SOIL FERTILITY & HEALTH

LACA February 14, 2018

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FUNCTIONS OF SOILS

- Medium for plant growth
- Regulator of water supplies
- Recycler of raw materials
- Modifier of the atmosphere
- Habit for soil organisms
- Engineering Medium

External Factors Control Plant Growth

- Air
- Temperature
- Light
- Mechanical support
- Nutrients
- Water
- The soil provides at least some of all these factors except air

Essential Nutrients

- C H O
- N P K
- Ca Mg S
- B Cl Cu Fe Mn Mo Zn

Non-Mineral Nutrients

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)
- Used in photosynthesis

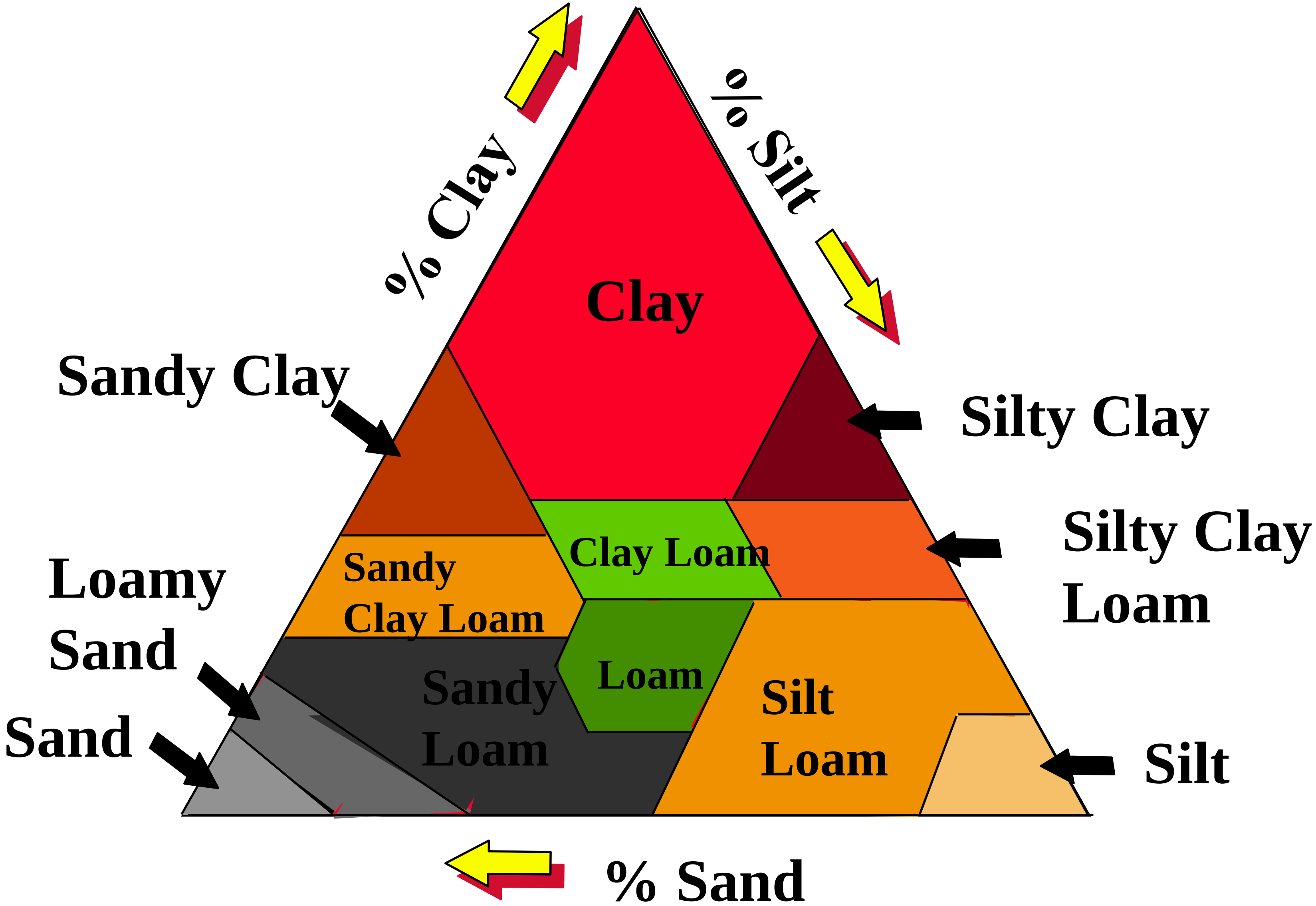
Mineral Nutrients

Major Nutrients

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Secondary Nutrients
- Calcium (Ca)
- Magnesium (Mg)
- Sulfur (S)

Micronutrients

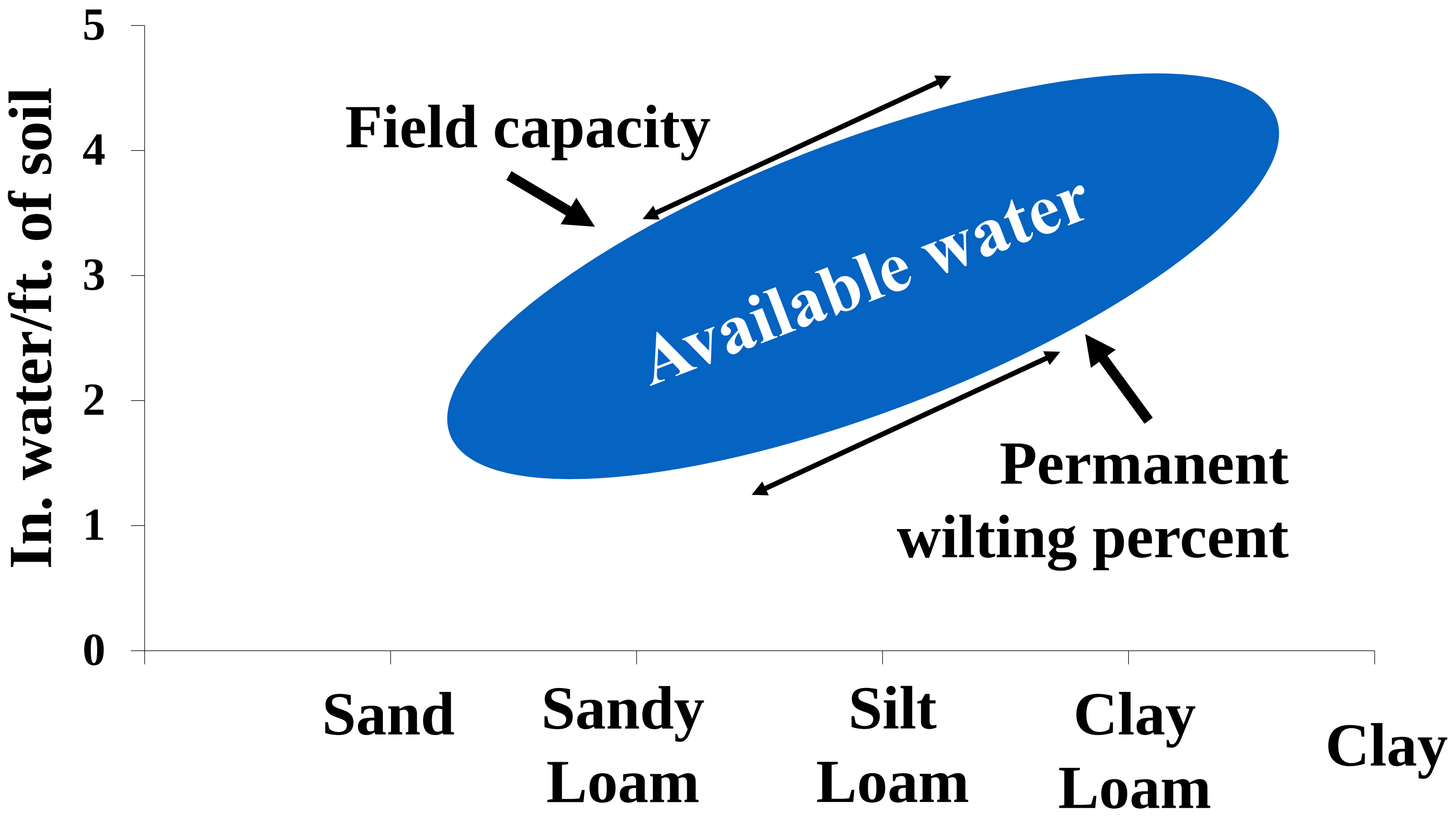
- Boron (B)
- Chloride (Cl)
- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Molybdenum (Mo)
- Zinc (Zn)

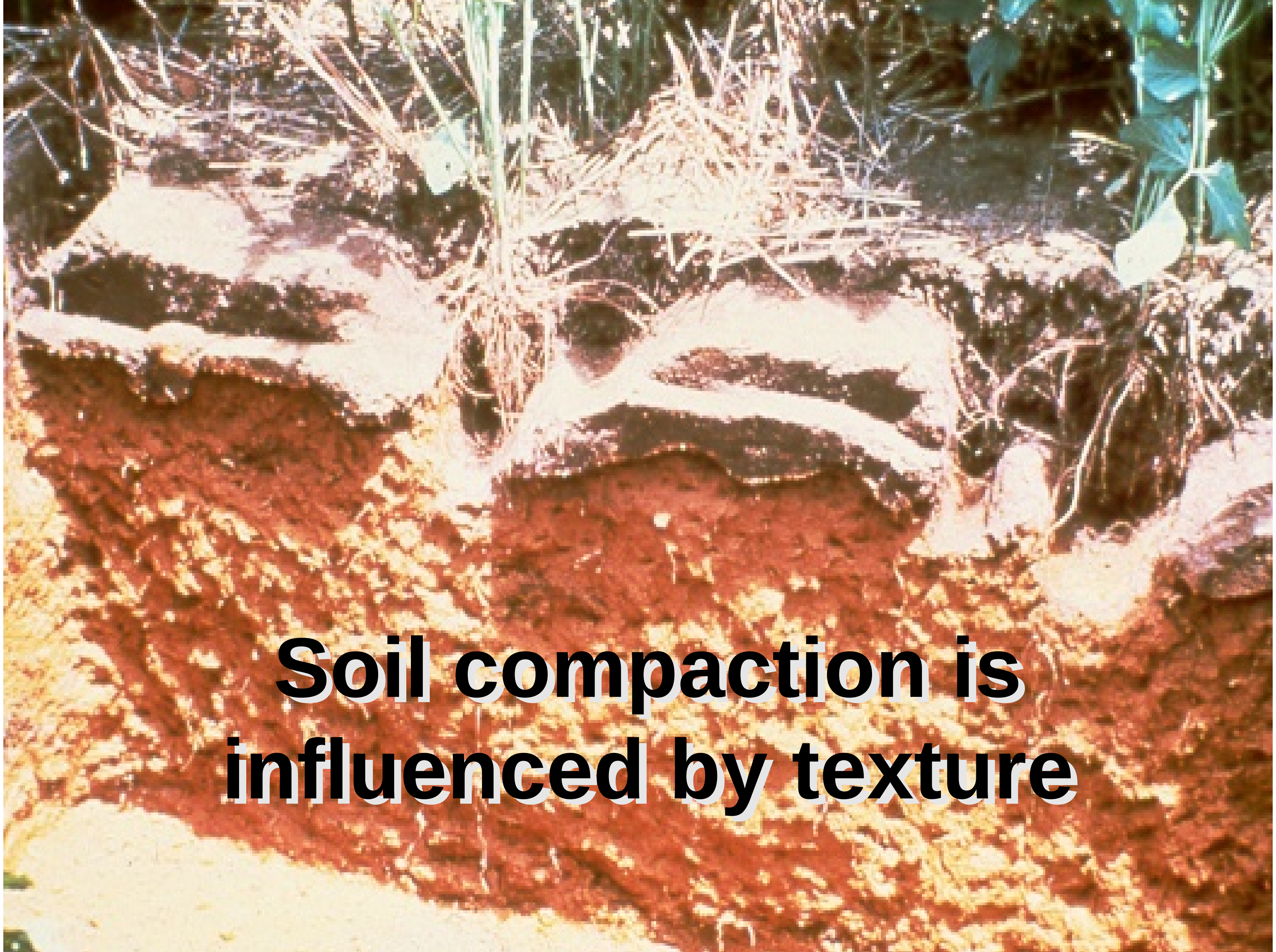


% Clay
% Silt
% Sand
Clay
Sandy Clay
Silty Clay
Silty Clay Loam
Clay Loam
Sandy Clay Loam
Loam
Loamy Sand
Sandy Loam
Silt Loam
Sand
Silt

Soil texture determines a soil’s waterholding capacity

Relationship between Soil Texture and Water Availability




Soil compaction is
influenced by texture

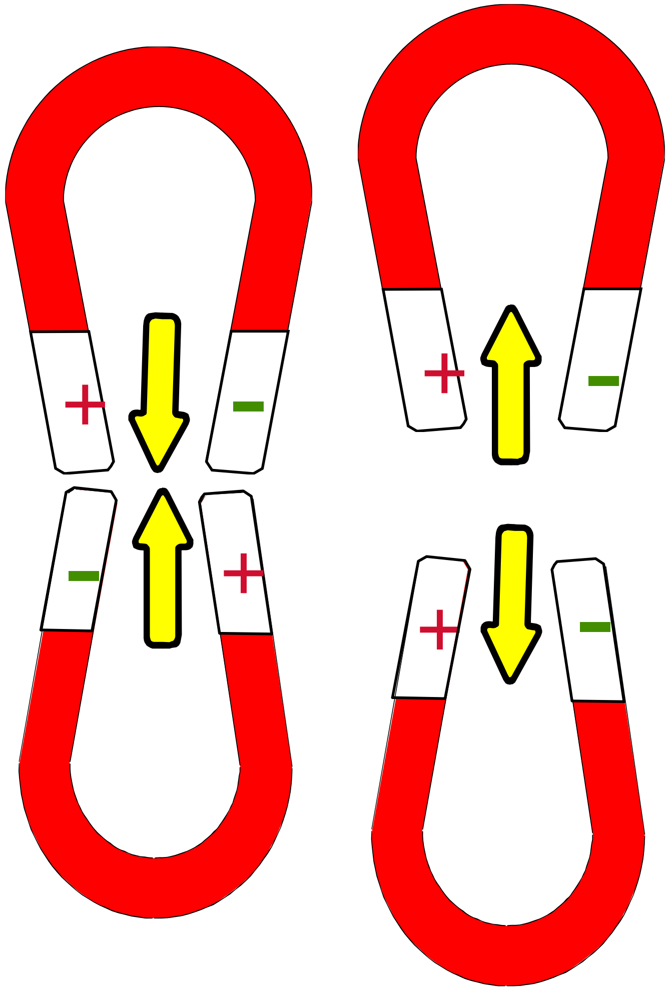
The Idea Soil For Crop Production

- Medium texture and organic matter for good air and water movement
- Sufficient clay to hold soil moisture reserves
- Deep, permeable subsoil with adequate fertility levels
- Environment for roots to go deep for moisture and nutrients

