THE UNIVERSITY OF MAINE

Fundamentals of Soil Fertility Management

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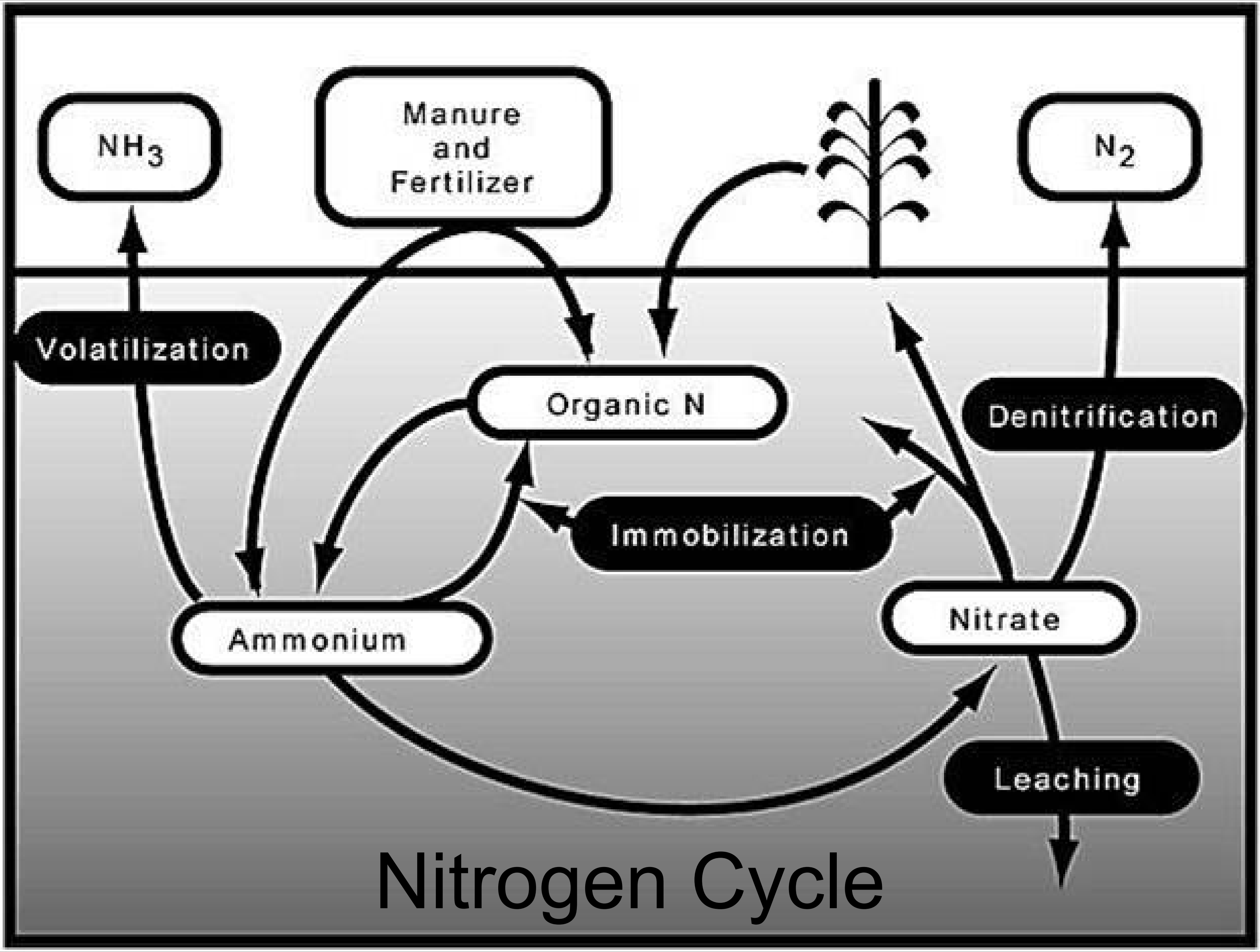
Nitrogen:
The Most Common Deficiency



Nitrogen Cycle

Potato Nitrogen Uptake Profile

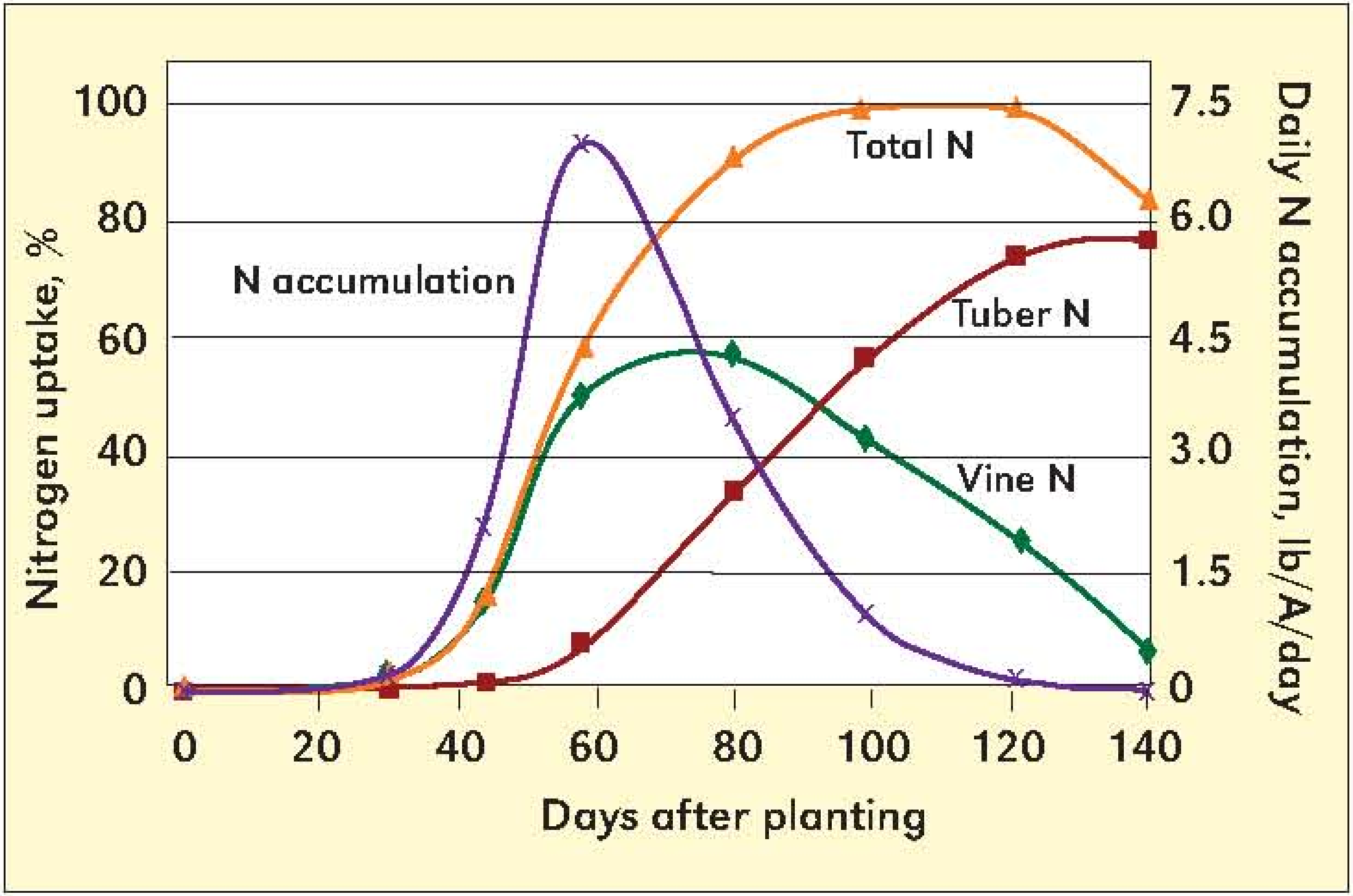


Figure 2. Seasonal N accumulation by Russet Burbank potato vines, tubers, and whole plants (left axis) and the average daily N accumulation rate (right axis) growing near Becker, Minnesota. Nitrogen uptake is expressed as a percent of the total seasonal accumulation.

