Virginia Cooperative Extension

Virginia Tech
Invent the Future

Virginia State

Soils and Fertilizers Chapter 2

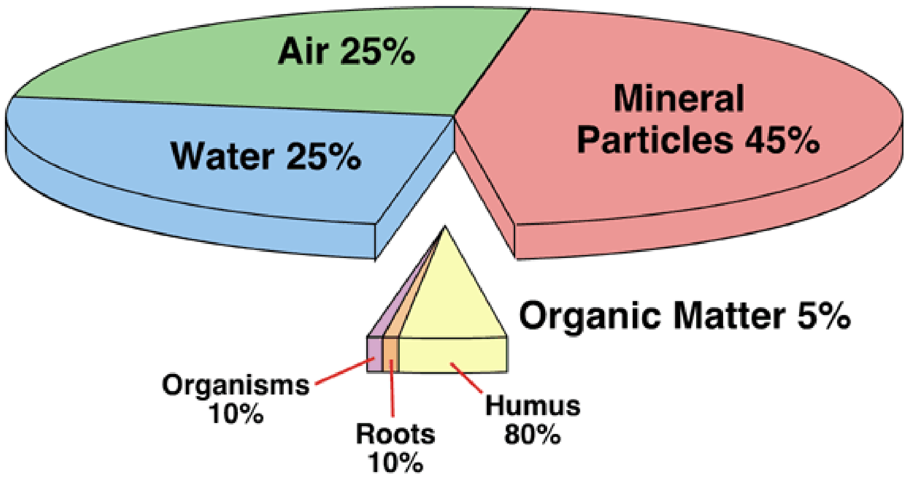
Sherry Kern
Virginia Beach Master Gardener
Tree Steward

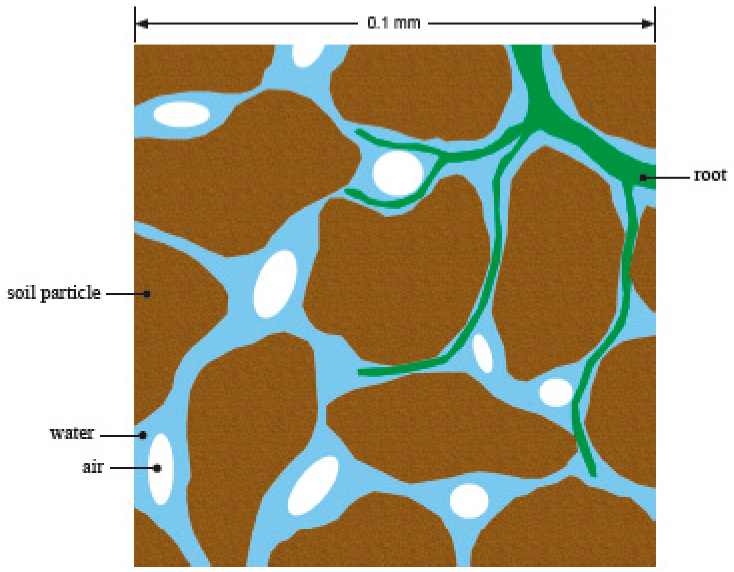
Soil—
It's Not Dirt!

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

An Ideal Soil

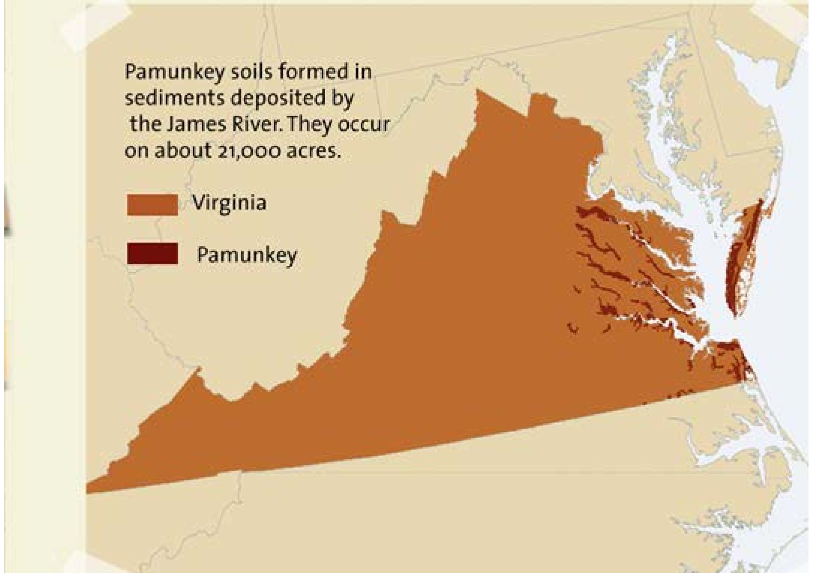
- Agriculturally productive soils have **both** organic and mineral components
- A typical mineral soil consists
  - Minerals
  - water
  - Air
  - Organic material