Clay in Soils

- The kind of parent material and the degree of weathering determine the kinds of clays present in the soil

Unlikes attract



Likes repel

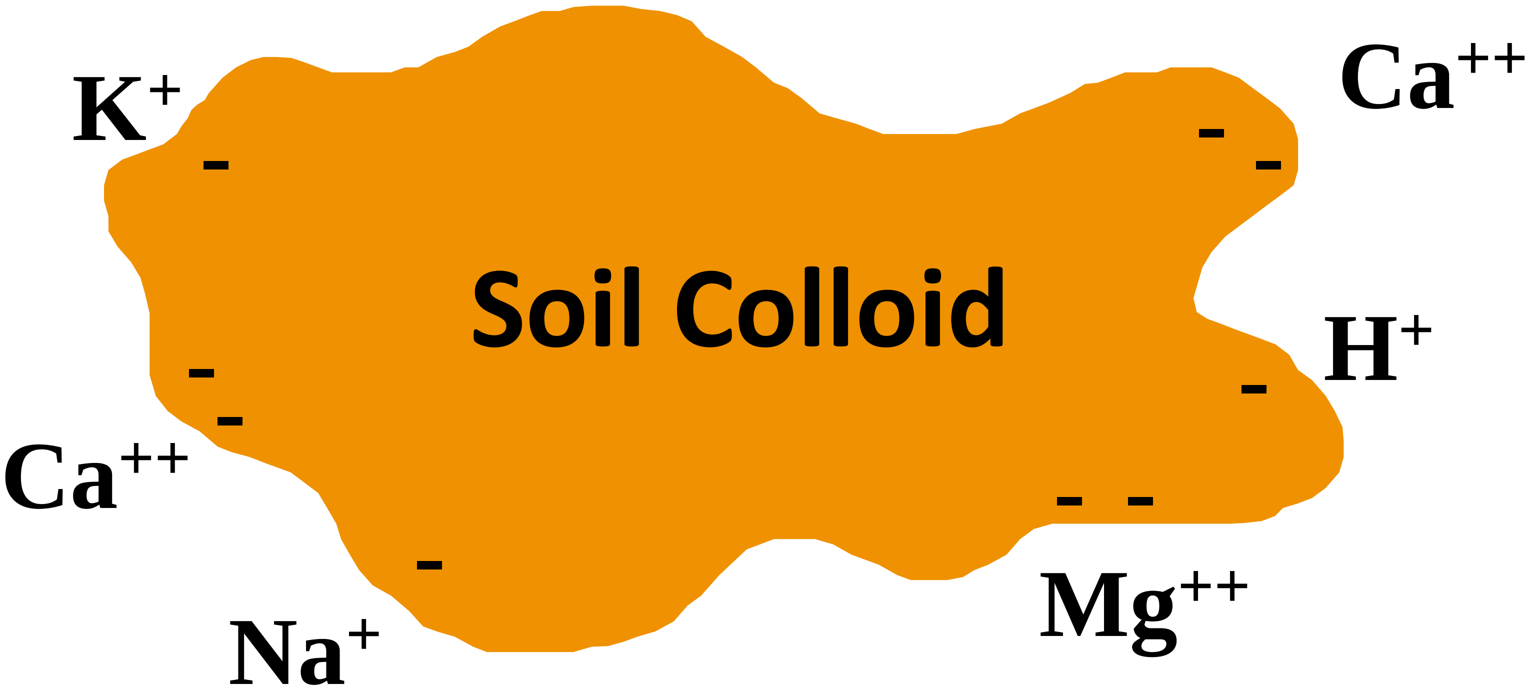
Positively Charged Ions Are Cations

Nutrient	Chemical Symbol	Ionic Form
• Potassium	K	K^+
• Sodium	Na	Na^+
• Ammonium	N	NH_4^+
• Hydrogen	H	H^+
• Calcium	Ca	Ca^+
• Magnesium	Mg	Mg^{++}

Negatively Charged Ions Are Called Anions

Nutrient	Chemical symbol	Ionic form
Chloride	Cl	Cl^{-}
Nitrate	N	NO_3^{-}
Sulfate	S	$SO_4^{=}$
Borate	B	$BO_4^{\equiv}$
Phosphate	P	$H_2PO_4^{-}$

Negatively Charged Colloids Attract Cations



Cation Exchange Capacity

- The total number of exchangeable cations a soil can hold.
- The amount of its **negative** charge

Clay and Organic Matter Have the Greatest Influence on CEC

Clay

- 10-150
- Meq/100g

Organic Matter

- 200-400
- Meq/100g

Anion Retention In Soils

- Phosphate is held strongly due to quick formation of insoluble compounds
- Sulfate is held loosely in some low pH soils
- Nitrate and chloride are not held in soils and move freely with soil water

Soil Organic Matter Benefits Soil in Many Ways

- Improves physical condition
- Increases water infiltration
- Improves soil tilth
- Decreases erosion losses
- Supplies plant nutrients
- Increases CEC

Organic Matter Decomposition

- Will eventually increase soil nutrient supplies of most nutrients
- Will temporarily tie up soil N when a high C residue is incorporated

Soil Depth Influences Relative Productivity

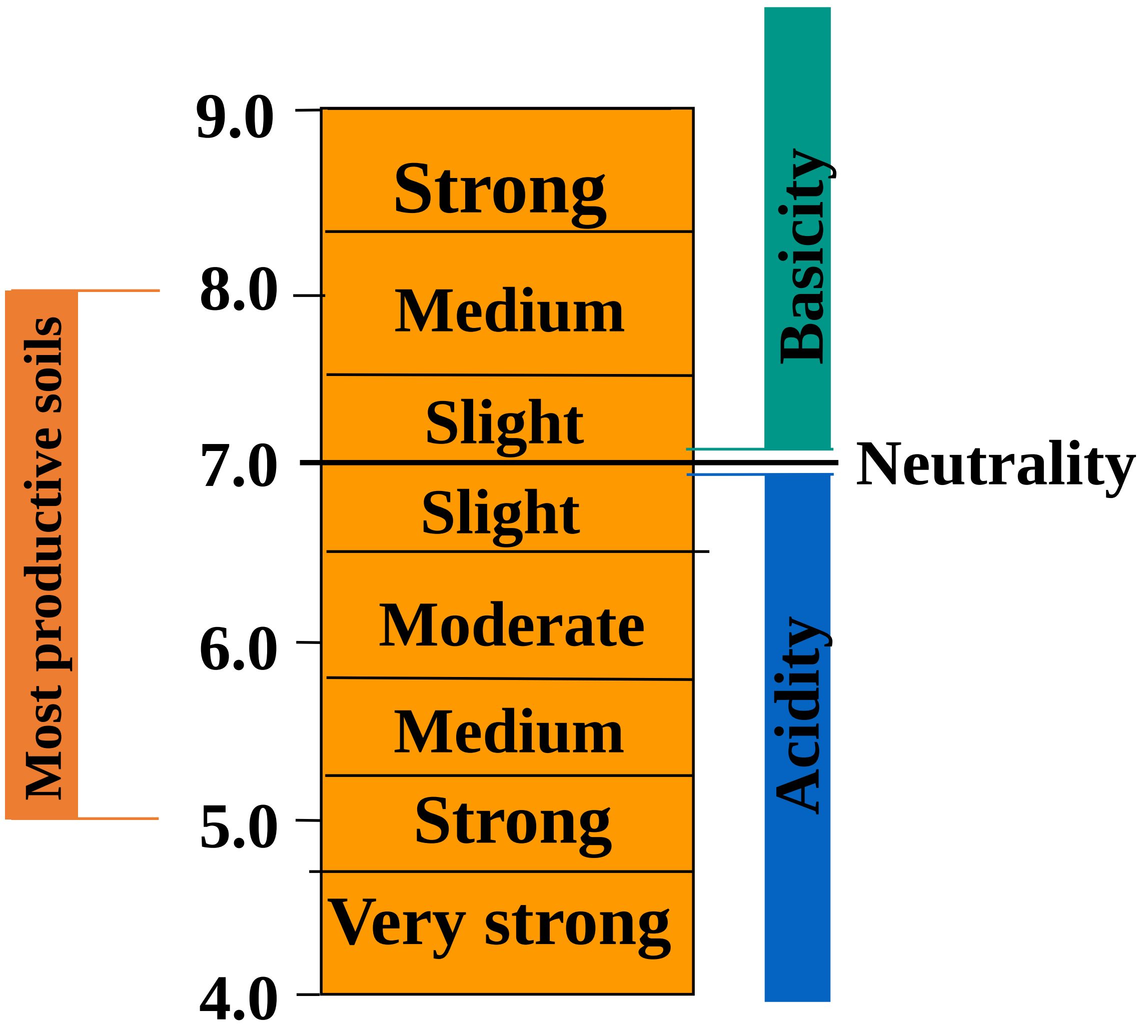
Soil depth usable by roots, ft.	Relative productivity, %
1	35
2	60
3	75
4	85
5	95
6	100

Factors Affecting Soil Organisms

- Moisture
- Temperature
- Aeration
- Nutrient supply
- Soil pH
- Cropping system

Soil pH

pH value defines relative acidity or basicity



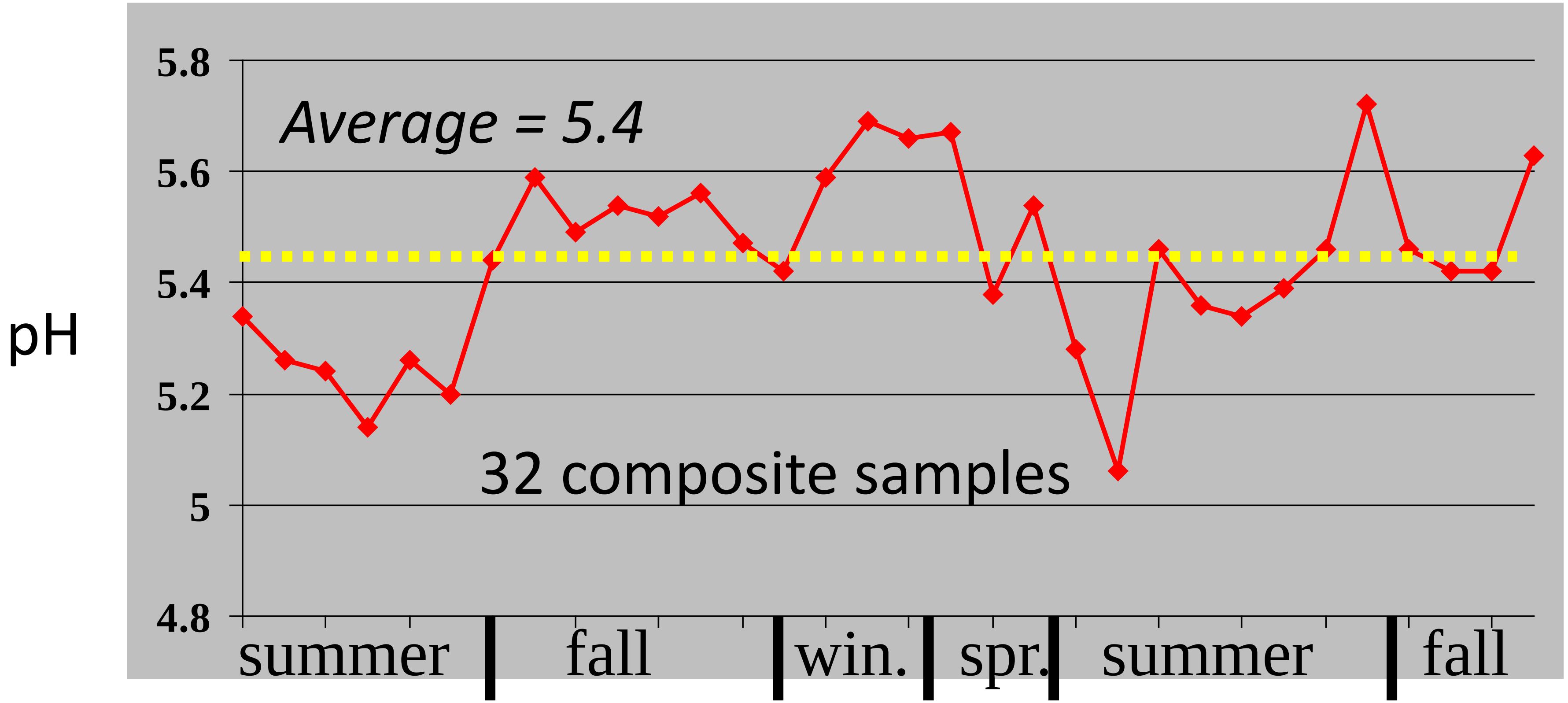
Soil pH Measures Hydrogen Ion Activity

Soil pH		Acidity/basicity compared to pH 7.0
9.0		100
8.0	Basicity	10
7.0		Neutral
6.0		10
5.0	Acidity	100
4.0		1,000