Corn Nitrogen Uptake Profile

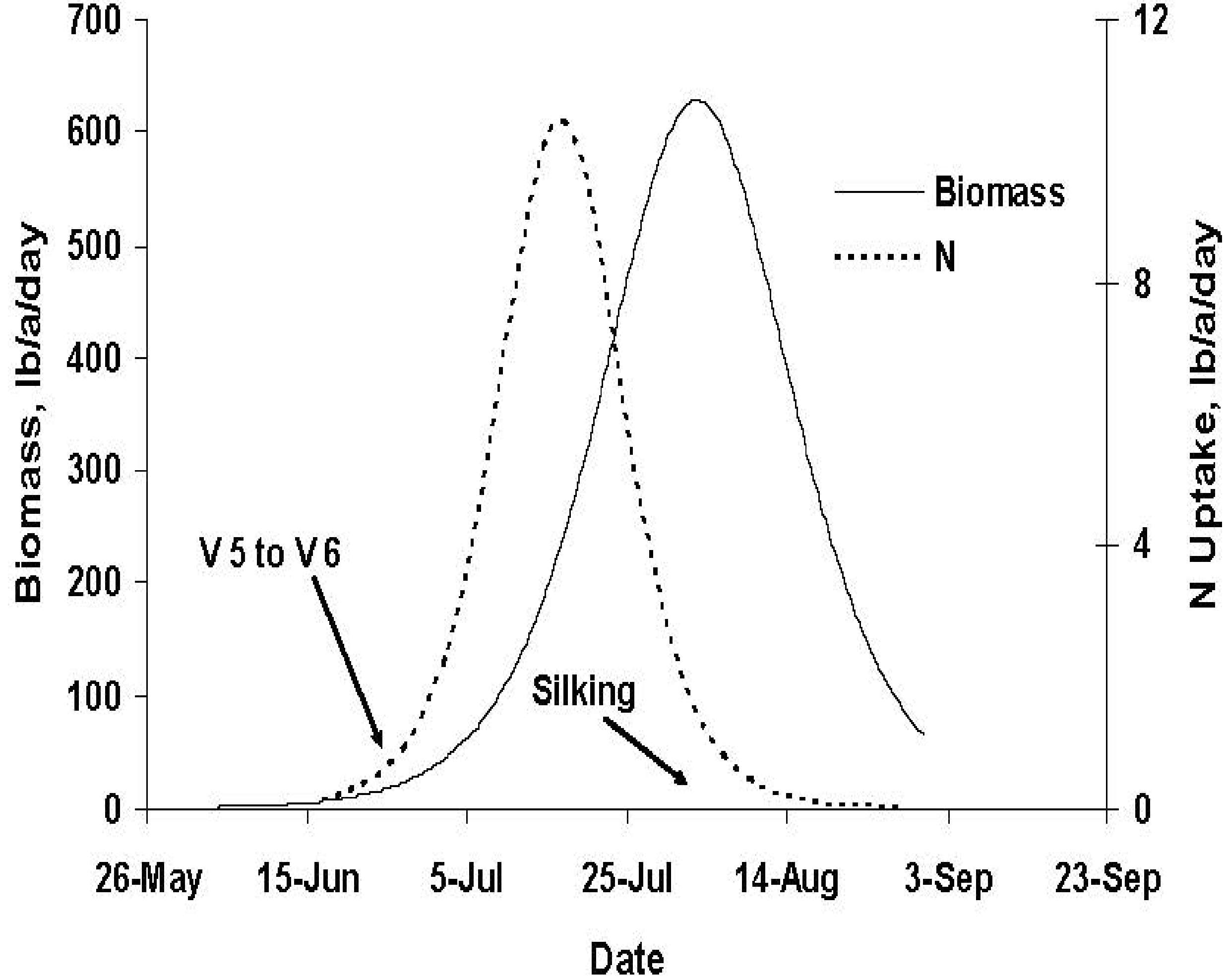


Figure 8.—Coho sweet corn daily above-ground biomass (dry matter) and nitrogen accumulation.

Common Chemical N Sources

- Granular
  - Urea 46-0-0
  - Ammonium nitrate 33-0-0
  - Ammonium sulfate 21-0-0
  - MAP 11-50-0
  - DAP 18-46-0
- Liquid
  - UAN 30-0-0
  - Ammonium polyphosphate 10-34-0
  - Anhydrous ammonia 82-0-0

Acidifying Effect of N Fertilizers

pounds lime to neutralize 100 lb fertilizer

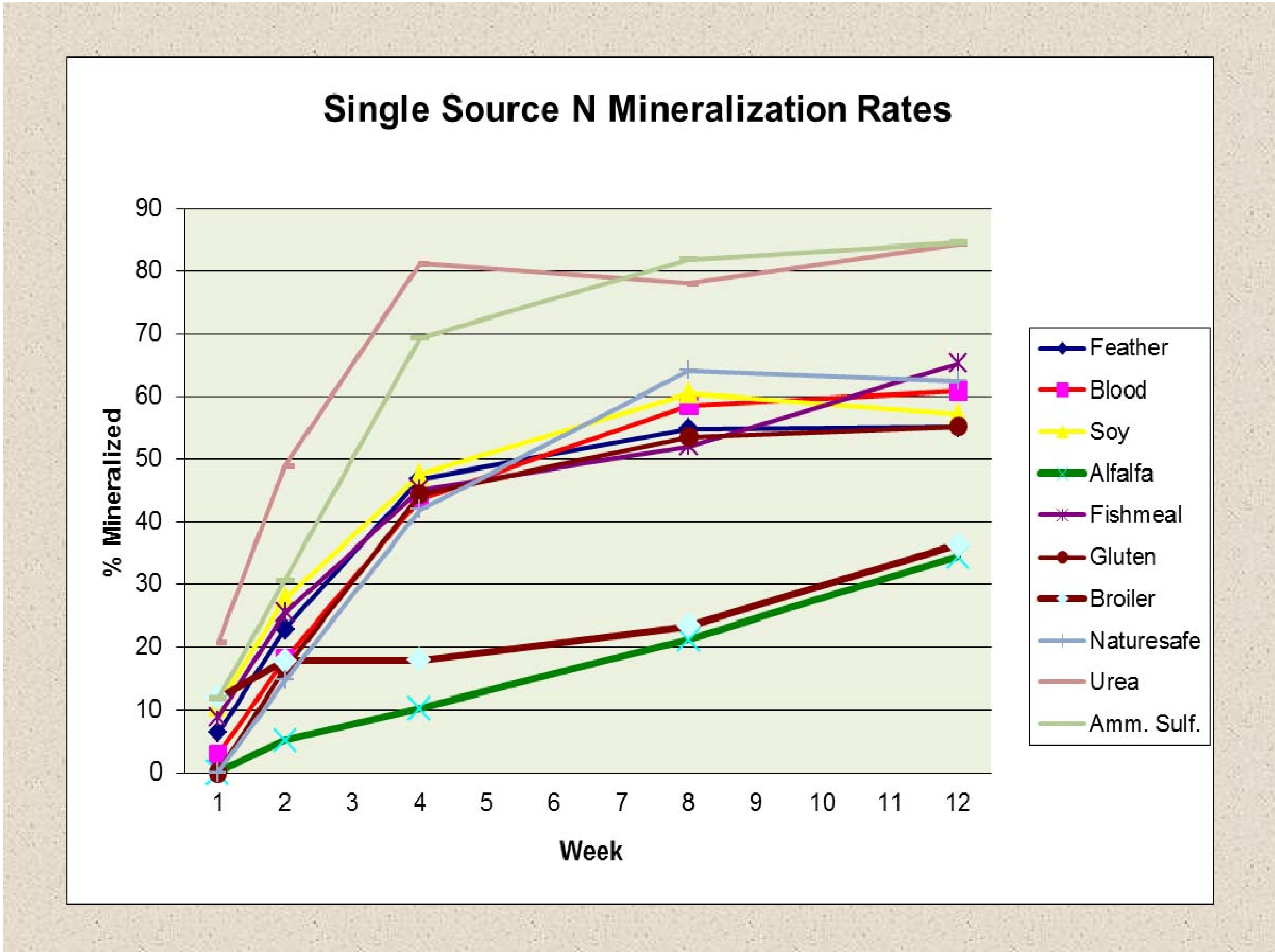
100 lb Urea	84 lb lime
100 lb Ammonium nitrate	63 lb lime
100 lb Ammonium sulfate	112 lb lime
100 lb MAP	65 lb lime
100 lb DAP	74 lb lime
100 lb UAN	54 lb lime
100 lb APP	53 lb lime
100 lb Anhydrous	148 lb lime

Non-Chemical Nitrogen Sources

- Plant or Animal Byproducts
- Animal Manures
- Cover Crops
- Compost
- Soil Organic Matter

Nitrogen Mineralization Studies Organic N Fertilizers

- Agehara & Warnke, Michigan St. (2005)
  - 3 temperatures (15, 20, 25 C) x 3 moisture levels
- Hartz & Johnstone, Cal. Davis (2006)
  - 4 temperatures (10, 15, 20, 25 C)
- Gale, et. al, Oregon St. (2006)
  - 22 C
- Darby, UVM (2012)
  - 2 soil textures (sandy & clay), 22 C
- Hoskins, UMaine (2014)
  - 60 F



Single Source N Mineralization Rates
% Mineralized
0
10
20
30
40
50
60
70
80
90
Week
1
2
3
4
5
6
7
8
9
10
11
12
Feather
Blood
Soy
Alfalfa
Fishmeal
Gluten
Broiler
Naturesafe
Urea
Amm. Sulf.

