Soil and Fertilizer Management

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Soil and Fertilizer Management

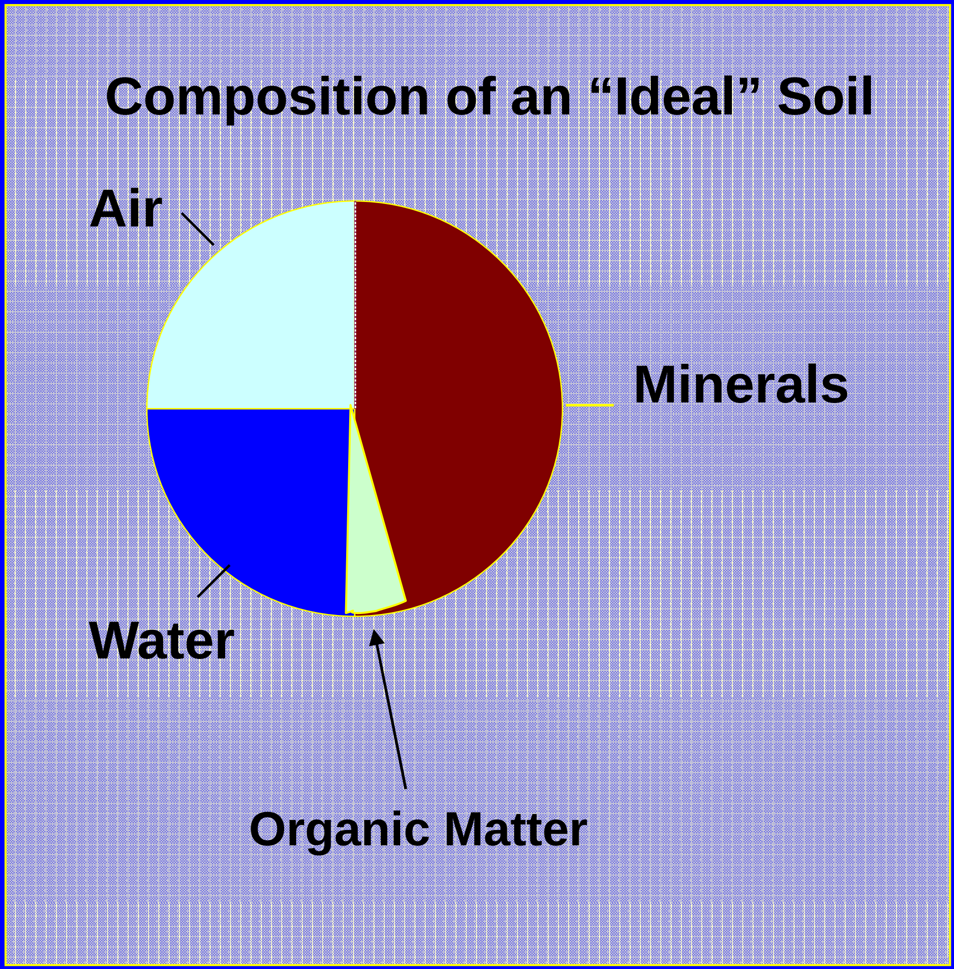
Chapter 3 Master Gardener Handbook

- Soil Formation
- Physical Properties
- Soil Water
- Soil Fertility
- Fertilizer Basics
- Nutrients Needed for Plants
- Amendments

Outline for the Day

1. Lecture format
2. Break
3. Lecture format
4. Hands on Exercise
5. Lunch
6. Dig Hole
7. Lecture format

Soil Composition



Soil Formation

- **Soils are formed by the interaction of five dynamic factors:**
  1. **Climate (temperature and rainfall)**
  2. **Organisms (bacteria, plants, fungi)**
  3. **Relief (topography, runoff, drainage)**
  4. **Parent Material (bedrock, alluvium)**
  5. **Time**

Climate

Affects the nature of the soil due to temperature, moisture, depth of weathering, etc.

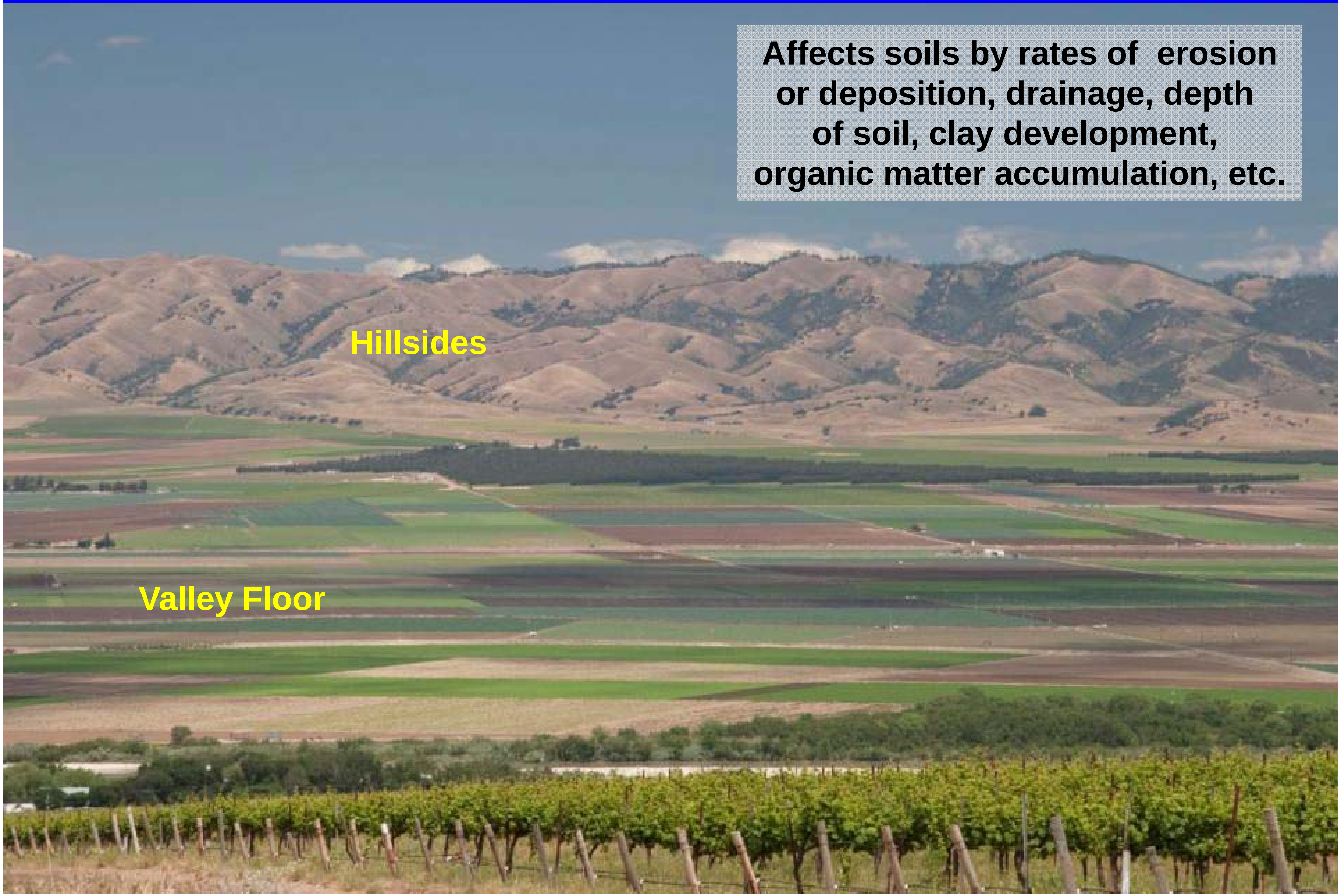
Organisms

Affect organic matter levels, storage and cycling of nutrients, etc.

Is there soil on the moon?

Topography

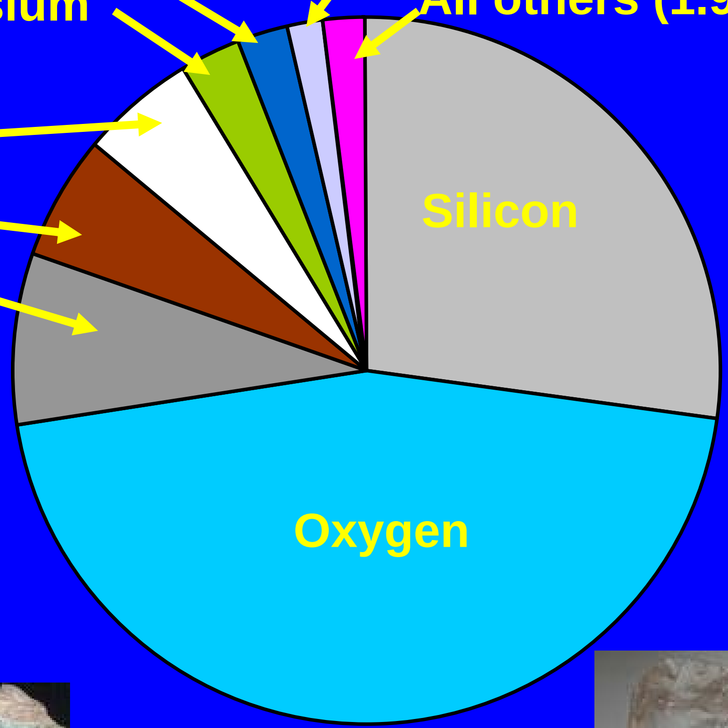
Affects soils by rates of erosion or deposition, drainage, depth of soil, clay development, organic matter accumulation, etc.



