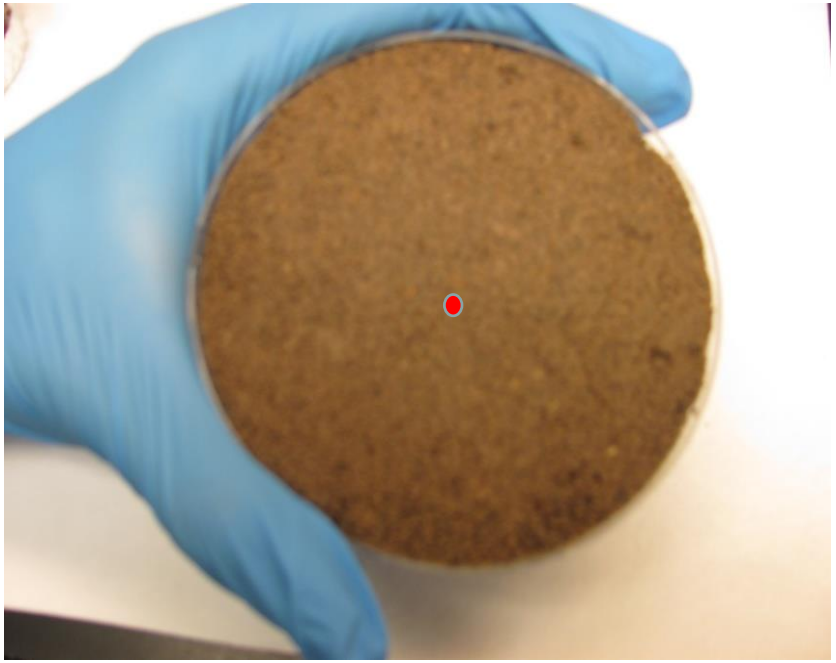
- Secondary orthophosphate ion $=$

$$HPO_4$$

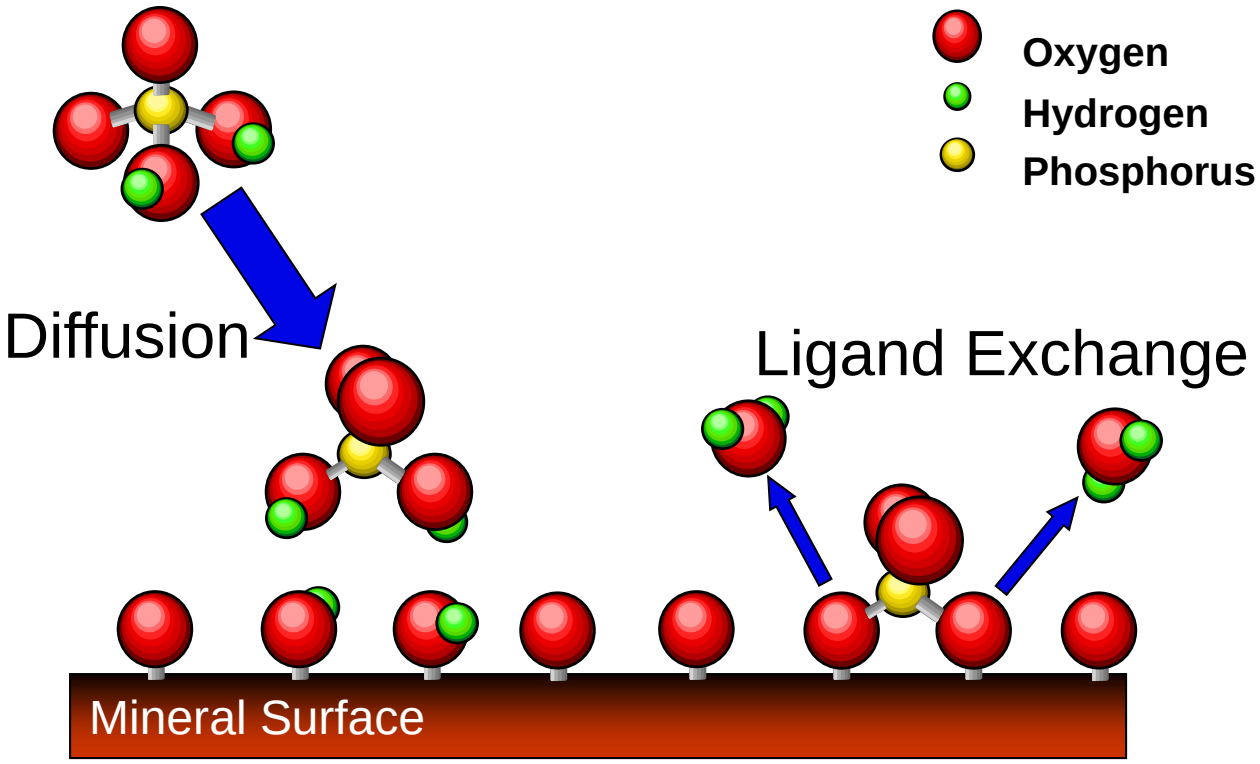
What happens after phosphorus is added to soil?

Well, it depends…

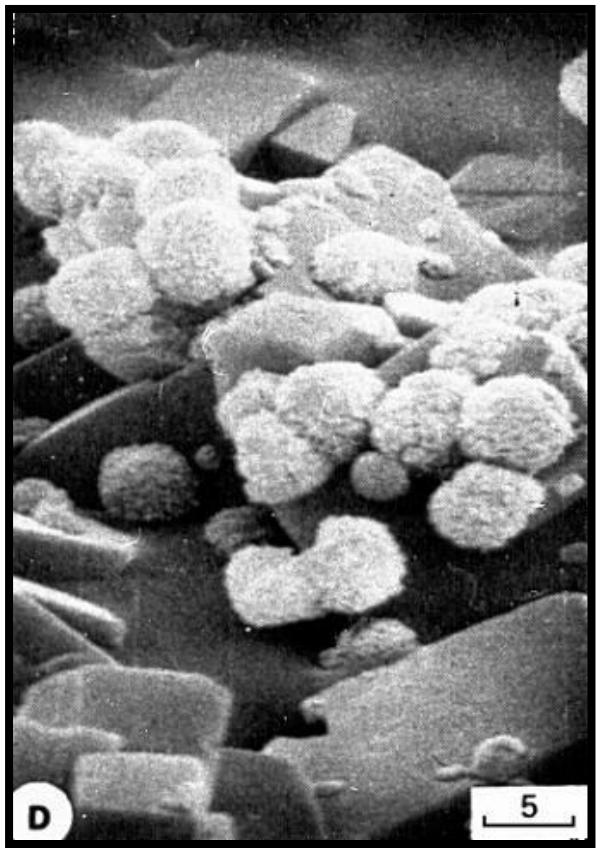
Soil minerals
Soil pH
Fertilizer source
Placement
Time
Rate
Plant species
etc.