N concentration, C/N, release of N.

(Soil Science, 1942, Vol 54: 411-423)

Fertilizer Material	N ratio %	Total C/N	Added N converted to nitrate in soil at %-20 days	%-40day
Seed Meals:				
Soybean meal	7.6	4.7	*61*	*65*
Cottonseed meal	7.2	5.4	49	54
Castor pomace	5.0	9.4	60	67
Cocoa meal	3.0	15	14	22
Plant materials:				
Alfalfa hay	2.8	21	24	32
Peanut hull meal	1.2	54	15	15
Wheat straw	0.31	197	-16	-15
Animal products:				
Hoof meal	14.3	3.3	65	68
Bone meal	4.2	3.5	7	10
Dried Blood	13.8	3.5	60	66
Dry fish scrap	9.3	4.4	59	63
Animal tankage	8.6	5.3	37	45
Manures:				
Peruvian guano	14.0	1.3	80	77
Horse manure	1.5	33	-19	-16

Nitrogen from Manures

Manure C:N Ratios

(UK Project NT2106)

- Bedded cattle: 13.7, 15.6 (NH_4 = 10% total N)
- Bedded swine: 9.3, 10.0 (NH_4 = 10% total N)
- Poultry layer: 3.8, 5.0 (NH_4 = 46% total N)
- Liquid cattle: 5.3, 9.6 (NH_4 = 54% total N)
- Liquid swine: 1.9, 3.2 (NH_4 = 75% total N)

Long Term Release Rates Manure Organic N (Cornell)

- Year 1:
  - 55 % (poultry)
  - 35 % (all other liquid)
  - 25% (all other solid)
- Year 2: 12 % (all sources)
- Year 3: 5 % (all sources)


Nitrogen from Cover Crops

Cover Crop Nitrogen Credits (Cornell)

- Grass sod plowdown
  - ✓50-60 lb N credit
  - ✓Release rate temp. dependent

- Legume sod plowdown
  - ✓50 % Stand: 90-100 lb N credit
  - ✓50+ % Stand: 120-130 lb N credit

➢ Cool soil release rate roughly 50% in 30-40 days
  - ✓assumes spring incorporation

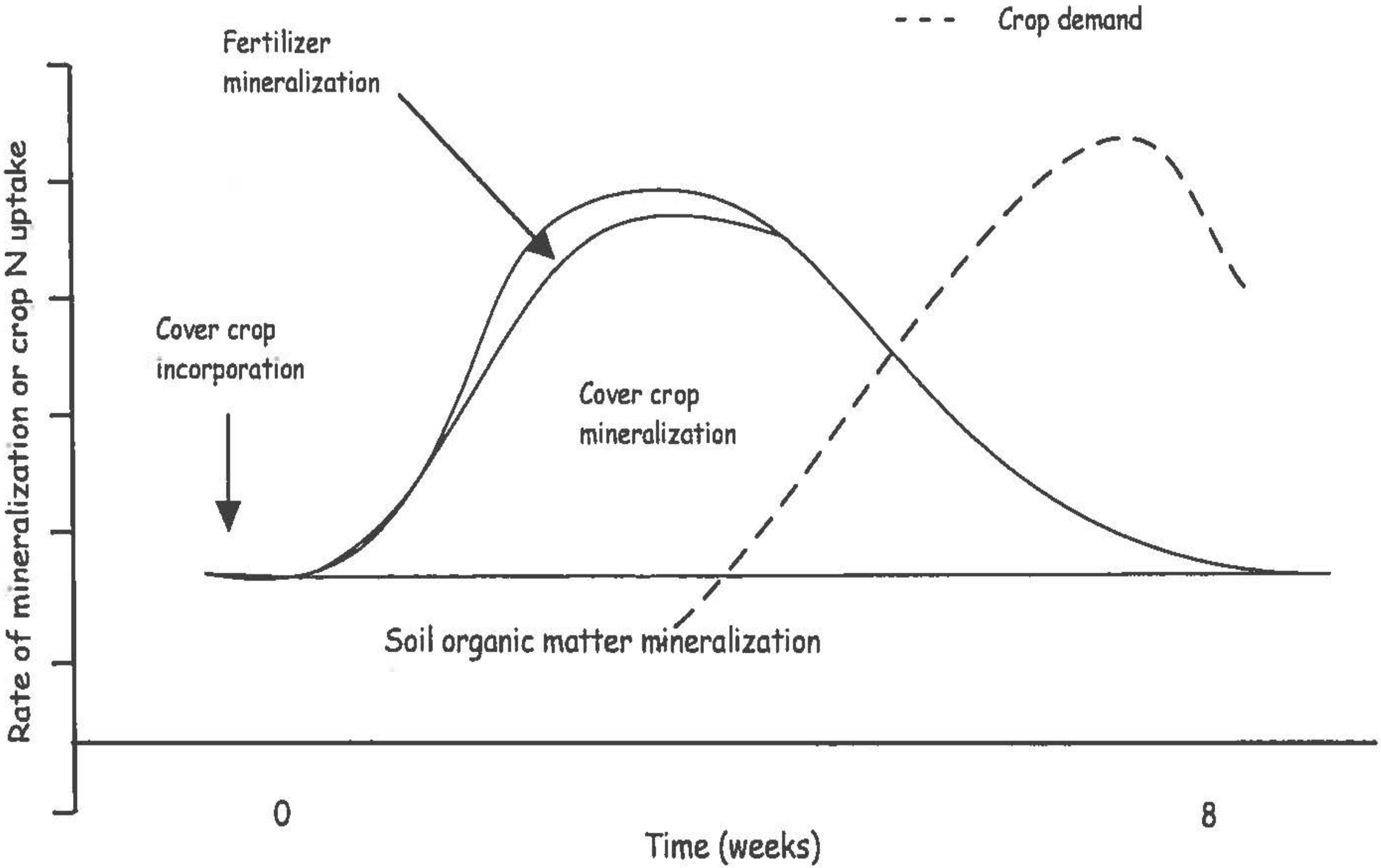


Fig. 2. Timing of nitrogen (N) mineralization from soil organic matter, cover crop residue, and organic fertilizer in relation to crop N uptake (from Gaskell et al., 2006).

Nitrogen Release Summary

“Fresh” Organic Matter

- C:N Balance Effect

< 10 C:N = rapid release of available N

most plant, animal meals, manures > 5 % N (DW)

10-20 C:N = gradual release of available N

20-40 C:N = very slow release of available N

> 40 C:N = tie up of available N (Immobilization)

Nitrogen Release Summary
"Fresh" Organic Matter

- Soil Temperature Effect

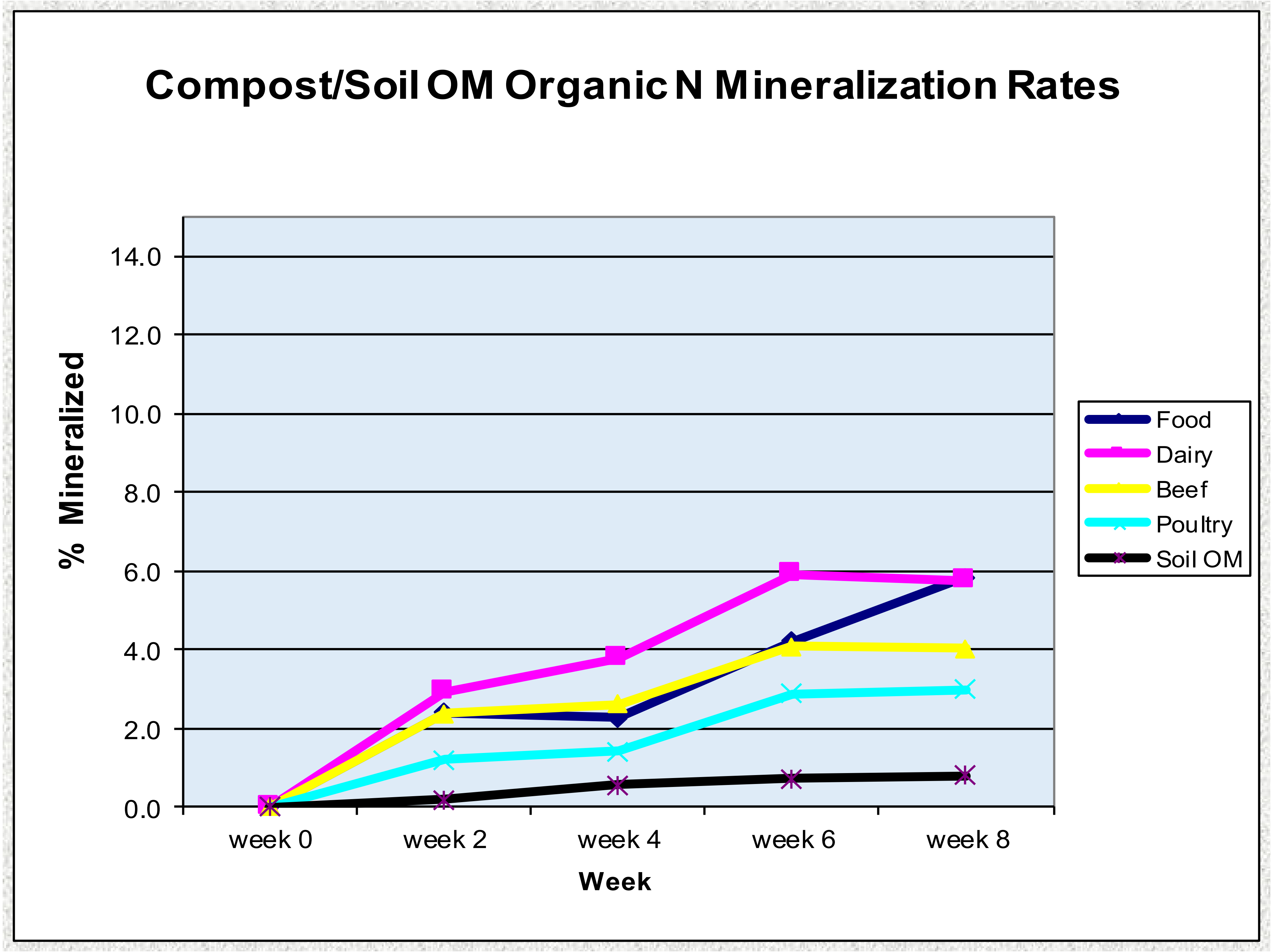
  - ✓Each 14-18 F (8-10 C) increase Doubles Rate