Parent Material

Serpentine Soils

Elements of the Earth's Crust by Weight Percentage




Amphibole


Feldspar


Carbonate


Phosphate


Quartz

Time

Affects the development of claypans, clay development & content, organic matter content and other soil characteristics

How old would a volcanic soil be?

Soil Formation Terminology

- **Sedentary or residual soil : formed from bedrock weathering (formed in place)**

- **Transported soils are moved to a new location by natural forces:**

  stream transported = alluvial

  ocean transported = marine

  wind-deposited = aolian

  glacially transported = glacial

The Soil Profile Basics

- As soils age, they differentiate into a profile of distinct layers, or horizons (A, B, and C)
- Note: Many profiles around urban areas have been disturbed and may not show distinct horizons

A horizon

Mostly what we farm

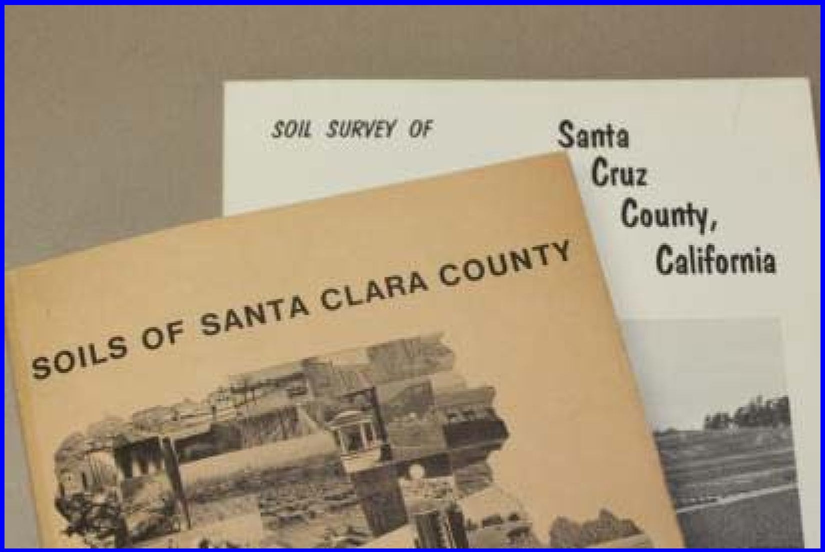
B horizon (subsoil)

C horizon
(Weathered Parent Material)

Soil Types

- Soil surveys were published for all counties in California
- Now all information is on the web:

http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

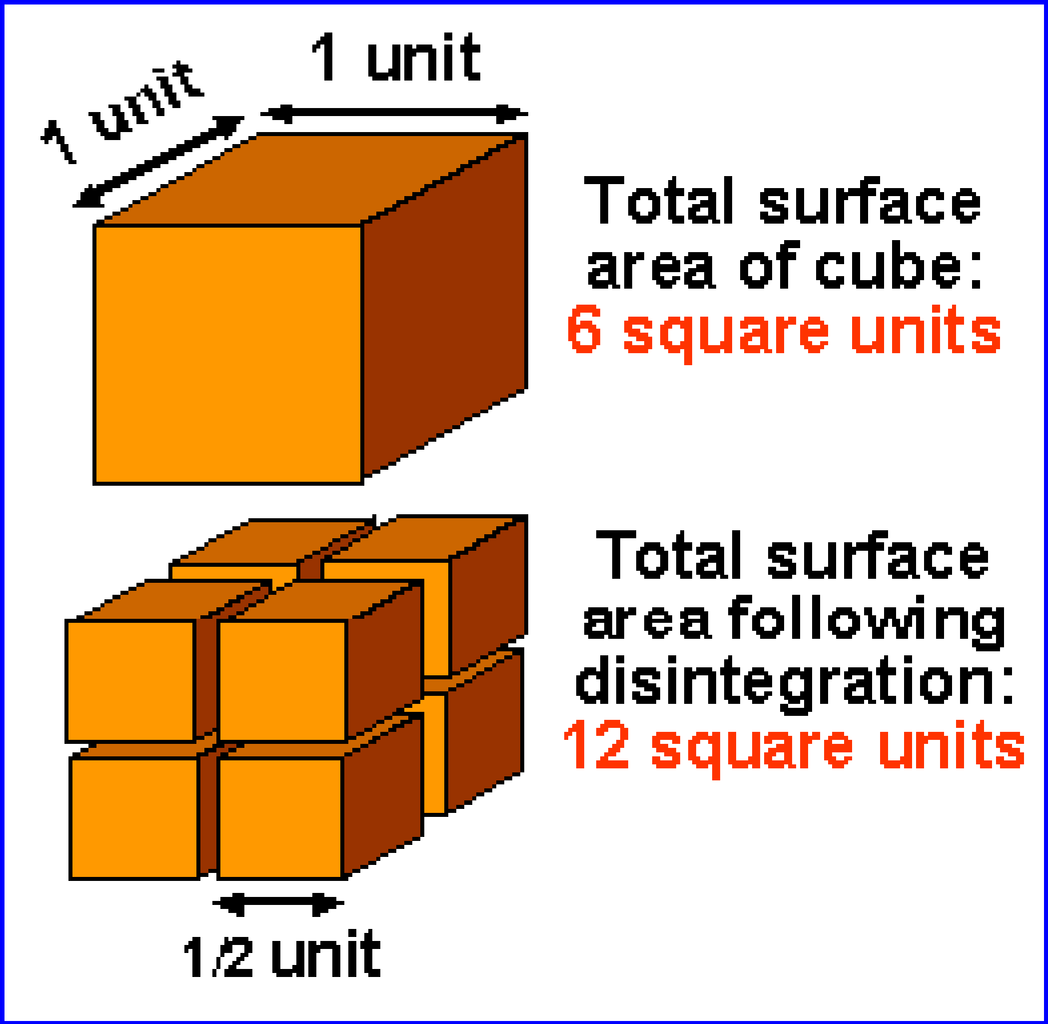


Important Physical & Chemical Properties of Soil

1. Soil Minerals
2. Soil Texture
3. Cation Exchange Capacity
4. Bulk Density
5. Soil Structure
6. Soil Porosity
7. Soil Color
8. Soil Depth
9. Soil Organic Matter
10. Soil Organisms

1. Soil Minerals

- Sand
  - Largest particle, least surface area
  - Ranges from 10 - 1000 times bigger than the largest clay particle
- Silt
  - Intermediate sized particles
- Clay
  - Smallest particle, greatest surface area
  - Thousands of times more surface area than silt, a million times more surface area than coarse sand
- Clay forms as larger primary minerals weather and reform into silicate sheets

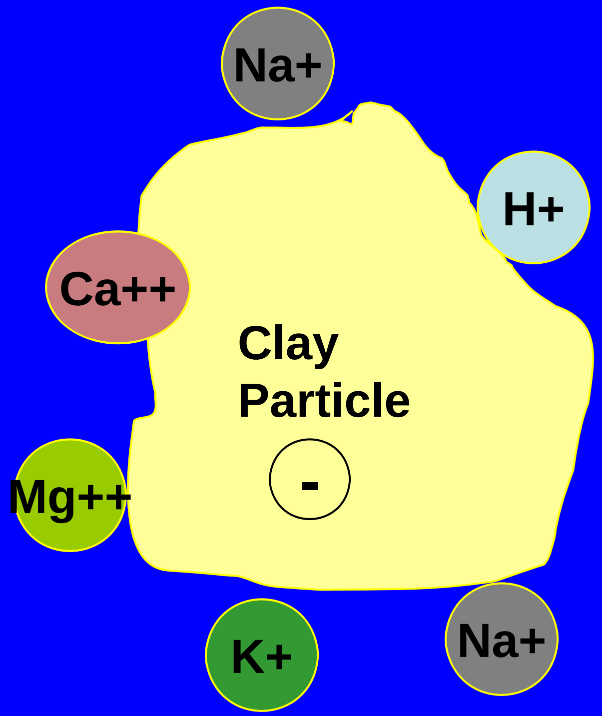

1 unit
1 unit
Total surface area of cube:
6 square units
Total surface area following disintegration:
12 square units
1/2 unit

Impact of Soil Components on CEC and Surface Area

Soil Component	Surface Area (meters^2/gram)
• Organic Matter	500-800
• Montmorillonite clay	600-800
• Silt	0.045
• Sand	0.0045