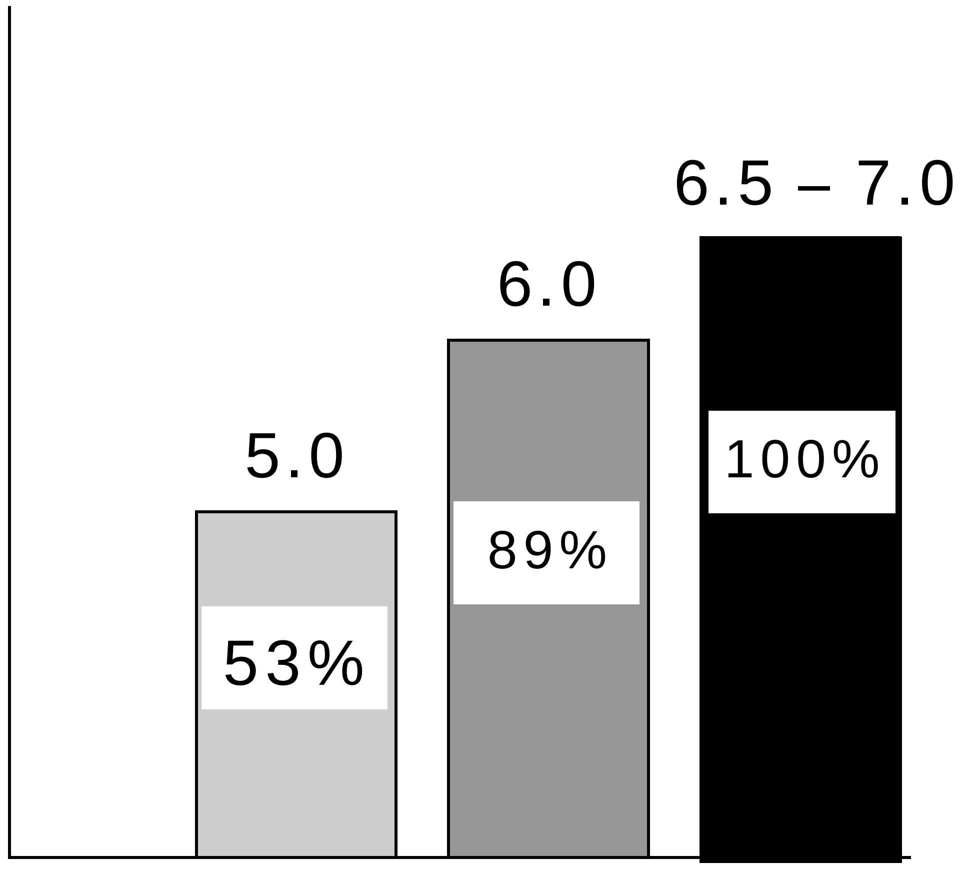
A Soil's pH Is Affected by Several Factors:

- **Decomposition of organic matter**
- **Parent material**
- **Precipitation**
- **Native vegetation**
- **Crops grown**
- **Soil depth**
- **Nitrogen fertilization**
- **Flooding**

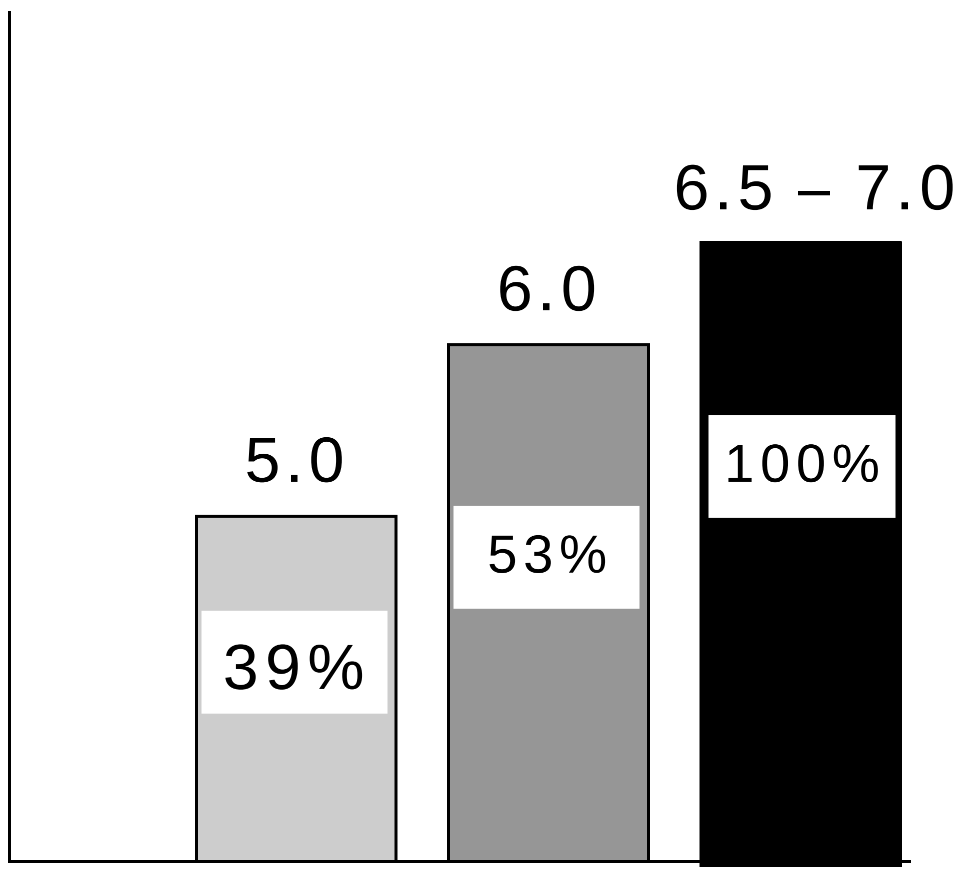
Seasonal Variations in Soil pH Dundee silt loam (Maples ans Keogh 1972, (Arkansas)



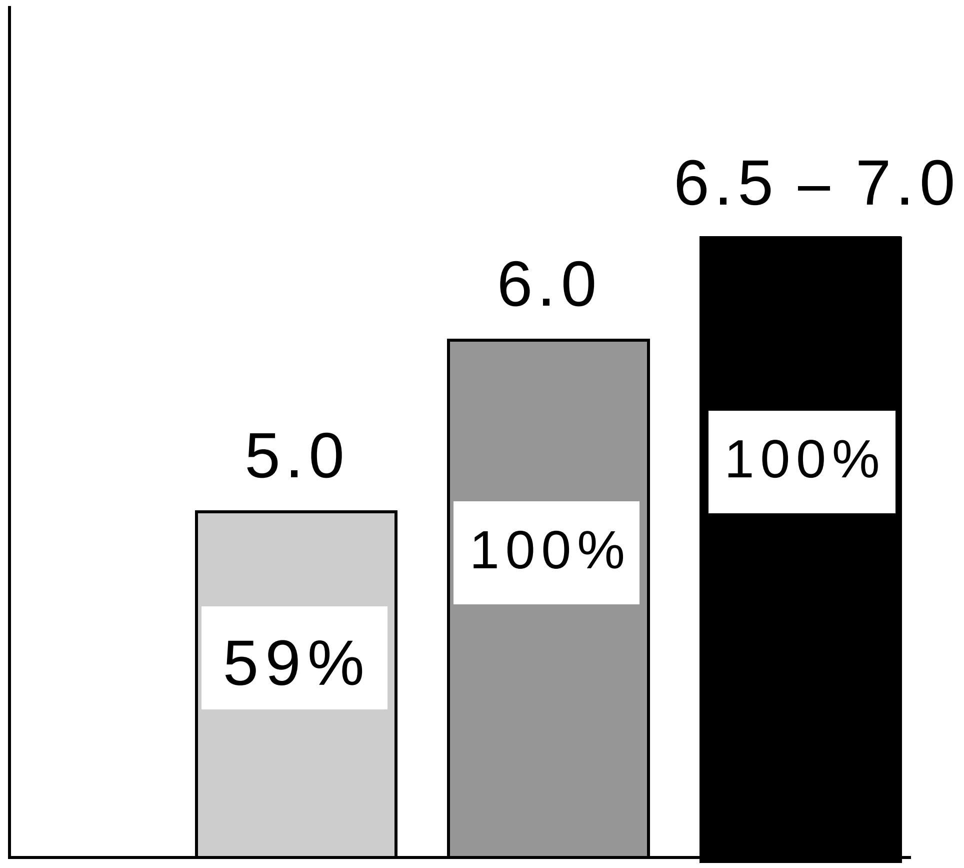
pH vs Nitrogen Efficiency



pH vs Phosphorus Efficiency



pH vs Potassium Efficiency




Fertilization, particularly N,
speeds the rate that
acidity develops

Lime Corrects Problems from Excessive Acidity

- Reduces Al and other metal toxicities
- Improves soil physical condition
- Stimulates microbial activity . . . including those symbiotic bacteria that fix N
- Increases CEC in variable charge soils
- Improves availability of several nutrients
- Supplies Ca and Mg for plants

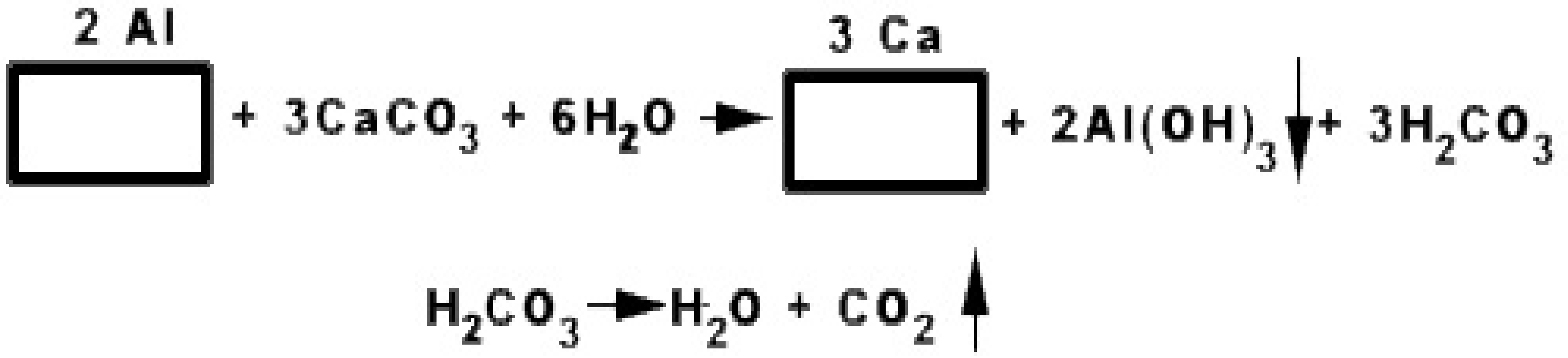
Soil Acidity Affects Plant Growth

- Aluminum, Fe and Mn can reach toxic levels because of increased solubilities in acid soils
- Reduced activity of organisms responsible for the breakdown (mineralization) of organic matter
- Possible Ca deficiency . . . but most likely an Mg deficiency

Soil Acidity Affects Plant Growth

- The performance of soil-applied herbicides can be adversely affected
- Reduced activity of symbiotic N fixing bacteria
- Clay soils high in acidity are less highly aggregated
- Availability of nutrients such as P, K and Mo is reduced
- Tendency for K to leach is increased

How Lime Reduces Soil Acidity

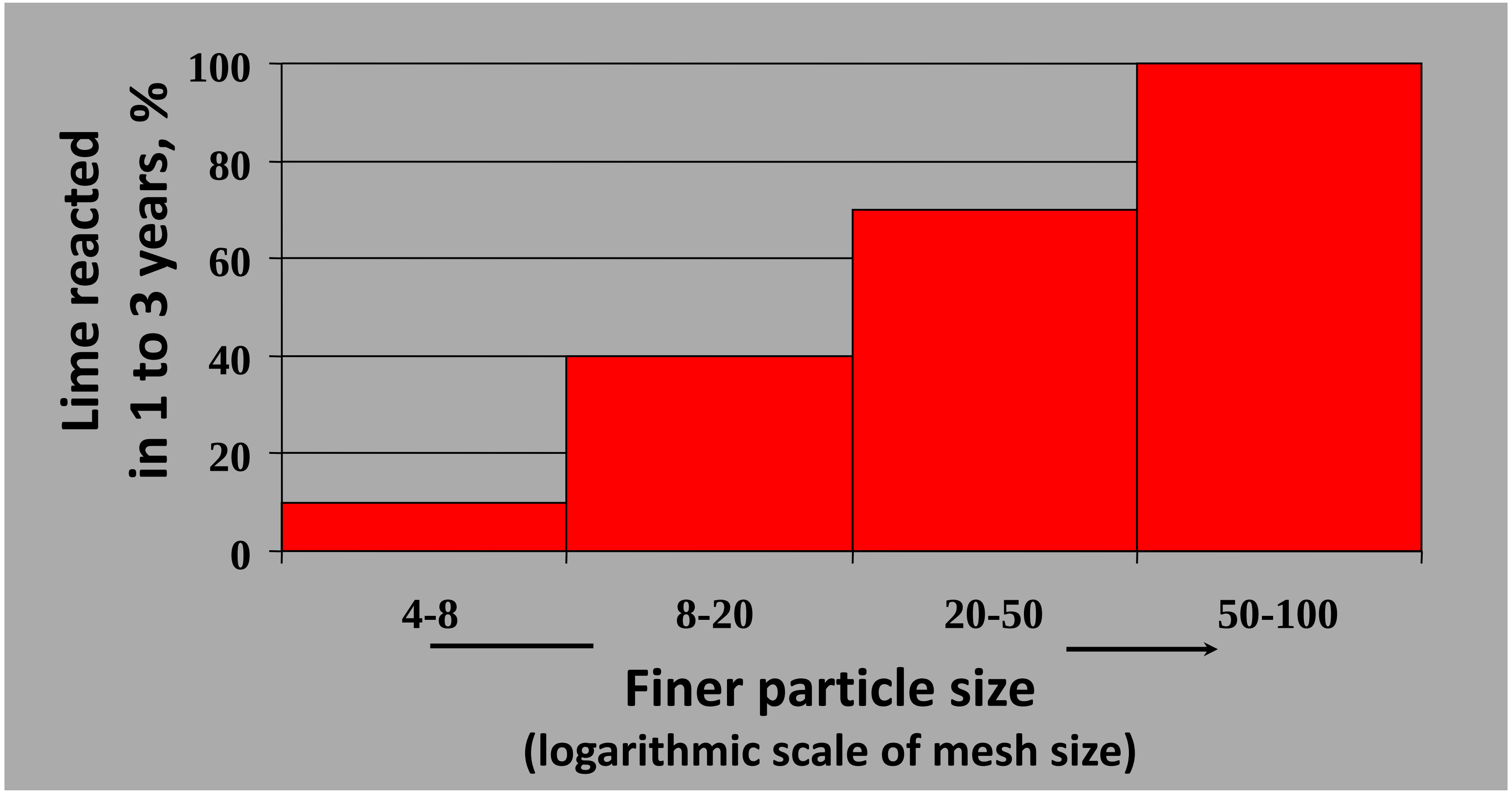


- Al removed from CEC replaced by Ca
- Al precipitates
- H^+ becomes H_2O

Factors in Addition to Soil pH Which Influence the Frequency of Liming

- Soil texture
- Rate of N fertilization
- Rate of crop removal of Ca and Mg
- Amount of lime applied
- pH range desired