  Q10 Factor: N mineralization rate change for every 10 C change in soil temperature

  - ✓Q10 = 2X to 3X in most studies

Nitrogen Release

from "Biologically Processed" Materials


Compost/Soil OM Organic N Mineralization Rates
% Mineralized
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
week 0
week 2
week 4
week 6
week 8
Week
Food
Dairy
Beef
Poultry
Soil OM

Best Nitrogen Mgt Practices

- Split N application
  - Soil OM and Compost for slow background release
  - ½ rate N fertilizer at planting OR
  - Slow release N fertilizer at planting (ex: ESN, broiler)
  - PSNT @ 20-30 days to spot check available N
  - ✓ Sidedress @ 20-30 DAP with faster release N source (if needed)

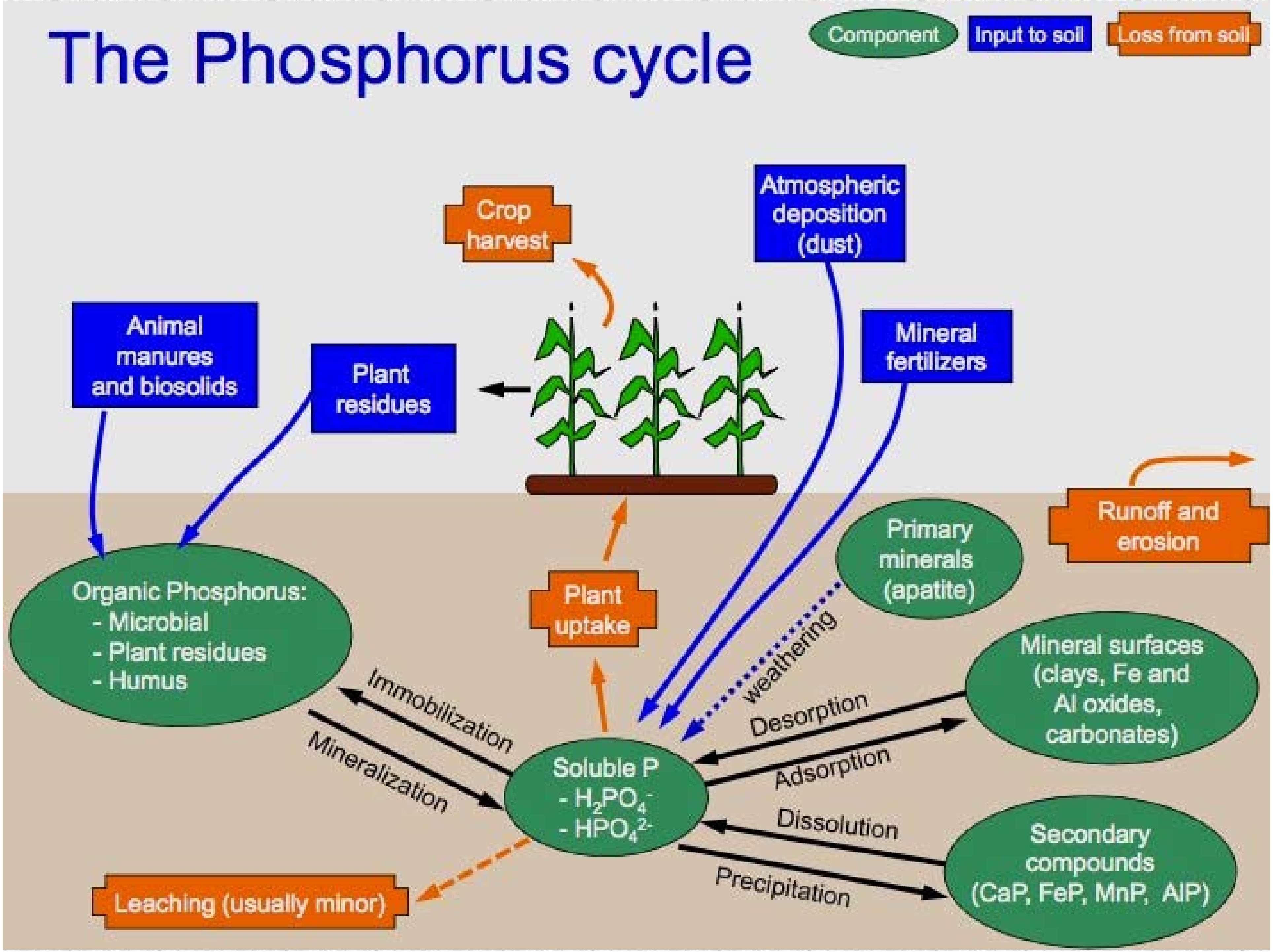
Best Nitrogen Mgt Practices

- Include legumes in rotation
  - Can provide 50-100 % total N requirement
  - Extended release if mature higher C:N
  - Provides “foundation” nitrogen well into season

Best Nitrogen Mgt Practices

- Break up traffic/tillage pans
  - Drastically improves soil drainage
  - Better able to infiltrate high rainfall events
  - reduces denitrification losses from saturated soil

- ✓ Mechanical ripping (broadfork or shank)
- ✓ Strong taproot crops (“bio-drilling”)
  - Sweet clovers
  - Canola
  - Tillage radish


The Phosphorus cycle
Component
Input to soil
Loss from soil
Crop harvest
Atmospheric deposition (dust)
Animal manures and biosolids
Plant residues
Mineral fertilizers
Runoff and erosion
Primary minerals (apatite)
Organic Phosphorus:
- Microbial
- Plant residues
- Humus
Plant uptake
weathering
Mineral surfaces (clays, Fe and Al oxides, carbonates)
Immobilization
Desorption
Mineralization
Adsorption
Soluble P
- $H_2PO_4^-$
- HPO_4^{2-}
Dissolution
Secondary compounds (CaP, FeP, MnP, AlP)
Precipitation
Leaching (usually minor)