Clay Content of Soil is Critical

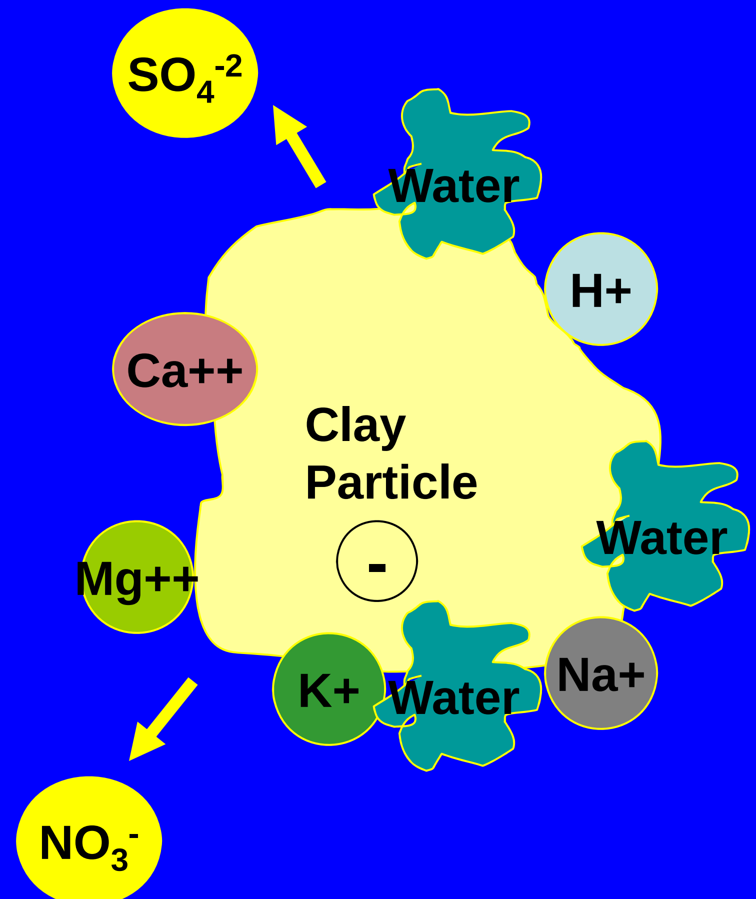
1. **Small clay particles have more surface area**
   - **Chemical reactions occur on the surface**
2. **Clay particles are negatively charged**
   - **Positively charged ions (cations) are essential plant nutrients and are attracted to the negative clay particles**



Clay Content of Soil is Critical

3. **Clay has a high affinity for water**

4. **Clay particles repel negatively charged nutrients**



2. Soil Texture

- Soil texture: relative proportions of sand, silt, and clay mineral particles in a given soil
- General Categories of Soil Texture:
  - Course texture = sandy
  - Medium texture = loamy soil
  - Fine texture = “heavy soil”, clay
- Soil texture can be determined by feeling the soil….
  - Do the ribbon test on moist soil to determine texture

Effects of Soil Texture

- **Course textured soils**
  - **warm up faster in the spring**
  - **can have greater water infiltration**
  - **have less ability to hold nutrients and store water**
- **Fine textured soils**
  - **hold more water and nutrients**
  - **have less drainage potential, aeration and pore space**
- **Ideal Textures : sandy loam, loam and clay loams**
  - **This mix of particles holds sufficient water but still permits infiltration and percolation**

3. Cation Exchange Capacity

- Cation Exchange Capacity (CEC) = the amount of cations that can be absorbed or held by a soil
- Fertile soils have higher CEC: can hold more nutrients (greater reservoir)
- CEC is determined by
  - Amount and type of clay in soil
  - Organic Matter Content

Impact of Soil Components on CEC and Surface Area

Soil Component	CEC (meq/100 grams)
• Organic Matter	200-400
• Montmorillonite clay	80-150
• Kaolinite clay	3-15
• Silt	----
• Sand	----

4. Bulk Density

- **Bulk Density = Weight per Volume of a substance**
- **Materials with more pore space have a lower bulk density**
  - **Solid rock : 2.65 grams per cubic cm**
  - **Sandy soils : 1.6 grams per cubic cm**
  - **Clay soils : 1.2 grams per cubic cm**

5. Soil Structure

- Most soil particles exist in clumps known as aggregates (clods)
- Soil structure is the way in which aggregates are arranged
- Soil texture cannot be changed, but soil structure can be changed
- This is one of the most commonly asked questions – improving the soil structure of clays

Soil Structure : Aggregation

- Aggregation means soil structure development
- Deflocculation is the dispersal of aggregate particles (caused by sodium salts)
- Aggregate binding agents: clay, organic matter, microbial exudates, earthworms, tilling operations, root growth, climatic cycles (freezing and thawing), calcium salts
- Sandy soils support very little aggregation

Soil Structure:
Crusting vs Crumb Structure

Crusted, sealed, tight soil
poor water and air infiltration

Crumb structure
good water & air
infiltration

Maintaining Soil Structure

- Years of formation can be destroyed quickly with poor management
- Avoid working or walking on soil when wet
- Let soil drain 1-2 days before working, more drainage time is needed for clay soils

6. Soil Porosity

Pore space conveys oxygen, water, dissolved nutrients and gives roots space to grow

- Macropores: larger pores usually occupied by air (formed by rotting roots and earth worms)
- Micropores: smaller pores responsible for water storage

7. Soil Color

- Color is a function of:
  - amount of organic matter
  - type of parent material
  - weathering forces and climate
  - type of salts present
  - aeration of the soil

- Can be a useful indication of the soil health and productivity

Soil Color

Dark colored soils usually contain higher organic matter (1.5 – 2% in the Central Coast)

Soil Color

Old soils are frequently red or yellow, indicating nutrient loss and build up of iron

8. Soil Depth

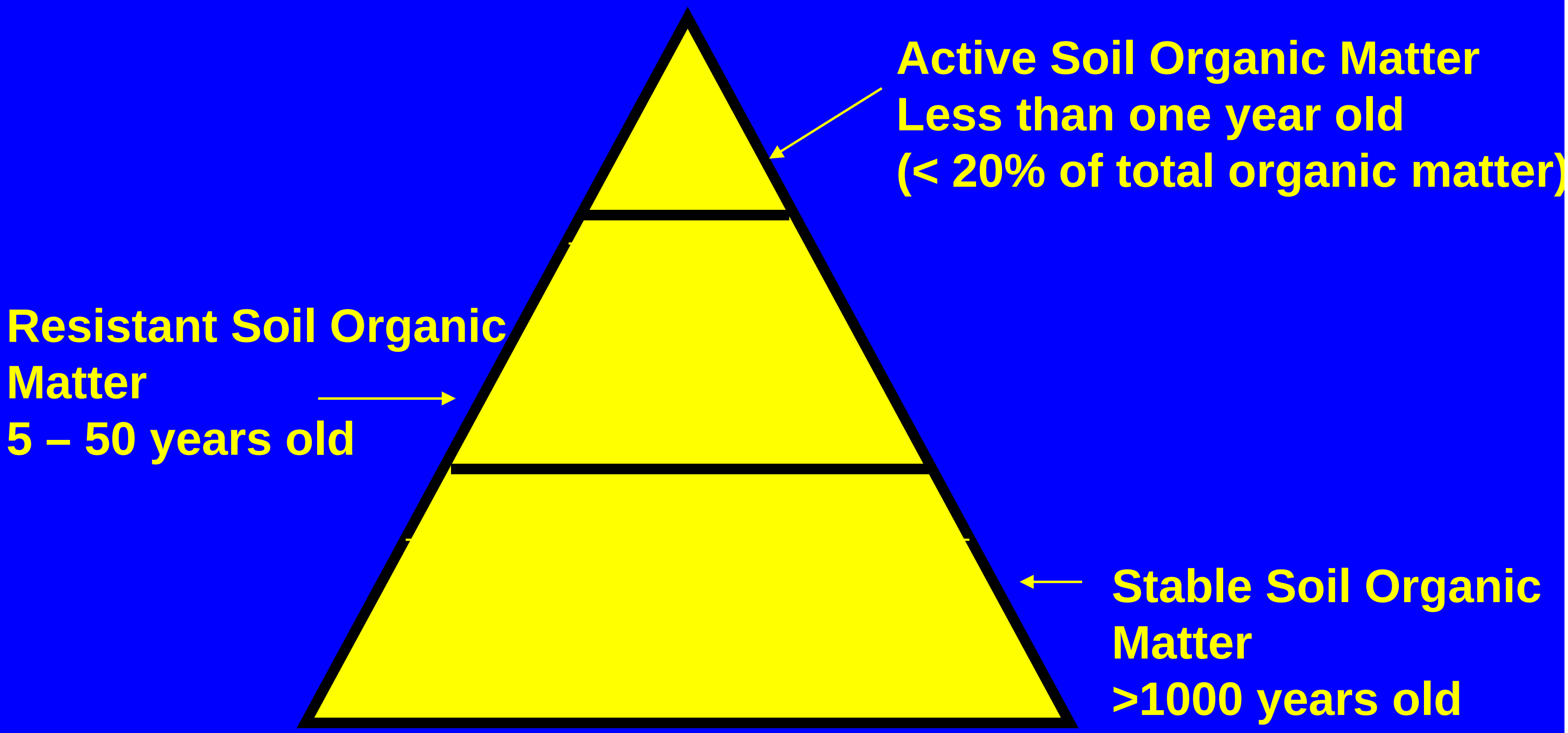
- Soil Depth : Vertical distance between the soil surface and a layer that stops the downward growth or roots (i.e., bed rock, gravel, claypan or hardpan)
- Deeper soil means a greater total water and nutrient storage capacity

Depth (feet)	Category
< 1	Very Shallow
1 – 2	Shallow
2 – 3	Moderately Deep
3 – 4	Deep
> 4	Very Deep

9. Soil Organic Matter

- **Organic matter content depends on climate and soil type**
- **1% in well-drained dry regions to 50% in poorly drained swamps**
- **Frequent tillage and crop removal tend to decrease natural levels of organic matter**
- **Organic matter can be built up by adding organic amendments**

Make up of Soil Organic Matter



Soil Organic Matter : Humus

- Humus is organic matter that is resistant to further decomposition, composed mainly of humic and fulvic acids
- Like clay, humus is negatively charged and attracts plant nutrients and water
- Humus increases cation exchange capacity and serves as a reservoir of plant nutrients
- Humus aids in forming granular soil structure