Phosphorus adsorption on soil surfaces

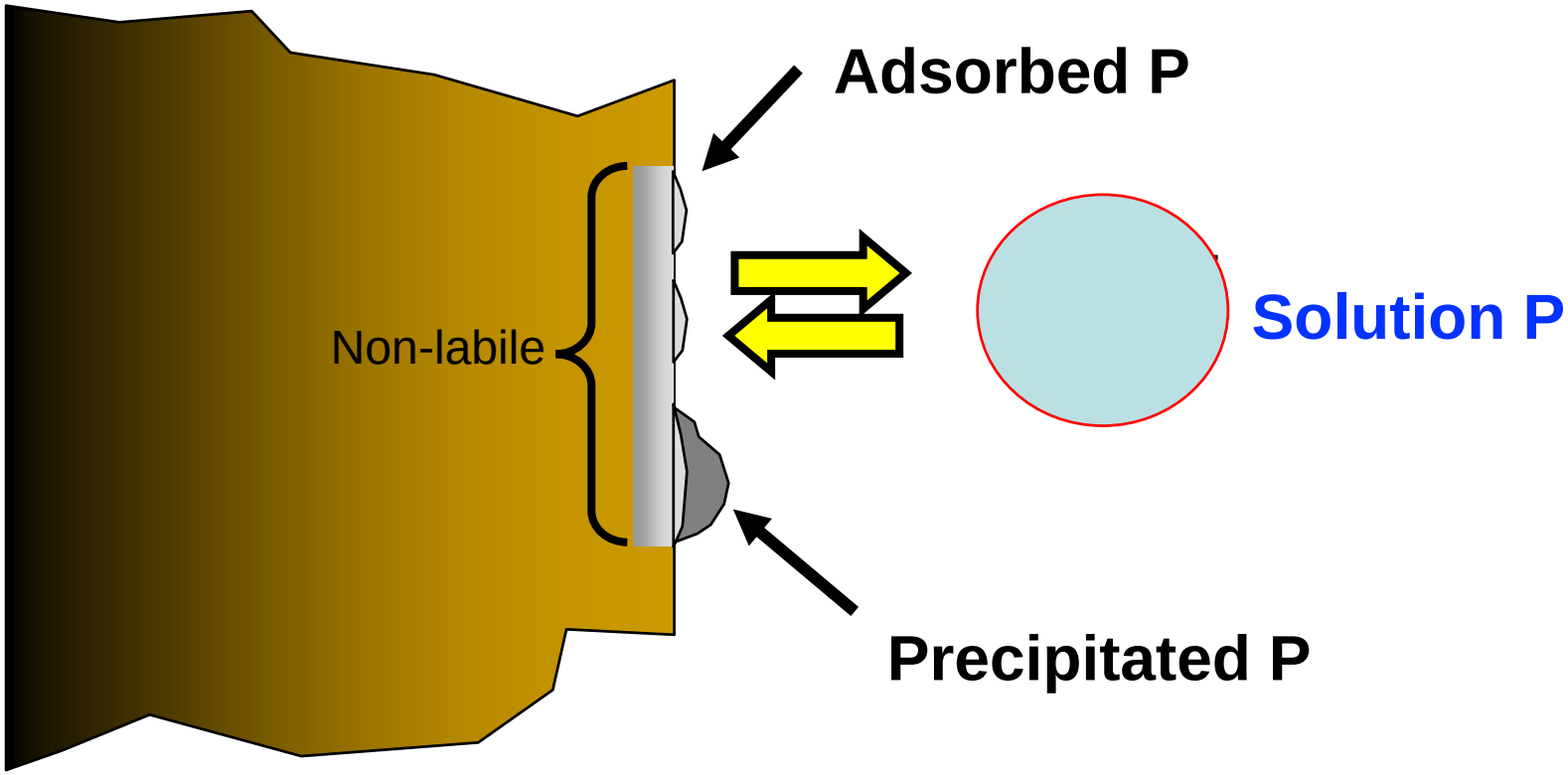


Phosphorus can react with soil cations and minerals to **precipitate** and form new solid materials (Ca, Mg, Al, Fe)



P minerals precipitating on the surface of calcite

Phosphorus on surface of soil particles



How do plant roots recover phosphorus from the soil?

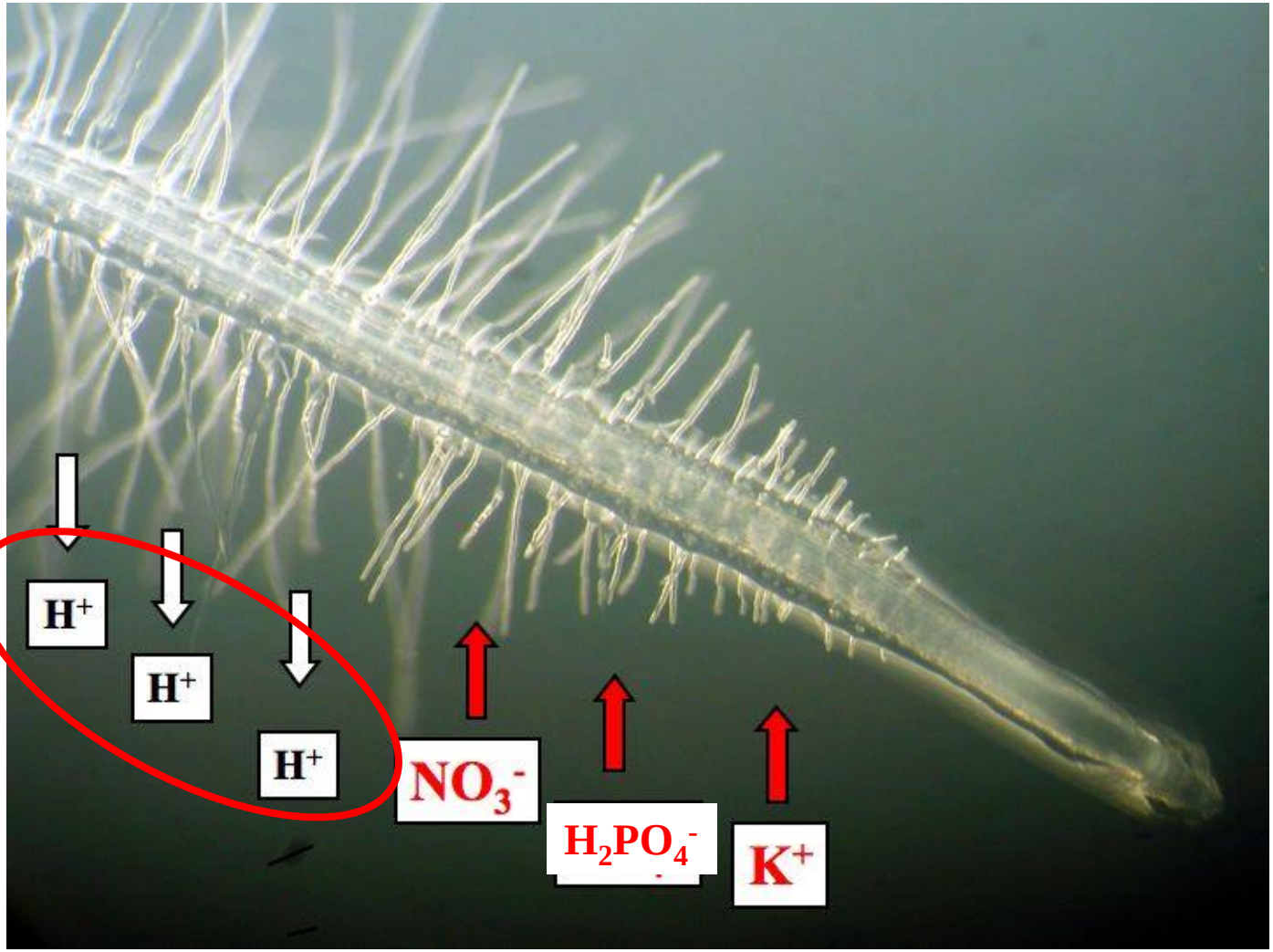
Brief overview:

