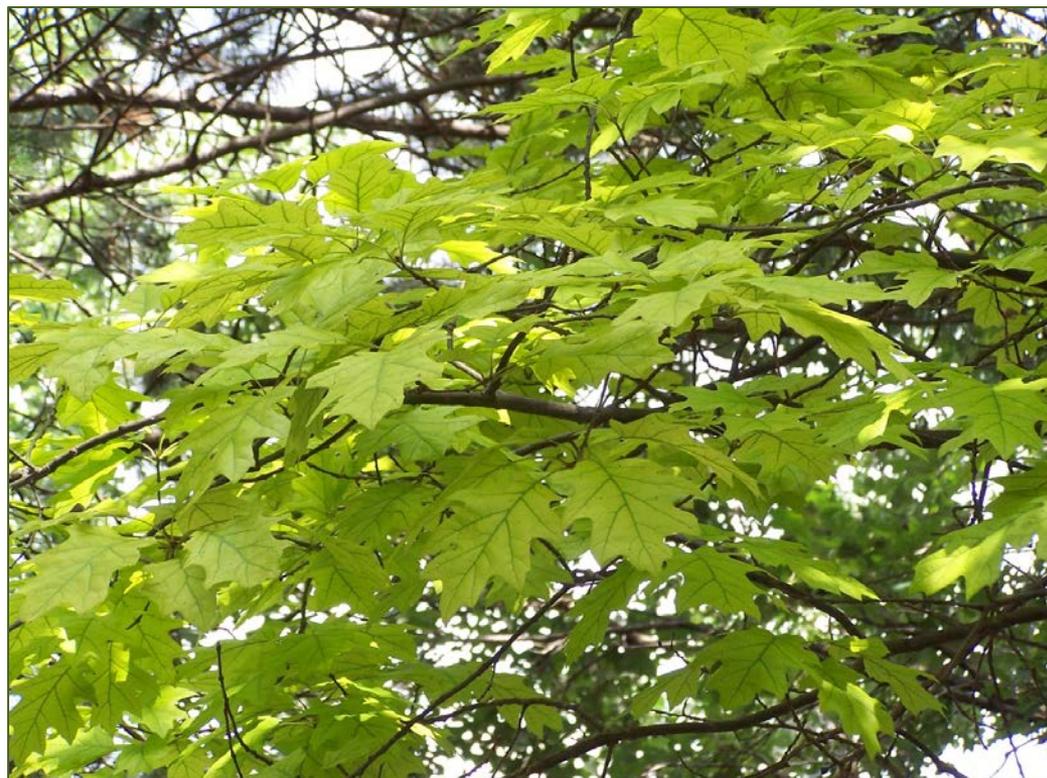


# Soils and Fertilizers Chapters 3 & 4

Sherry Kern  
Virginia Beach  
Master Gardener  
Tree Steward



# Soil— It's Not Dirt!

- outer, weathered superficial layer of the earth's crust
- physical, chemical, and biological factors
  - parent rock material
  - climate
  - organisms
  - topography
  - time

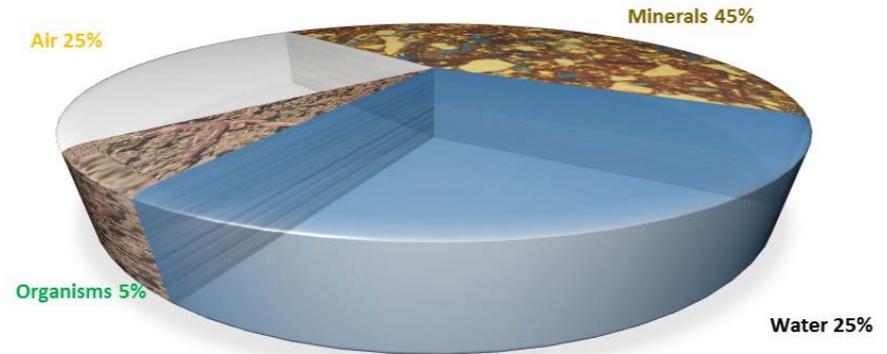


# An Ideal Soil

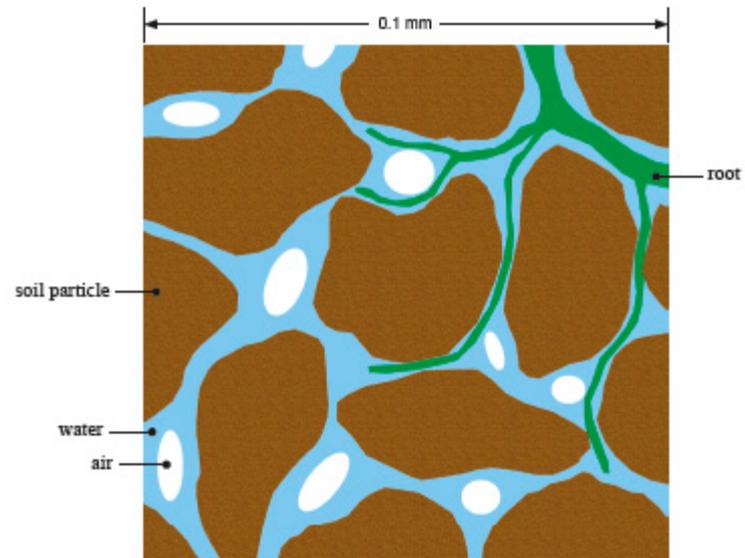
- Agriculturally productive soils have **both** organic and mineral components
- A typical mineral soil consists