10. Beneficial Soil Organisms

- **Most live in the soil surface near roots**
- **One gram of soil may contain:**
  - **4 billion bacteria**
  - **1 million fungi**
  - **20 million actinomycetes**
  - **300,000 algae**
  - **One or two earthworms**

Earthworms

- Earthworms are part of the soil macro fauna (visible organisms)
- Earthworms feed on plant residues and their movement stirs and aerates the soil
- Excreta is an excellent fertilizer high in phosphates, potassium, nitrogen, calcium, and magnesium

Saprophytes (Bacteria and Fungi)

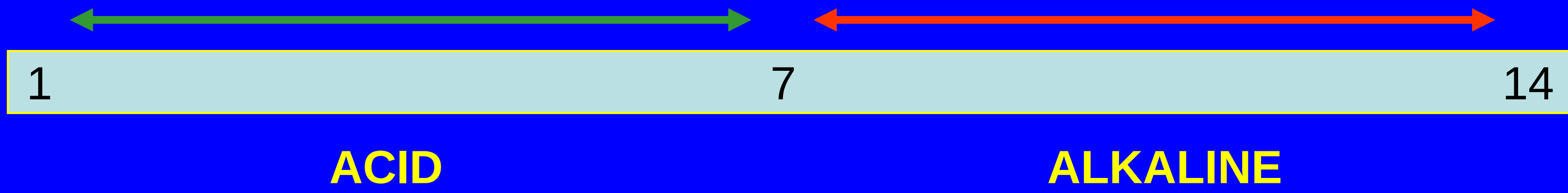
Saprophytes: Beneficial soil microorganisms which feed on decaying plant material

Functions of Saprophytes:

1. **Enzymes are used to transform complex organic molecules into simple nutrients that become available to plants**
2. **Make humus**
3. **Make gummy substances that bind the soil particles**

Soil pH

- Soil acidity or alkalinity effects nutrient availability
- pH scale



- Most California soils range from 5 to 8.5
- Crop plants do best in slightly acidic to neutral soils (pH 5.5 to 7.5)
- Note : azaleas, rhododendrons and blueberries prefer acid soils

Soil pH and Nutrients

- At higher and lower pH, some important nutrients precipitate and cannot be absorbed by plants
- Soil pH also effects the amounts of toxic minerals
  - Acids soils may contain toxic levels of aluminum and manganese
  - Alkaline Soils may contain excessive amounts of toxic salts and sodium

Management of Soil pH

- **pH too low**
  - **Add lime (calcium carbonate, dolomite, etc) or wood ashes**
- **pH too high**
  - **Add sulfur (particle size effects speed of reaction)**
  - **May take several months to lower pH**
  - **Note: Gypsum (calcium sulfate) improves water filtration, does not lower pH**

Lime Requirement to Raise pH

In the top 6” of soil

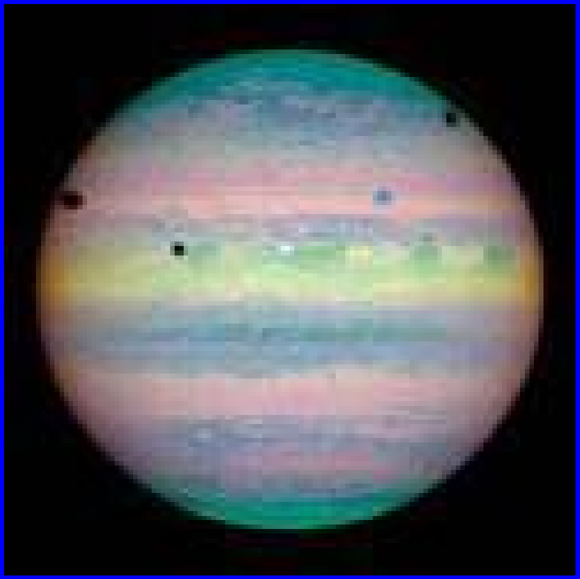
Lbs limestone per 100 sq ft	Sand	Sandy Loam	Loam	Clay Loam
6.0 to 6.5	1.5	3.2	4.2	5.5

Sulfur Requirement to Lower pH

In the top 6" of soil

Lbs elemental sulfur per 100 sq ft	Sand	Loam	Clay
7.0 to 6.5	0.25	0.35	0.70

Hands On Exercise



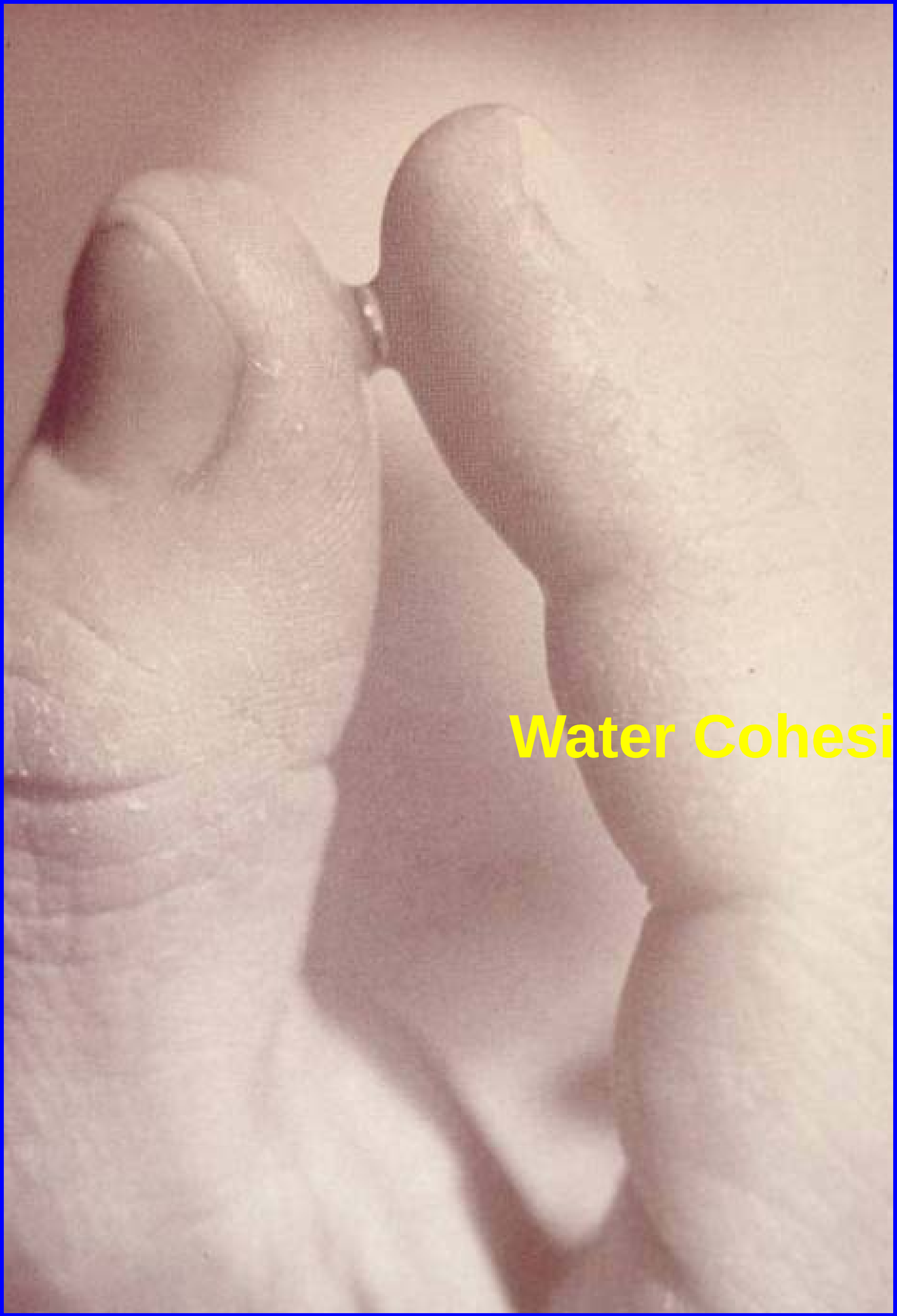
Soil Water Terms

- Water infiltrates and percolates in the soil
- Fate of water in soil:
  - Transpiration (water lost at leaf surfaces through stomata)
  - Evaporation (water lost as vapor at the soil surface)
- Collectively known as evapotranspiration

Soil Water

- Soil Water carries dissolved nutrients to plant roots
  - Interception of nutrients
  - Passive diffusion
- Plants compete with other forces for water
  - Cohesion is the tension between water molecules
  - Adhesion is the attraction of water to soil particles

