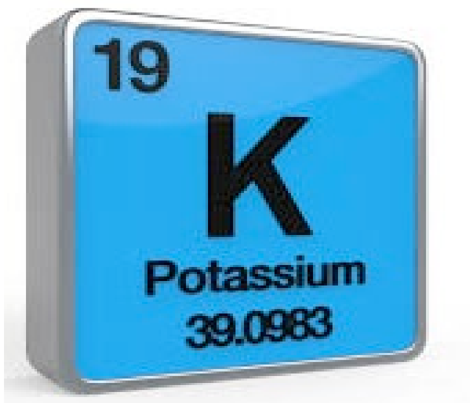
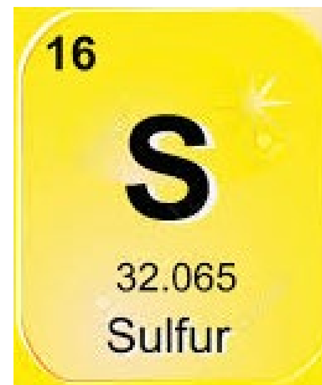
Nutrient Cycles: *Part 2*

Potassium & Sulfur





Jesse Radolinski	Gurpal Toor
Postdoctoral Researcher	*Professor & Extension Specialist*

@JesseRadolinski
@ToorUMD

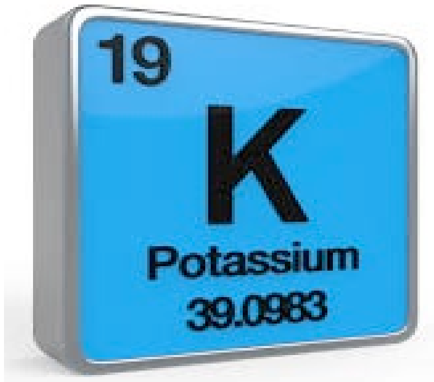
Nutrients: *Plant food; essential for crop production*

K deficiency in Corn

S deficiency in Corn

Images from Better Crops (1997), Vol. 81. No. 3

Potassium (K) Cycle



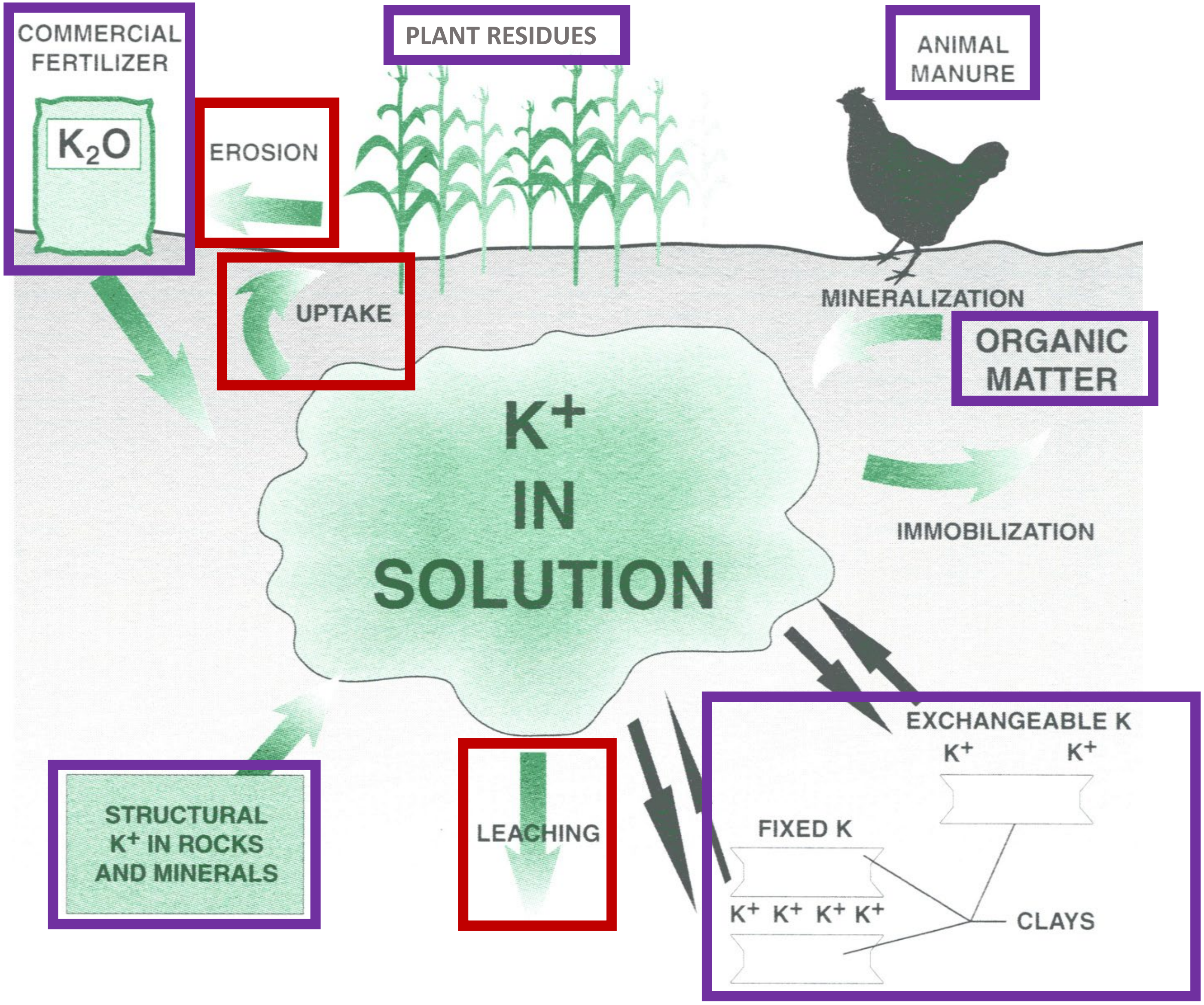
- Simpler cycle than N
  - no oxidation and reduction
  - no gaseous forms
- Soluble K can be "fixed" to less available forms in some soils
  - different mechanism than P
  - no water quality issues

Topics

1. **K in soils:** origin, cycling
2. **K in plants:** uptake, distribution
3. **K in fertilizers:** production, availability, fixation
4. **K in manures:** solubility