1. Dissolved phosphorus moves from area of high concentration to an area of low concentration (process of diffusion)

2. Roots modify the surrounding soil:

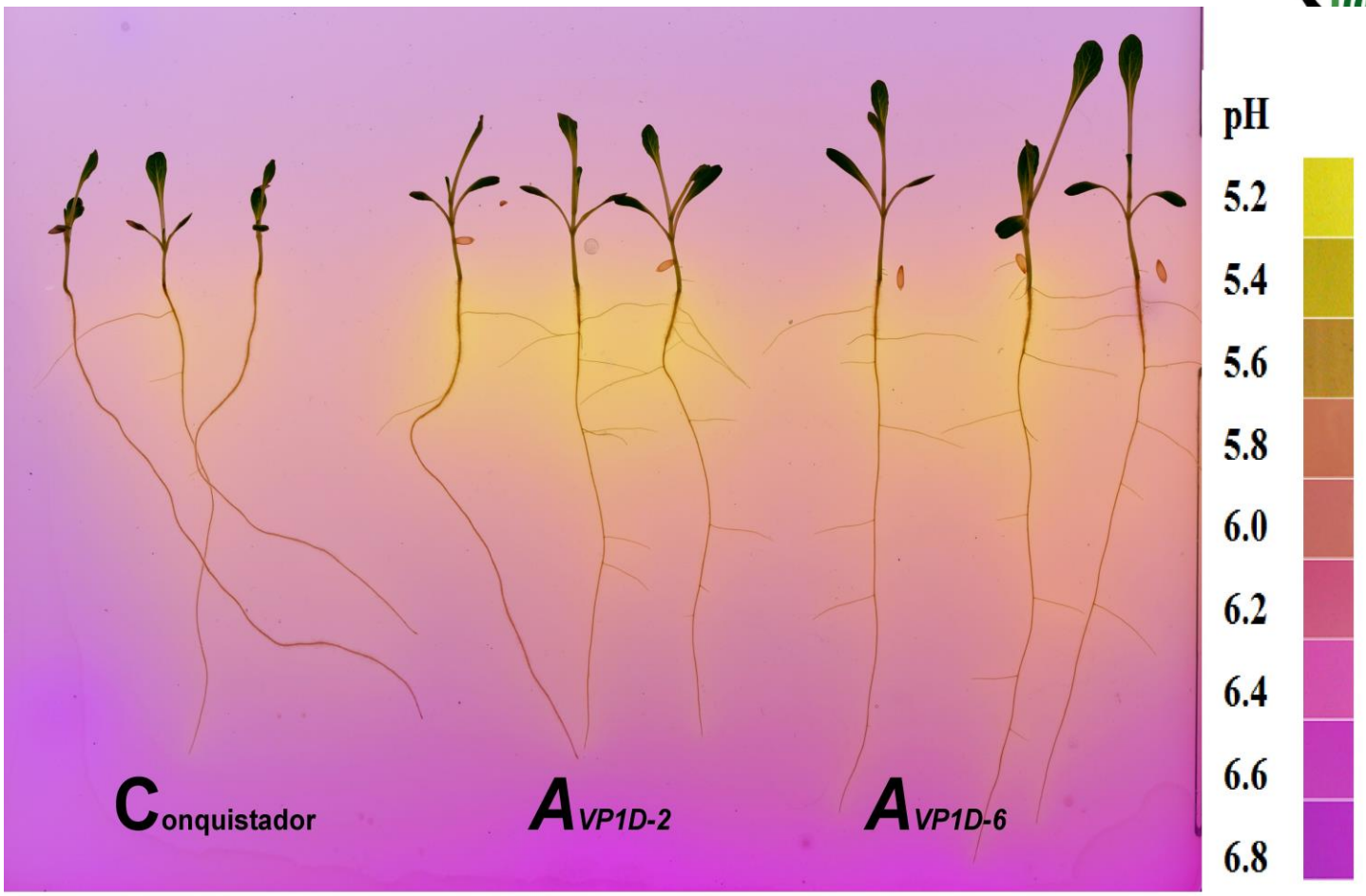
- Plant roots combine with fungi
- Plant roots release organic acids to solubilize P
- Plant roots release enzymes that liberate P from organic matter

Rhizosphere acidification is one mechanism for phosphorus nutrition



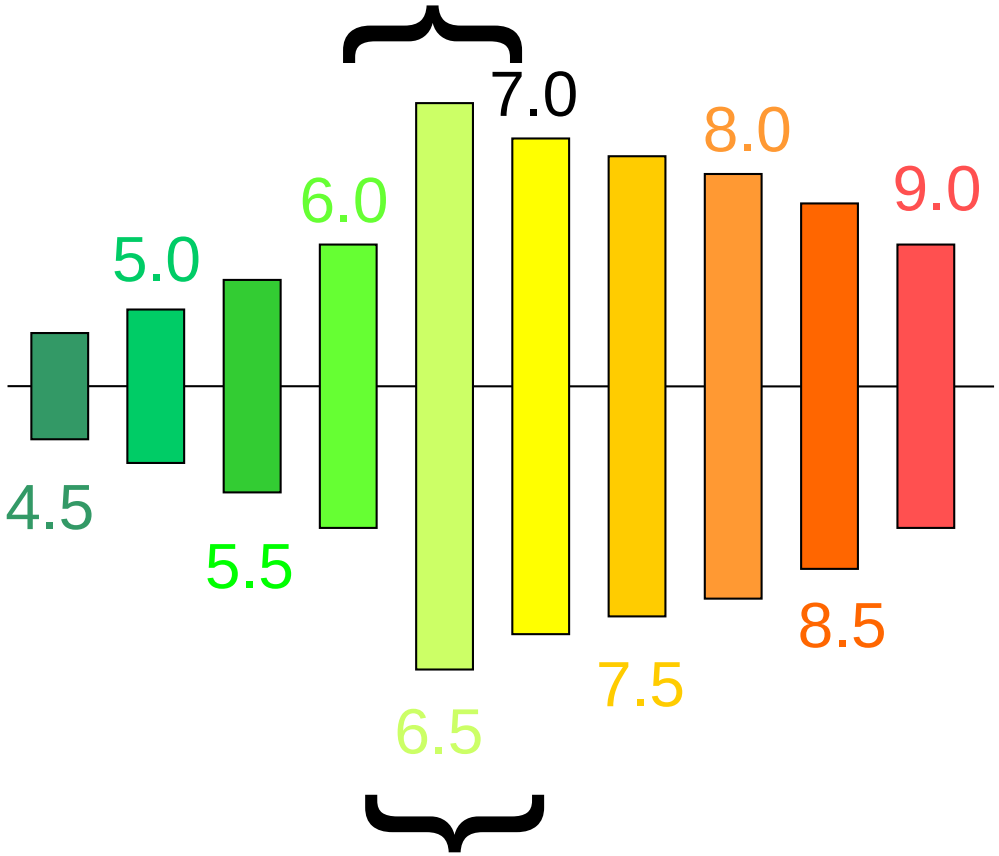
Yellow color indicates acid excreted by lettuce roots

Roberto Gaxiola,
Ariz. State Univ.