- Minerals
- Organic material

- Water
- Air



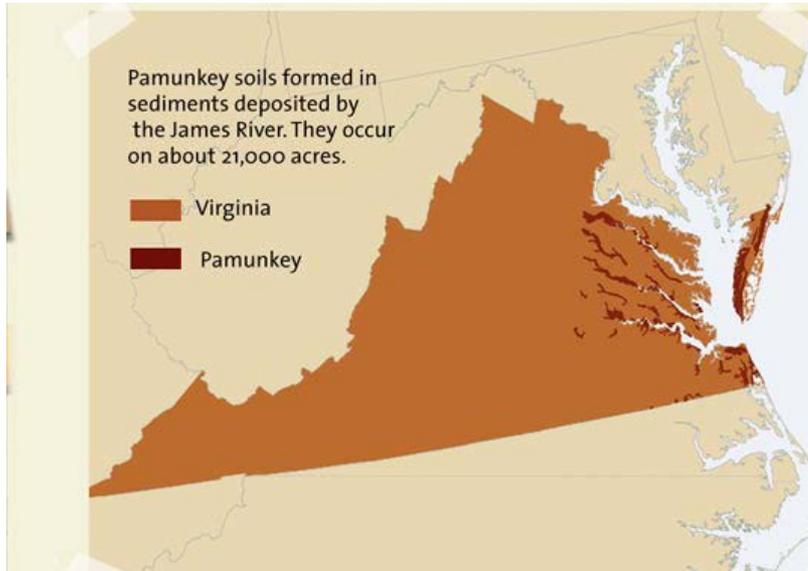
SOIL COMPOSITION %



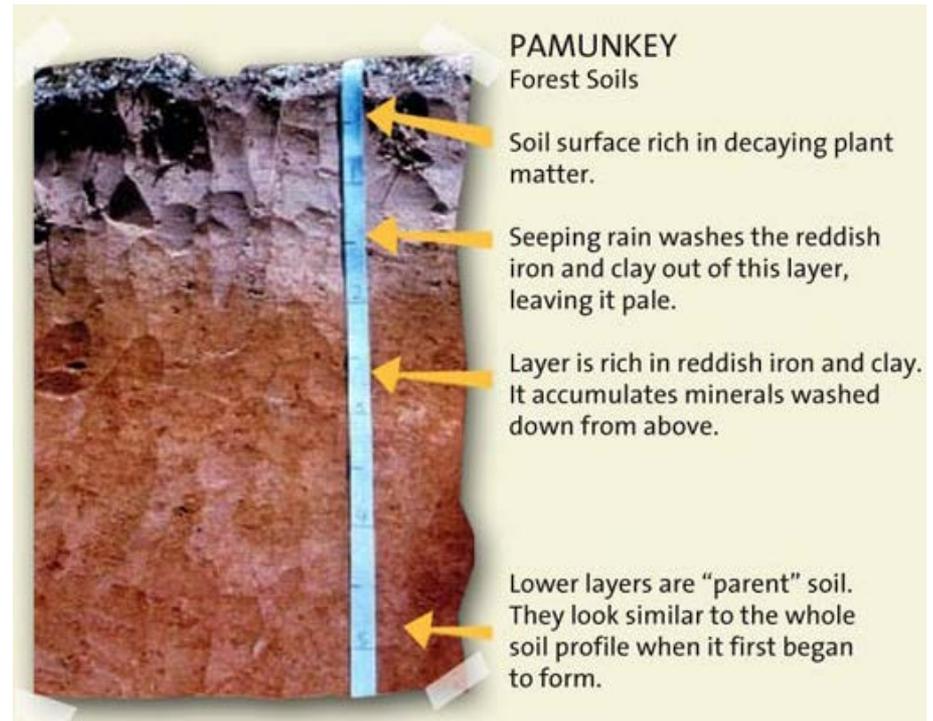
# The Role Of Soil In Plant Growth

- Reservoir
  - Nutrients
  - Gases
  - Water

- Physical Support

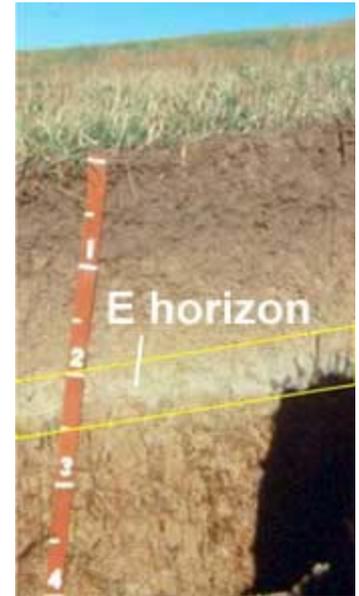


## Pamunkey—Virginia’s State Soil Fine-loamny



# The Soil Profile

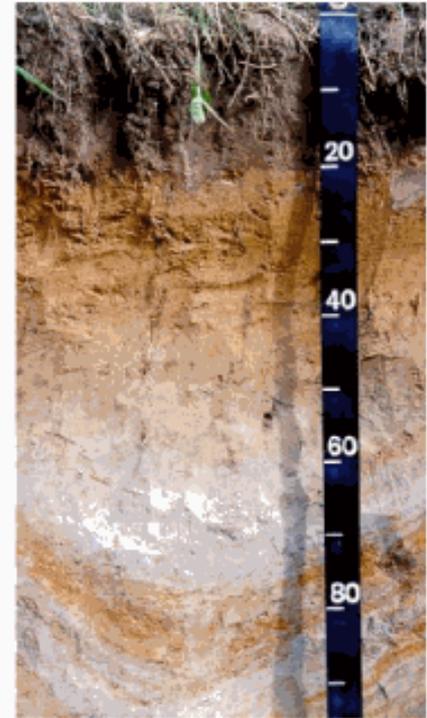
- **Vegetative cover (O horizon)** – leaf litter
- **Topsoil (A-Horizon)**
  - High organic content and dark color
  - Experiences the most leaching and weathering
- **Subsurface (E-Horizon)**
  - Depletion of organic matter, clay, iron, and Al
- **Subsoil (B-or C-Horizon)**
  - **B is bright orange and C is whiter**
  - “catch zone”
  - Minimal organic matter
  - Accumulation of clays, calcium carbonates, and mineral oxides
- **Parent Material (R-horizon/hard bedrock)**



Plant and Soil  
Sciences eLibrary  
2016

# What does soil color indicate?

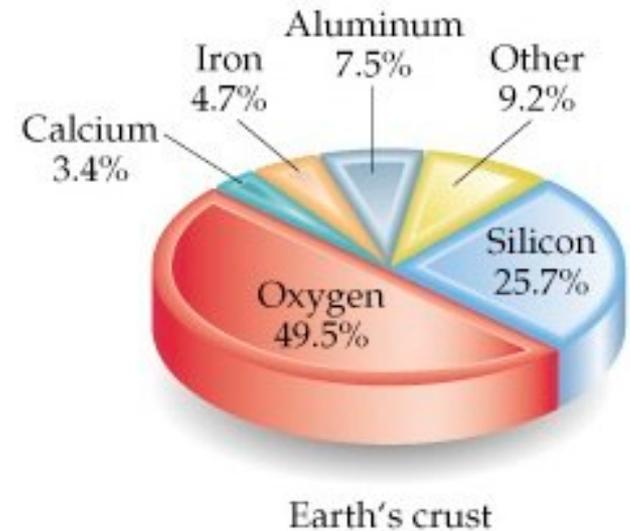
- Darker (gray, dark brown, black)—has more organic matter
- Reddish-yellowish—well-drained; iron content
- Light to whitish—low fertility; leached
- Yellow—drainage impediments
- Blue-gray—WET; usually high aluminum content



# Aluminum in soil

Toxic to plants in acidic soils

- The most abundant metallic element in the earth's crust
- Can interfere with plant uptake of phosphorus
- Inhibits root growth
- As soil pH decreases, the solubility of aluminum increases.