Particle Size Determines Lime Reactivity




Calcareous soils
usually have pHs
in the range
of 7.3 to 8.4


Sodic (alkali) soils
usually have pHs
above 8.5


NITROGEN
THE SUPERSTAR

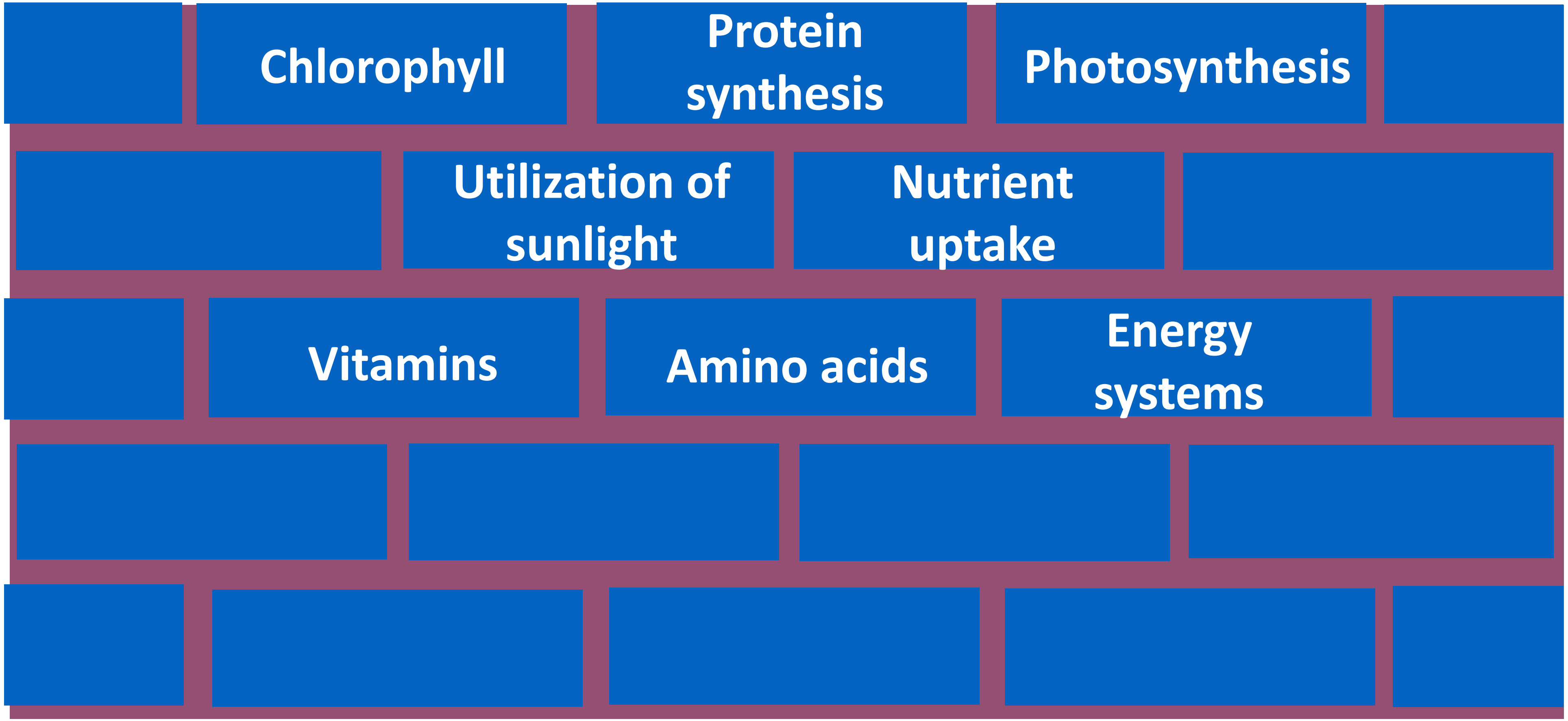
Crops Have High Nitrogen Requirements

Crop	Yield level	N taken up in total crop, lb
Alfalfa*	8 tons	450
Coastal bermudagrass	8 tons	368
Corn	160 bu	213
Cotton (lint)	1,500 lb	180
Oranges	540 cwt	265
Soybeans*	60 bu	315
Wheat	60 bu	113

***Legumes get most of their N from the air**


Agronomic crops
use both NO_3^-
and NH_4^+ forms of N

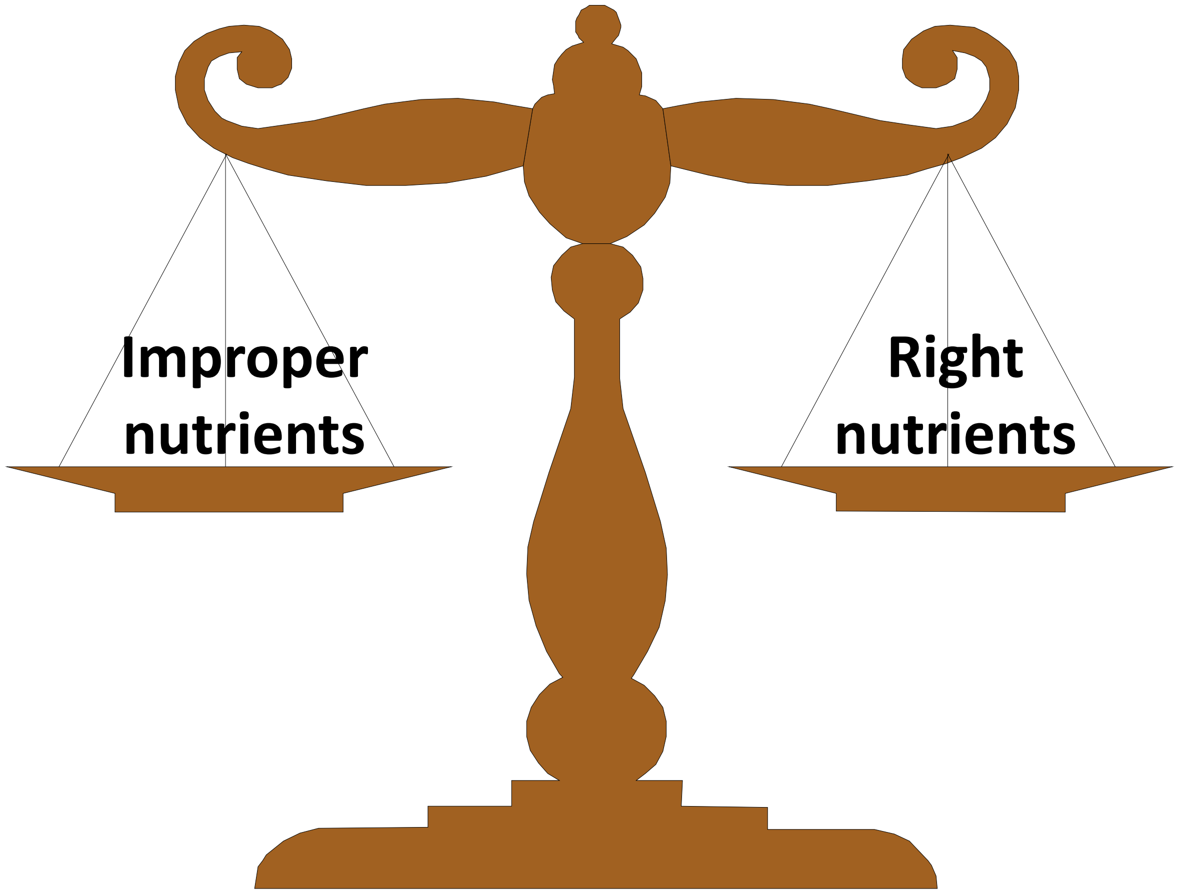
Nitrogen Essential for:



Nitrogen Deficiency Symptoms Include…

- Slow growth; stunted plants
- Less tillering in small grains and other grasses
- Lower protein; fewer leaves
- Early maturity, limiting yield potential
- Higher moisture content in corn grain at maturity

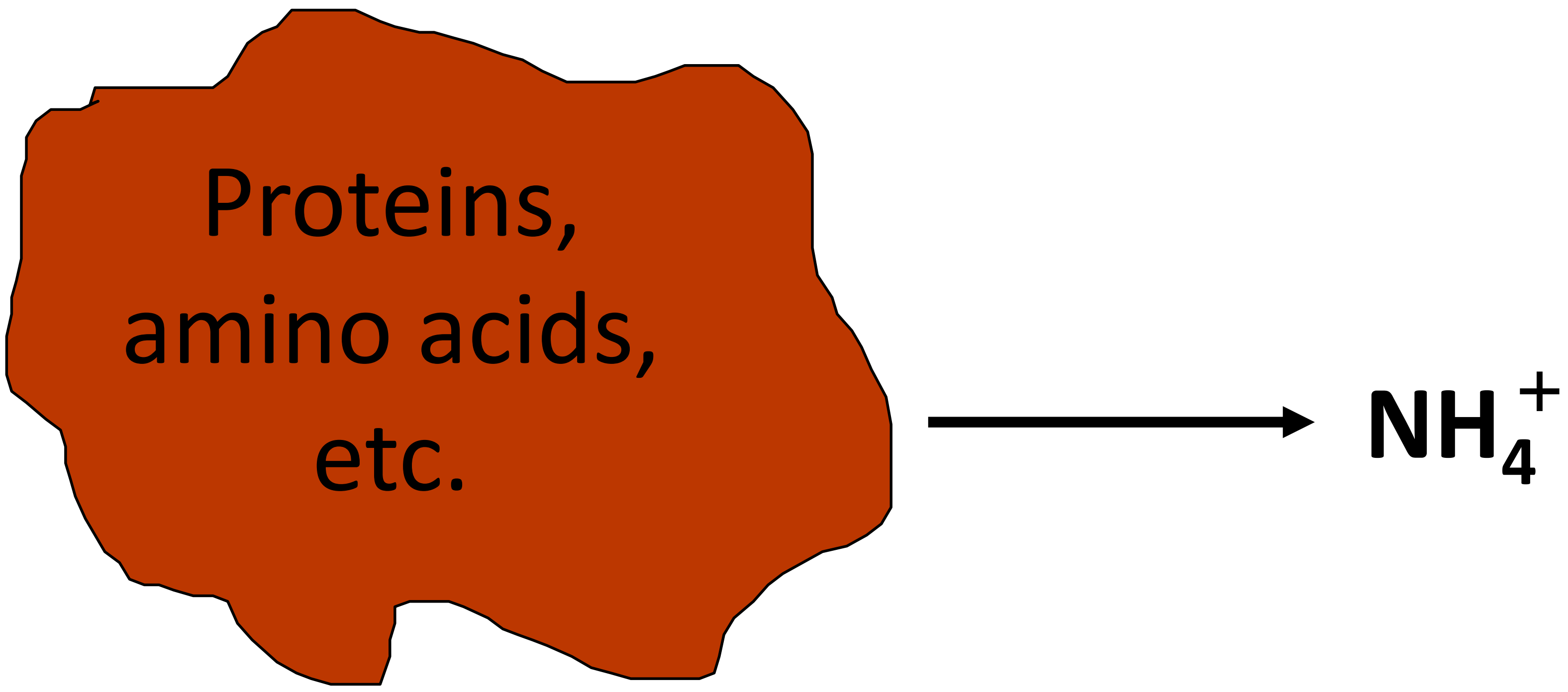
Nutrient imbalance, not too much N, is the cause of delayed crop maturity




Most N used by crops
comes from the atmosphere

Mineralization:

The microbial breakdown of soil organic matter, resulting in the release of energy and inorganic nutrients available for plant growth