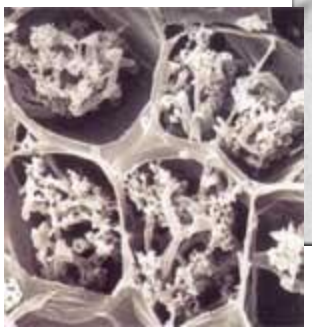


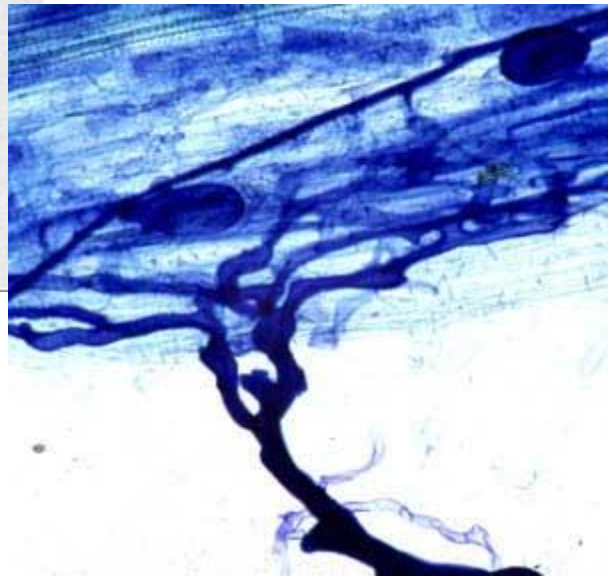
Root growth and rhizophere acidification of conventional and AVP1 romaine lettuce

Soil pH and Phosphorus Availability



Arbuscular Mycorrhizal Fungi





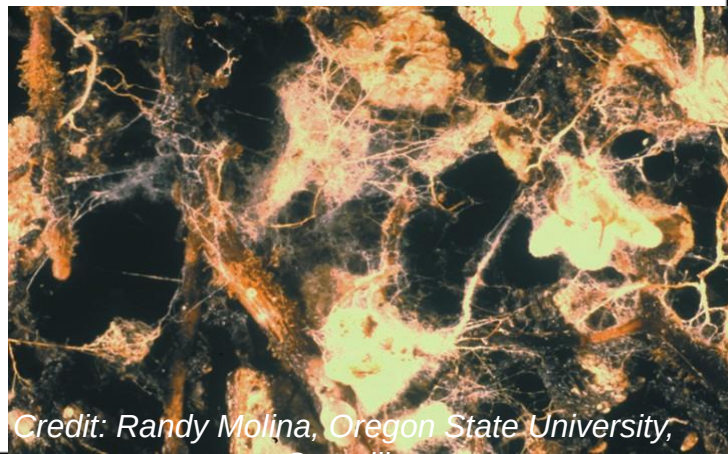
…allows P to be extracted to a lower concentration, but provides no additional P to the rootzone

Arbuscular Mycorrhizal Fungi

- Symbiotic association between fungus and root
  - Root provides food (carbon source)
  - Fungus increases root exploration and nutrient uptake… esp. when plants are stressed for P
- Organic Agriculture may increase mycorrhizal infection
- Sometimes increase P uptake/crop growth

…and sometimes not

Even with VAM, all crops still respond to P additions when soil reserves are low



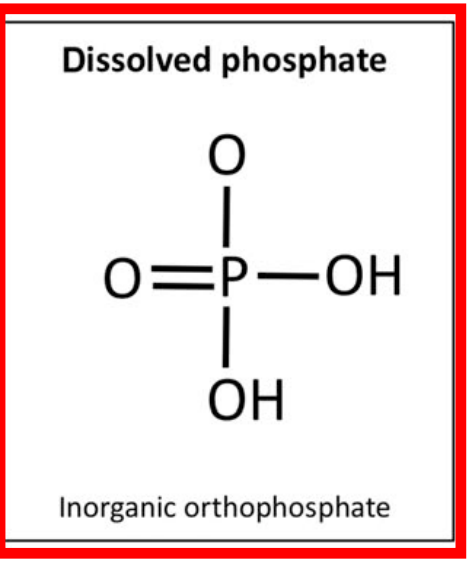
Credit: Randy Molina, Oregon State University,

Effect of tillage on mycorrhizal infection and P nutrition of corn

Intense tillage **reduces** root-fungi interaction

	Mycorrhizae	P-uptake		
	3-leaf	3-leaf	6-leaf	Harvest
	% of No-till	*kg P/ha*		
No-till	100	0.06	0.26	17.5

Common forms of soil phosphorus

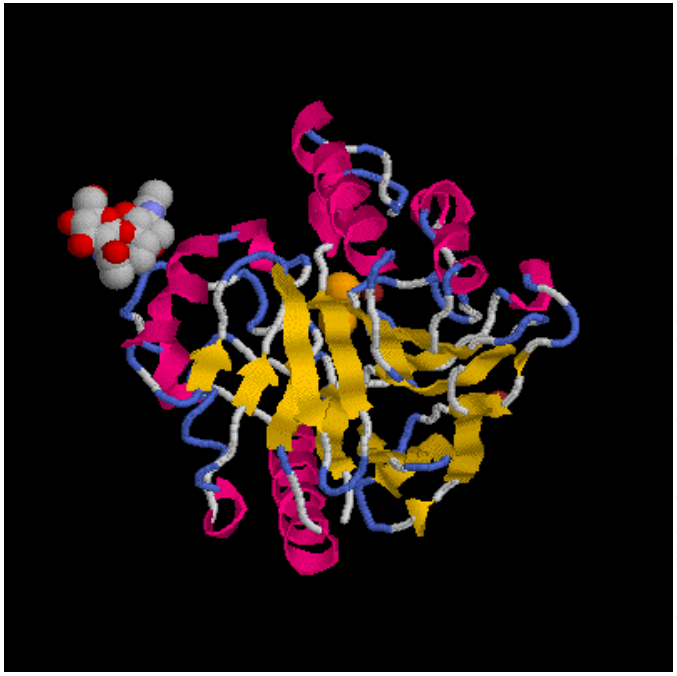


$H_2PO_4^{2-}$

Roots and microbes produce enzymes that break down organic P compounds into phosphate

http://biochem.siu.edu/chime_rasmol/zinc_proteins/alk_phos_rc.htm

Alkaline phosphatase



http://biochem.siu.edu/chime_rasmol/iron_proteins/p_acid_phos_rc.htm

Acid phosphatase

Manures and Composts as P Sources

Majority of P in manures and composts is **inorganic P**

Source	% Organic P	% Inorganic P
Feedlot manure	25	75
Composted manure	16	84
Dairy	25	75
Poultry litter	10	90
Swine	9	91

Source: Eghball et al., 2002. J. Soil Water Conserv. 57:470-473.