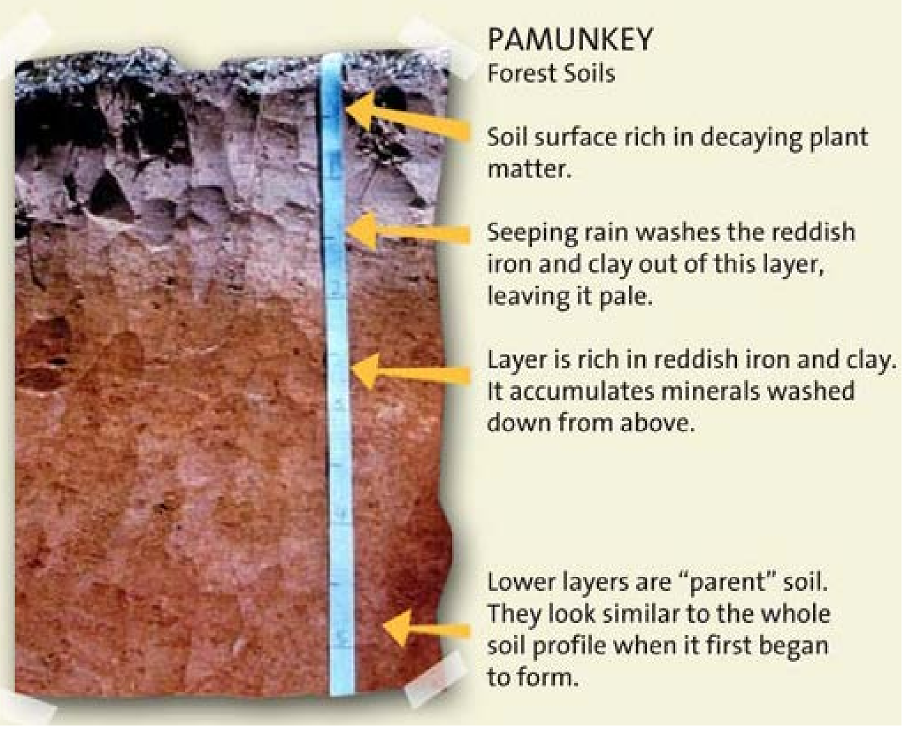


The Role Of Soil In Plant Growth

- Reservoir
  - Nutrients
  - Gases
  - Water
- Physical Support



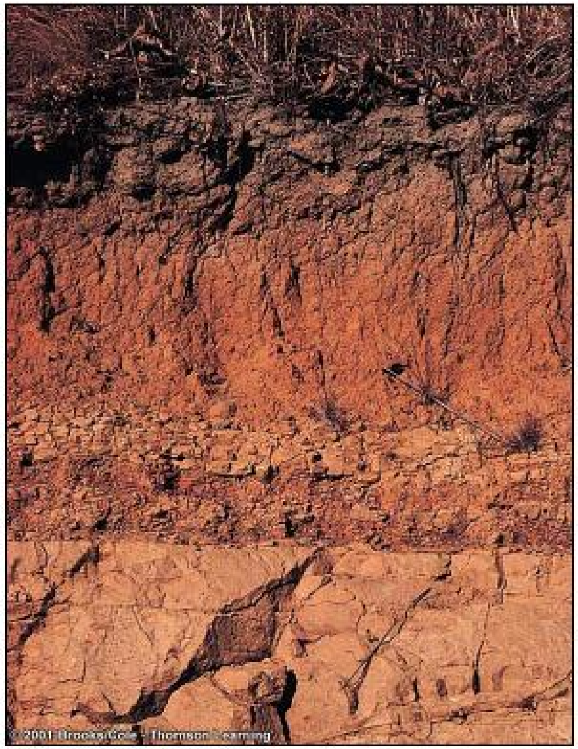
Pamunkey—Virginia's State Soil
Fine-loamny