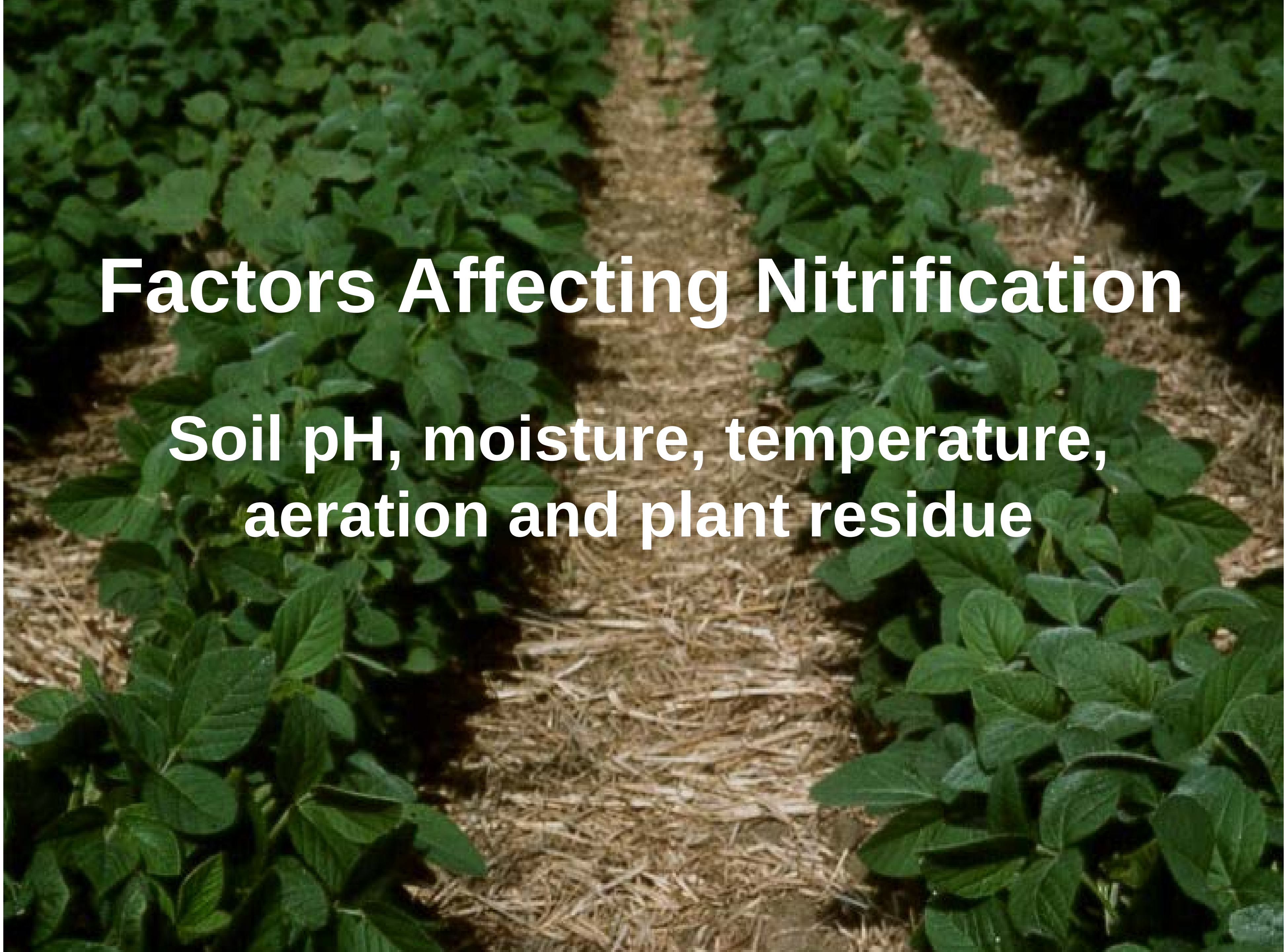
Ammonification

$$NH_4^+ \xrightarrow[\text{bacteria}]{\text{Oxygen plus}} NO_3^-$$

Nitrification

$$NO_3^- \xrightarrow[\text{bacteria}]{\text{Lack of oxygen } (O_2)} N_2O,\ N_2$$

Denitrification



Factors Affecting Nitrification

Soil pH, moisture, temperature, aeration and plant residue


Nitrogen Can Be Lost from
the Soil in Several Ways
Crop removal
Volatilization
Denitrification
Leaching

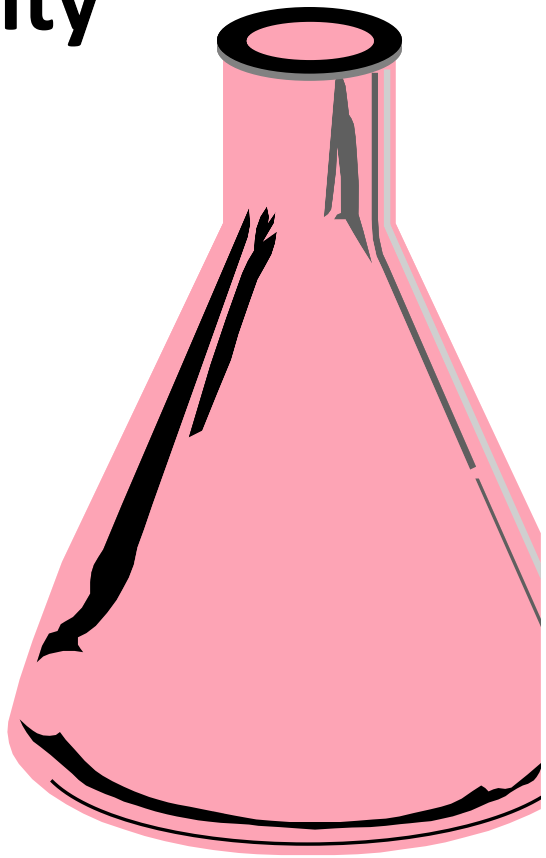
Conditions that Favor Volatilization Loss from Soil Applications of Urea

Surface application

Presence of urease enzyme

High temperatures

Nitrification and Nitrogen Leaching Increase Soil Acidity



- **Nitrification** - H^+ is released during the conversion of NH_4+ to NO_3-
- **Leaching** - NO_3- carries basic ions with it. They are replaced by H^+

Phosphorus

Crops Take Up Large Quantities of Phosphorus

Crop	Yield level	P_2O_5 taken up in total crop, lb
Alfalfa	8 tons	120
Coastal bermudagrass	8 tons	96
Corn	160 bu	91
Cotton, lint	1,000 lb	51
Oranges	540 cwt	55
Soybeans	60 bu	58
Wheat	60 bu	41

Seeds Contain More Phosphorus than Other Plant Parts

Crop	Plant part	Yield level	P content, %
Corn	Grain	150 bu	0.22
	Stover	7,500 lb	0.17
Cotton	Seed	2,000 lb	0.66
	Stalks	2,500 lb	0.24
Soybeans	Grain	50 bu	0.42
	Straw	7,000 lb	0.18
Wheat	Grain	60 bu	0.42
	Straw	5,400 lb	0.12

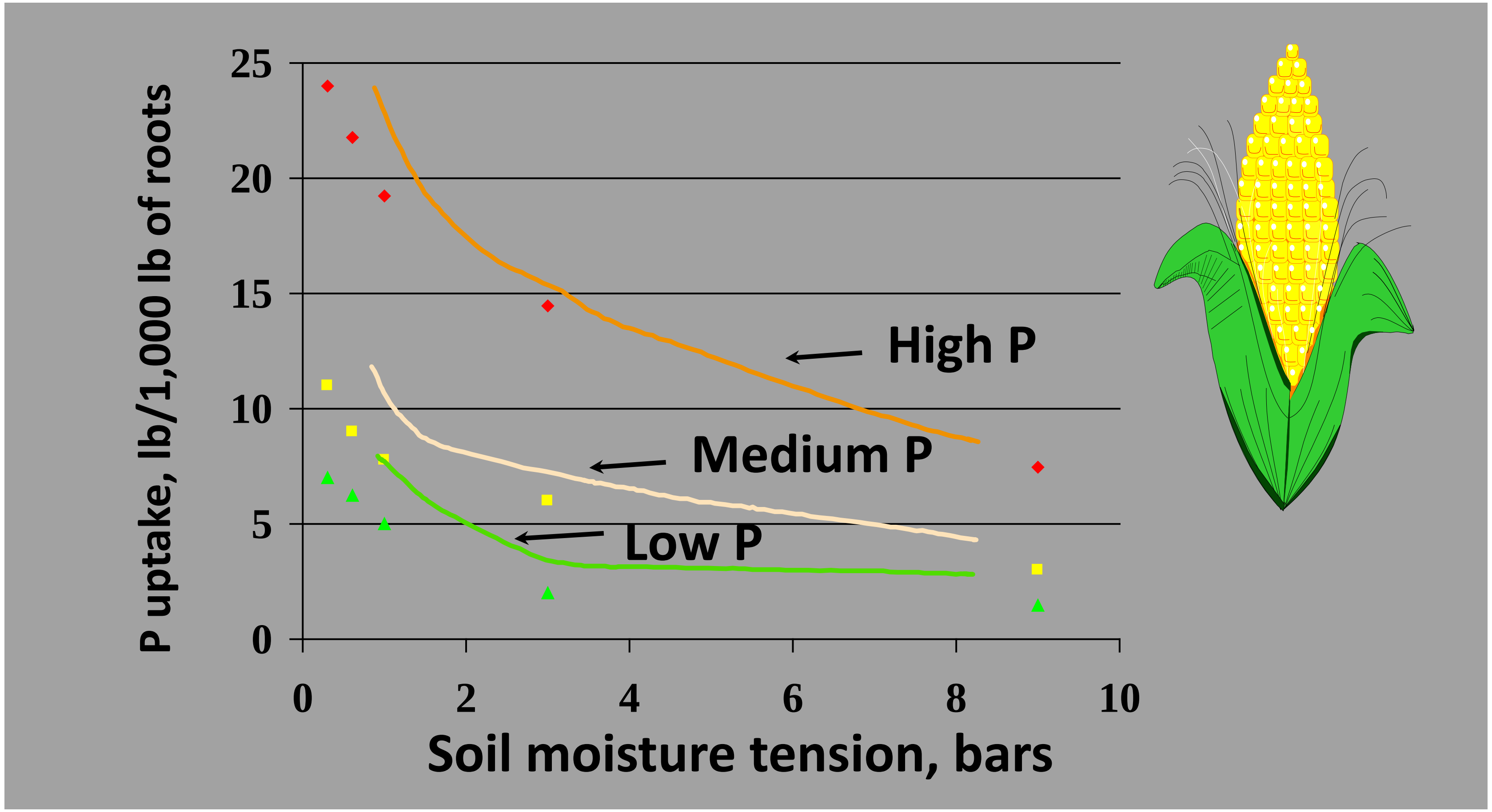
Phosphorus Is Taken Up by Plants as:

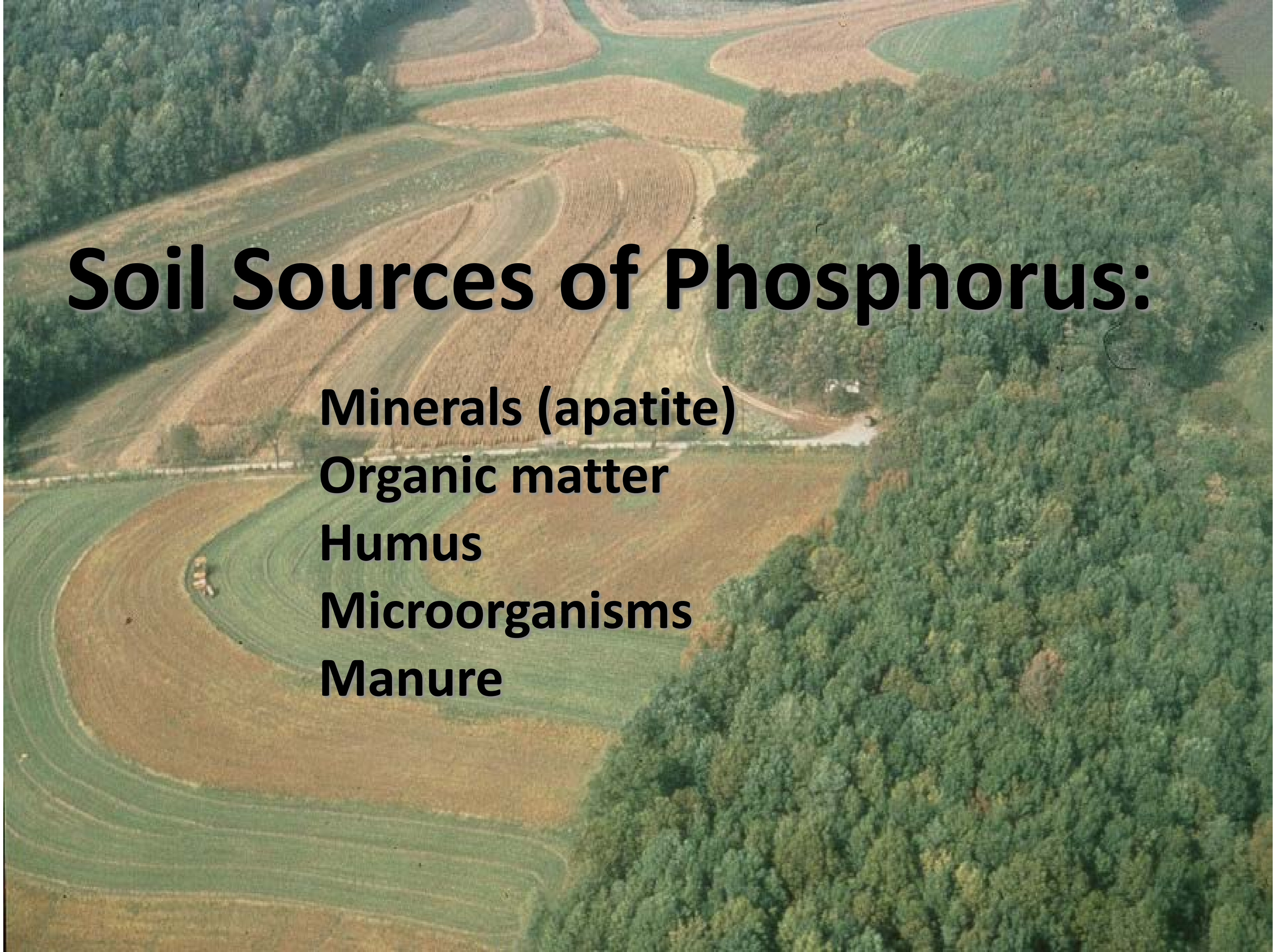
- Primary orthophosphate ion $(H_2PO_4)^-$
- Secondary orthophosphate ion $(HPO_4)^=$