1. K in Soils

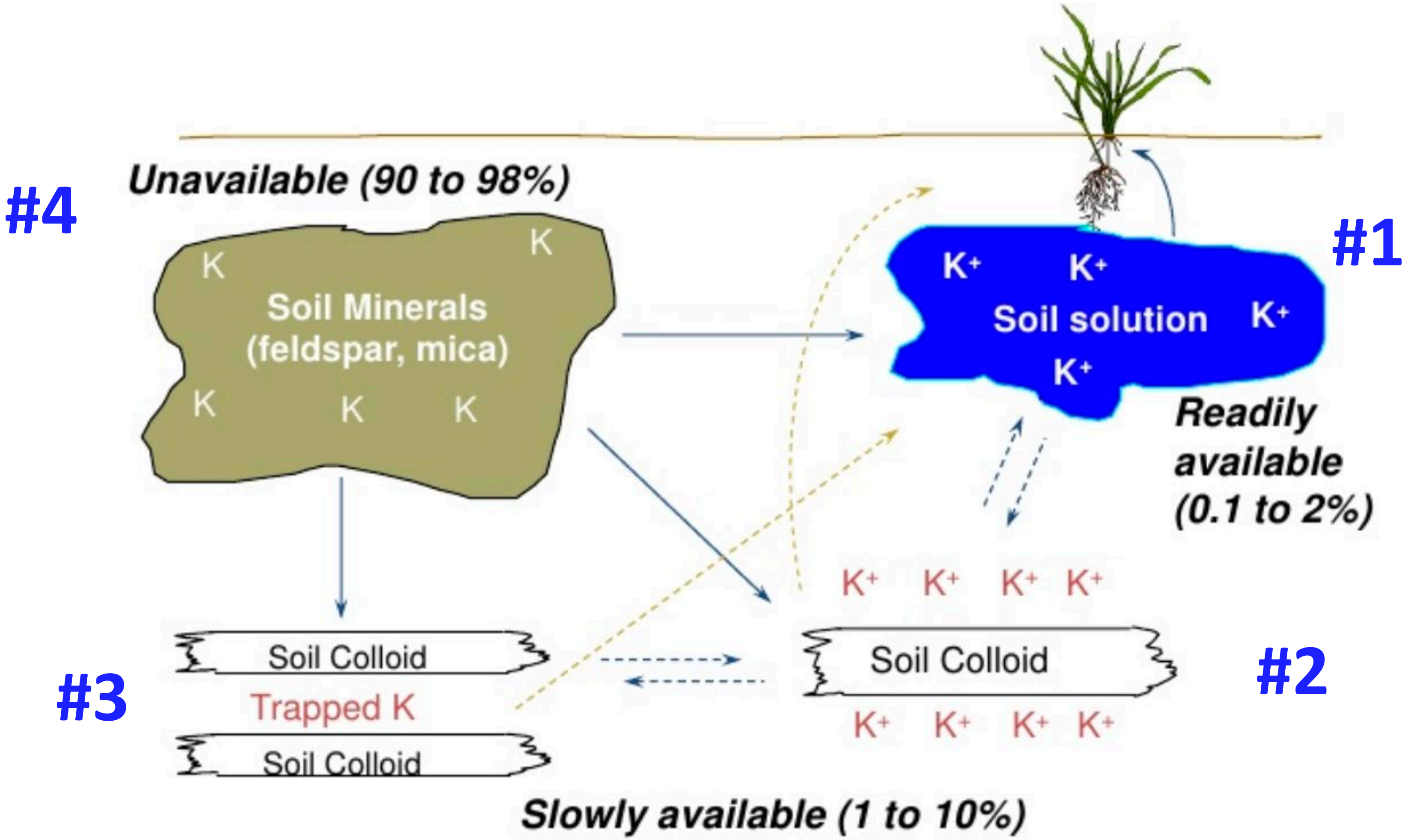
Sources
Losses



Maryland Cooperative Extension, 2000

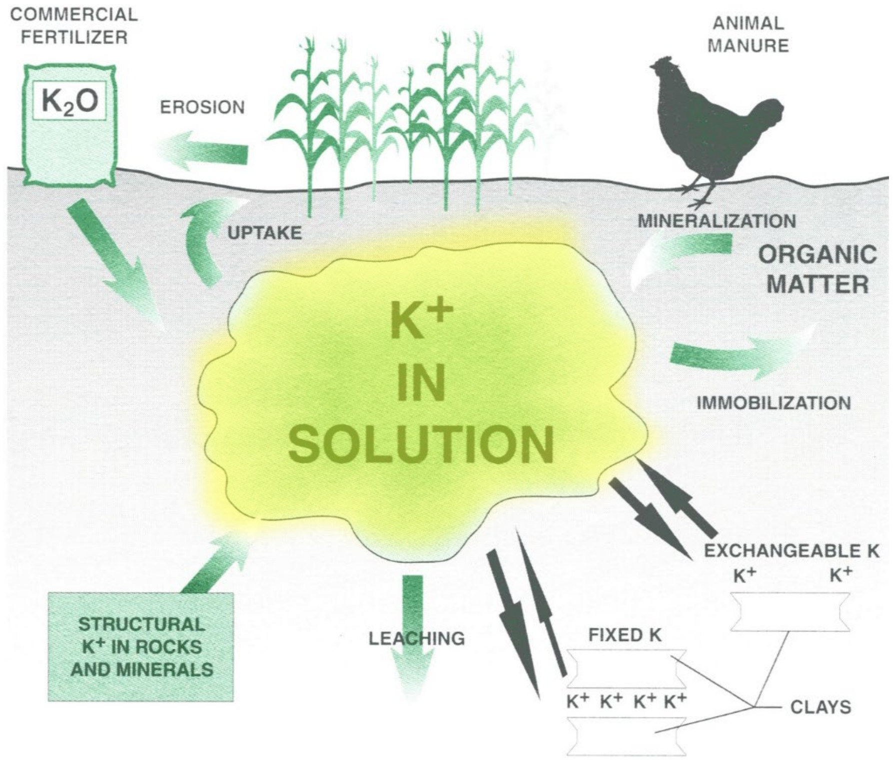
K Availability in Soils

Total K in Soil: About 24,000 lbs/acre



#1 Soil Solution K

- Readily available for plant uptake
- Only 0.1–0.2% of total K in soils, which means 24 to 48 lbs/acre