Bone Meal:

Bones are **very slow to dissolve** in our environment…
will not meet plant P requirements in a reasonable period

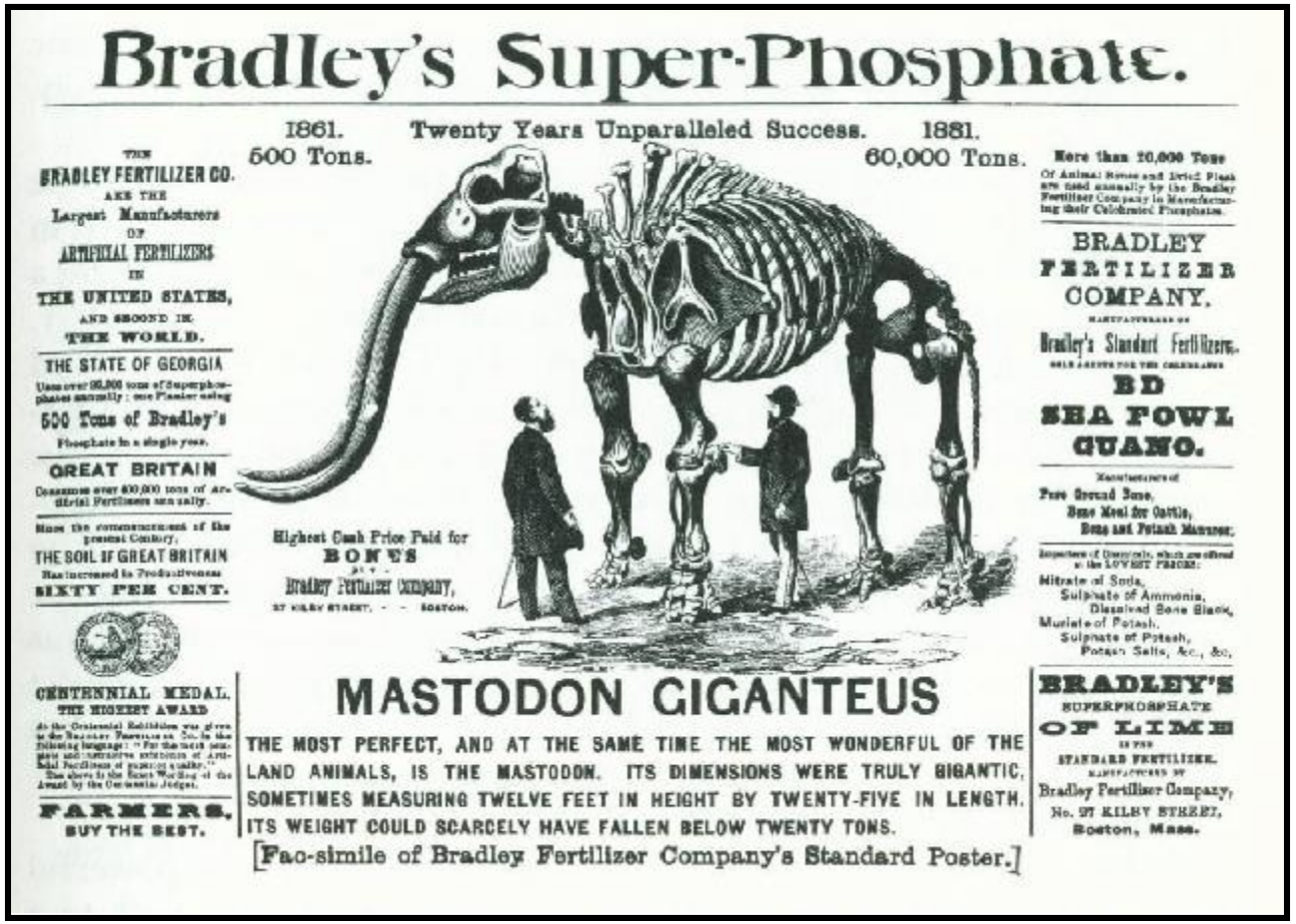
Bone Meal

Primary mineral is
Hydroxyapatite

grinding bones increases reactive surface area

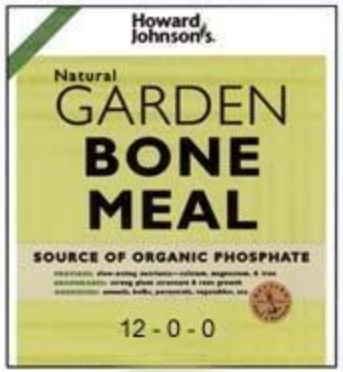
reacting bones with acid makes
"single super phosphate"

Early P fertilizers were made from adding acid to animal bones



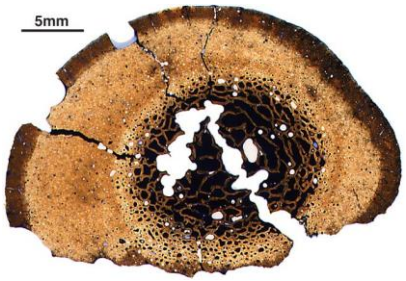
[Fac-simile of Bradley Fertilizer Company's Standard Poster.]

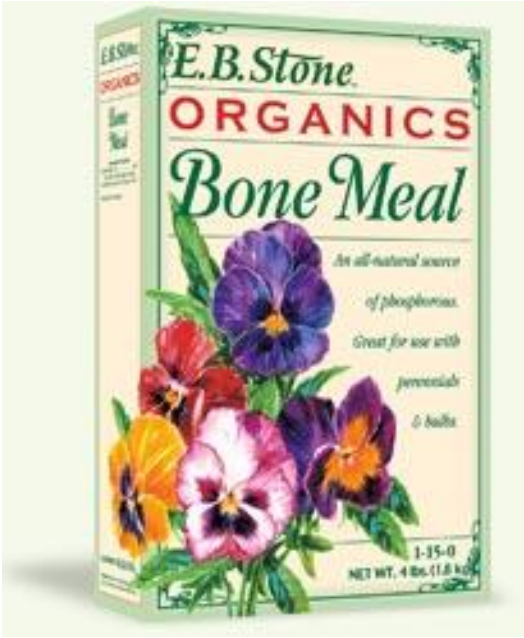
Acidity required to dissolve the bone minerals - soil acidity or mineral acids


Howard Johnson's
Natural
GARDEN
BONE
MEAL
SOURCE OF ORGANIC PHOSPHATE
12 - 0 - 0


Fish Bone Meal
3-16-0

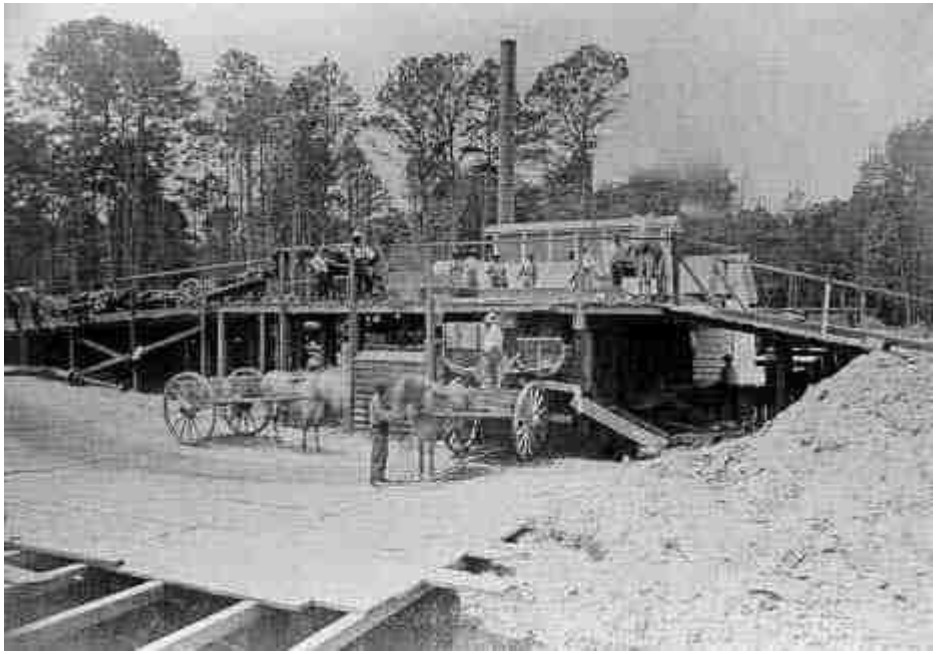

DR. Q's
BONE
MEAL
0.5-15.0
A natural source
of phosphorus.
100%
organic
Net Weight 20 lbs. / 9.072 kgs.