Some Roles Phosphorus Plays in Plant Growth

- Photosynthesis and respiration
- Energy storage and transfer
- Cell division and enlargement
- Early root formation and growth
- Improves quality
- Vital to seed formation
- Transfer of hereditary traits

P Level Affects P Uptake by Corn during Periods of Moisture Stress

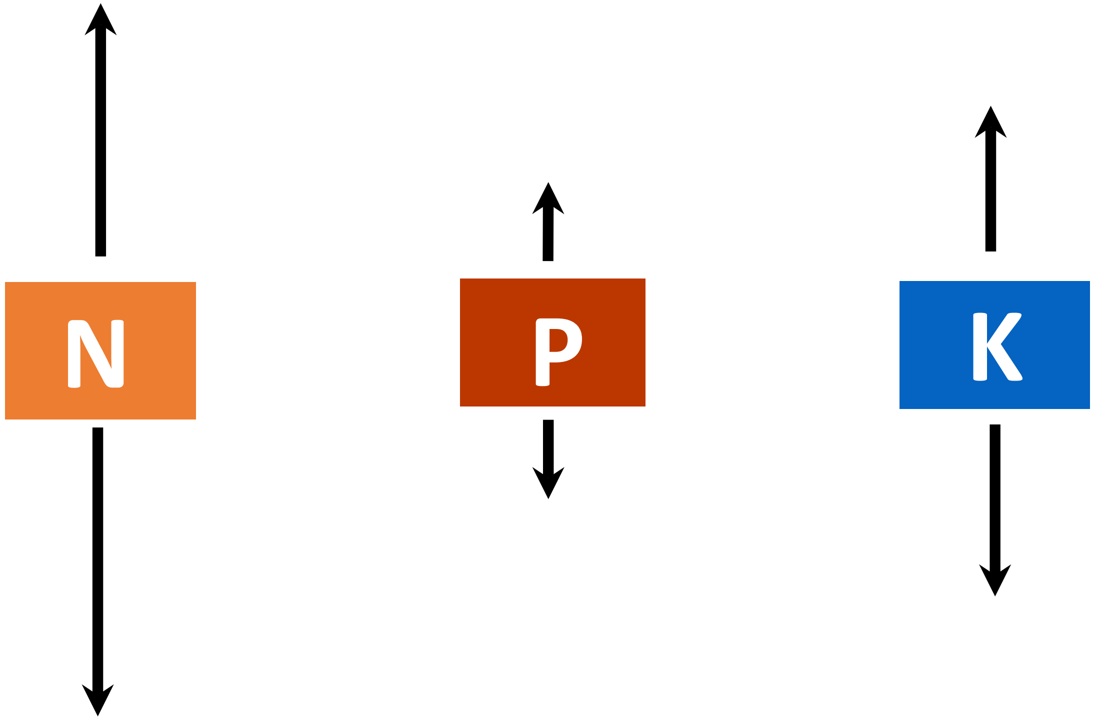




Soil Sources of Phosphorus:

- Minerals (apatite)
- Organic matter
- Humus
- Microorganisms
- Manure

Relative Movement of N, P, K in the Soil



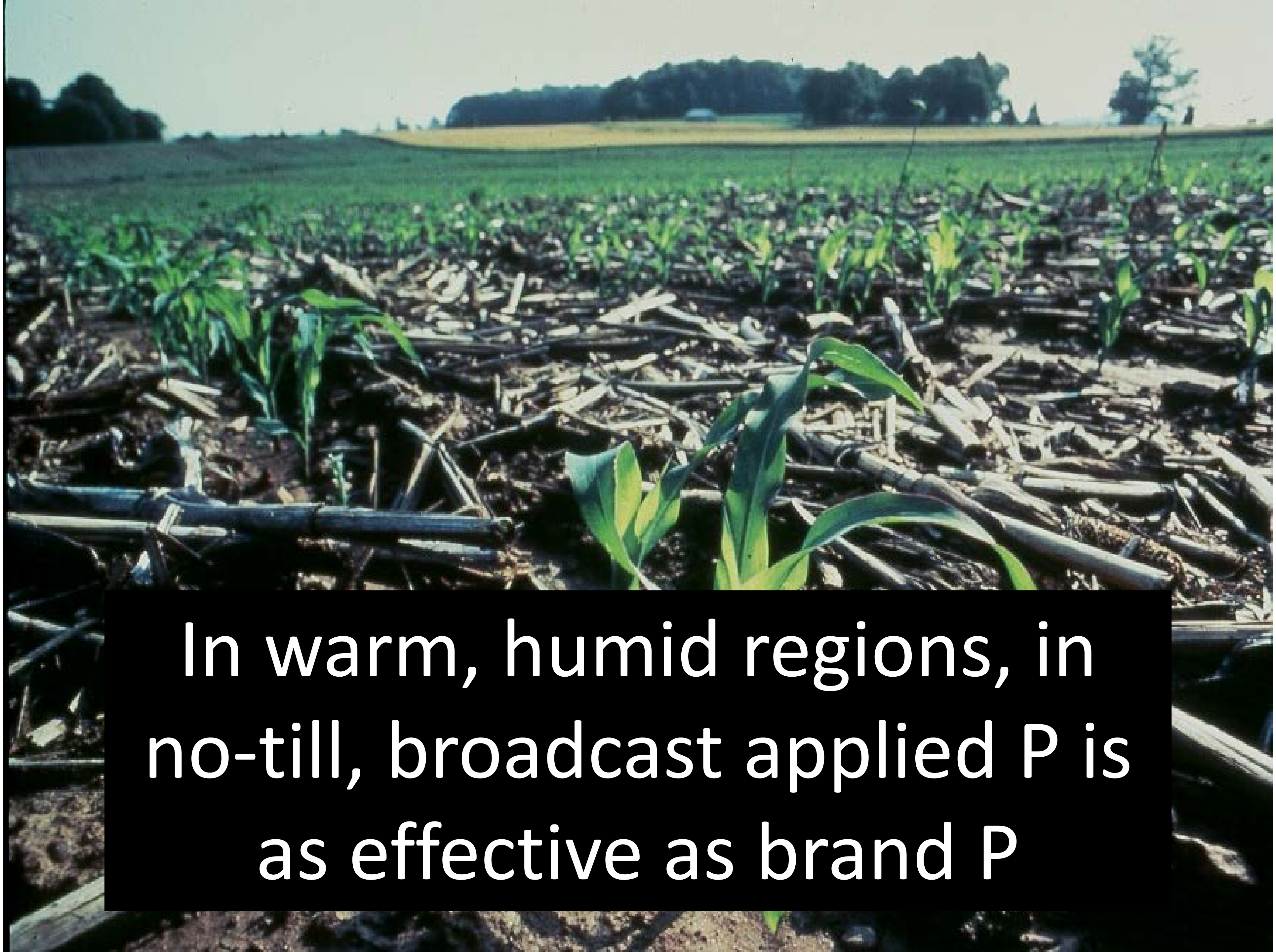
Factors Influencing Amount of P Recovered during First Year after Fertilization

Amount of clay
Type of clay
Time of application
Temperature
Soil pH
Crop grown

Aeration
Moisture
Compaction
Other nutrients
Soil P status

Several Factors Influence Phosphorus Placement

- Soil fertility levels
- Crop(s) to be grown
- Tillage methods, equipment and timing
- P fixing capacity of the soil



In warm, humid regions, in no-till, broadcast applied P is as effective as brand P

Potassium

Potassium Taken Up by Some Agronomic Crops

Crop	Yield level	K_2O taken up in total crop, lb
Alfalfa	8 tons	480
Coastal bermudagrass	8 tons	400
Corn	160 bu	213
Cotton (lint)	1,000 lb	85
Oranges	540 cwt	330
Soybeans	60 bu	205
Wheat	60bu	122

Potassium

- Taken up by the plant as K^+
- Does not form organic compounds in the plant
- Is vital to photosynthesis and protein synthesis
- Is associated with other metabolic functions