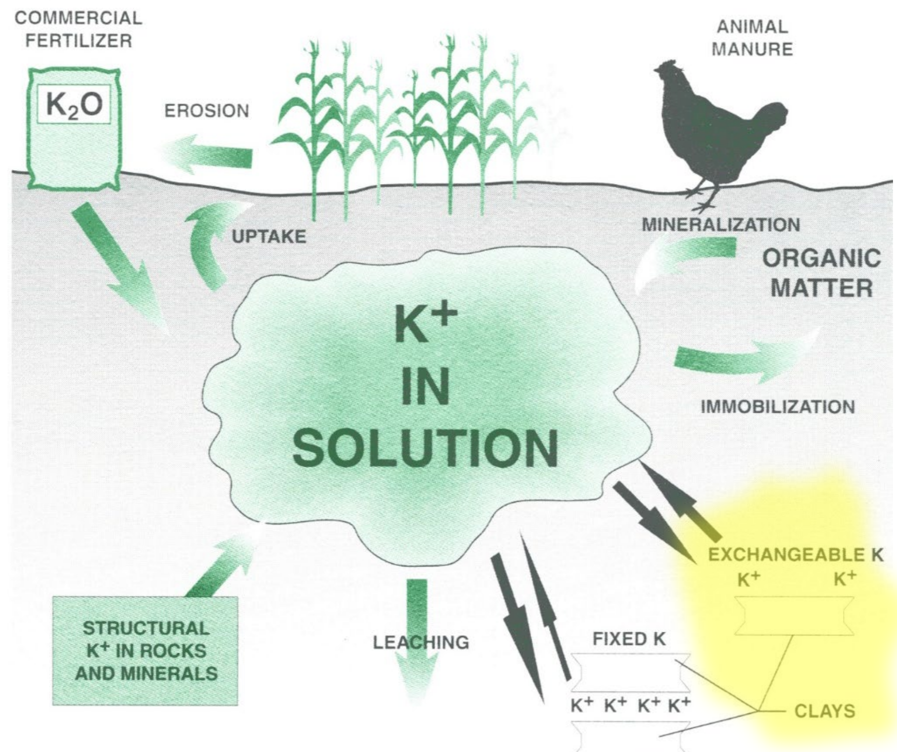


Total K in Soil: ~24,000 lbs/acre

#2 Exchangeable K

Total K in Soil: ~24,000 lbs/acre

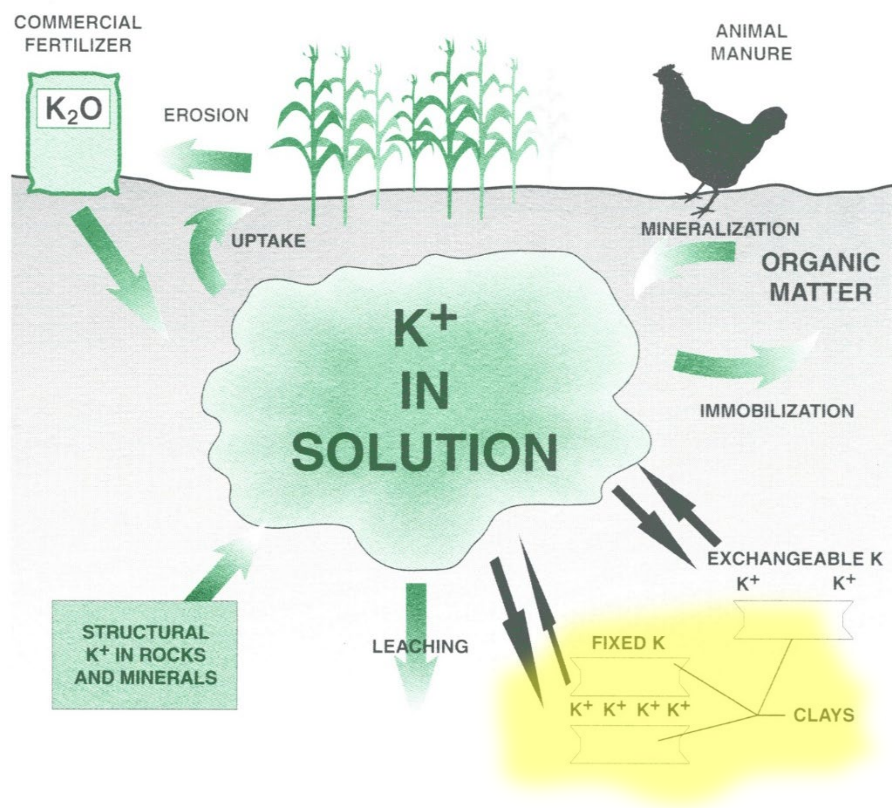
- K^+ at exchange sites on soil colloids
  - in equilibrium with K^+ in soil solution. Replenishes the soil solution
- Readily available for plant uptake
- Usually less than 1% of total K in soils, which means 240 lbs/acre



#3 Fixed K

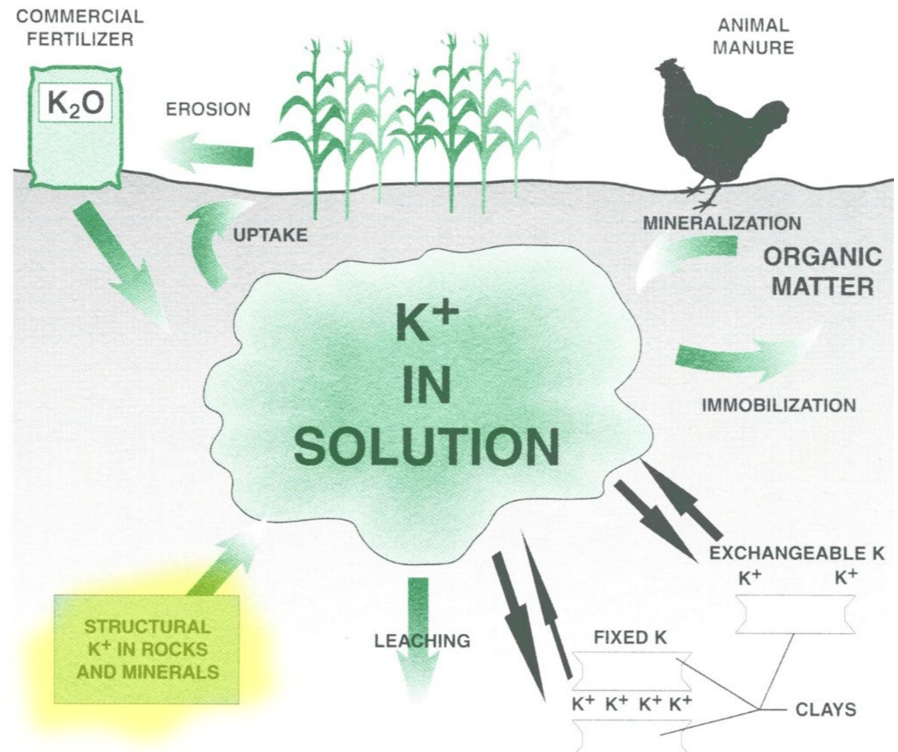
Total K in Soil: ~24,000 lbs/acre

- Fixed as K^+: trapped in interlayers of clay minerals
- Non-exchangeable
- Minimally available by weathering
- About 1-10% of total K in soil, which means 240 to 2,400 lbs/acre



#4 Mineral (structural) K

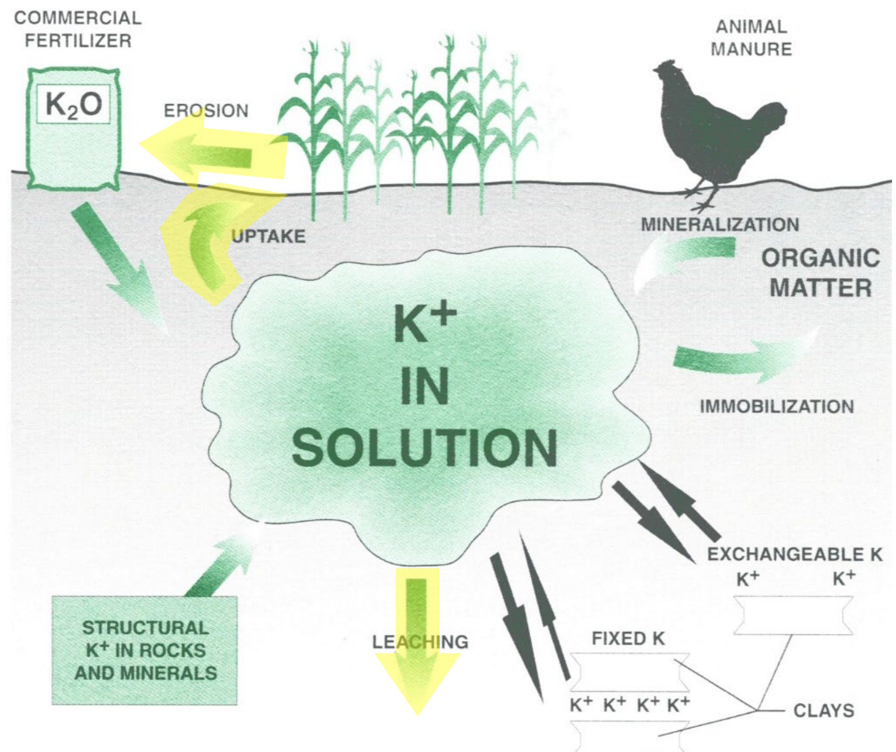
- Relatively unavailable
- K is a structural component of primary minerals such as feldspars and micas
- 90–98% of total K in soil, which means 21,600 to 23,520 lbs/acre