*Hydrangea macrophylla* 'Altona'

# Soil Properties

## Solids, liquids, and gases

- Physical—can be seen and felt
  - Texture
  - Structure
  - Color
  - Pore space
  - Depth
  - Drainage
  - Surface features
- Chemical
  - pH
  - Cation exchange capacity (CEC)

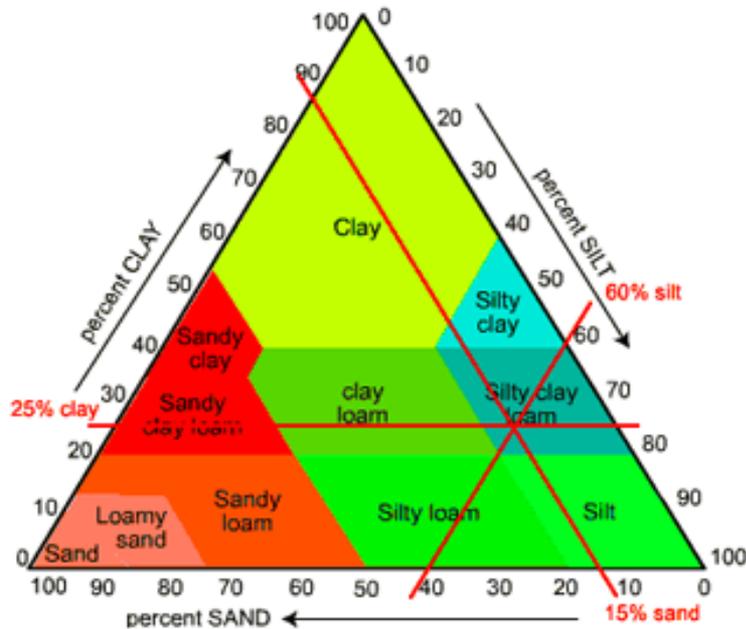


# Properties of Soils Cont'd

- Affects plant growth and development
- Affected by the plants it supports
- Manipulated by humans
- Deciduous—prefer warmer temperatures, wetting & drying
- Conifer—prefer cooler temperatures; stays wet longer



# Soil Textural Triangle



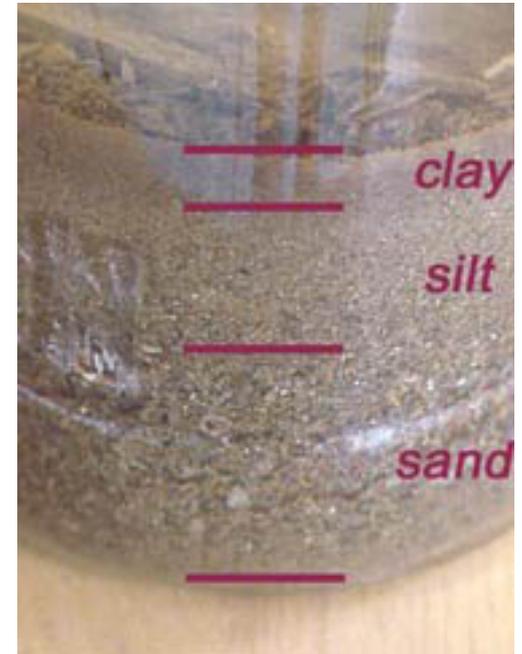
- In Virginia
  - Loam
  - Sandy loam
  - Silt loam
  - Silty clay loam
  - Clay loam

<http://www.landscapeandgardentoday.com/Garden/WaterWiseGardening.php>

# Texture

- The relative proportions of three basic particle sizes
  - sands
  - Silts
  - clays
- Affects soil porosity, water holding capacity, and drainage
- cannot be permanently changed in the field
- also affects fertility because clay soils have high

**CEC (Cation Exchange Capacity)**



# Determining soil textures

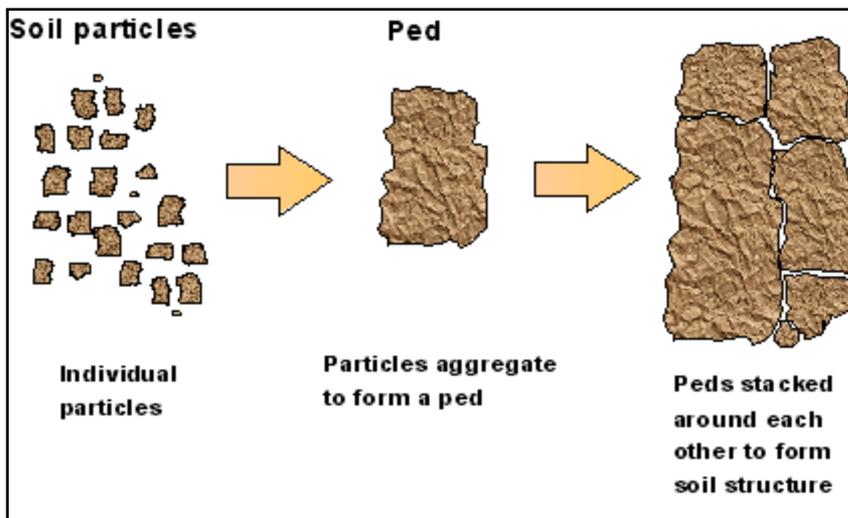
- “ribbon” test
  - <2 inches—about 25% clay
  - 2 to 3-1/2 inches long, then it has about 40 percent clay
  - > 3.5 inches—50% or more clay
- Palm rub—make a muddy puddle in your palm. How gritty does this feel?



Kansas State University  
Agricultural Experiment  
Station and Cooperative  
Extension Service

# Structure

- Arrangement of sand, silt, and clay particles
- Jar test
- Peds or aggregates
- Affects texture



# Structure affects...

- pore size
- water holding capacity
- infiltration rate
- permeability of a soil