Water Tension



Water Cohesion

Soil Water Content

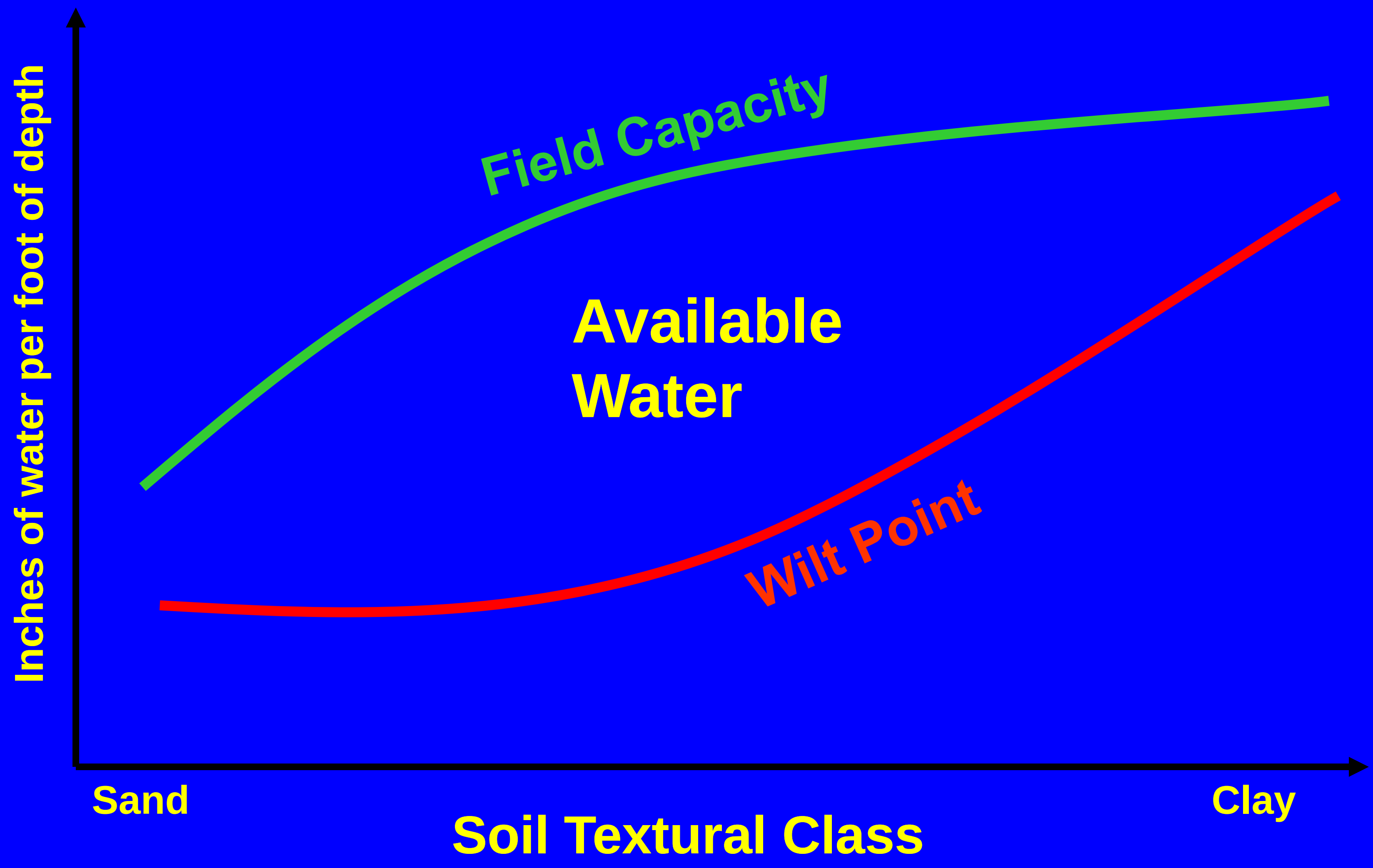
- **Saturated : When all the pore spaces are filled with water**
- **Gravitational Water: Water that drains freely because of gravity, remaining water is held by cohesion and adhesion**
- **Field Capacity : Maximum amount of water that can be held against the downward force of gravity when excess water is applied**
- **Permanent Wilting Percentage: The amount of water in soil from which plants are unable to extract any water for growth**

Soil Water

- The strength of cohesion and adhesion forces are influenced by total pore volume (porosity) of the soil
  - Clay soils hold water tightly because of smaller, negatively charged particles
  - Sands and coarse textured soils have less water-holding capacity

- Water furthest away from each soil particle is held loosely, and easier for plants to absorb
- Plants exert force to pull water away from the soil by transpiring through their leaves

Plant Available Water



Soil Fertility and Plant Nutrition

- **A fertile soil contains 17 nutrient elements in optimal amounts and in a chemically absorbable form**
- **Of the 17 elements…..**
  - **3 are taken from the air**
  - **14 are absorbed by roots**
    - **Primary nutrients**
    - **Secondary Nutrients**

      → **Macronutrients : measured by percent**

    - **Micronutrients**

      → **Measured as parts per million**

Common Problems in CA

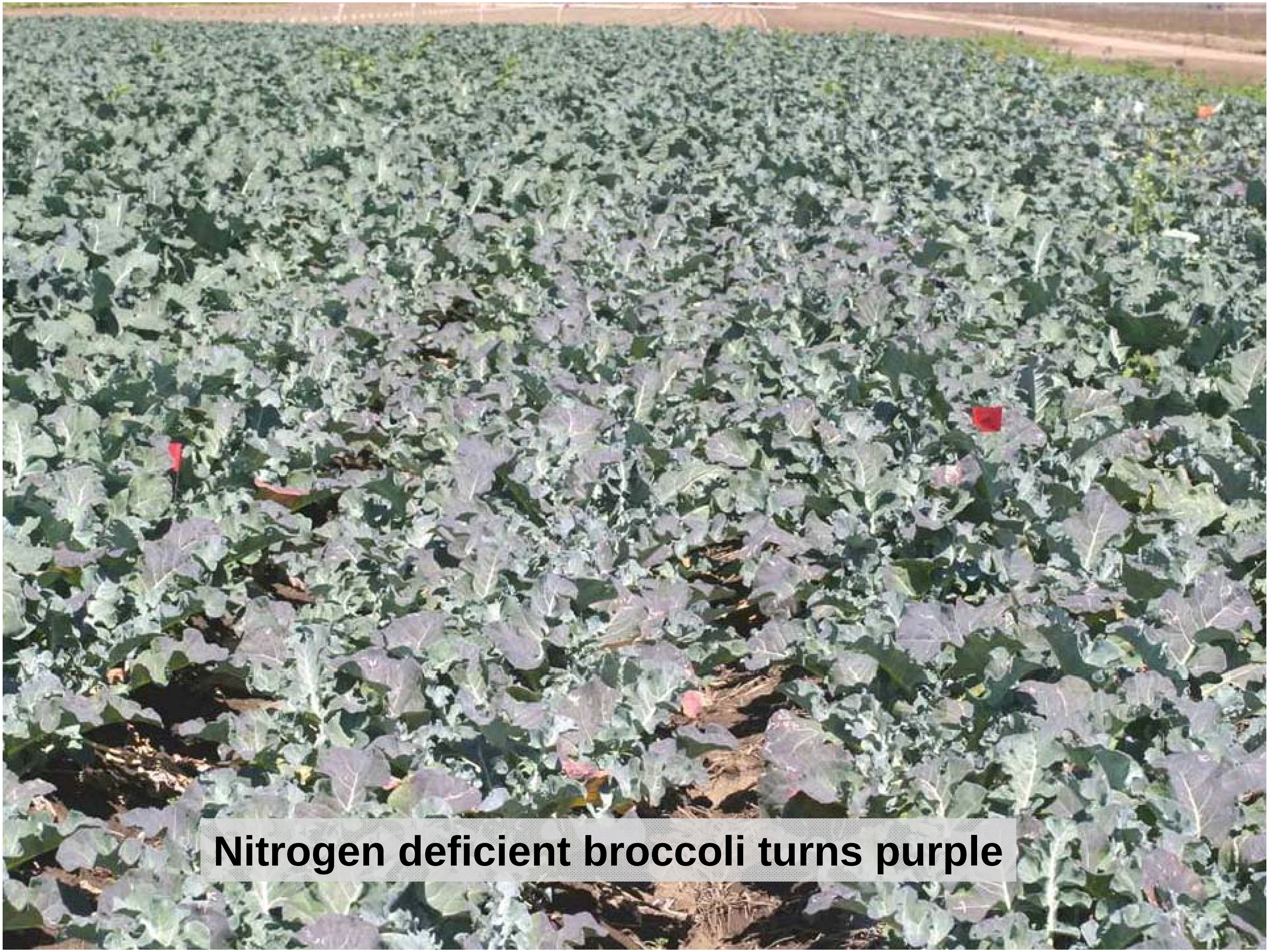
- **Common Deficiencies –**
  - **Nitrogen**
  - **Potassium**
  - **Phosporus**
  - **Zinc**
  - **Iron**
- **Common Toxicities –**
  - **Boron**
  - **Chlorine**
  - **Sodium**

Nitrogen

- **Very important for many aspects of growth and development**
- **Taken up as NO_3^- (nitrate) and NH_4^+ (ammonium)**
- **Nitrogen in fertilizers converted to nitrate by microorganisms**
- **Deficiency: chlorosis (yellowing) of older leaves (nitrogen moves to younger tissue when limited)**
- **Excess: Dark green, excessive vegetation growth**


Deficient Spinach


Older Leaves Turn Yellow



Nitrogen deficient broccoli turns purple

Phosporus (P)

- Stimulates early growth and root formation, promotes seed formation, important in photosynthesis

- Deficiency:
  - Occurs in highly weathered soils with claypans or hardpans, or soils with long cropping history
  - Causes plant stunning and purplish casts on leaves


Phosphorus deficiency can show purpling,
but most common symptom is stunting

Potassium (K)

- Important for stomate opening/closing, cell division, starch and protein synthesis, size and quality of fruit and disease resistance
- Taken up as K^+
- Can be tied up in soil minerals
- Deficiency: Symptoms include scorching along leaf margins, slow growth, weak stems, poor roots

Vigorous
root system
reduced K
deficiency

Weak
root system
increased K
deficiency

Nematodes causing potassium deficiency on peppers

Calcium (Ca)