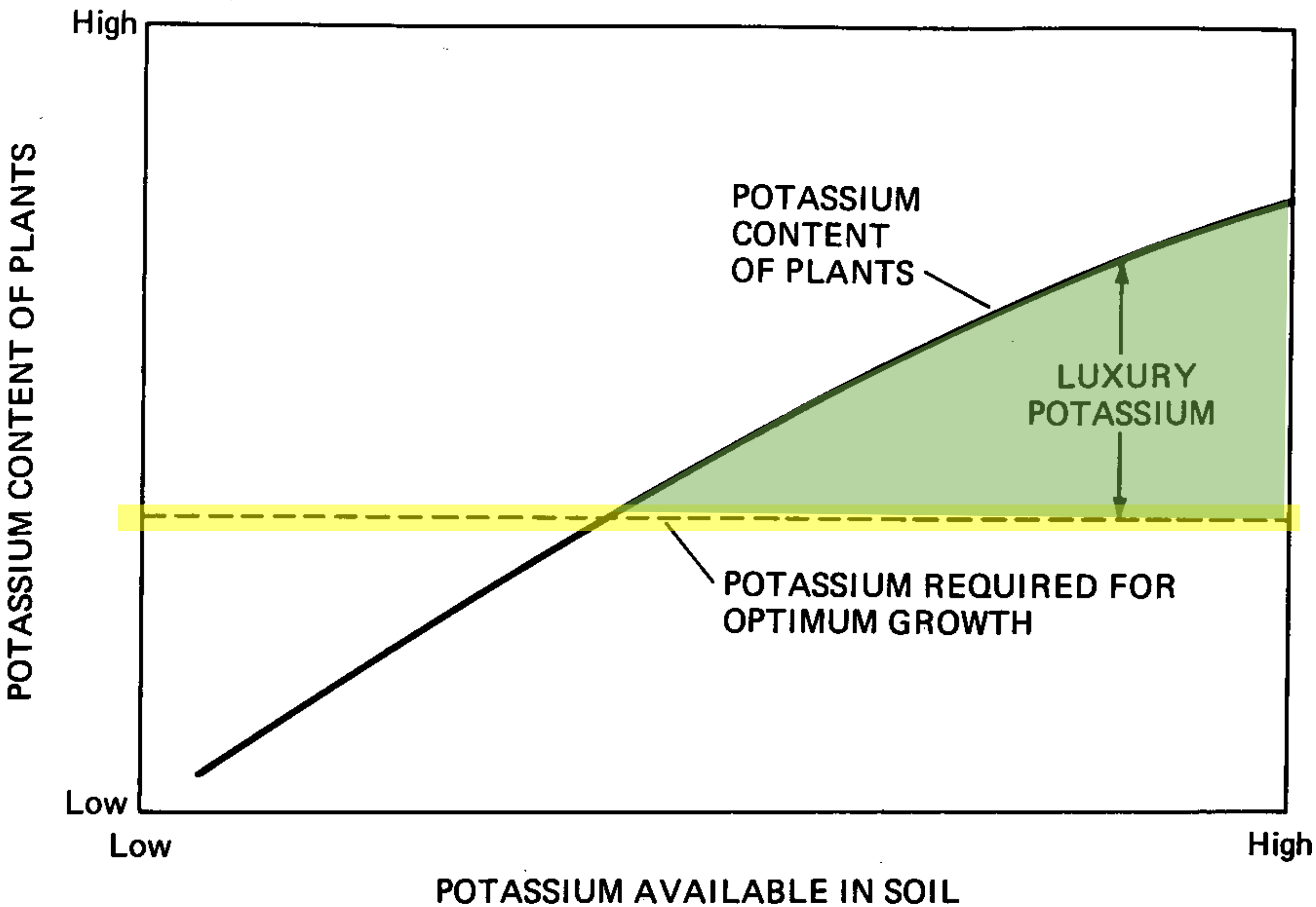
Total K in Soil: ~24,000 lbs/acre

K Loss from Soils: *3 Ways*

- Leaching
  - coarse soils/high rainfall
- Erosion
- Crop removal
  - luxury consumption



Luxury Consumption:



Luxury consumption of potassium by plants. If excess amounts of potash fertilizers are applied to soil, plants will absorb potassium in quantities exceeding that required for optimum yields. This may be wasteful if crops are completely removed from the soil.

N.C. Brady, 1974

2. K in Plants

Concentrations in Plant Dry Matter

Element	Concentration (mmol/g)	#atoms	Function
Molybdenum	0.001	1	N fixation
Copper	0.10	100	Component of enzymes
Zinc	0.30	300	Activates enzymes
Manganese	1.0	1000	Activates enzymes
Iron	2.0	2000	Chlorophyll synthesis
Boron	2.0	2000	Cell wall component
Chlorine	3.0	3000	Photosynthesis reactions
Sulfur	30	30000	Amino acids
Phosphorus	60	60000	Nucleic acids
Magnesium	80	80000	Part of chlorophyll
Calcium	125	125000	Cell wall component
Potassium	250	250000	Catalyst, ion transport
Nitrogen	1000	1000000	Proteins, amino acids

Micronutrients

Plants need more K than all nutrients except N.

Source: Jones (2012)

Role of potassium in plant nutrition

Remains in ionic form inside plants (rather than being incorporated into organic molecules)

Very important osmotic regulator (lowers water potential inside of plant cells)

Activator of over 80 enzymes

1-4% of plant dry matter (similar to N)

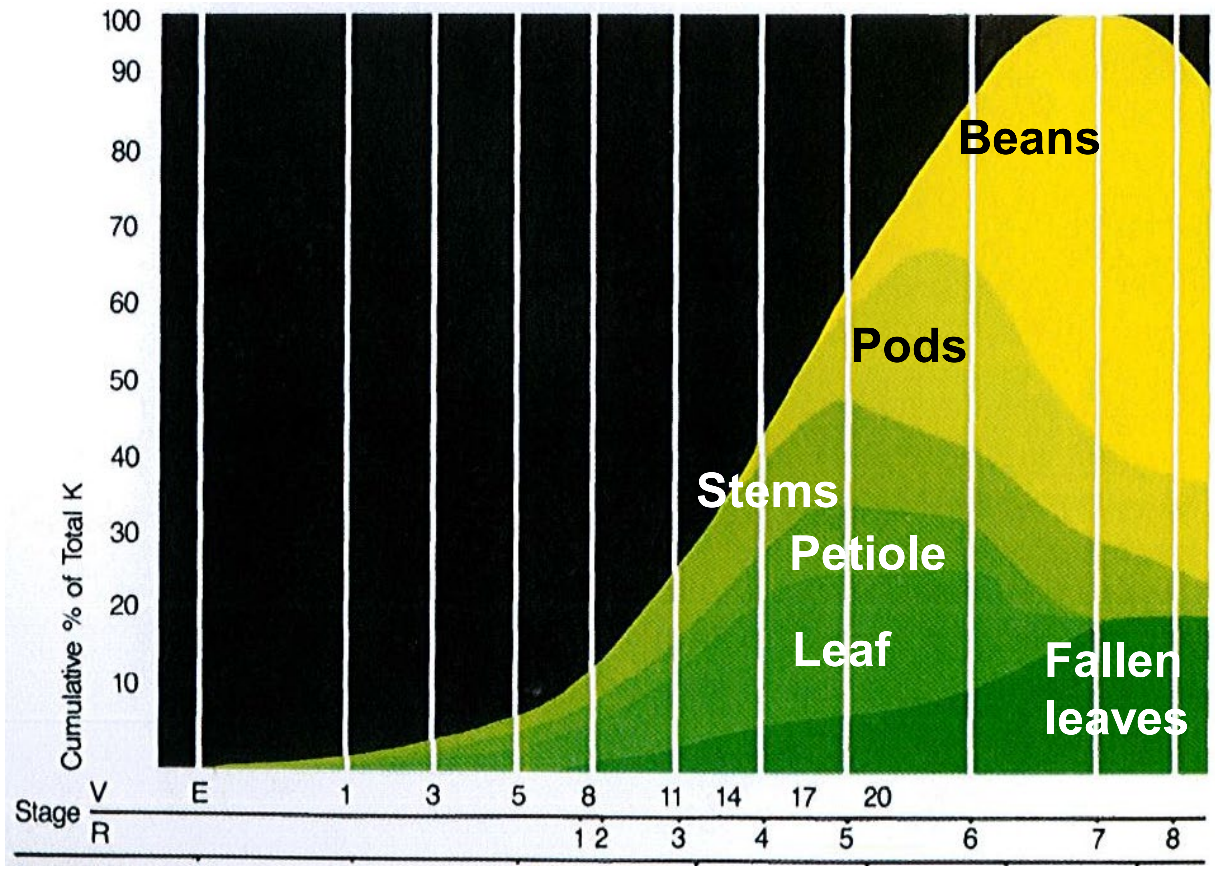
Important for tolerance of environmental and biotic stresses (drought tolerance, winter hardiness, resistance to fungal pathogens, resistance to insects)