- **Structure can be destroyed! How?**

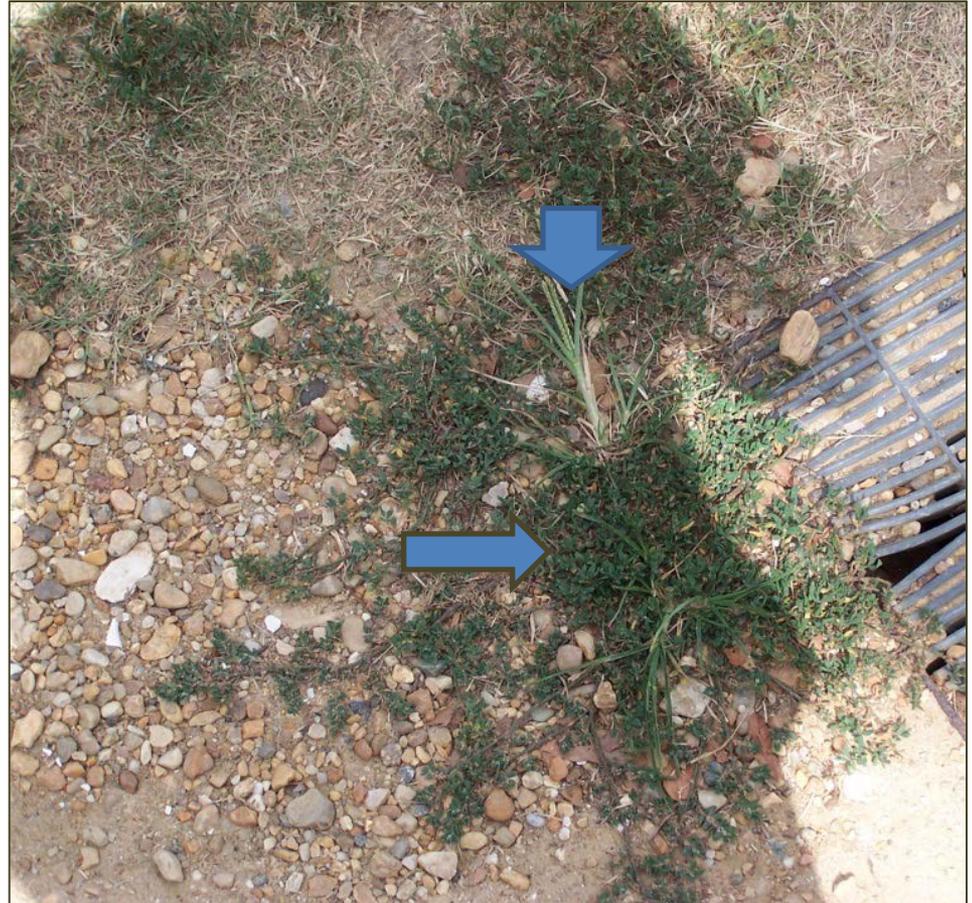
<p>Characteristic of surface (A) horizons. Subject to wide and rapid changes.</p>	<p><b>SPHEROIDAL</b></p> <p>Granular (poros)</p> <p>Crumb (very poros)</p>	
<p>Common in E-horizons, may occur in any part of the profile. Often inherited from parent material of soil, or caused by compaction.</p>	<p><b>PLATE-LIKE</b></p>	
<p>Common in B-horizons, particularly in humid regions. May occur in A-horizons.</p>	<p><b>BLOCK-LIKE</b></p> <p>Angular blocky</p>	
	<p>Subangular blocky</p>	
<p>Usually found in B-horizons. Most common in soils of arid and semi-arid regions.</p>	<p><b>PRISM-LIKE</b></p> <p>Columnar (rounded tops)</p>	
	<p>Prismatic (flat, angular tops)</p>	





# Compaction

- Structure changed by rainfall, tillage and traffic
- **Compaction** increases soil bulk density and decreases pore size, water infiltration rate, and air space
- Metal rod test
- What are your weeds telling you?



# Ways to improve soil structure

- Add Ca
- Maintain appropriate amount of pore space
- Add OM
- Maintain a good CEC
- Maintain a vegetative cover



# Effects of depth and erosion

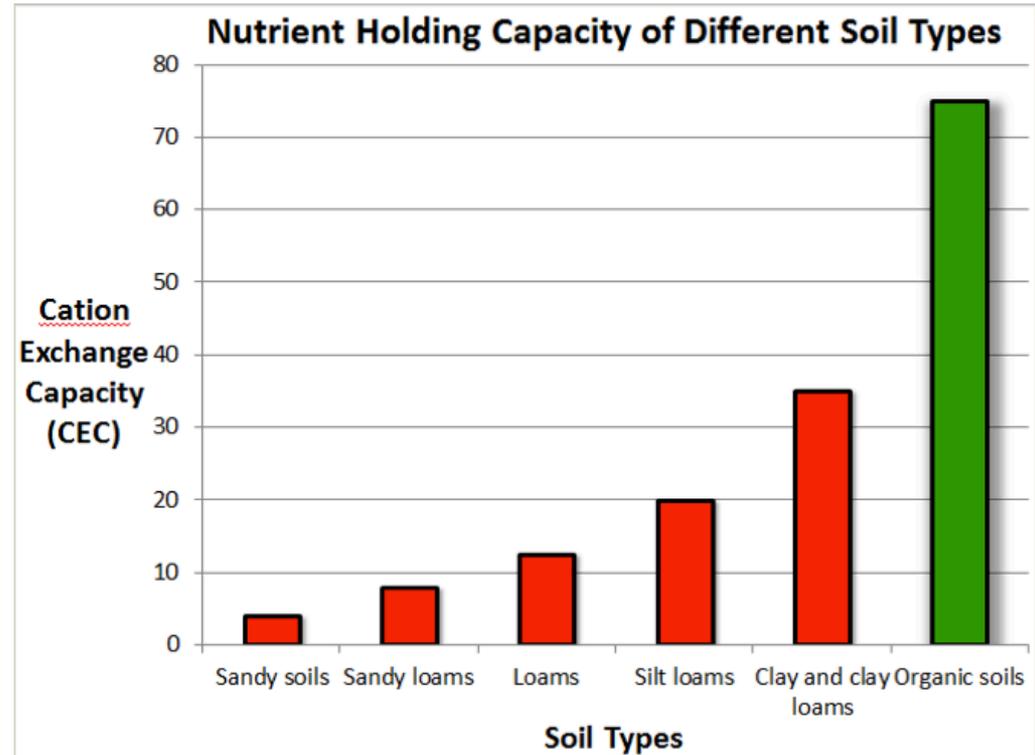
- Shallow vs deep soils
- Bare earth
- Tillage
- Mulching
- Right plants for soil conditions