The Soil Profile

- **Vegetative cover (O horizon)** – leaf litter
- **Topsoil (A-Horizon)**
  - Characterized by 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)**

Typical Soil Profile



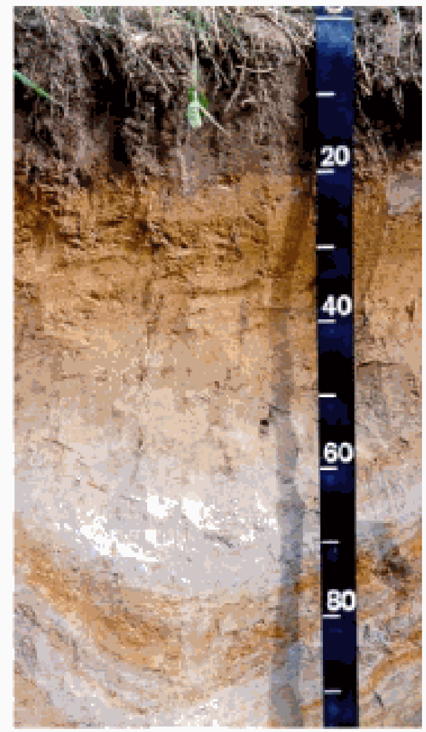
- O Horizon Fallen Leaves
- A Horizon Top Soil
- B Horizon Higher Mineral And Lower Organic Conte
- C Horizon Gravel and Rocks
- Bedrock

Fig 30.3

Rodney Brundage, WVU

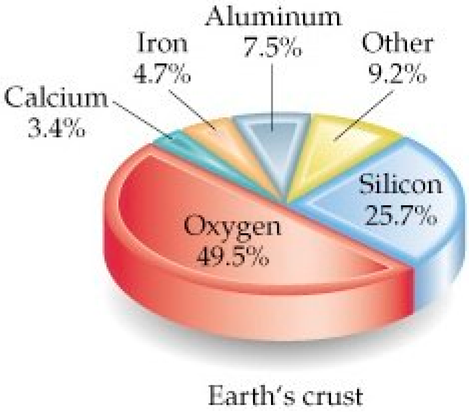
What does soil color indicate?

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



Aluminum in soil

- The most abundant metallic element in the earth's crust
- High levels can also interfere with plant uptake of phosphorus.
- As the soil pH decreases, the solubility of aluminum increases.



Hydrangea macrophylla 'Altona'

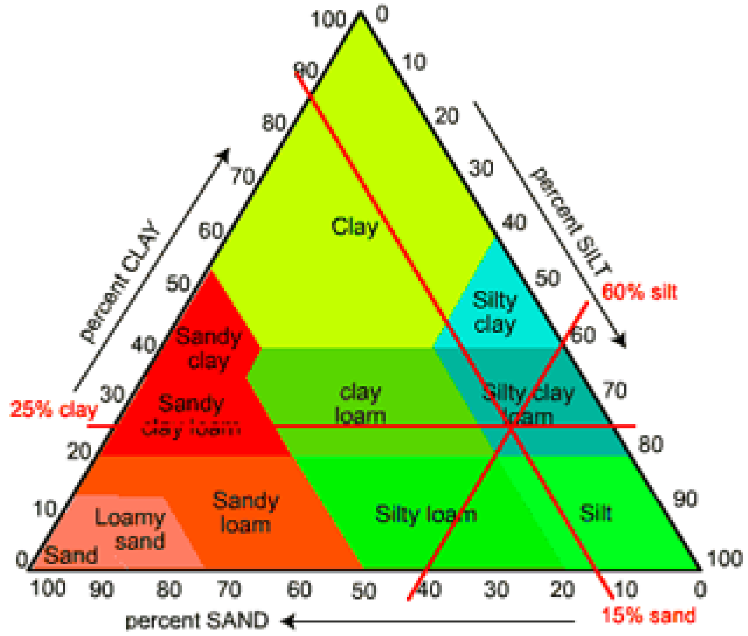
Soil Properties
Solids, liquids, and gases