- Essential component of plant cell walls and membranes
- Young tissues show deficiencies first
- Excess calcium lead to high pH
- Deficiency:
  - Reduced terminal growth of shoots
  - Blossom end rot of tomatoes
  - Tip burn on lettuce, cabbage

Calcium Deficiency


Blossom end rot tomato


Tip burn lettuce


Leaf distortion spinach


Leaf blackening strawberry


Blossom end rot pepper

Magnesium (Mg)

- Important part of chlorophyll molecule, aids in mobility of phosphorus
- Very mobile within plants
- Deficiency:
  - Marginal necrosis and intervenal chlorosis

Magnesium toxicity

Sulfur (S)

- Taken up as SO_4^{-2}
- Deficiency: Not common, can occur in high rainfall areas and in rangeland

Zinc (Zn)

- An important component of enzymes including those involved with plant hormone synthesis
- Deficiency:
  – Can be easily measured with extractable zinc soil tests
  – Affects the growing point of plants
  – Plants can show interveinal chlorosis and stunting of terminal growth


Iron (Fe)

- Essential component of chlorophyll synthesis

- Deficiency:
  - Due to high pH,
  - Common when acid-loving plants are in alkaline soils

Blueberry with iron chlorosis

Manganese (Mn)

- Important component in enzyme catalysts for many reactions
- Excess: Only seen in highly acidic soils
- Deficiency:
  - Interveinal and marginal chlorosis of young leaves


Possible manganese excess on Romaine lettuce

Boron (B)

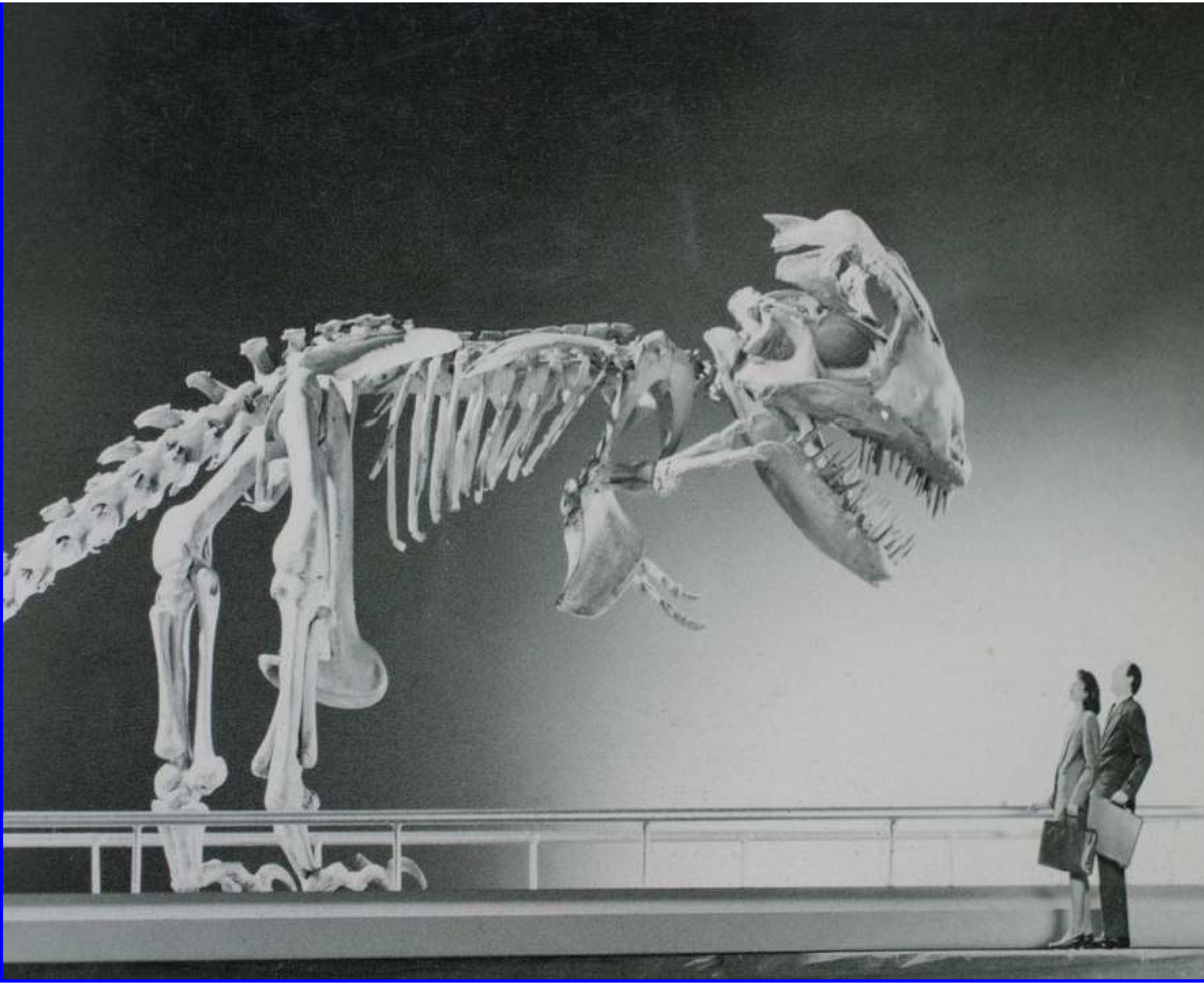
- Important in meristem differentiation

- Toxicity is marginal burn on leaves
  - Very common in some parts of the State (i.e. Hollister area)
- Deficiencies common in intensive cropping systems
  - Occasionally applied to celery and strawberries

Boron deficiency on broccoli from Indiana

Hunger Signs in Plants : General Notes

- Master gardeners need to know signs of nutrient deficiency, toxicity, or imbalance!
- Sometimes plants do not show symptoms until severe stress has occurred
- Visual diagnoses are usually not enough -tissue and soil analysis are often needed to solve the problem



Organic Fertility Management of Gardens

- “Feed the Soil to Feed the Plant”
- This is the basic precept to organic soil management
- It is carried out by practices that increase soil organic matter, biological activity and nutrient availability

Building up Organic Matter

- Over time, adding materials such as green manures (cover crops), crop residues and compost builds up the levels of organic matter
- As soil organic matter increases, the ability of the soil to supply nutrients to the crop also increases

Sources of Organic Matter for Your Garden

Commercial Compost

Household Compost

Manure

Mulches

Benefits of Organic Matter

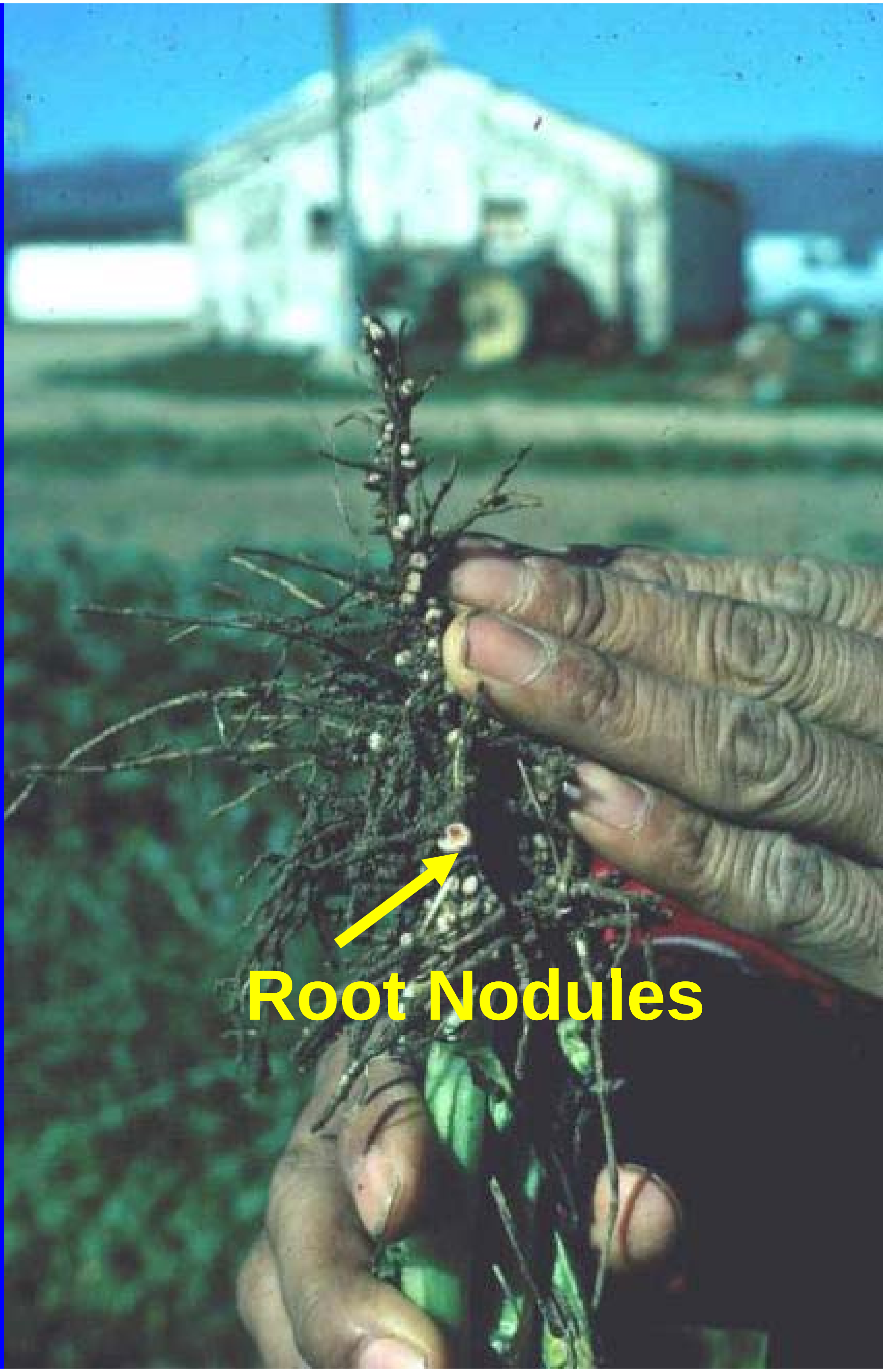
- Organic materials can contain 0.5 to 3.0% of Phosphorus and Potassium and can supply all of the needed micronutrients
- They supply it in a slow and steady fashion that is appropriate to the plants needs