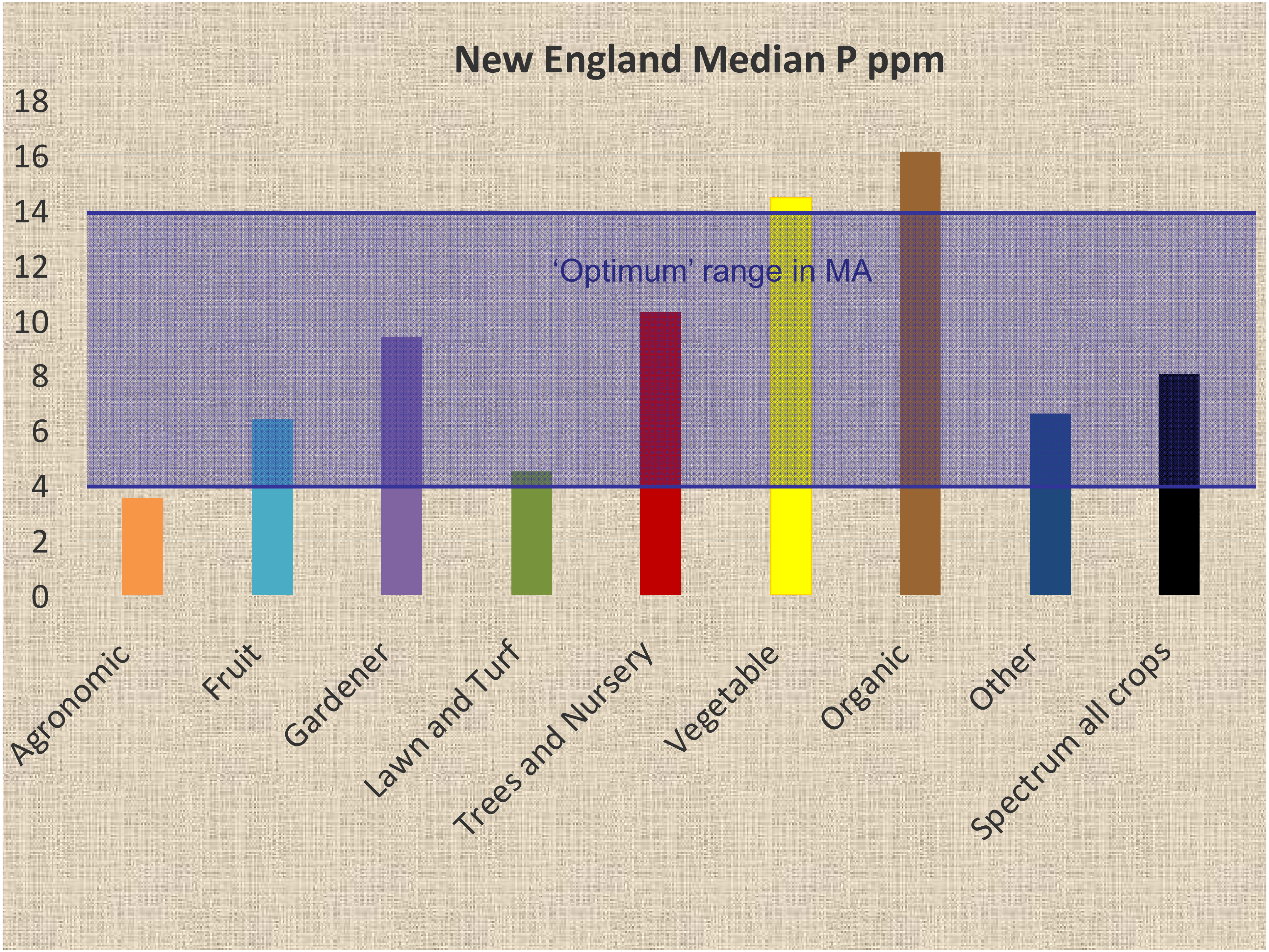
Plant Available Phosphorus Overview

- P forms many stable compounds & complexes
  - ✓ with Al & Fe at low pH
  - ✓ with Ca and Mg at high pH
  - ✓ with organic matter/humus at any pH
  - ✓ in microbial biomass after recent application

- Many forms become unavailable (temp or perm)

- Minimize losses to unavailable forms
  - ✓ Maintain soil pH between 6 & 7
  - ✓ Stable OM additions: compost, cover crops

Soil Testing Trends


New England Median P ppm
18
16
14
12
10
8
6
4
2
0
'Optimum' range in MA
Agronomic
Fruit
Gardener
Lawn and Turf
Trees and Nursery
Vegetable
Organic
Other
Spectrum all crops

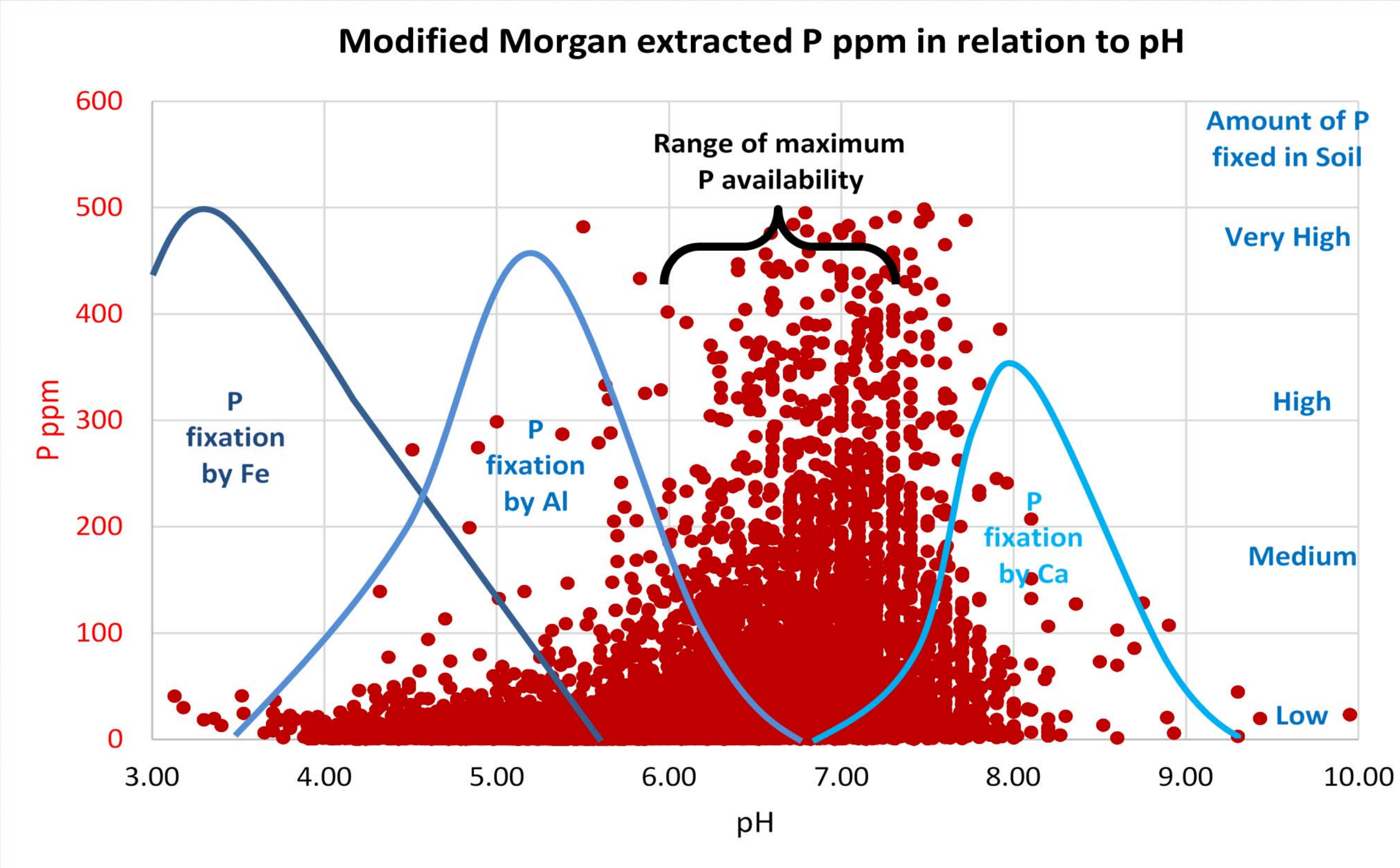
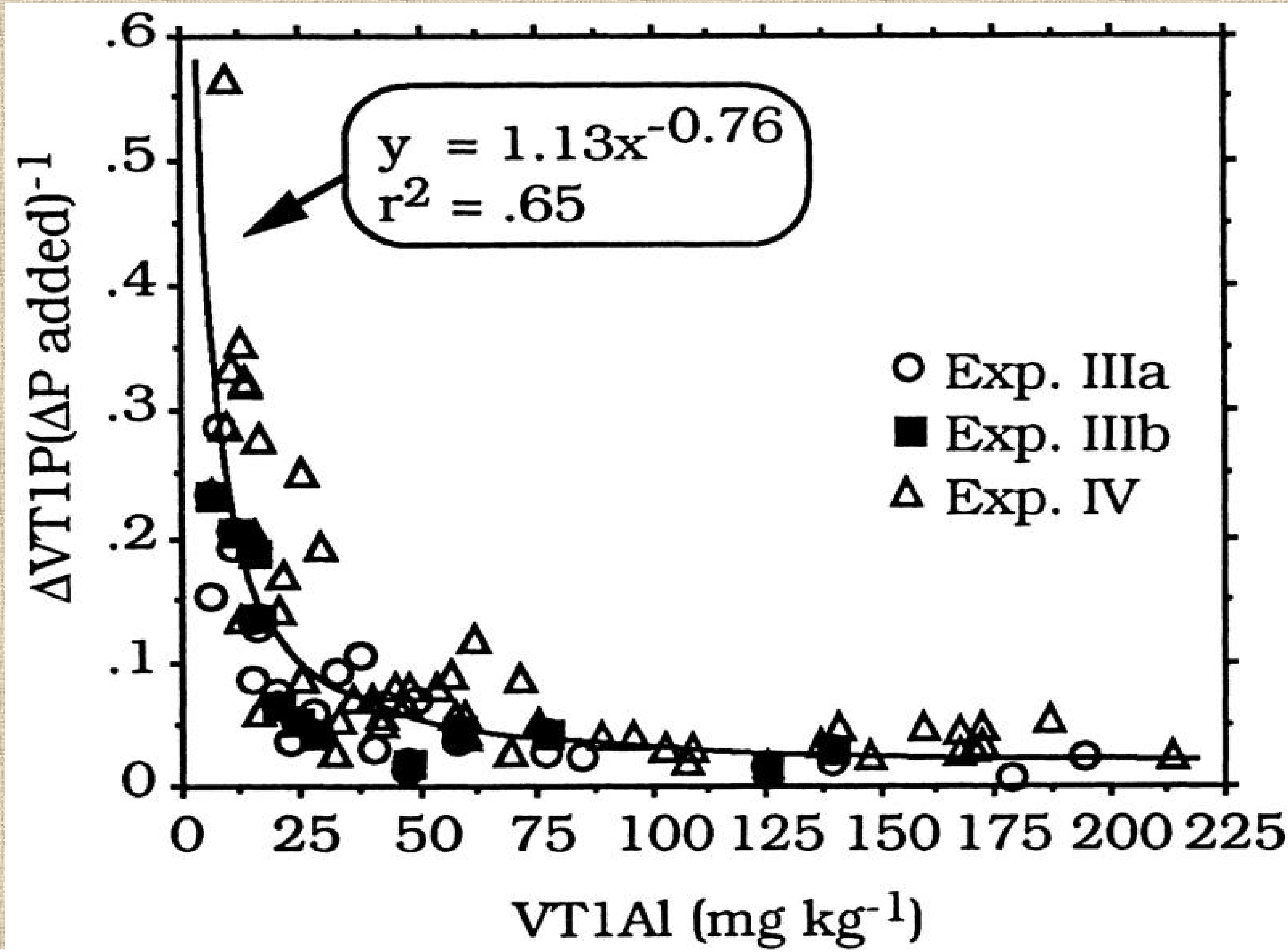