- Physical—can be seen and felt
  - Texture
  - Structure
- 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

Soil Textural Triangle



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

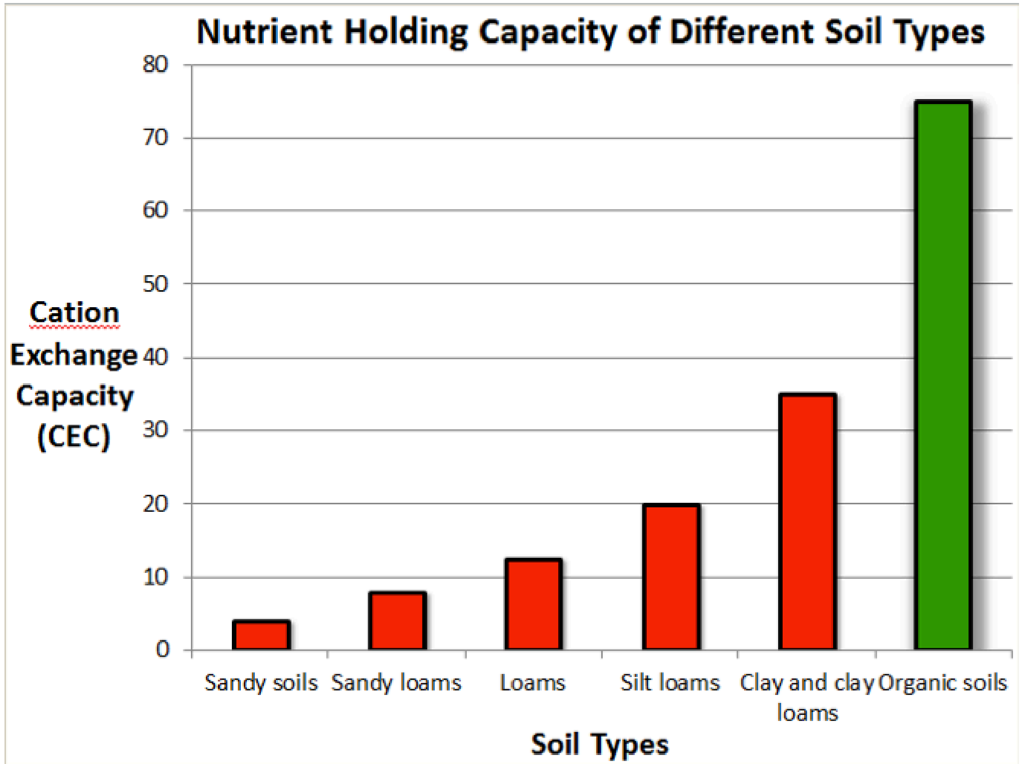
Texture

- The relative proportions of three basic particle sizes
  - **sands**
  - **silts**
  - **clays**
- Loams contain all three size classes in equal proportions
- 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)

Cation Exchange Capacity (CEC) aka "static cling"

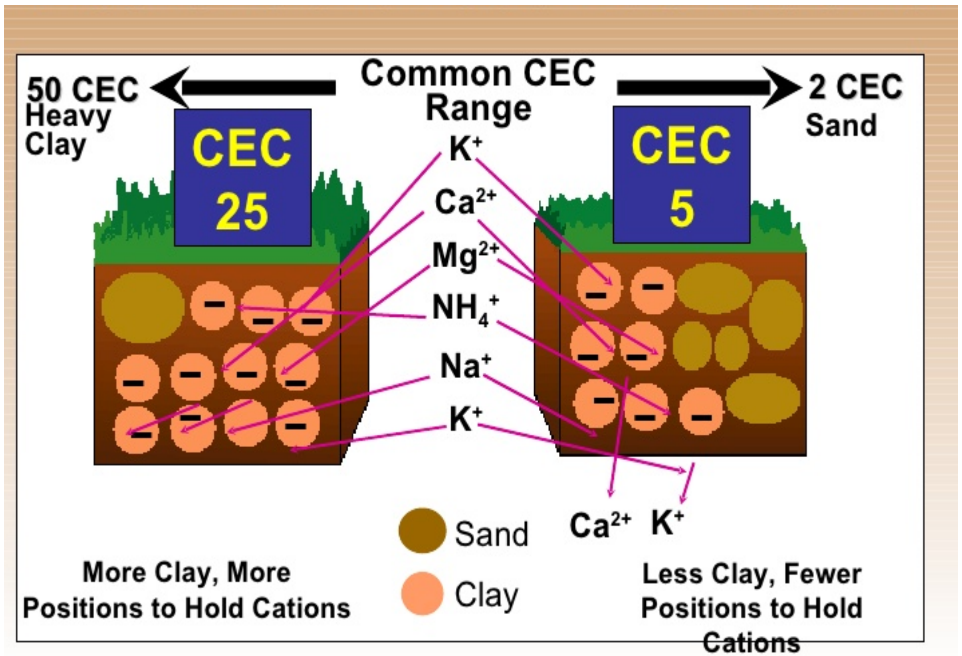
– Index of soil fertility.
  - *the measure of how many negatively-charged sites are available in your soil*—capacity to attract, hold and exchange these cations (Ca, Mg, Na, K)