COVER CROPS

Legumes

• Bell beans, vetches, peas, clovers, burr clover and many others

• They provide a net input of nitrogen into the crop production system by fixing atmospheric nitrogen into a form useable by crops




FAMILY FLOUR
PYRAMID ORCHARDS APPLES

Fertilization of Garden Soils

- Nutrition management in gardens is relatively simple in California
- Most soils have sufficient levels of essential nutrients
- The use of composts and manures supply the majority of all nutrients that are needed
- Mostly garden soils require small amounts of supplemental nitrogen fertilizer to achieve good growth

Sources of Nitrogen

- Organic matter - manure, compost, prior crop residues, mulches
- Cover crops
- Organic fertilizers
  - Recycled nutrients (slaughter house by products, mined guano, fish, seed meals)
- Commercial fertilizers
  - Salts of ammonium & nitrate as well as urea

Understanding Fertilizers

- **Labels show percentage of: Nitrogen-Phosphorus-Potassium**
- **Example: A 100 lb bag of 12-12-12 contains 12 pounds of the following:**
  - **Nitrogen (N)**
  - **Phosphorus (P_2O_5)**
  - **Potassium (K_2O)**

Common Dry Organic Fertilizers

Fertilizer	Nitrogen	Phosphorus	Potassium
Feather Meal	12	0	0
Blood Meal	13	0	0
Meat Meal	8	5	1
Bone Meal	2	5	0
Fish Meal	10-11	6	2
Chicken Manure	2-3	1.5	1.5
Alfalfa Meal	4	1	1
Kelp	<1	0	4

Nitrogen Availability from Dry Organic Fertilizers

- In general nitrogen release from organic materials is a two stage process where 50-60% of the N is released in the first two weeks mostly by hydrolysis
- This is from the breakdown of simple compounds such as urea and proteins

Nitrogen Availability from Dry Organic Fertilizers

- **There is then a slower release that is accomplished by microbial degradation of more complex molecules that may extend over a period of several months**

Nitrogen Availability from Liquid Organic Fertilizers

- **These materials generally have rapid N availability**
  - **70-80% in 1st 2 weeks**
- **Their cost per unit of nitrogen can be much higher than other sources of organic N**

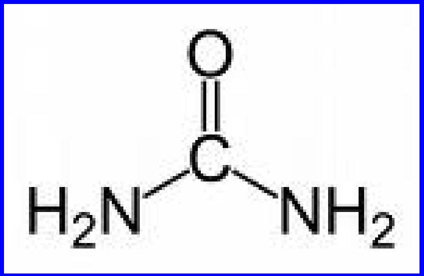
Out of the 5% in the fish Emulsion:
- **1.5% is ammonical & urea**
- **3.5% is water soluble (probably amino acids and proteins which are rapidly broken down)**

For further information on organic fertility management

- http://anrcatalog.ucdavis.edu/
  - Go to free publications
    - Soil Fertility Management for Organic Crops
    - Publication Number: 7249
- http://cemonterey.ucdavis.edu/
  - Search “Crop Notes” newsletter for articles on organic fertilizers

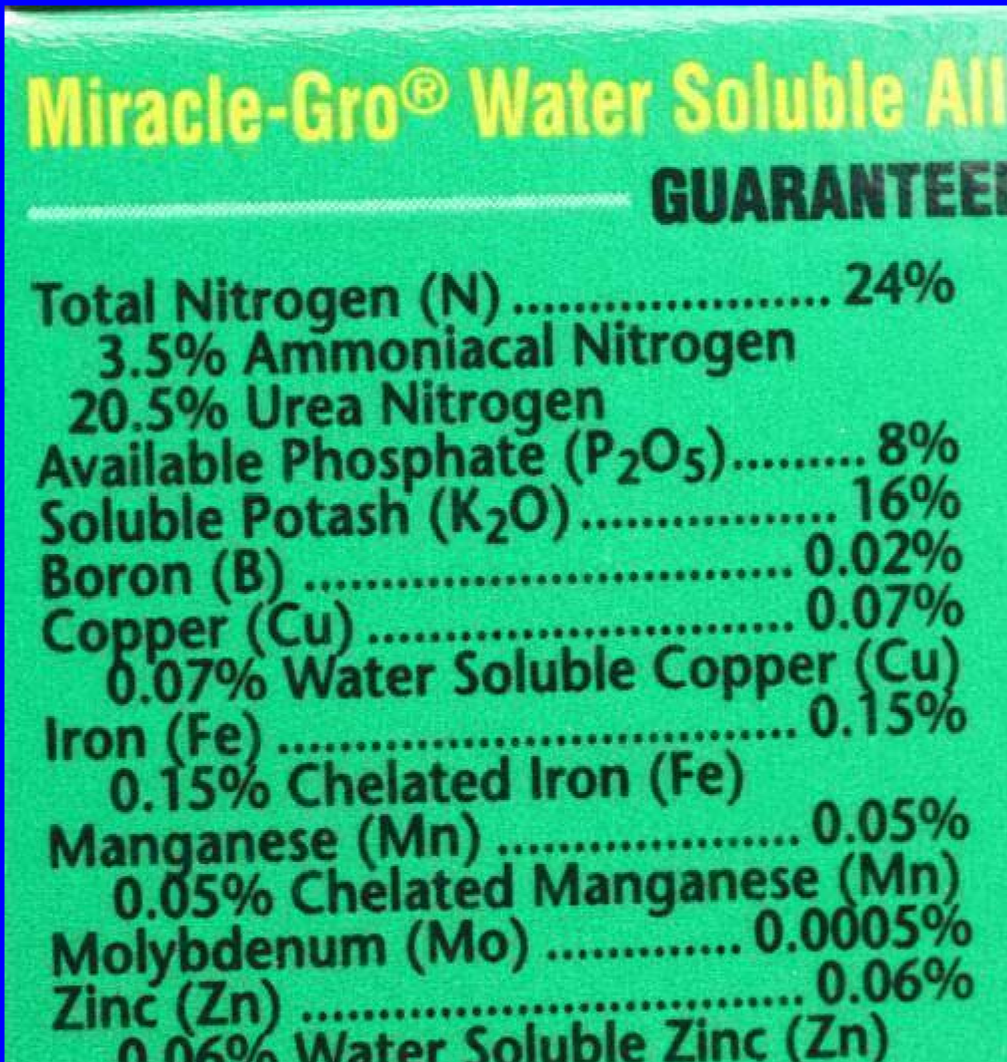
Conventional Nitrogen Fertilizers

- The nitrogen comes as ammonium and nitrate salts or as urea
- Examples include ammonium sulfate, calcium nitrate, urea
- Urea and needs to be broken down enzymatically to ammonium and is most slowly available of these three forms

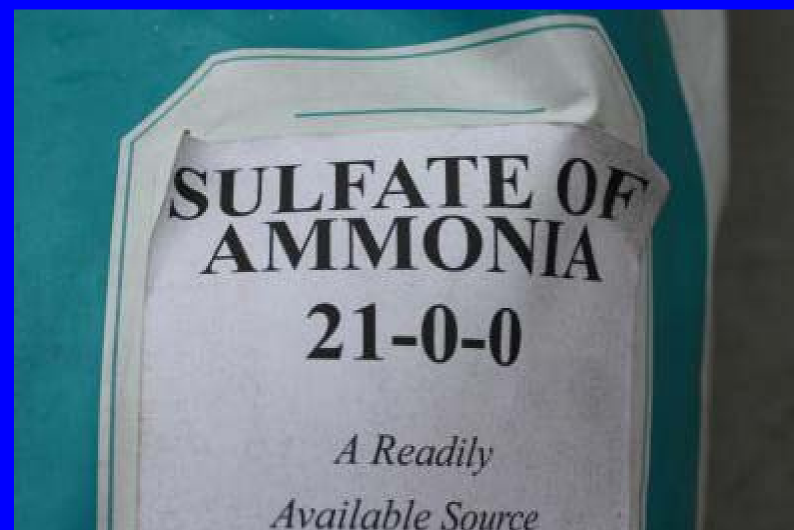


Urea

Thinking about the source of N for your needs



A fertilizer with N,P,K & micros expensive per unit of N



Ammonium sulfate inexpensive source of N

Nitrogen Conventional Fertilizers

- Some plants are sensitive to large quantities of ammonium in their tissue
- Urea and ammonium fertilizers can build up high ammonium in the soil, especially when soil temperatures are cool (<50 ºF)