Important for crop quality (flavor, color, stem strength)

Demand of K by Soybean

(Cumulative % of Total Uptake)

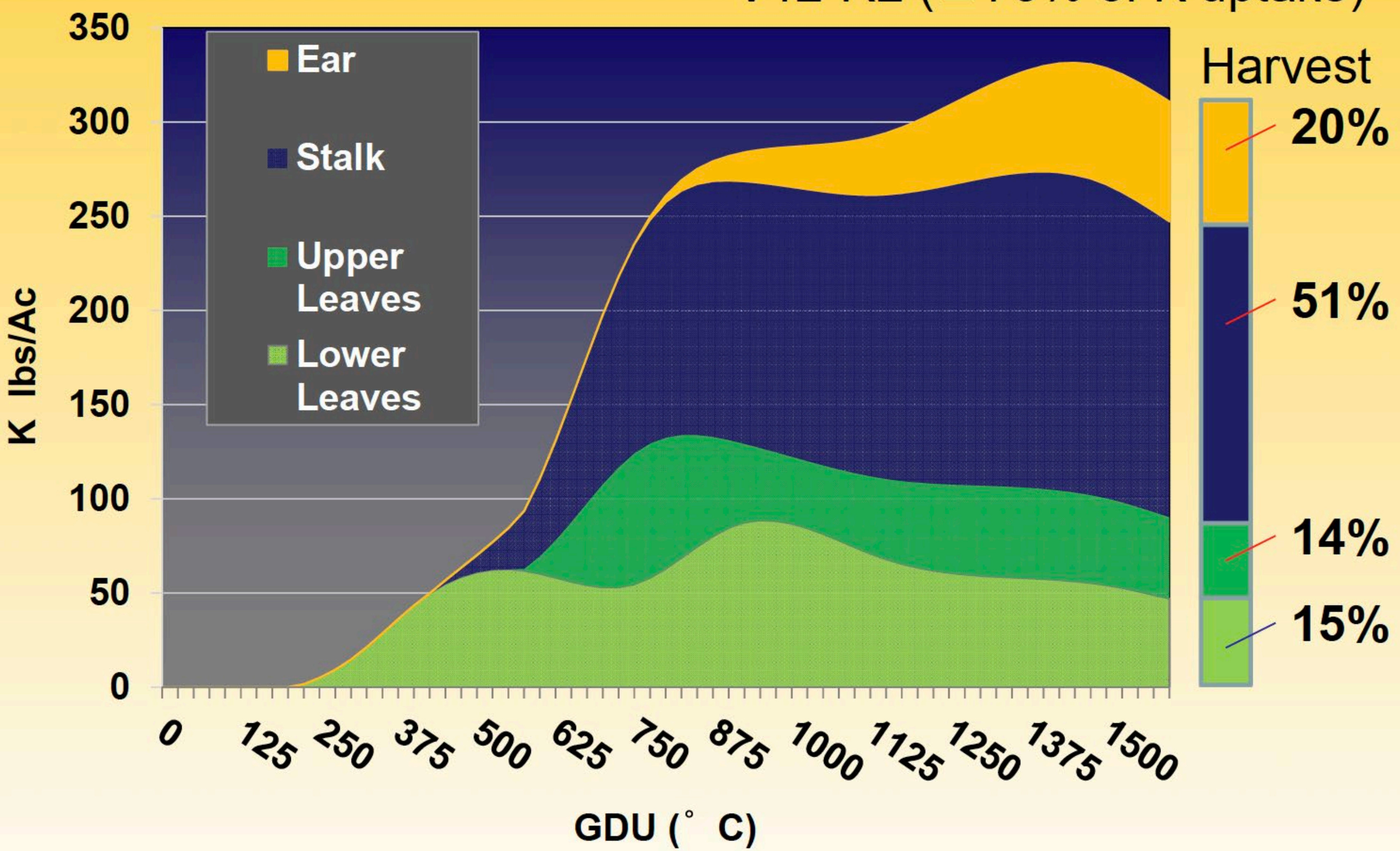
- Low demand early season
- K greatest need is during pod fill
- Max daily uptake
  - *4.9 lb K_2O / acre*
  - 0.9 lb P_2O_5 / acre