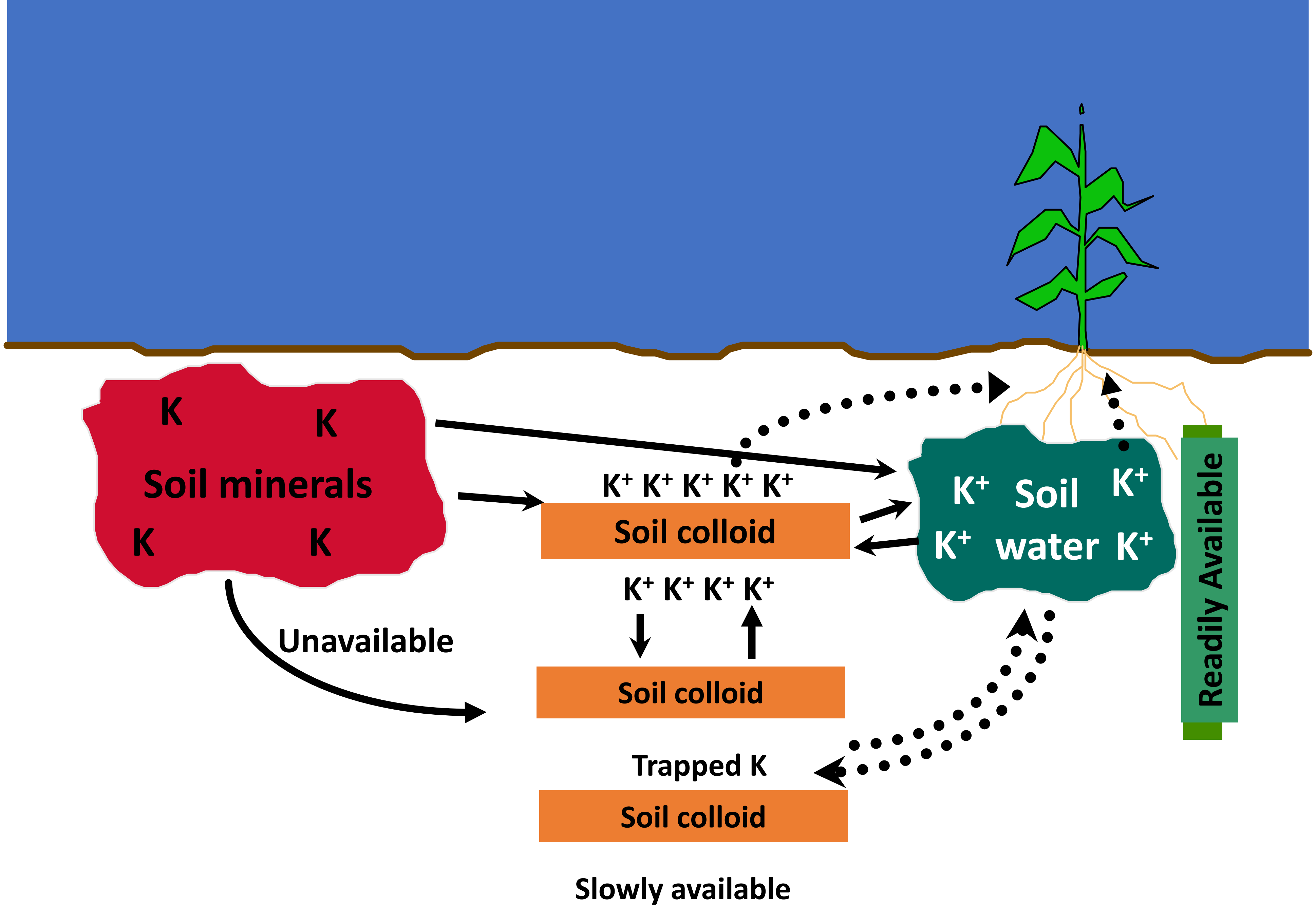

Potassium increases
water use efficiency and
reduces drought stress

Potassium Functions in Plants

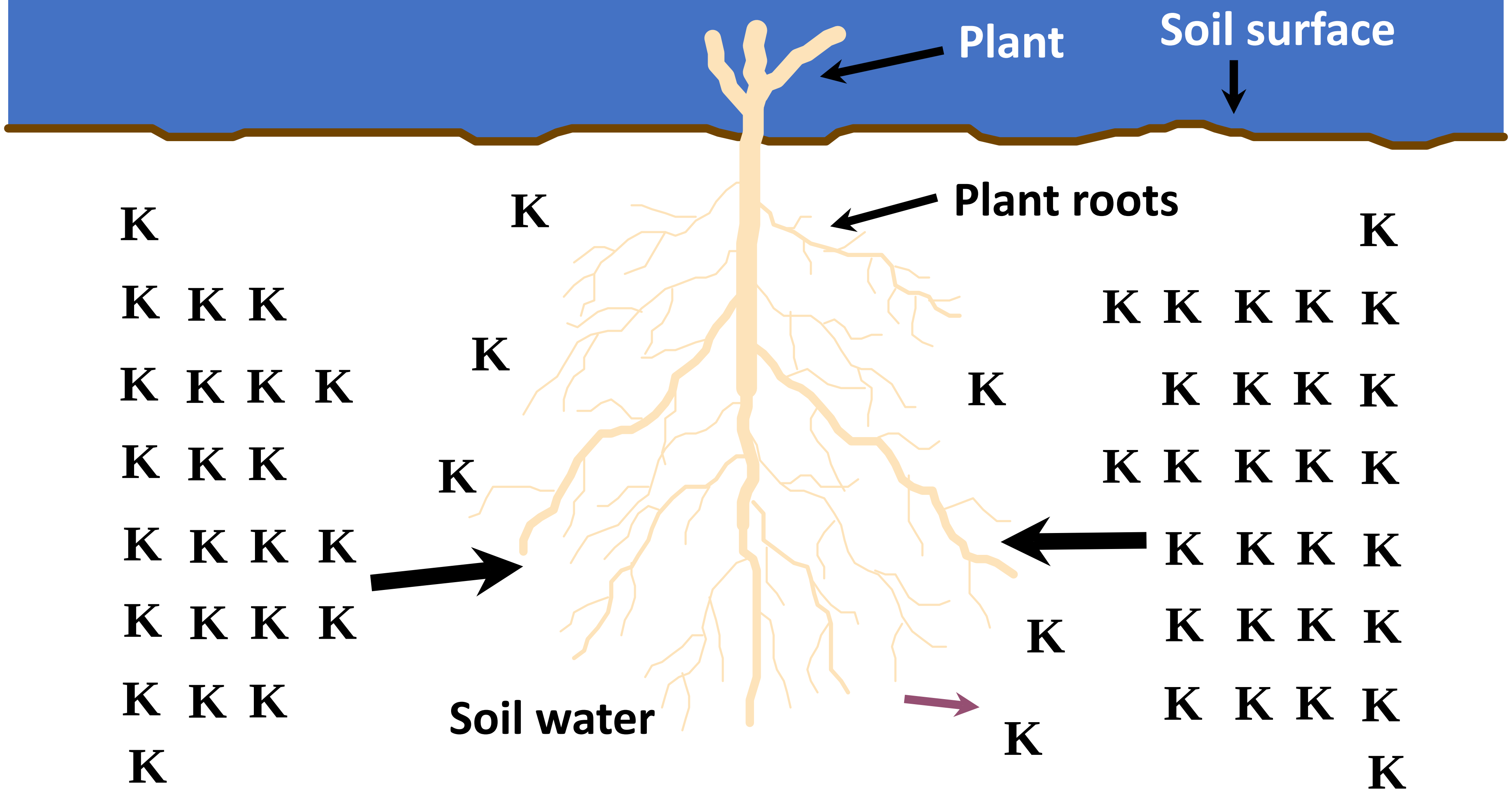
- Protects against moisture stress
- Helps retard disease
- Reduces plant lodging
- Reduces diseased and shriveled soybean seed
- Increases stand in grasses

Potassium in Soils

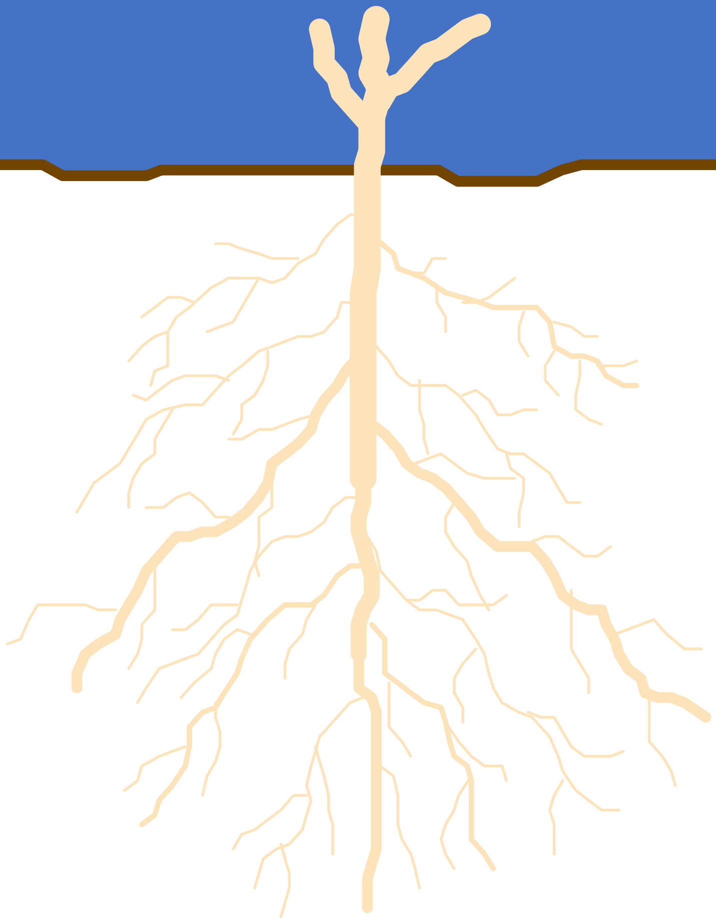
- Soils may contain 20,000 lb/A of K, or more
- Only a small amount is available during the growing season


K
K
Soil minerals
K
K
K⁺ K⁺ K⁺ K⁺ K⁺
Soil colloid
K⁺ Soil K⁺
K⁺ water K⁺
Readily Available
K⁺ K⁺ K⁺ K⁺
Unavailable
Soil colloid
Trapped K
Soil colloid
Slowly available

Potassium Moves to Plant Roots by Diffusion



Fate of Fertilizer K in the Soil



- **Held in exchangeable form**
- **Remains in soil solution**
- **Taken up by growing crop**
- **Leached in sandy or organic soils**
- **Fixed (unavailable or slowly available)**

Factors Reducing Rate of Diffusion and Restricting Root Growth Decrease K Uptake

- Soil aeration
- K fixation
- Cation Exchange Capacity (CEC)
- Compaction
- Soil test K
- Soil temperature
- Soil moisture

Secondary Nutrients

Calcium Content of Soils

- Arid, calcareous soils contain highest levels
- Newly drained organic soils often contain little Ca
- Clays contain more Ca than sands

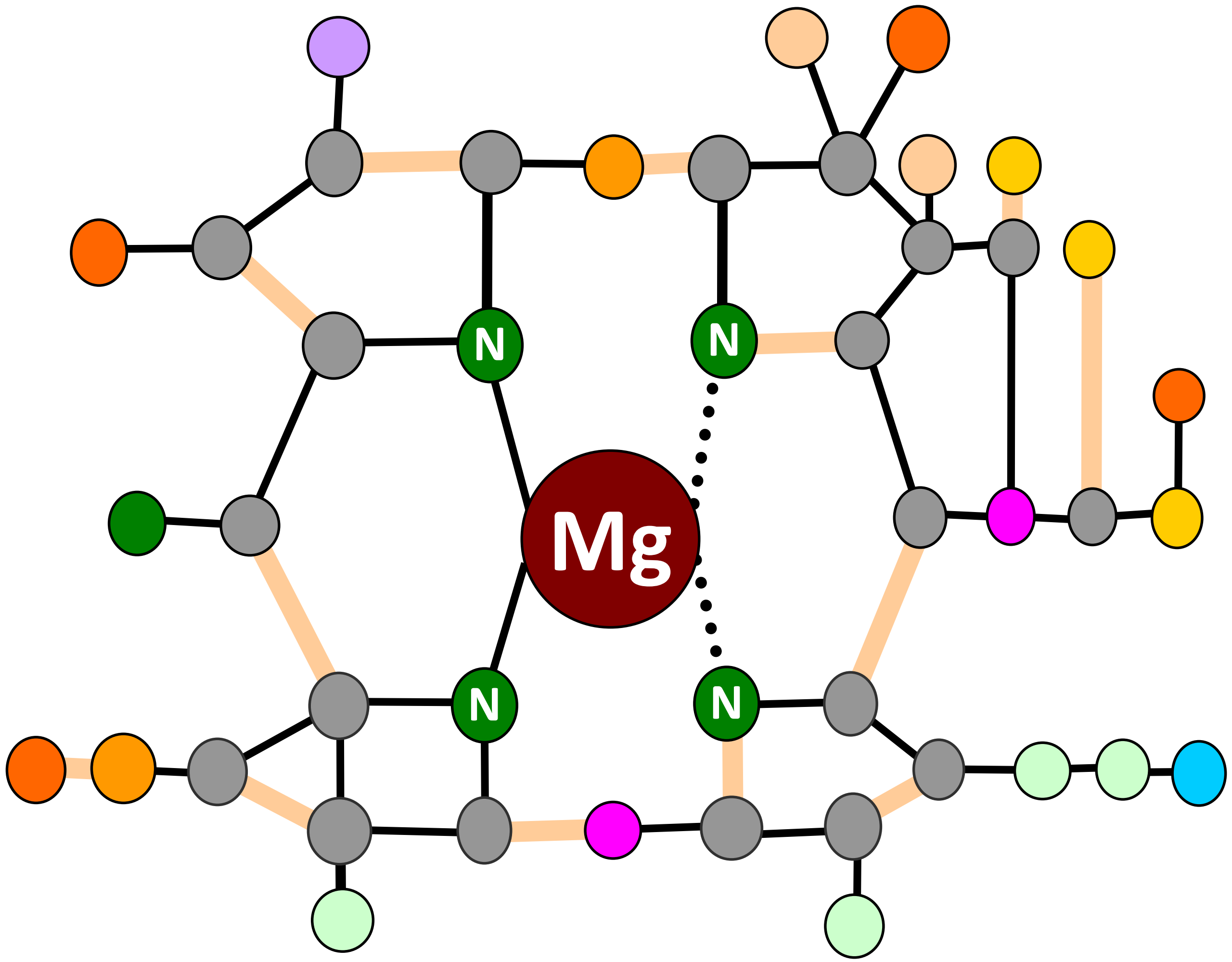
Calcium is usually the most dominant exchangeable cation, normally occupying 70 to 90 percent of the soil's CEC

In addition to being the dominant cation on the soil's CEC complex, Ca is:

Present in soil solution

A part of the structure of several minerals in the soil

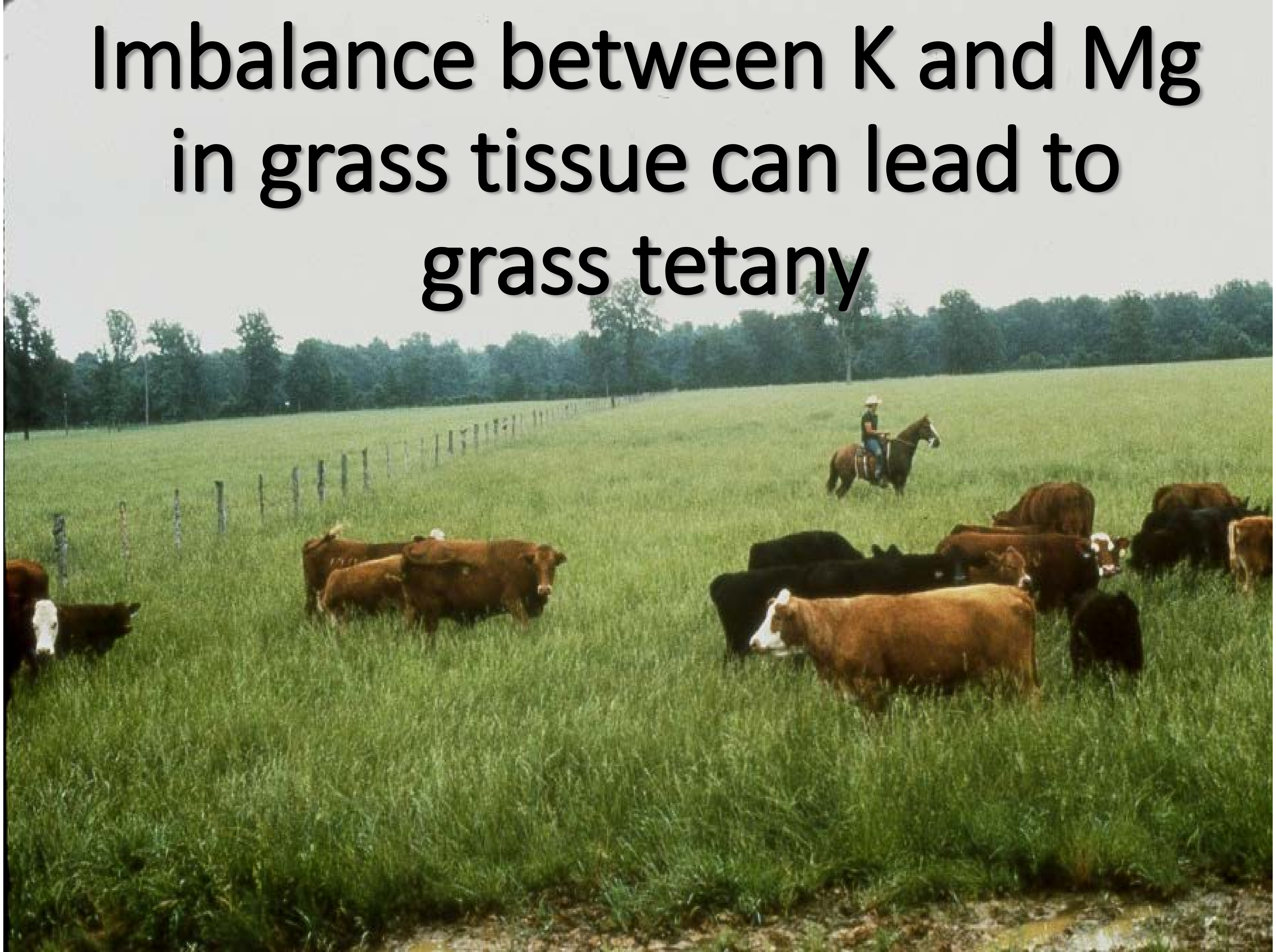
Magnesium is the central atom in the chlorophyll molecule



Some Facts about Soil Magnesium

- Held in exchangeable form by soil colloids
- Present in soil solution
- Most Mg deficiencies occur on coarse-textured, acidic soils
- Deficiencies on calcareous soils where irrigation water contains high bicarbonates
- Mg can be deficient on sodic soils