5mm


E.B. Stone
ORGANICS
Bone Meal
An all-natural source
of phosphorus.
Great for use with
perennials
& bulbs
1-15-0

Rock Phosphate

First U.S. phosphate deposits discovered and developed in South Carolina (1867)



Rock P is reacted with sulfuric acid or phosphoric acid to make the P soluble

What happens to rock P?

$$2\ Ca5F(PO_4)_3 + 7\ H_2SO_4 \rightarrow 3\ Ca(H_2PO_4)_2 + 7\ CaSO_4 + 2\ HF$$

Rock phosphate

Soluble phosphate

Reaction requires **acidity** to take place and release plant-available phosphate

Approved Rock P Sources

Phosphate Rock (OMRI)

HumaPhos (Midwestern Bio-Ag)
Ida-Gro pelletized Phosphate (Soda Springs)
Ida-Gro powdered
Montana Gray Rock (Montana Gray Rock)
Montana Natural Rock Phosphate (Pacific Calcium)
Phosphate Rock (North Country Organics)
Phyta-Grow Granular Rock P (Calif Organic Fert)
Rock Phosphate (E.E.G.A.L. Farm Service)
Rock Phosphate (Fertrell Co.)
Tennessee Brown Rock (Calcium Silicate Corp.)

Green Manures as a P Source?

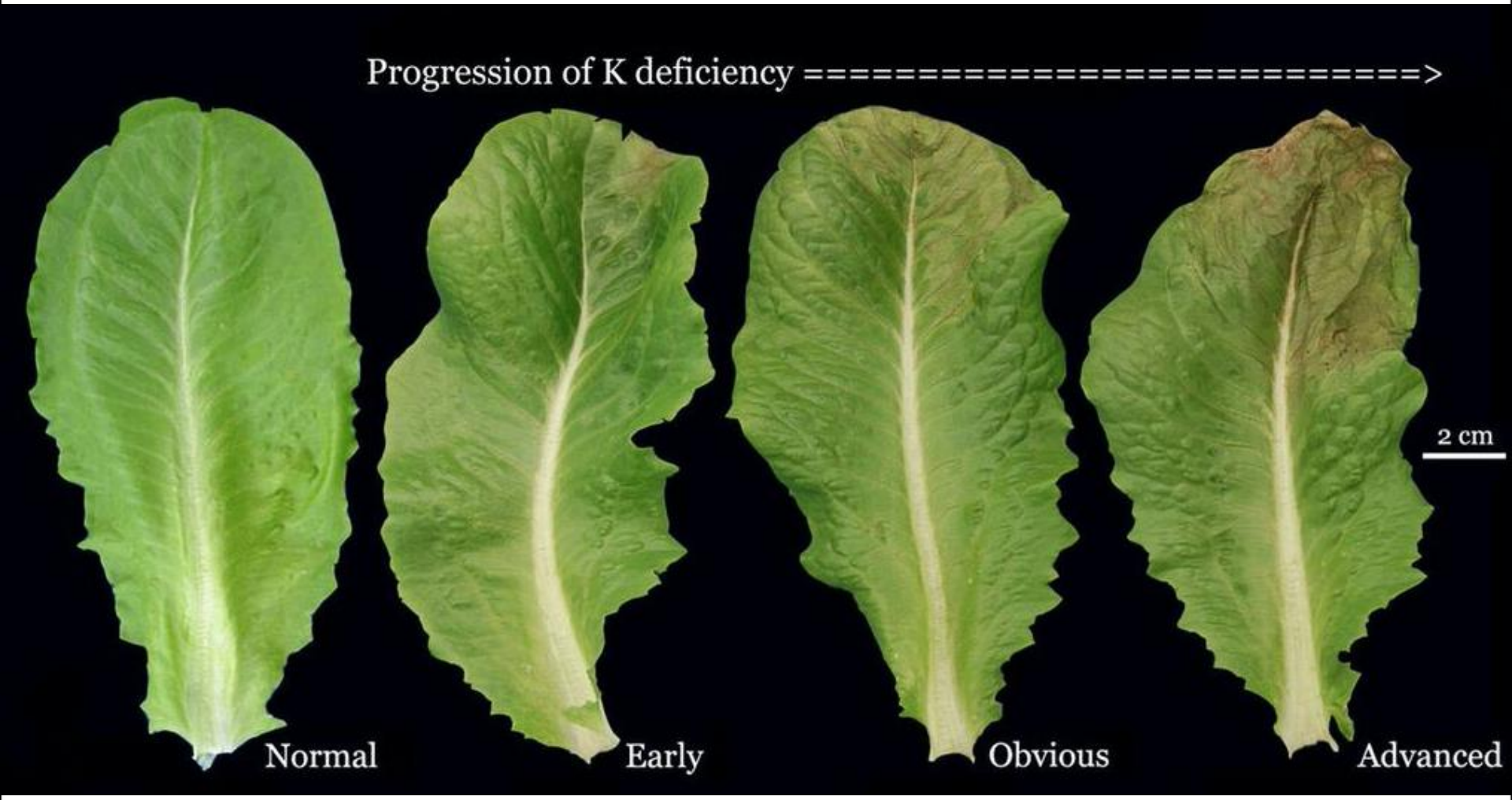
- Green Manures – legume crops grown and tilled in to soil (not harvested).
- Some species can extract soil P that is unavailable to other crops or deeper soil
  (e.g., white lupin, faba bean, alfalfa)
- Decomposition releases P
- Some green manures may decrease P uptake of succeeding crop (e.g., white lupin).

- Green manures may increase P availability, but are <u>not a P source</u>

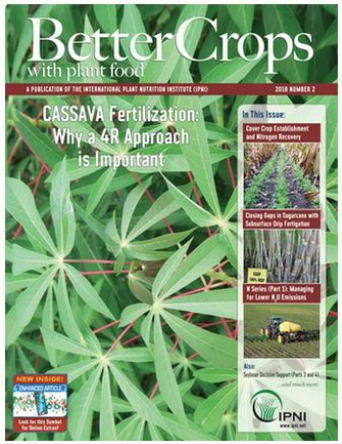

K-deficient Romaine


K-deficient Romaine

K-deficient Romaine




K-deficient butter lettuce



Summer, 2018

Don’t overlook potassium!

IPNI

Quality: Potassium Management is Critical for Horticultural Crops

By Robert Mikkelsen

Quality, What is it?

Potassium is frequently referred to as the “*quality*” nutrient for plants. Quality has many characteristics and the most important aspects of quality will depend on the specific crop. For example, with citrus, it may be the thickness of the peel and Vitamin C concentration, for apples, sugar concentrations, while for tomatoes, the development of uniformly red fruit rich with lycopene. The specific quality parameters for each crop will vary and should be well understood to maximize crop nutritional practices and market profitability (Kumar et al., 2006).

While many “quality” benefits are generally understood, it can be difficult to define and quantify the exact benefits of K (Lester et al., 2010a). Most notably, the lack of quality is frequently observed when the plant K supply becomes

iStock Images

Vitamin C

Application of K to the soil or plant foliage has been shown to increase the concentration of Vitamin C in a variety of fruit crops. While citrus is the most frequently cited example, increased Vitamin C has been reported in crops such as cucurbits, cauliflower, onion, banana, guava, and papaya (Imas, 2013). Muskmelon also had higher concentrations of Vitamin C as a result of foliar K sprays (Lester et al., 2010b).