# Cation Exchange Capacity (CEC) aka “static cling”

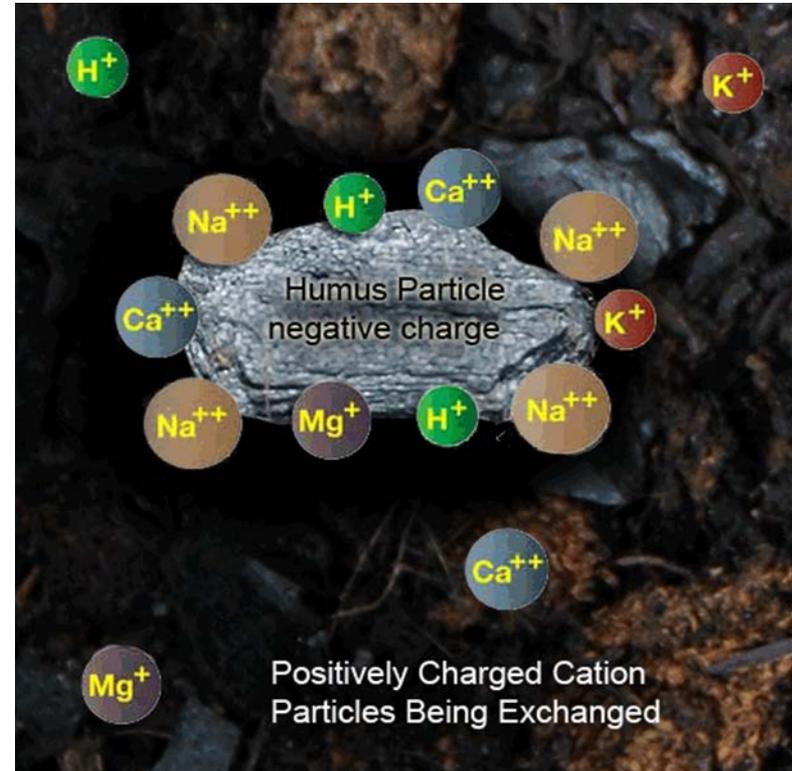
Index of soil fertility—  
*the measure of how many negatively-charged sites are available in your soil*—  
capacity to attract, hold and exchange these cations (Ca, Mg, Na, K)



The higher the CEC, the higher the negative charge and the more cations that can be held.

# Essential Nutrient Cations Ammonium and Aluminum are cations too!

- Clays
  - negatively charged
  - large surface areas
  - highest CEC



**50 CEC**  
(Heavy  
Clay)

**Common CEC Range**

**0 CEC**  
(Sand)

**SOME PRACTICAL APPLICATIONS**

**Soils with CEC 11-50 Range**

- High clay content
- More lime required to correct a given pH
- Greater capacity to hold nutrients in a given soil depth
- Physical ramifications of a soil with a high clay content
- High water-holding capacity

**Soils with CEC 1-10 Range**

- High sand content
- Nitrogen and potassium leaching more likely
- Less lime required to correct a given pH
- Physical ramifications of a soil with a high sand content
- Low water-holding capacity

# Can you have too much CEC?



# “Don’t Guess, Soil Test!”

## Virginia Tech Soil Testing Laboratory

Publication 452-125

Soil Sample Information Sheet for

Home Lawns, Gardens, Fruits, and Ornamentals

- **SOIL TESTS DESIRED**
- Routine (soil pH, P, K, Ca, Mg, Zn, Mn, Cu, Fe, B, and **estimated CEC**)
- Organic Matter – Determines percentage in soil  
– no recommendation given
- Soluble Salts – Determines if fertilizer salts are too high

# Soil Chemical Properties

## 16 Essential Nutrients

- **13 essential elements** + C,H,O
- **Macronutrients**—used in relatively large amounts and are often prone to deficiency in the soil
- **Micronutrients**—used in trace amounts and not frequently deficient in field soils.
  - especially critical in greenhouse soilless medias and can be toxic under certain conditions

# Essential Nutrients

- Primary Macros
  - Nitrogen N
  - Phosphorous P
  - Potassium K
- Secondary Macros
  - Calcium Ca
  - Magnesium Mg
  - Sulfur S
- Micronutrients
  - Boron B
  - Iron Fe
  - Molybdenum Mo
  - Manganese Mn
  - Zinc Zn
  - Copper Cu
  - Chlorine Cl

(Some sources include Nickel and/or Cobalt)

# “Freebie” macronutrients

When was the last time you bought a bag of hydrogen?

- Carbon
- Hydrogen
- Oxygen



# Mobility of nutrients within plants

- Mobile nutrient—can be “mined” for use at other sites within the plant
  - Nitrogen, phosphorus, potassium, magnesium, etc.
- Immobile nutrient—cannot be “mined”; stays in the spot where it first was sent

**CuBS CaFé + Mn**



# Nitrogen (N)

## Essential macronutrient

- The “BIGGIE”
- Absorbed as
  - inorganic nitrate ( $\text{NO}_3^-$ )
  - ammonium ( $\text{NH}_4^+$ )
- Promotes leafy top growth
- Mobile in plant
- Has its greatest effect for 3 to 4 weeks after application
- Can be luxurious
- In fertilizers as **urea, ammonium, nitrate**



# Name three things that can happen to nitrogen.

1. Uptaken by plants
2. Leached or eroded
3. Volatilized into atmosphere as a gas



# What happens when too much nitrogen is applied?

- Can delay maturity—flowering and fruiting
- Little to no fruit set
- Lower sugar content
- Cause hollow stems in broccoli
- Formation of sweet potatoes limited
- Secondary factor in blossom end rot
- Fusarium blight, powdery mildew in turfgrass
- Brown patch in fescue

# Soil Sampling for the Home Gardener

## Virginia Tech Publication 452-129

“A soil test is not usually performed for the presence of N (nitrogen). ... Due to nitrogen’s potential for rapid changes in availability in the soil, a soil test may show nitrogen levels that no longer exist. Soil Testing Laboratories still provide nitrogen fertilizer recommendations. The recommendations are based on years of research that has determined plant nitrogen needs.”

# Phosphorous (P)

## Essential Macronutrient

- For root and fruit production
- Often fixed in the soil
- Mobile in plant
- Soluble in pH range of 6 to 7.5, around 6.5—  
means it dissolves in water and is uptaken by  
plants
- In fertilizers as  **$P_2 O_5$  (phosphate)**

# Potassium (K)

## Essential Macronutrient

- For cold hardiness, disease resistance, and general durability
- Readily leached from and fixed by soils
- In fertilizers as  **$K_2O$  (potash)**

# Calcium (Ca)

## Essential secondary macronutrient

- An essential part of plant cell wall structure
- Provides for normal transport and retention of other elements
- Sources are **dolomitic lime, gypsum, and superphosphate**



Bitter pit of apple due to calcium deficiency



# Iron (Fe)

## Essential Micronutrient

- Most abundant element in native soils
- Immobile in plants
- Component of many enzymes and a catalyst in the synthesis of chlorophyll
- Deficiency symptoms—**interveinal chlorosis** of young foliage and can occur in both acid and alkaline soils



# Chelates

## Iron, zinc, magnesium

- Example: There is plenty of iron in soil, but pH isn't favorable for the plant being grown so plant can't uptake iron.
- Use a chelate! Chemical "claws" that hold metal ions in solution
- Nutrient held by the chelate will remain available to the plant for a longer period of time.