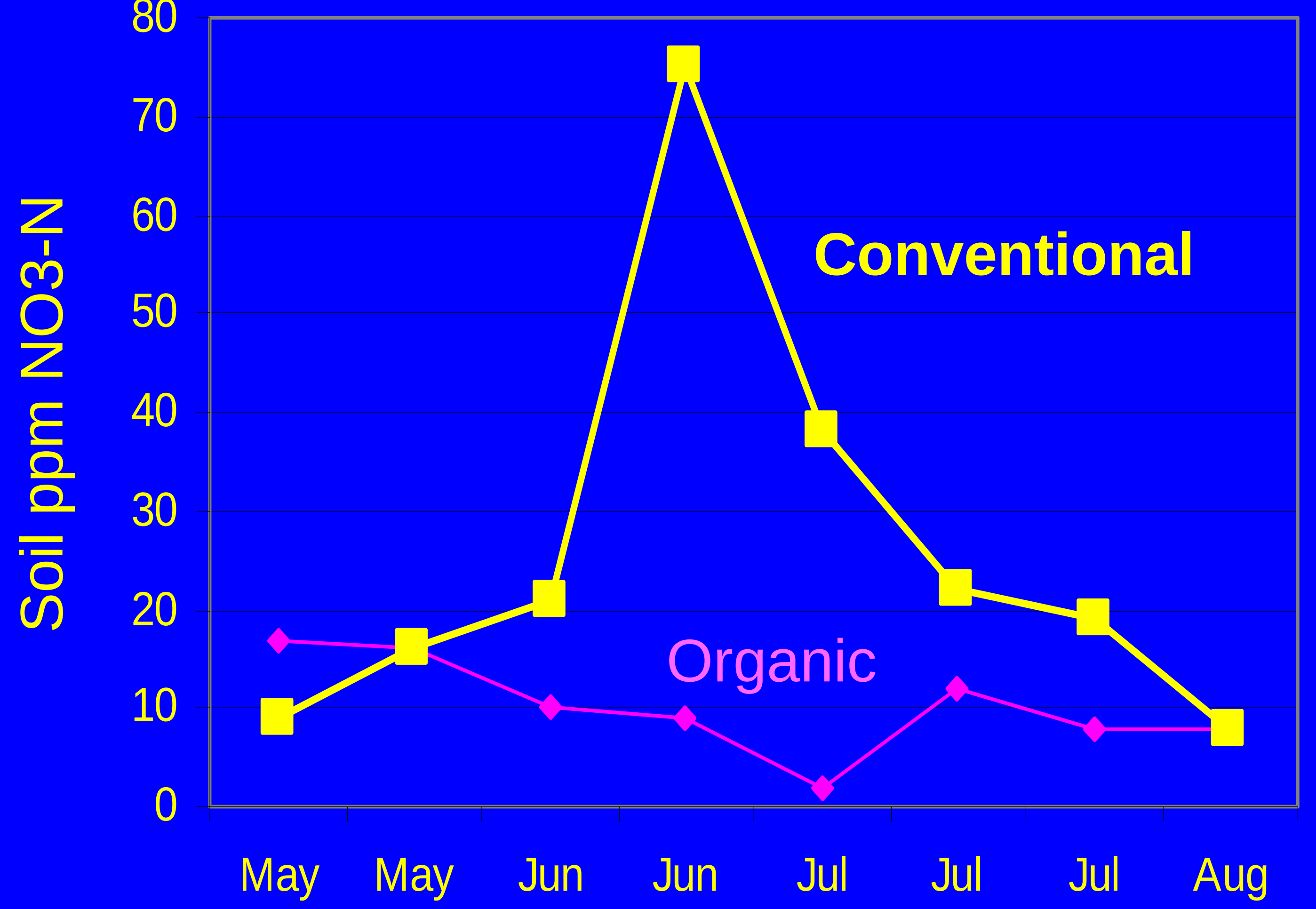
Nitrogen Conventional Fertilizers

- Some plants are not sensitive to ammonium
- Ammonium and urea are commonly found in azalea and citrus fertilizers
- Ammonium mineralizes rapidly to nitrate in warm soils (>60 ºF)

Phosphorus and Potassium Fertilizers

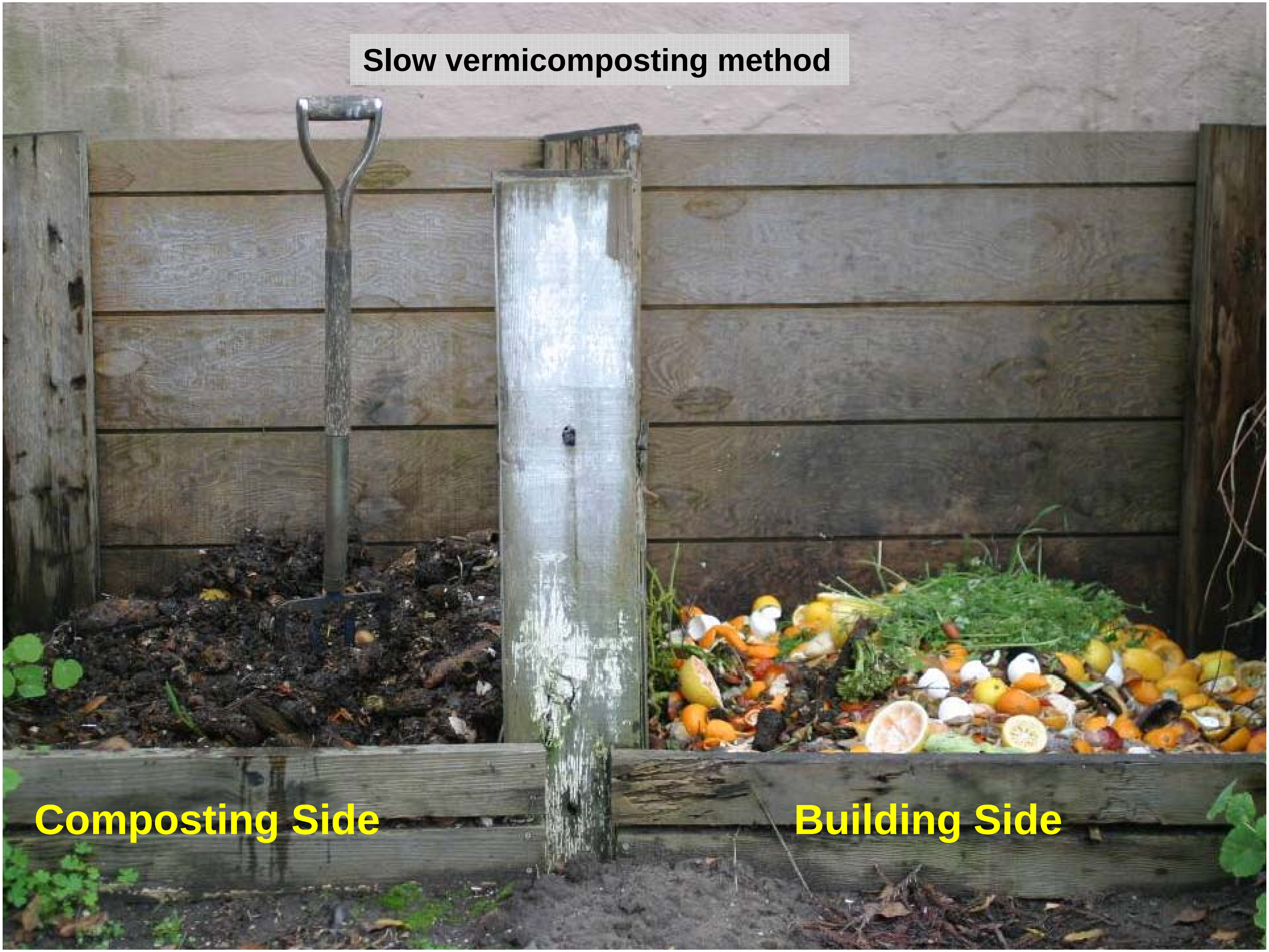
- P & K can be supplied by composts and mulches
- Many fertilizers contain all three of these nutrients, but you have to carefully decide if all three are necessary

Comparison of Organic and Conventional Onions, Hollister, 1996



Tour of Richard’s Garden


Intensive Kitchen Garden
(with gopher wire underneath)


Slow vermicomposting method
Composting Side
Building Side


Composting intensive kitchen garden


Composting intensive kitchen garden


Sweet Corn
Winter Squashes
More Extensive Area in the Back for land intensive crops

Comparison of Soil Analyses Garden and adjacent pasture

Soil Characteristic	Garden (more inputs)	Pasture
pH	5.2	4.8
CEC	8.3	4.4
Total Nitrogen (%)	0.09	0.06
N storage (lbs/A)	1,800	1,200
Organic Matter (%)	1.6	1.1
Nitrate-N (ppm)	70.9	12.1
Phosphorus (ppm)	47.0	32.8
Potassium (ppm)	139	114


Goat provide manure/bedding
Horse manure

Cover crops over the winter

Fertilizer Used

Meat Meal 8-5-1

Buy 50 lb bags at Cal Agra in Hollister

This application technique applies about 1.5 ounces Of 8-5-1/plant which is equivalent to about 1.3 lbs/1000 ft^2 Or about 45 lbs N/A which is a moderate amount of N. It comes out to about 90 lbs N/A for sweet corn

Fruit Trees

Mulching cover crops wit
organic materials slowly
provides trees with nutrier


Beneath the mulch
low decomposition
release of nutrients


lovers & grasses between trees

Thank You For Your Attention