Nitrate Assimilation and Protein Synthesis

Potassium plays an important role in converting nitrate into amino acids and proteins. An insufficient supply of K may result in both lower nitrate uptake from the soil and slower nitrate assimilation into amino acids and proteins. Potassium deficiency can result in accumulation of low molecular weight sugars and carbohydrates, along with soluble-N compounds in the plant.

Nitrate accumulation in K-deficient plants can be a concern where limits have been established (such the European Union nitrate limit for leafy vegetables). When nitrate is rapidly converted to protein, the concern for healthier food is satisfied.

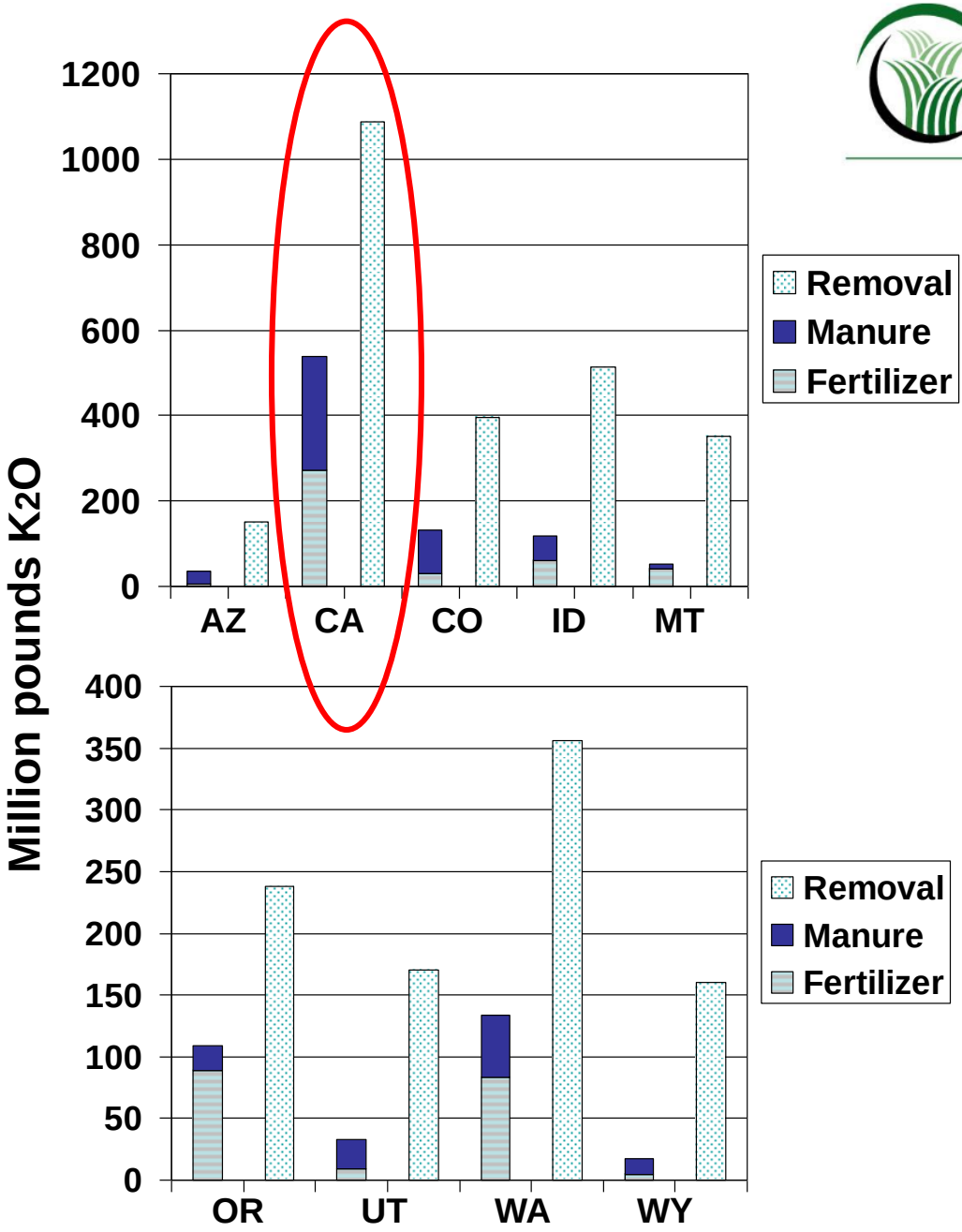
Appearance of Fruits and Vegetables

An adequate K supply has been linked to improved visual appearance of many horticultural crops. For example, banana is a crop that frequently responds favorably to K

http://www.ipni.net/bettercrops

We have a **potassium deficit** in Western Ag and in North America

2 pounds K removed for every one pound replaced in California



Where does potash come from?

All commercial potash deposits come from marine sources:

Ancient seas that are now covered: Canada and New Mexico

Where does potash come from?

All commercial potash deposits come from marine sources:

Ancient seas that are now covered: Canada and New Mexico

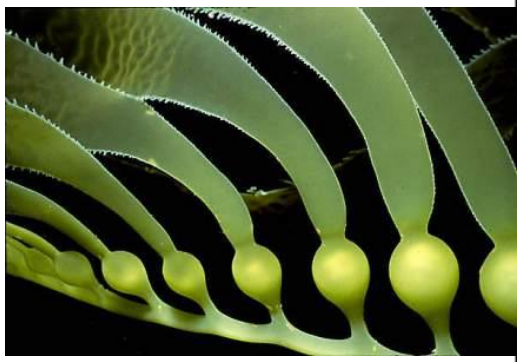
Salt water brines: Great Salt Lake, Dead Sea

Raw ore is washed to remove sodium and produce commercial fertilizer

Kelp-based products are available as specialty K products

Kelp Meal (~0-0-2)

- Algit Norwegian Kelp Meal (Ohrstrom (P.B.) & Sons, Inc.) **A**
- Fertrell's North Atlantic Kelp Meal (Fertrell Company) **A**
- Ground Seaweeds (ABK-GASPÉSIE, INC.) **A**
- GroundsKeeper's Pride Kelp Meal 1-0.15-1.5 (Int Comp. **A**
- Kelp Meal Fertilizer (Acadian Seaplant) **A**
- Kelpropac (Productos del Pacifico, S.A. de C.V.) **A**
- Thorvin™ Kelp for Plants (Thorvin, Inc.) **A**
- Thorvin™ Kelp for Plants (Thorvin, Inc.) **A**
- Tidal Organics Kelp Meal (Tidal Organics, Inc.) **A**
- Wegener's Oceanic Kelp Meal 1-0.15-1.5 (Rambridge Wholesale Supply) **A**



Common Organic Potash Fertilizers

- **Muriate of potash (KCl)**

  (0-0-60)

NOT allowed in U.S.