# Cu vat for pickling



# Soil Organic Matter (OM)

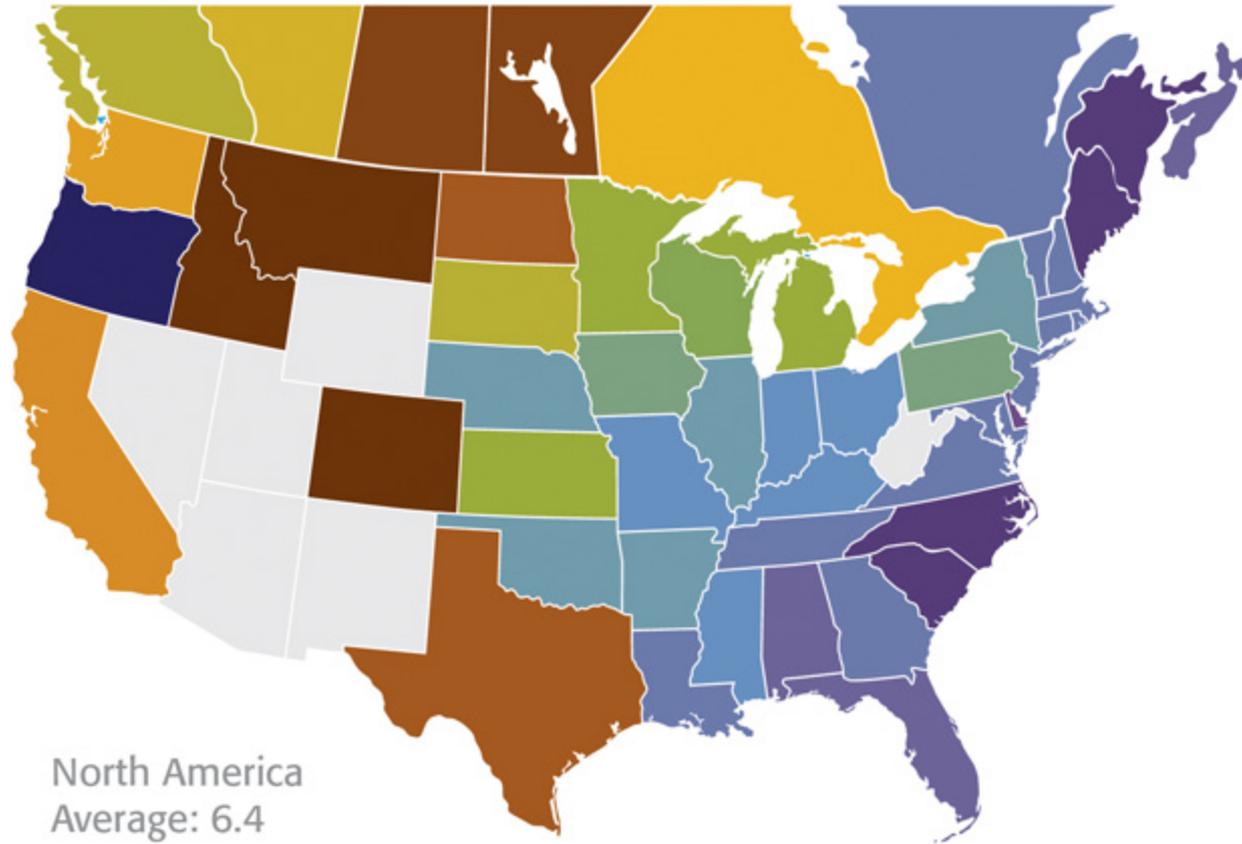
- Results from plant or animal residues
- Plant residues and green manure
- Organics are important sources of essential nutrients, improve soil structure, buffer soils, and increase water holding capacity of soils
- Microorganisms important decomposers
- Organic matter gradually releases its essential nutrients—difficult to measure



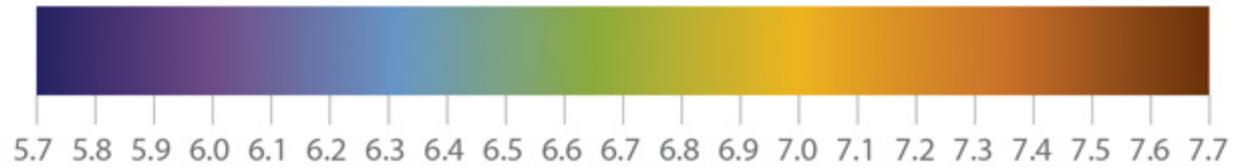
# pH

- Acid soils—high annual rainfall
- Adding limestone ( $\text{CaCO}_3$ ) increases pH
- Adding sulfur or aluminum sulfate decreases pH
- Poor rainfall increases soil pH
- Most N fertilizers decrease pH
  - ammonium ( $\text{NH}_4^+$ ) decreases pH
  - urea decreases pH (from ammonia and carbon dioxide)
  - nitrate ( $\text{NO}_3^-$ ) increases pH
- **pH is very difficult to change**

# MEDIAN SOIL pH

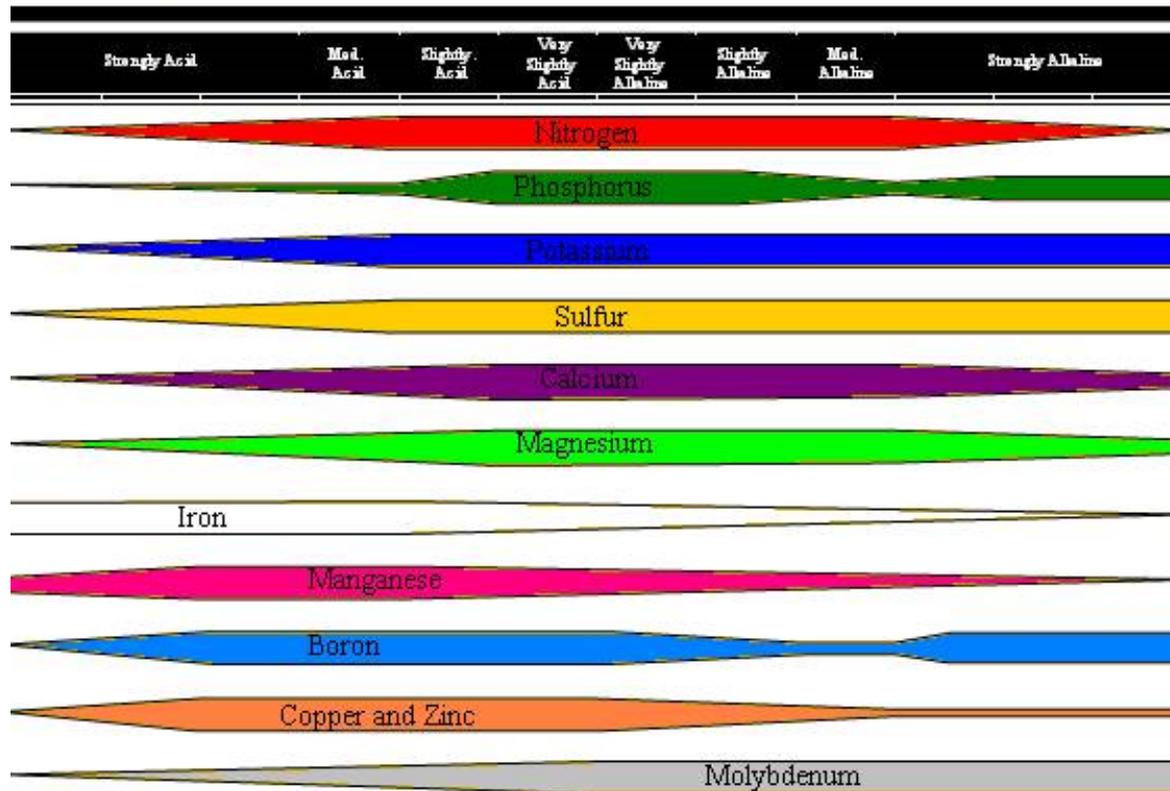


North America  
Average: 6.4



Values calculated in 2010 from 4.3 million samples.