Imbalance between K and Mg in grass tissue can lead to grass tetany



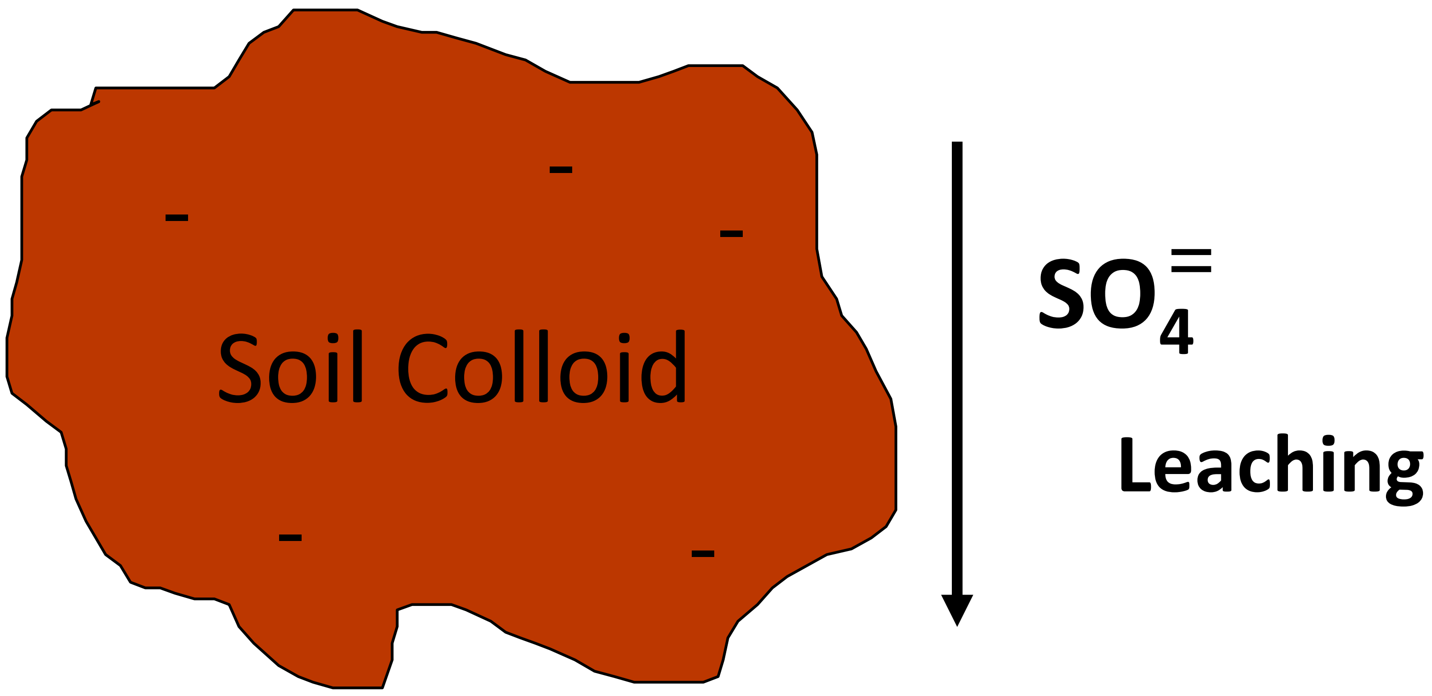
S

Plants take up sulfur primarily as sulfate (SO_4), but can also absorb sulfur dioxide (SO_2) gas through their leaves

=

Sulfur:

- Is a constituent of proteins
- Helps develop enzymes and vitamins
- Promotes nitrogen fixation by legumes
- Aids in seed production
- Is necessary for chlorophyll format**ion**



$SO_4^{=}$ is not attracted to negatively charged soil colloids

In the Early Stages:

- N deficiencies appear on older leaves
- S deficiencies appear on new growth

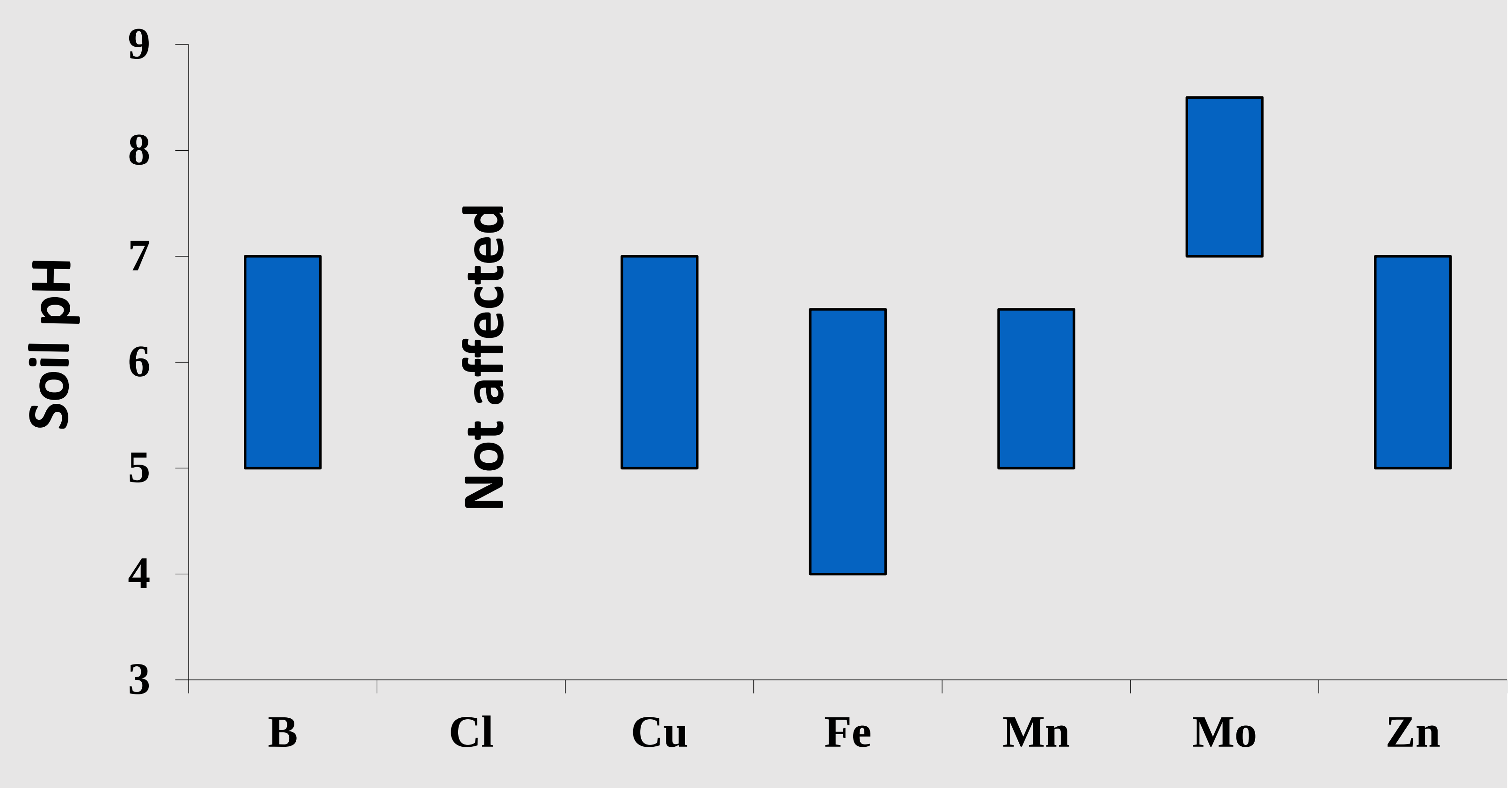
The Micronutrients

The Seven Micronutrients

- **Boron (B)**
- **Chloride (Cl)**
- **Copper (Cu)**
- **Iron (Fe)**

- **Manganese (Mn)**
- **Molybdenum(Mo)**
- **Zinc (Zn)**

Best pH Range for Micronutrient Availability



Some Roles of Boron in Plants - Essential:

- In germination of pollen grains
- For growth of pollen tubes
- For seed and cell wall formation
- For protein formation
- For sugar translocation

Factors Affecting Boron Availability

- Organic matter
- Weather conditions
- Soil pH
- Soil texture
- Leaching

B

Copper

- Copper will most likely be deficient on organic soils, sandy soils, or calcareous soils
- Small grains may show copper deficiency as well as vegetable, and citrus crops

Factors which Can Contribute to Iron Deficiencies

- Imbalance with metals such as Mo, Cu and MN
- Excessive soil P
- Wet, cold soils
- High soil pH
- High soil bicarbonate levels
- Plant genetic differences
- Low organic matter

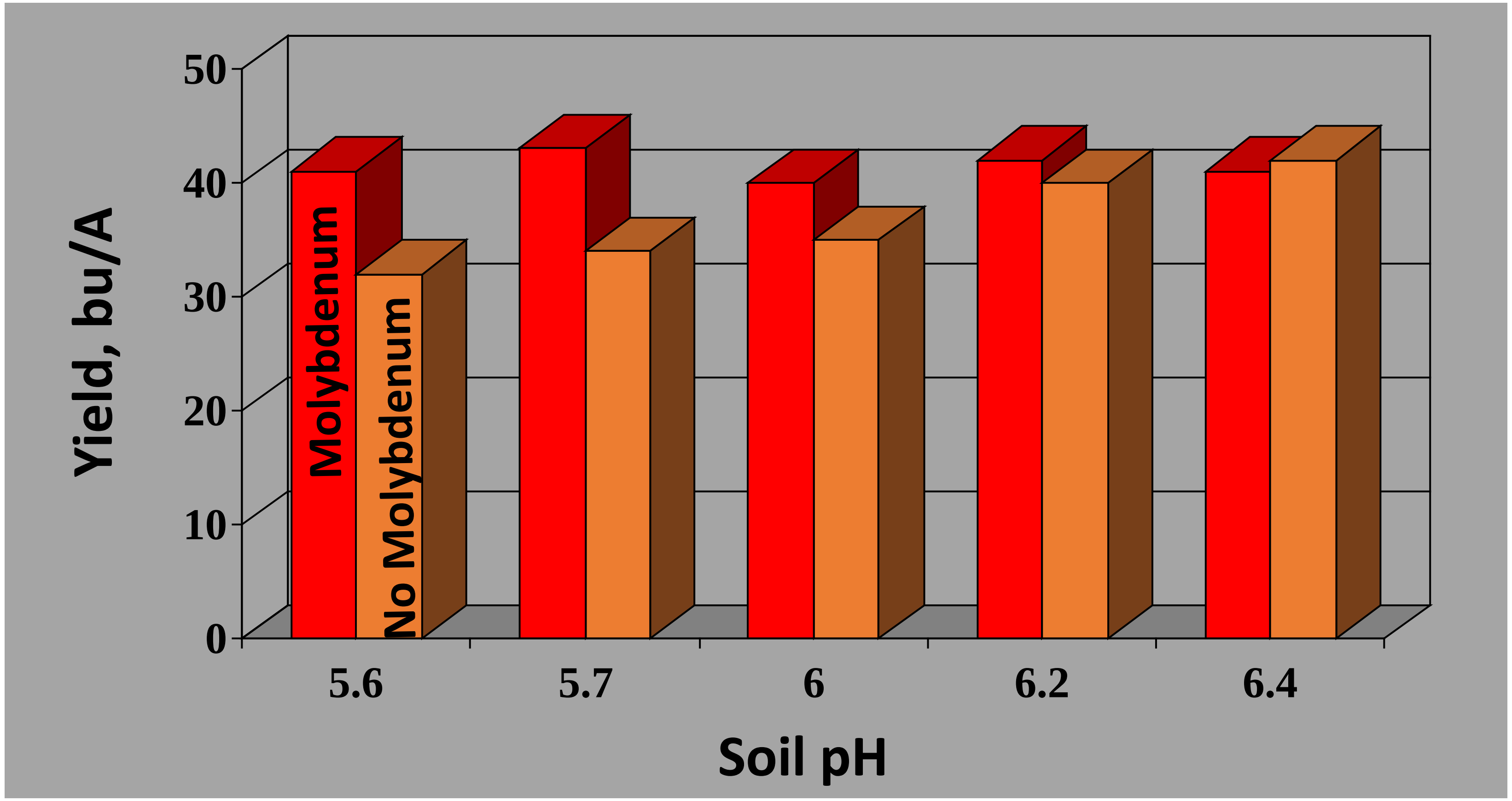
Functions of Manganese in the Plant

- Part of the plant enzyme systems
- Activates several metabolic reactions
- Aids in chlorophyll synthesis
- Accelerates germination and crop maturity
- Increases plant availability of P and Ca

Some Causes of Manganese Deficiency

- High soil pH
- Imbalance with other nutrients such as Ca, Mg and Fe
- Soil Moisture
- High organic matter soils during cool spring when soils are waterlogged

Soybean Response to Molybdenum at Varying Soil pH Levels



Some Plant Functions of Zinc

- Aids in the synthesis of enzyme systems
- Promotes certain metabolic functions
- Necessary for the production of chlorophyll and carbohydrates

Factors and Conditions Affecting Zinc Availability

- Soil texture and pH
- Soil phosphate levels
- Soil organic matter
- Leveling for irrigation
- Leaching
- Cold, wet soils
- Soil biological activity

Zn

Some Functions of Chloride in Plants

- Involved in energy reactions, including the chemical breakdown of water
- Activates several enzyme systems
- Involved in the transport of cations
- Regulates stomatal guard cells, thus controlling water loss and maintaining turgor

Soil Health

- Contributes to sustainable production
- Profitable production
- Protects the environment

Soil Health Factors

- Good micro organism population
- Crop rotation
- Leave residue on the soil
- Keep tillage to a minimum
- Use buffer strips
- Keep cattle out of moving water
- Apply chemical at the right time.