Common Organic Potash Fertilizers

- **Potassium Sulfate (K_2SO_4)**
  (0-0-50 + 18S)

Solar evaporation (**allowed**)

Reaction of KCl with
sulfate source (not allowed)

Potassium sulfate production from the **Great Salt Lake**

Potassium Sulfate (~0-0-50)

- Ag Granular SOP Organic (Great Salt Lake Minerals) **A**
- Champion Sulfate of Potash Granulated (SQM NA Corp.) **A**
- Choice Granular SOP Organic (Great Salt Lake Minerals) **A**
- Mid Granular SOP Organic (Great Salt Lake Minerals) **A**
- Mini Granular SOP Organic (Great Salt Lake Minerals) **A**
- Natural Sulphate of Potash (North Country Organics) **A**
- Quick Solution (Pacific Coast Resources Corp.) **A**
- Soluble Fines SOP Organic (Great Salt Lake Minerals) **A**
- Standard SOP Organic (Great Salt Lake Minerals) **A**
- Standard Sulfate of Potash (SQM North America Corp.) **A**
- Ultra Fines™ Sulfate of Potash (Diamond K Gypsum) **A**
- Water Soluble Sulphate of Potash (SQM NA Corp.) **A**

Common Organic Potash Fertilizers

Potassium magnesium sulfate
(K-Mag, Sul-Po-Mag, Trio)
(K_2SO_4 – $2MgSO_4$)

(0-0-22 with 22% S + 11% Mg)

Langbeinite is mined directly in New Mexico

Allowed as organic source of K

Langbeinite (~0-0-22)

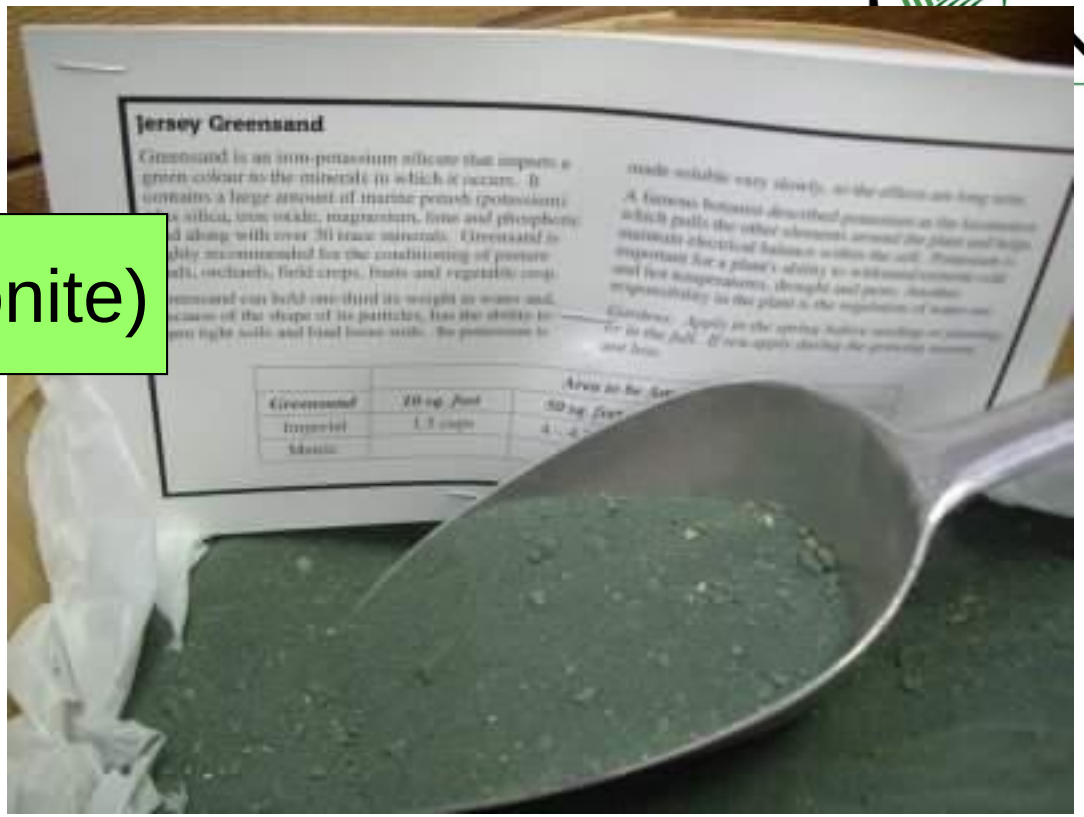
- ~~K-Mag® Natural Granular (Mosaic USA, LLC)~~
- ~~K-Mag® Natural Standard (Mosaic USA, LLC)~~
- Trio (Intrepid) **A**
- KMS (Diamond K Gypsum) **A**

Potassium Nitrate (~13-0-44)

Mined on Chile… (OK)

Reaction of KCl and nitric acid (not allowed)

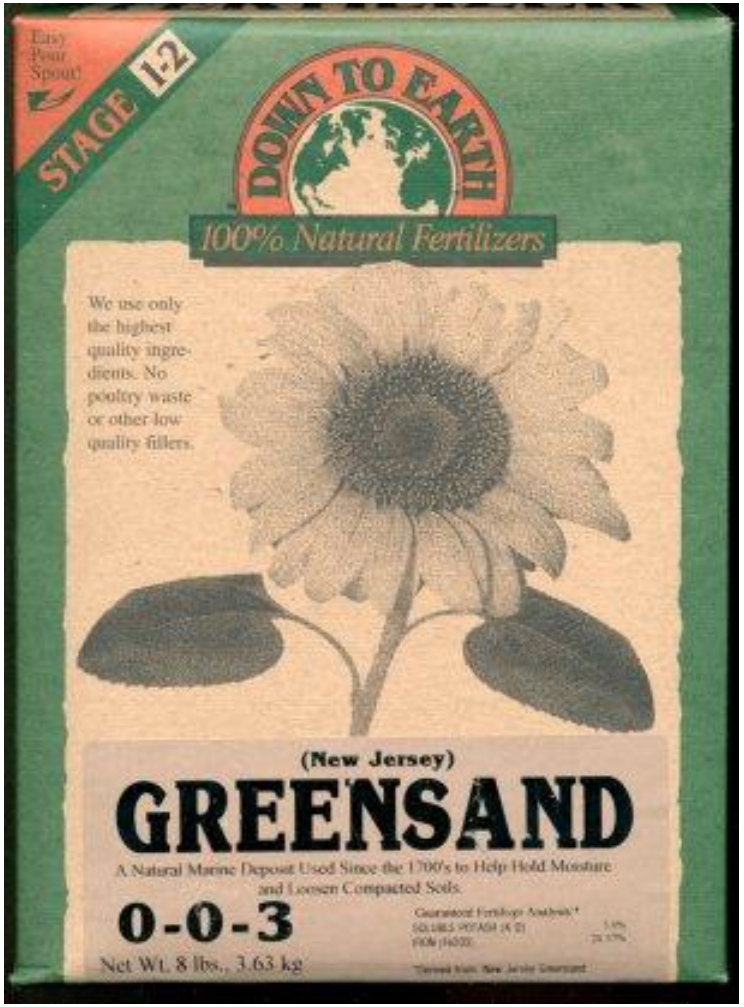
Greensand (glauconite)



Greensand (glauconite)

Developed as potential K source

- low K (3 to 7% K2O)
- very low solubility
- bulky and expensive to transport
- poor source of plant-available K



Greensand (Glauconite) (~0-0-5)

- Greensand (North Country Organics) **A**
- Jersey Greensand (The Fertrell® Company) **A**

Ash (~0-2-5)

Only **wood** ash allowed…

manure, coal, biosolid ash not allowed

Highly variable:

contains whatever was in the wood when burned and was not volatilized

pH ranges from 9 to 13

Lime equivalent of 8 to 90% depending on many factors

Manure and Compost K

Highly variable K content depending on the feedstock manure characteristics, and manure handling

Generally very soluble and readily available (K is not part of cells)

Animal K is largely excreted in the urine…

so manure handling makes a large difference

Many excellent organic nutrient sources for P & K

… but also many lousy sources of nutrients

- **Start with soil testing to establish need for P & K**
- **Use appropriate nutrient source that will accomplish your goal**

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