# pH vs Availability of Nutrients



# Why are you adding fertilizer to the soil?

- Replace lost nutrients
- Maintain lost nutrients
- Can you add too much?





Tim McGee

# Eutrophication

## Fertilizers as pollutants



UF IFAS FFL program

# Different forms of lime

- Limestone = calcium carbonate
- Dolomitic limestone = calcium carbonate with magnesium
- Gypsum = calcium sulfate (does not reduce soil acidity)
- Wood ash = alkaline

# To lower pH

- Elemental sulfur
- Aluminum sulfate—  
faster than sulfur but  
need to use lots more



# Organic Fertilizers

- Disadvantages

- Bulky and require large amounts of storage space
- Low nutrient content
- Difficult to quantify
- Generally slow to release
- Difficult to uniformly apply
- Applied only to the soil

- Advantages

- Improve soil structure and microbes
- Supply microorganisms
- Urea 46 – 0 – 0 (may not be considered an organic fertilizer)



# Organic Fertilizer Alternatives

- **Green Sand:** from sedimentary marine deposits. Contains potassium and iron.
- **Blood Meal:** a byproduct of the meat packing industry. Steamed and dried; high in phosphorous.
- **Compost:** one of the best all-around garden materials for soil improvement.
- **Cottonseed Meal:** a byproduct from cotton processing and a good source of nitrogen.
- **Wood ash:** alkaline, contains K



Helen Gazeley

GrowWe

# Organic Fertilizer Alternatives Cont'd

- **Fish Emulsion:** a fish processing byproduct. Mild, nontoxic, and good for use with tender plants.
- **Super Phosphate:** rock phosphate combined with sulfuric acid to produce phosphorus in a form easy for plants to uptake.
- **Composted Manure:** for soil conditioning or use in the compost pile.



# 5-2-0 Organic Based Fertilizer

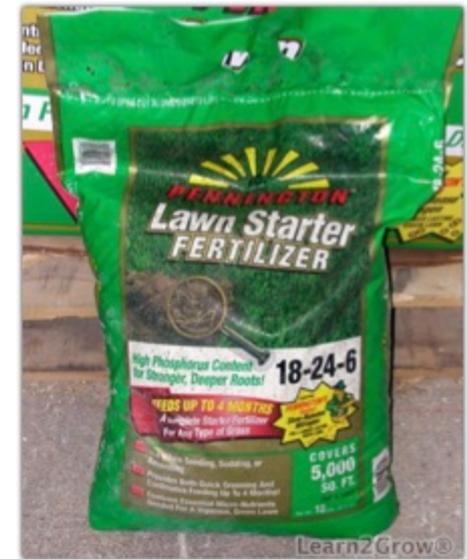
## Milorganite Professional with 4% iron

- Non-burning organic fertilizer, rich in water insoluble nitrogen. The naturally slow releasing Nitrogen and added complex Iron result in a lawn with the color you desire without excessive growth (or mowing!). Ideal for trees, shrubs and ornamentals too.  
Use April through October. 50 lb bag covers 3,100 sq.ft.



# Inorganic Fertilizers

- Easy to store
- Higher analysis than organics
- Custom formulated
- Easy to apply and apply uniformly
- Available in solid and liquid formulations
- Can be applied to the soil and/or foliage
- Accurate quantitative application
- Nutrients are readily available
- Gardeners can mix their own formulations accurately
- Can pull water OUT of soil if applied too heavily or without water
- Can be expensive
- Most are salts



# Fertilizer Analysis

- Incomplete
  - 15 - 0 - 0
  - 13 - 0 - 44

- Complete
  - 20 - 20 - 20
  - 20 - 10 - 20
  - 15 - 2 - 20



GUARANTEED ANALYSIS	
TOTAL NITROGEN (N).....	24.0%
6.2% AMMONIACAL NITROGEN	
17.8% UREA NITROGEN*	
AVAILABLE PHOSPHORIC ACID (P <sub>2</sub> O <sub>5</sub> ).....	6.0%
SOLUBLE POTASH (K <sub>2</sub> O).....	12.0%
TOTAL SULFUR (S).....	6.0%
2.0% FREE SULFUR	
4.0% COMBINED SULFUR	
IRON (Fe).....	1.0%

#313-1119

**DERIVED FROM:**  
Polymer-coated urea, sulfur-coated urea, urea, ammonium sulfate, di-ammonium phosphate, muriate of potash, iron sulfate and iron oxide.

# Fertilizer Nomenclature

- Fertilizer Analysis

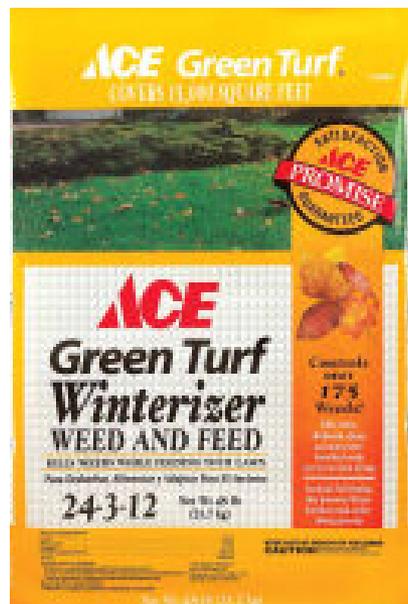
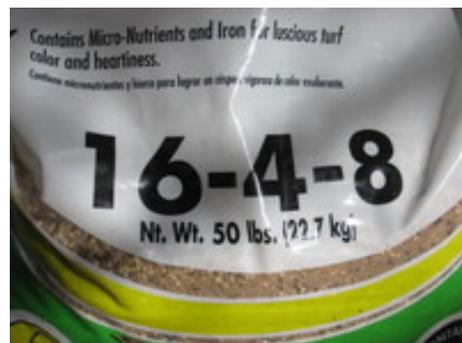
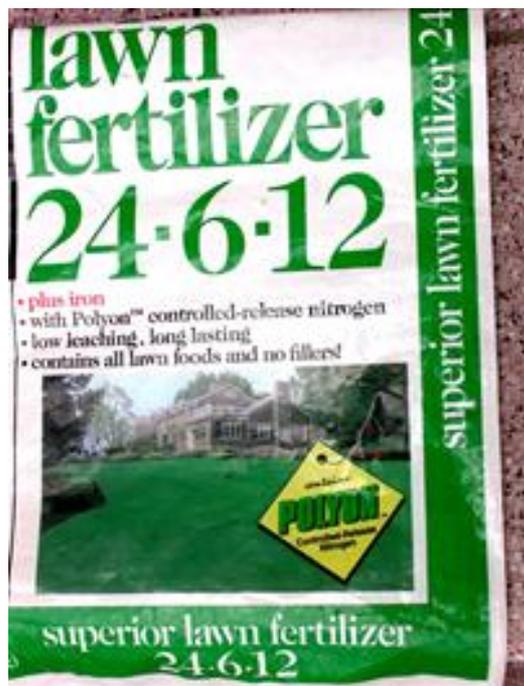
- N is  $\text{NO}_3^-$  or  $\text{NH}_4^+$  (100%)
- P is  $\text{P}_2\text{O}_5$  (.49)
- K is  $\text{K}_2\text{O}$  (.83)