How a Soybean Plant Develops- Iowa State. July 1985

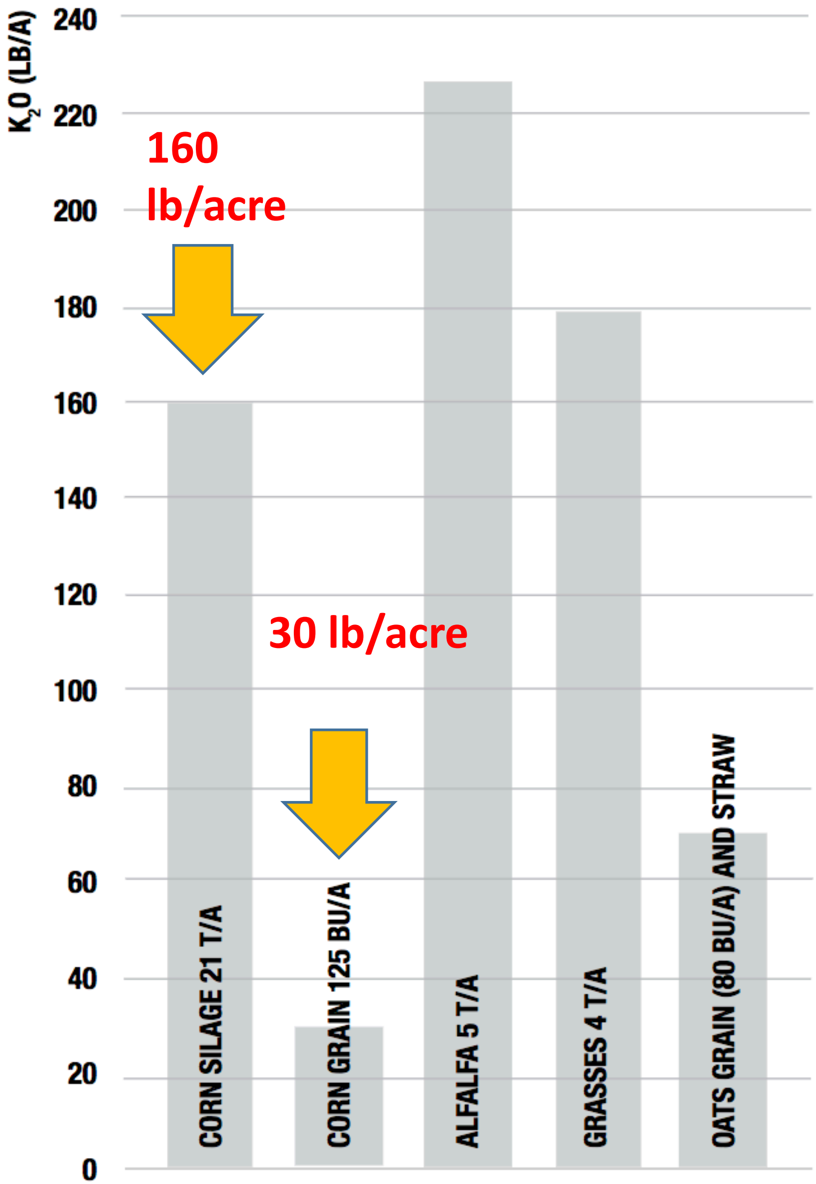
Corn aerial potassium accumulation

V12-R2 (±70% of K uptake)



From Karlen et al, 1988

Figure 1. Approximate removal of K_2O in harvested portion of common Pennsylvania crops.



K removal is ~5 times higher for Corn for Silage than Corn for Grain

Source: Managing K for Crop Production Factsheet. Penn State Extension

K Deficiency

- Shorter plants
- LAI ↓ – narrower and shorter leaves
- Delayed vegetative development
- Delayed tasseling and silking in corn
- ↑ purple stain in soybean
- Increased lodging
- Yield ↓
  – 10 to 25 bu in corn
  – 10 to 25% in soybean

Crop Production Systems

- Advances in crop management / genetics
- Production practices have changed
- Higher yields (soybean) achieved today*
  - *1950 - 18.5*
  - *1960 - 23.5*
  - *1970 - 23.4*
  - *1980 - 23.9*
  - *1990 - 26.9*
  - *2000 - 30.1*
  - *2010 - 34.3 (2010-2014)*

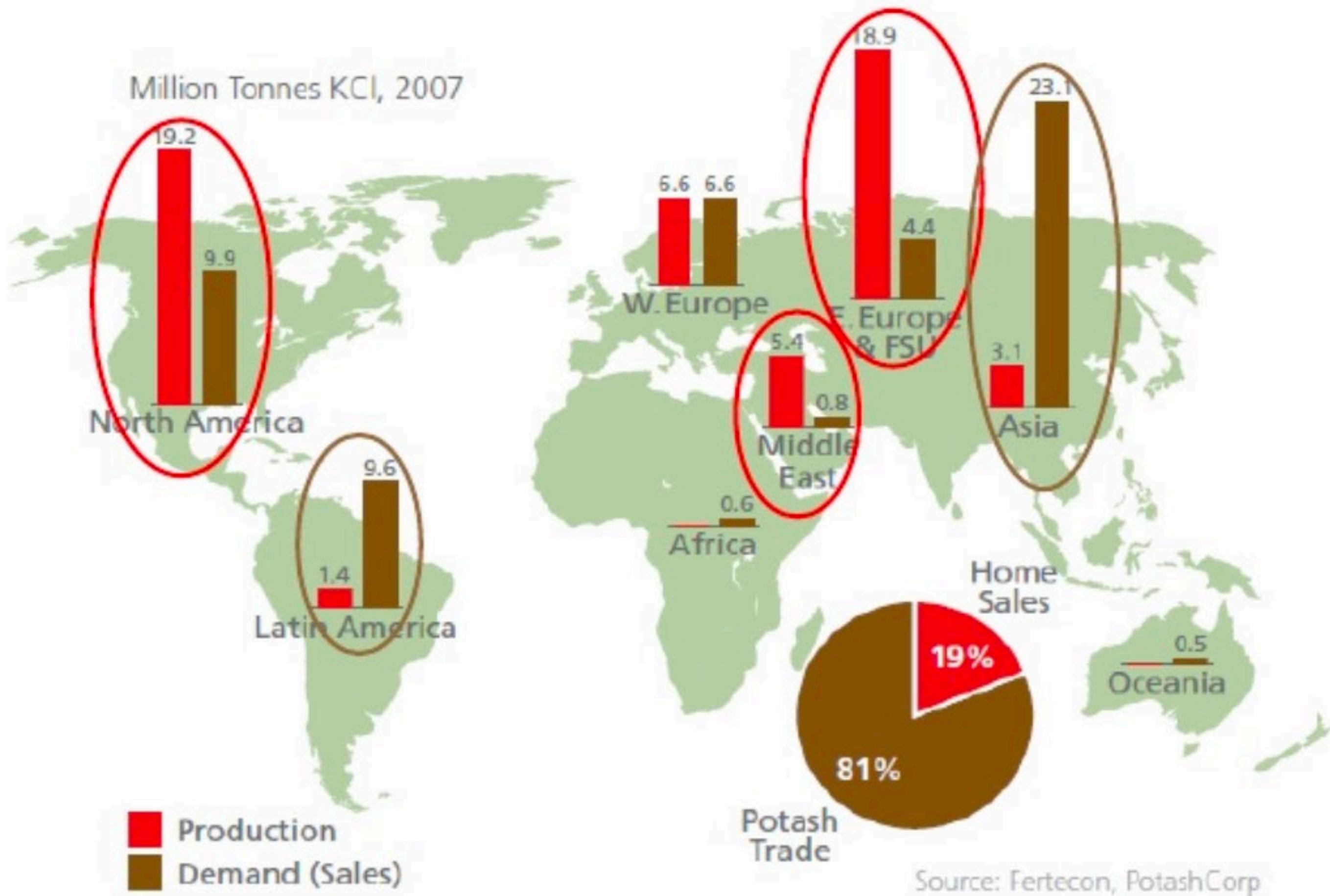
*National Ag Stats Service, 2015

- Higher crop yields, more crop removal
- If K deficient, field yield losses of 5 to 20%*
  - ↓Pod number
  - ↓ Seeds per pod
  - ↓ Seed weight

Parvej et al, 2015. AJ. 107: 943-950

3. K in Fertilizers

Global K fertilizer production and consumption



Total world production = 33 million metric tons of K_2O in 2007

Potassium Fertilizers

Material	Chemical Formula	K_2O Content %
"Potash" = muriate of potash = MOP		
potassium chloride	KCl	60
sul-po-mag	$K_2SO_4 2MgSO_4$	20
potassium nitrate	KNO_3	44
potassium sulfate	K_2SO_4	50