Figure 1 by Katie Campbell-Nelson. The red dots represent Modified Morgan extracted P levels in ppm from over 24,000 soil samples analyzed at the University of Massachusetts and Maine soil labs in 2015. Area underneath the blue lines represent P fixation by iron and aluminum phosphates at low pH and calcium phosphate at high pH.

STP Change vs Reactive Al (Magdoff, et al, 1999)



Phosphorus Mineralization Study

Montgomery, Ohno, et al (2004)

- Dairy, Poultry, Swine, Biosolids vs TSP
  - Blended with soil at 40 ppm total P (80 lb/A equiv.)
  - Perennial rye grown 18 weeks in greenhouse

- Plant uptake
  - ✓ 5–7 % recovery of applied P from Manures/Biosolids
  - ✓ 4.5 % recovery of applied P from TSP

- Residual soil test levels (Modified Morgan)
  - ✓ 4–7 % recovery of applied P from Manures/Biosolids
  - ✓ 2.5 % recovery of applied P from TSP

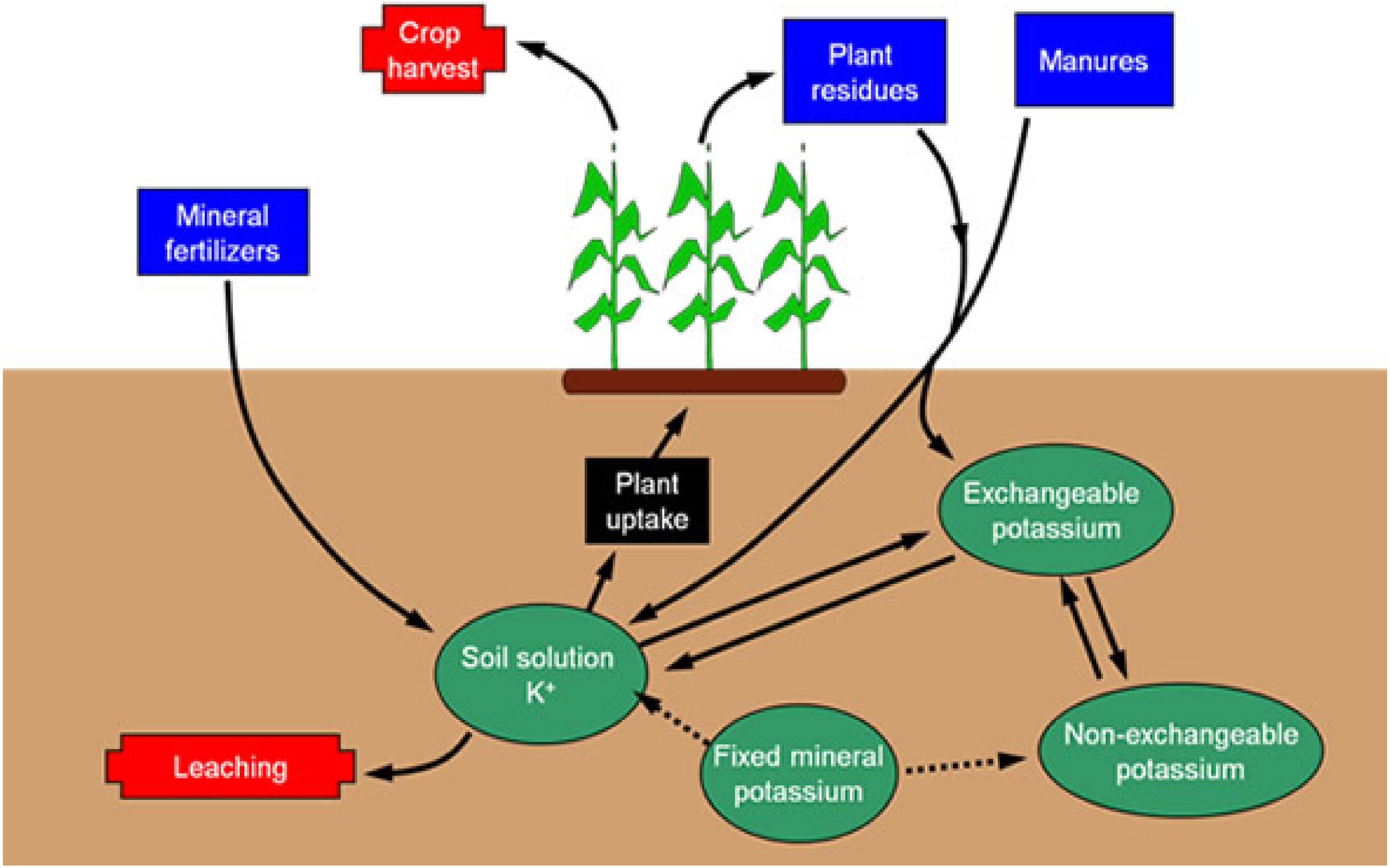
Relative Phosphorus Release Rates

- Chemical Sources Fastest
- Faster Natural Sources
  - ✓Bone meal/Bone char
  - ✓Fish meal
  - ✓Compost
  - ✓Animal manures (poultry>ruminants>horse)
  - ✓Cover crops
- Slower
  - ✓Rock phosphates (esp at pH > 6.5)

Phosphorus Best Practices

- Efficiency of phosphate can be improved
  - ✓ Band high P applications to limit soil contact
  - ✓ Cover cropping extends P availability
  - ✓ Soil pH & OM mgt. key to P efficiency
    - Soil pH 6 - 7 limits Reactive Aluminum
    - ❖ Improves efficiency of applied P