- Fertilizer Ratio

- Example: 20 - 10 - 20 = 2:1:2 ratio



# What is the analysis?



# Fertilizer Forms

- Granules
  - May be Slow Release—WIN
  - Spread evenly and easily
- Liquids
  - Made to be diluted with water—WSN
  - May also be applied to plant foliage



# Soil Nutritional Monitoring

- Visual diagnosis
- Soil test—measures the "active" acidity in the soil's water (or hydrogen ion activity in the soil solution)
- Foliar analysis



A fertilizer is labeled with 16 – 4 – 8 ...

1. What is the analysis?
2. What is the ratio?
3. 8.2% ammoniacal N—change to pH?
4. 5.8% nitrate—change to pH?
5. 2% urea—change to pH?
6. Overall change to pH?
7. If the bag weighs 40 pounds, then how much actual N is in the bag?

A fertilizer is labeled with 16 – 4 – 8 ...

1. What is the analysis?
2. What is the ratio?
3. 8.2% ammoniacal N—change to pH? **down**
4. 5.8% nitrate—change to pH? **up**
5. 2% urea—change to pH? **down**
6. Overall change to pH? **down**
7. If the bag weighs 40 pounds, then how much actual N is in the bag?

$$40 \times .16 = 6.4 \text{ lb of N}$$

# Methods of Applying Fertilizers



- Broadcasting—incorporate into soil
- Banding—especially for phosphorous
- Starter solutions—liquid high in phosphorous
- Side dressing—after plants are up and growing
- Foliar feeding—when a quick growth response is needed



# For Correct Timing Of Application, Know the...

- ... growth phases of the species such as warm-season vs. cool-season turf grasses
- ... effect of environmental conditions such as rain and temperature on various fertilizers
- ... release rate of a particular fertilizer

# Fertilizer Recommendations

- The crop to be fertilized
- Regional information on weather and soils
- Cropping history of the land
- Crop yield target



# Need to know...

- Analysis
- Rate of N recommended
- Area (square footage)
  - Rectangle:  $A = \text{length} \times \text{width}$
  - Triangle:  $A = (\text{base} \times \text{height}) \div 2$
  - Circle:  $A = \pi r^2$

**SAMPLE HISTORY**

Sample ID	Field ID	LAST CROP		LAST LIME APPLICATION		SOIL INFORMATION				
		Name	Yield	Months Prev.	Tons/Acre	SMU-1 %	SMU-2 %	SMU-3 %	Yield Estimate	Productivity Group
HCCG1										

**LAB TEST RESULTS (see Note 1)**

Analysis	P (lb/A)	K (lb/A)	Ca (lb/A)	Mg (lb/A)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	B (ppm)	S.Salts (ppm)
Result	16	165	1655	174	5.6	7.4	0.8	22.4	0.3	128
Rating	M-	M+	H-	H	SUFF	SUFF	SUFF	SUFF	SUFF	L

Analysis	Soil pH	Buffer Index	Est.-CEC (meq/100g)	Acidity (%)	Base Sat. (%)	Ca Sat. (%)	Mg Sat. (%)	K Sat. (%)	Organic Matter (%)
Result	5.5	6.06	7.1	28.5	71.5	58.4	10.1	3.0	3.6

**FERTILIZER AND LIMESTONE RECOMMENDATIONS**

Crop: VEGETABLE GARDEN (210)

**610. LIME RECOMMENDATIONS:** Apply 9 pounds of agricultural limestone (ground or pulverized) per 100 square feet. If lime is not going to be mixed into the soil, make several small applications of up to 5 lbs each, at intervals of 1 to 6 months, until the full amount is applied.

990. We are trying to improve our service. PLEASE take a moment to complete our brief, anonymous customer survey at [tinyurl.com/soiltestsurvey](http://tinyurl.com/soiltestsurvey)

**221. FERTILIZER RECOMMENDATIONS:** Apply 4 lbs of 5-10-10 per 100 square feet. For additional information on fertilization, see Note 19 (enclosed).

677. Soluble Salts are not high enough to cause salt injury.

“Do not over lime! Too much lime can be as harmful as too little.”

VT Explanation of Soil Tests

Recommendations for gardens and small areas are given per 100 sq ft.

Recommendations for lawns are given per 1000 sq ft.

# Fertilizer math using the

soil test listed on the previous slide

- If the dimensions of your garden are 20 feet by 30 feet, how many pounds of lime is recommended for you to apply to the area over 1 year? (9 lb per 100 sq ft)
- $20 \times 30 = 600$  sq ft
- $\frac{9}{100} = \frac{x}{600}$
- 54 pounds per 600 square feet

# Fertilizer math continued

4 lb of 5-10-10 per 100 sq ft

- You buy a 20 lb bag of 5-10-10. How much fertilizer will you apply to your garden?
- $\frac{4}{100} = \frac{x}{600}$
- You will apply 24 pounds per 600 sq ft.

# Fertilizer math continued

- How much actual N is being applied to your garden?
- $5\%$  of 4 lb = 0.2 lb per 100 sq ft
- $0.2 \times 6 = 1.2$  lb per 600 sq ft

# More math...

- Determine the amount of ammonium sulfate (21-0-0) needed for a 5000 square foot lawn if 1 lb of N per 1000 sq ft is needed.
- Determine how much 10-10-10 needs to be applied to ensure 2 lbs of phosphate per thousand sq ft in a garden that measures 20 X 10 feet.

# Biosphere 2