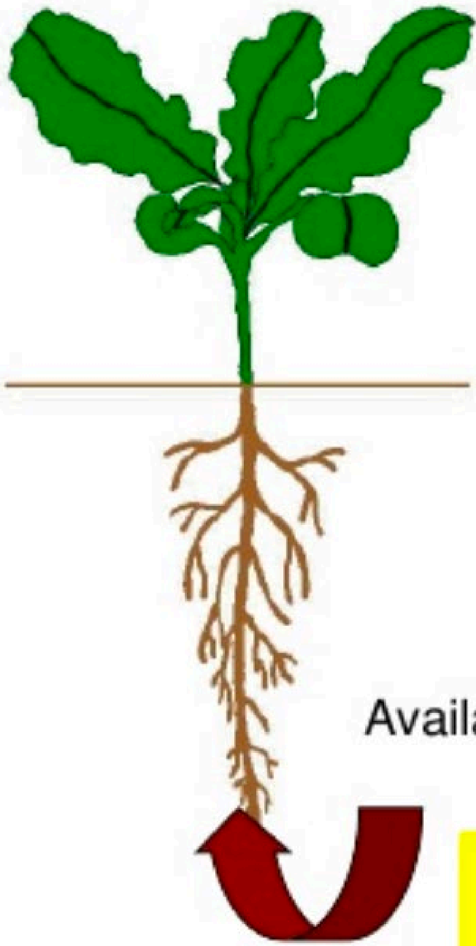
guaranteed analysis

Fertilizers do not actually contain K_2O

1 lb of elemental K = 1.2047 lbs of K_2O

Crops do not actually take up K_2O

What really happens to fertilizer K?



Only 20 to 60% of applied K is taken up by crops in year 1

Highest recovery on low K soils

Why??

Available K ⟷ Slowly Available K ⟷ Unavailable K

The K in KCl (muriate of potash) is near 100% plant available but is not the only source of K (and other cations) in the soil. Also, crop roots normally explore a much larger volume than the zone of amendment

4. K in Manures

Table 1. Average K_2O concentration in manure and variation in that concentration between farms.			
Manure	Moisture (%)	K_2O (lbs/ton)	Variation (%)
Cattle	85	10	36
Pigs	91	11	53
Poultry	30	30	39

- Manure is a a good source of K. But varies by water and bedding content.
- Manure nutrient analysis is the only sure way to know K.

Source: Managing K for Crop Production Factsheet. Penn State Extension

4. K in Manures (Con't)

- Potassium in animal manure (liquid) is almost totally dissolved in liquid fraction, so important to conserve this.
- Surface or incorporated manure application does not affect K content or availability.
- If a soil sample is taken after manure application, then the available manure K will be reflected in the soil test level and recommendations.
- If manure is applied after soil sampling, then manure K should be subtracted from the recommendations on the soil test report.
- Manure K is immediately available and may be considered a 1:1 substitute for K fertilizer.

Source: Managing K for Crop Production Factsheet. Penn State Extension

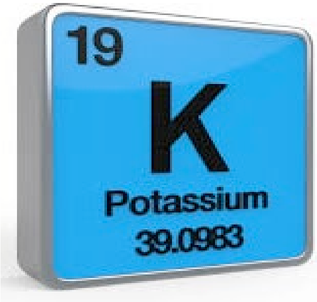
Principles of K Management

- Maintain soil pH for desired crop
- Utilize practices that reduce soil erosion
- Split application
  - reduce losses to luxury consumption

Take Home Messages

- K in soils: *Soil largest source of K. Keep an eye on soil test K levels.*
- K in plants: *Plants need K later in season, do split application. More K removal in silage than grain [so add more in silage]*
- K in fertilizers: *Murate of Potash main fertilizer. All K available, but quickly fixed in soil or leaches.*
- K in manures: *Immediately available. As good source as fertilizer.*

Managing Potassium (K)



- **Challenges**:
  - Soil tests exist
  - Hybrids/forages remove more K
  - Issue of depleting K in soils over long-term
- **Opportunities**:
  - Manage soil fertility
  - Soil sampling and testing is the key

K deficiency in Corn

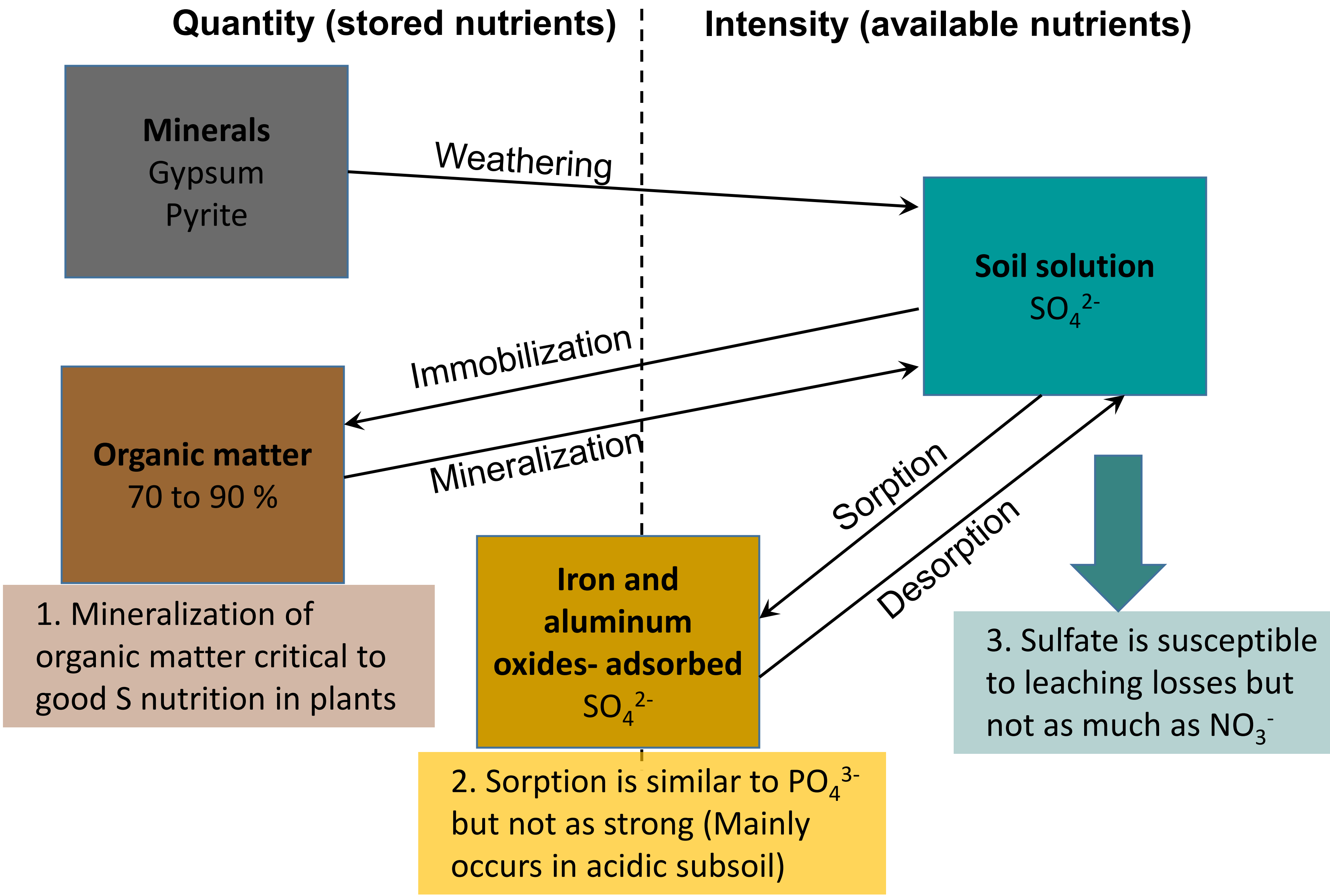
Sulfur

<u>Plant response to sufficient S</u>:

- Improves protein production and chlorophyll content
- Increased N use efficiency
- Improved animal nutrition (S containing amino acids)

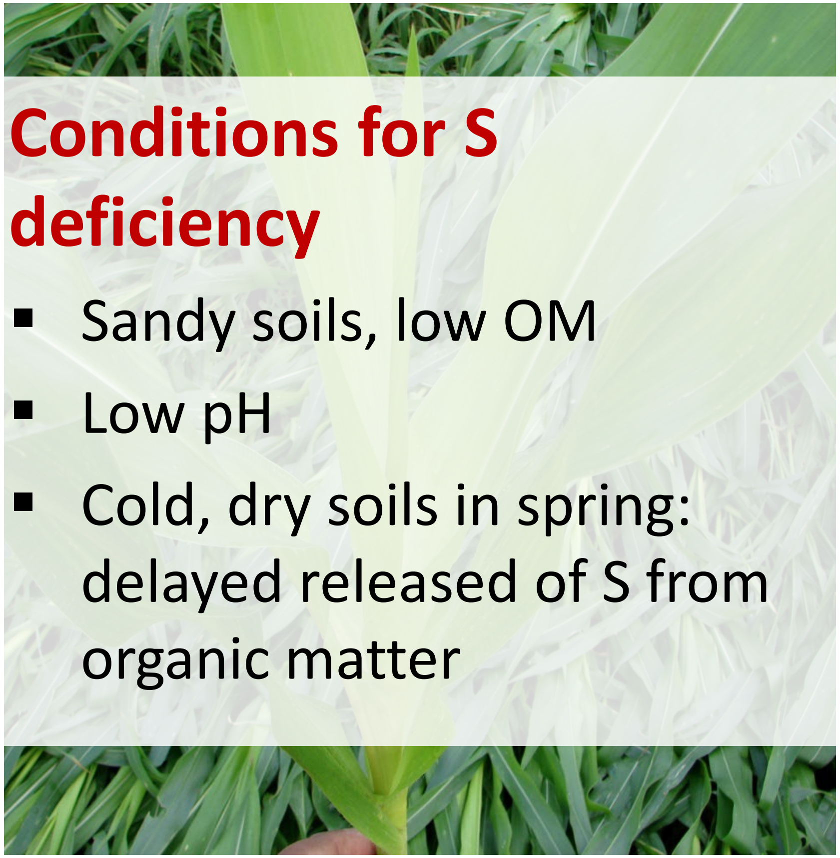
Alfalfa and members of mustard and onion families have high S requirement

Sulfur Cycle and Forms in soil



S Deficiency Symptoms

- Deficient plants stunted and pale green (lack of chlorophyll)
- Visual symptoms similar to N deficiency……but…



Sulfur deficient corn
S is relatively immobile, so
symptoms first appear upper leaves

Nitrogen deficient corn
N is a mobile nutrient, so
symptoms first appear lower leaves

Why S deficiency?

- **Clean Air Act:** Decrease in S emissions to atmosphere resulted in a decrease in atmospheric deposition
- **Changes in Fertilizers:** Ammonium sulfate and single superphosphate contained S and Ca
- **Higher Crop Yields:** remove more S
- **Leaching:** S is mobile and is easily leached from sandy soils

Sulfur deficient corn: *symptoms first appear upper leaves*

Diagnostic Tests for S

- **Soil testing:** Not very successful
  - S has similar behavior as N
  - Main source of S is mineralization of organic matter
  - Routine soil testing (Mehlich 3) can be used for monitoring soil levels but not for predicting response
- **Plant testing:**
  - Most definitive measure. Critical to test the correct plant part at right growth stage

Crop	Sufficiency range	Growth stage	Plant part
Corn	0.20 – 0.50%	Silking	Ear leaf
Alfalfa	0.25 – 0.50%	10% flowering	Top 1/3 of plant
Small Grains	0.20 – 0.40%	Before heading	Most recently mature leaf
Soybean	0.30 – 0.50%	Early flowering	Most recently mature leaf

Crop removal of S:

- Grain crops 5 to 15 lbs/A
- Forage crops 10 to 30 lbs/A

Sulfur Application Rate Guideline:

When a sulfur response is expected, apply:

Grain crops	5 to 20 lbs S /A
Forage crops	10 to 40 lbs S /A

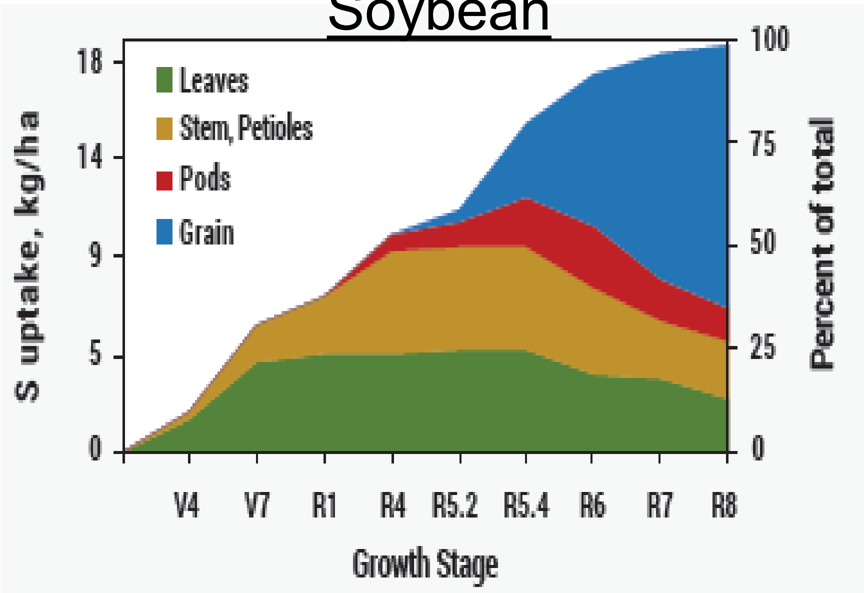
- Adjust rate for degree of deficiency and expected crop removal

Take Home Messages

- **Keep an eye on soil S levels**

- **S Fertilizers. Split if possible**
  - Ammonium sulfate (21–0–0-24)
  - Gypsum, 19% S
  - Ammonium thiosulfate, 26% S
  - Potassium sulfate (0–0–50–18)

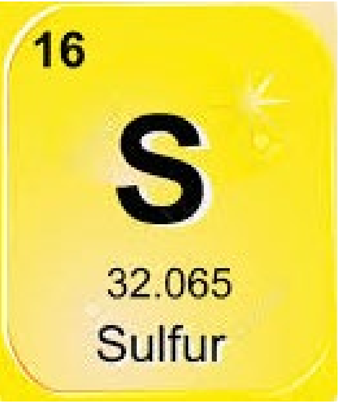
Soybean



1 kg/ha = 0.9 lb/ac

- **Manure/organic wastes:** as good as source as fertilizer. Skip fertilizer if adding manure:
  - Dairy (~20% dry matter): 4–8 lb S/ton
  - Poultry litter (75% dry matter): 5–6 lb S/ton

Managing Sulfur (S)



- **Challenges**:
  - Depletion of S levels in soils
  - Less atmospheric deposition
- **Opportunities**:
  - Deficiency symptoms similar to N
  - Regular soil testing is the key to monitor S levels

S deficiency in Corn

Questions?

Email: jradolin@mail.umd.edu; gstoor@umd.ed

@JesseRadolinski
@ToorUMD