The Potassium Cycle



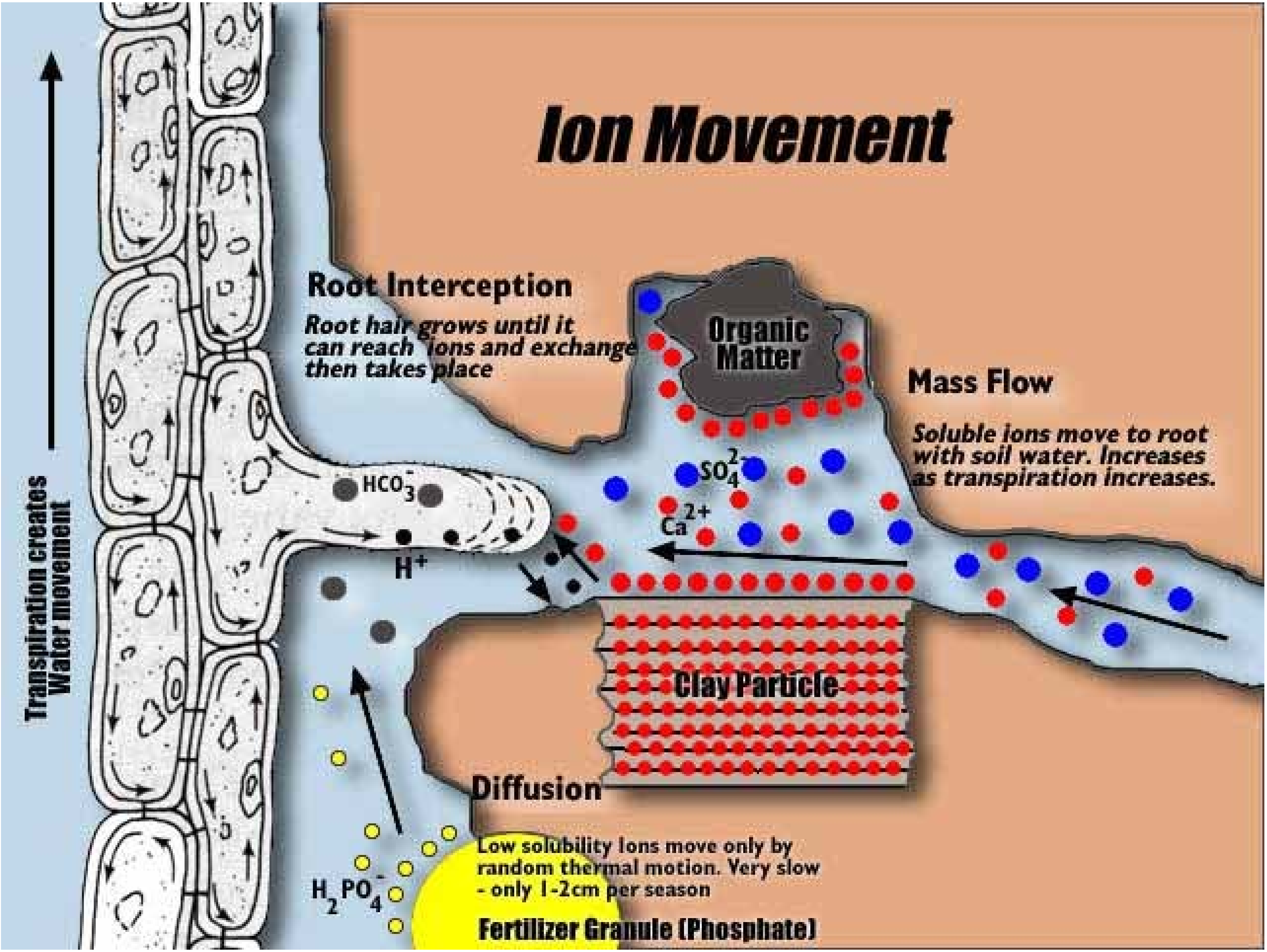
Suggested Potassium Sources

- ✓Muriate of potash (0-0-60) common chemical
- ✓K-Mag (0-0-22-11) if Mg also needed
- ✓Sulfate of potash (0-0-50) if no Mg needed
- ✓Wood ash, *only if lime is also needed*
- ✓Animal manures (esp dairy manure)

➢All are medium to fast release

Soil Potassium Dynamics

- K^+ soil chemistry primarily controlled by clays
- Not all exchange sites are created equal
  - ✓ Humus-based sites don't hold (+1) cations well
  - ✓ Clay-based sites have very high affinity for K

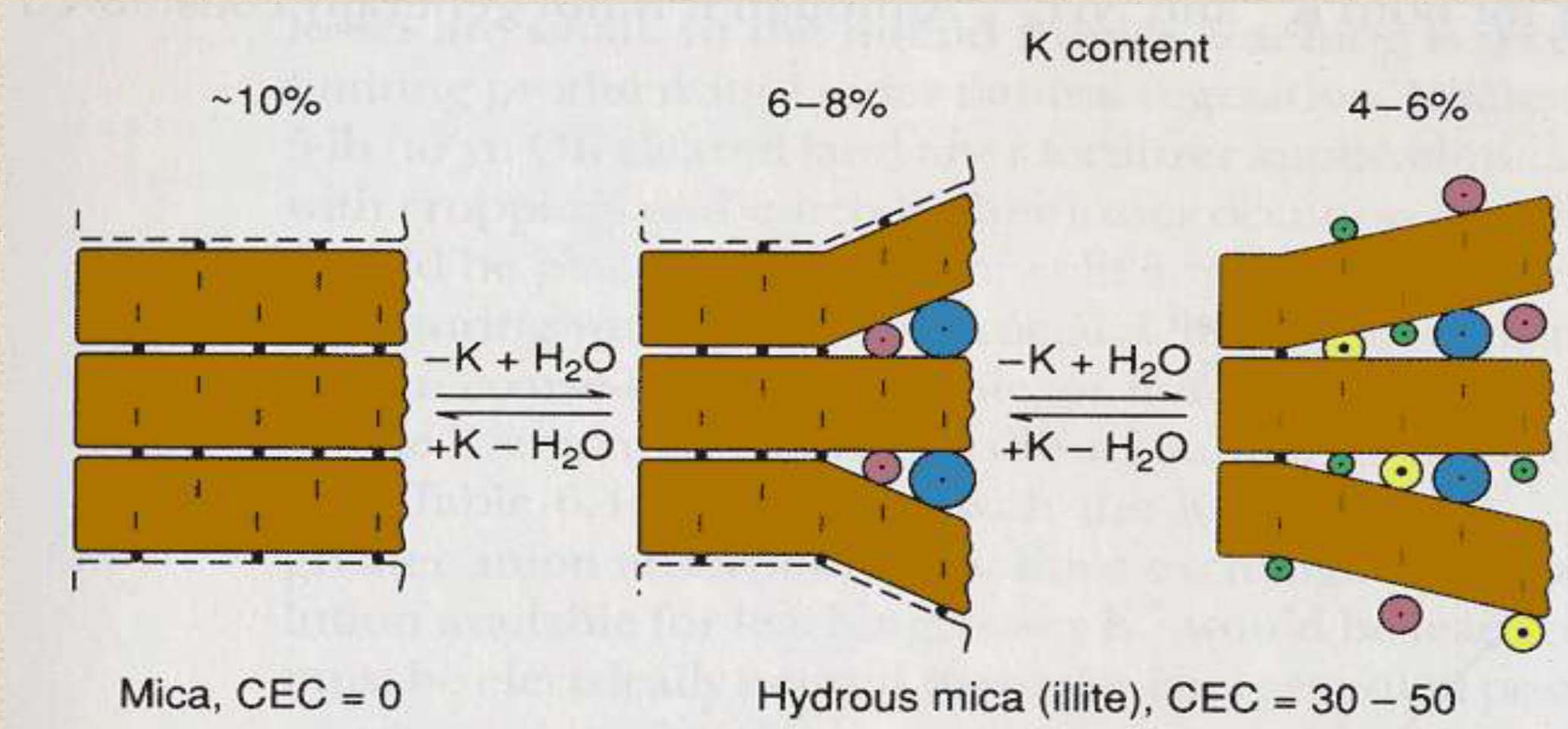

Ion Movement
Transpiration creates Water movement
Root Interception
Root hair grows until it can reach ions and exchange then takes place
Organic Matter
Mass Flow
Soluble ions move to root with soil water. Increases as transpiration increases.
HCO3-
SO4 2-
Ca 2+
H+
Clay Particle
Diffusion
Low solubility ions move only by random thermal motion. Very slow - only 1-2cm per season
H2PO4-
Fertilizer Granule (Phosphate)

K Fertilizer Efficiency

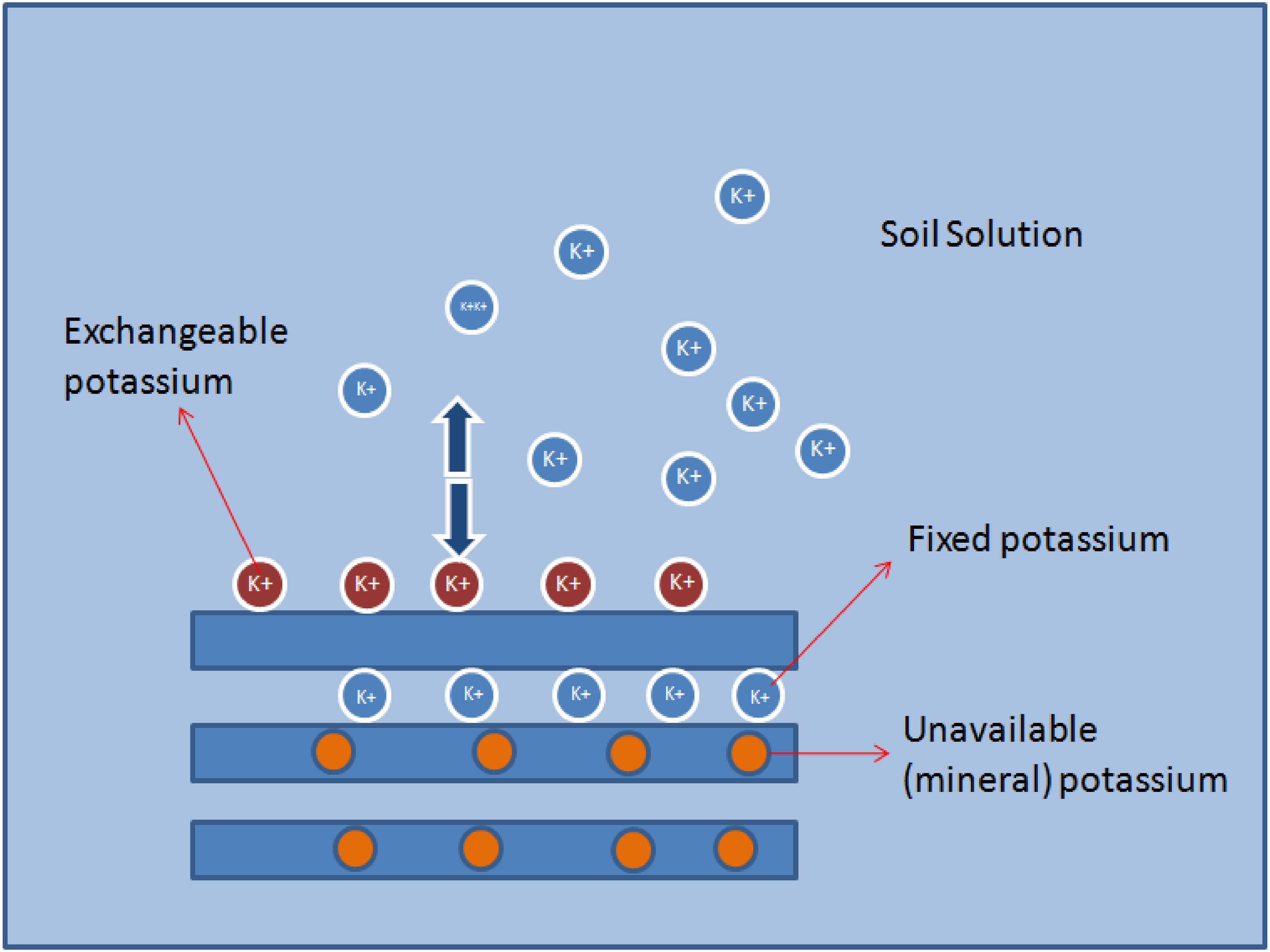
- ➢ Not all applied K remains available first year

- ✓ Common to lose 15 + %
  - – Depends on clay content
  - – Depends on level of K depletion

- ❖ Not a permanent loss



K content
~10%
6–8%
4–6%
−K + H2O
+K − H2O
−K + H2O
+K − H2O
Mica, CEC = 0
Hydrous mica (illite), CEC = 30 – 50


Soil Solution
Exchangeable potassium
Fixed potassium
Unavailable (mineral) potassium
K+

K Buffering Capacity
Determines BMP's

- Proportion of available K held back vs released

- ✓ Loamy soils (more clays) are well buffered
  (hold back more – give off less to soil water)

- ✓ Sandy soils (less clay) are poorly buffered
  (hold back less – give off more to soil water)

- High OM soils are also poorly buffered

Potassium Best Practices

- ➢ Sandy or higher OM soils deplete K faster

  Poor buffering->more in soil water-> faster uptake

- ✓ Split applications extend availability

- ➢ Loamy textured soils deplete K slower

  Well buffered->less in soil water->slower uptake

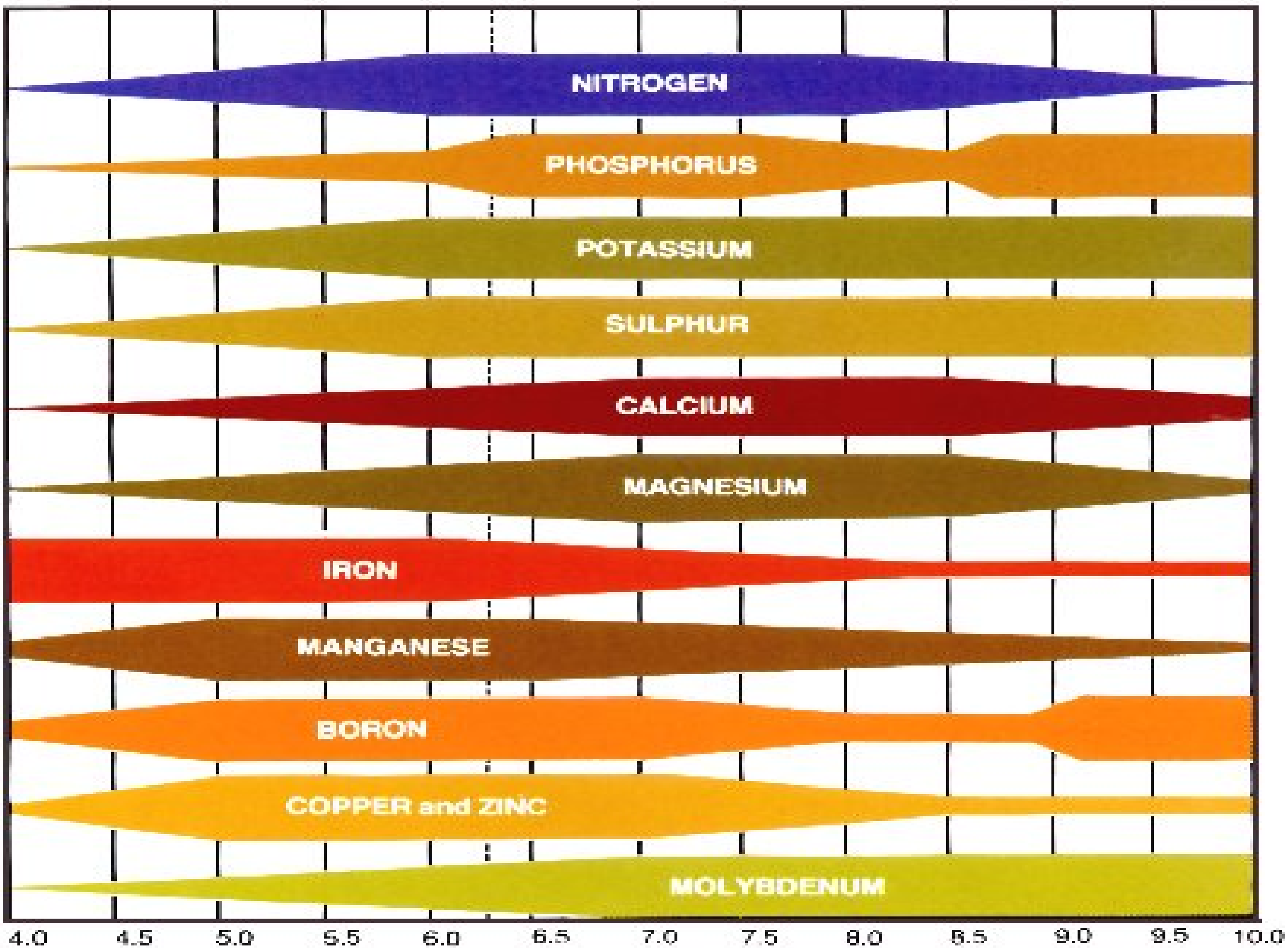
- ✓ Better suited to “front loading” at planting

Secondary Nutrients

- Ca
  - lime provides sufficient Ca (35-40%), if needed
  - Gypsum (23%) for acid-loving crops
- Mg
  - If lime needed – dolomitic lime (12-15 %)
  - If lime not needed, but K needed – K-Mag
  - Epsom salt (10 %)
- Sulfur (nutritional)
  - Yellow sulfur (90 %)
  - Sulfate of potash or K-Mag

Micronutrient Mgt

- Availability primarily controlled by pH and OM
  - high pH limits Fe first, followed by Mn, Zn, & Cu
- Low Cu very common, but rarely limiting
- Boron is most readily lost by leaching


NITROGEN
PHOSPHORUS
POTASSIUM
SULPHUR
CALCIUM
MAGNESIUM
IRON
MANGANESE
BORON
COPPER and ZINC
MOLYBDENUM
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0

Suggested Micronutrient Sources

- ✓ Borax(10%), Kelp meal or Greensand for B
  - Relatively fast release rates

- ➢ Foliar sprays for acute deficiencies
  - ❖ Solubor, Cu Fe Mn Zn sulfates, metal chelates
  - ❖ Do not exceed label application rates ! (B or Cu toxicity)

- ✓ Rock powders for Cu, Fe, Mn, and Zn
  - ❖ Granite dust, Basalt, raw minerals (ex/azomite)
  - gradual release rates

Questions?