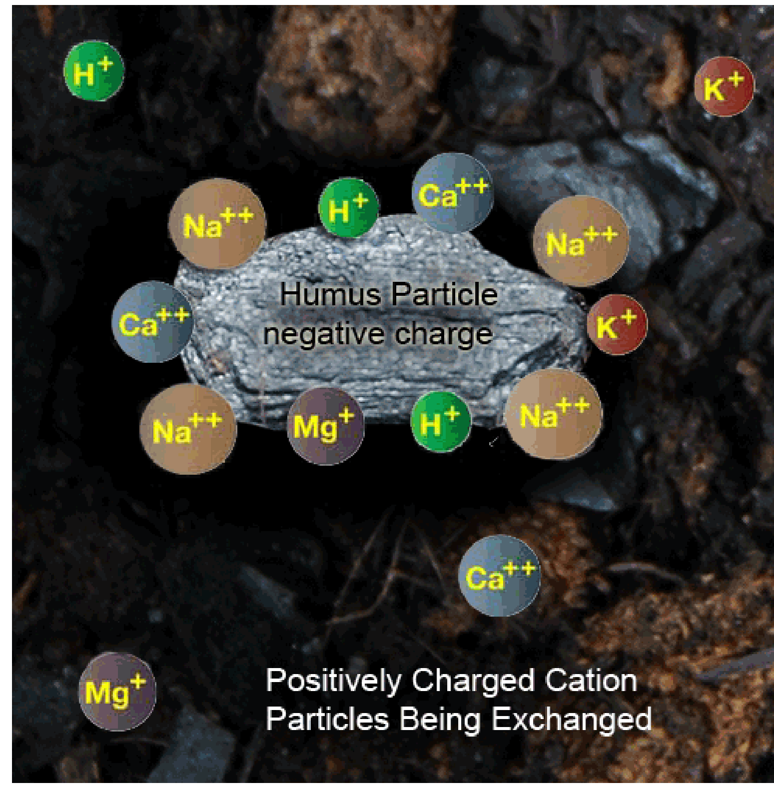
– Colloids with large surface areas, such as clays, which are negatively charged, have the highest CEC

– Organics also have colloidal properties

Essential Nutrient Cations Ammonium and Aluminum are cations too!



Andy Kleinschmidt	Don McClure
Extension Educator	Soil Scientist
Van Wert County	NRCS-USDA



Organic Soil Technology

50 CEC (Heavy Clay) ← **Common CEC Range** → **0 CEC** (Sand)

SOME PRACTICAL APPLICATIONS	
Soils with CEC 11-50 Range	Soils with CEC 1-10 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	• 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

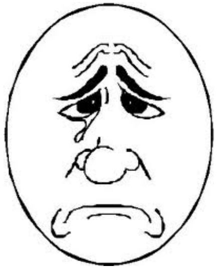
Structure

- arrangement of sand, silt, and clay particles
- “ribbon test”
- 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?**




Minnesota
345 DKP
10,000 lakes

Compaction

- Structure changed by rainfall, tillage and traffic
- **Compaction** increases soil bulk density and decreases pore size, water infiltration rate, and air space
- 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

Test Your Drainage

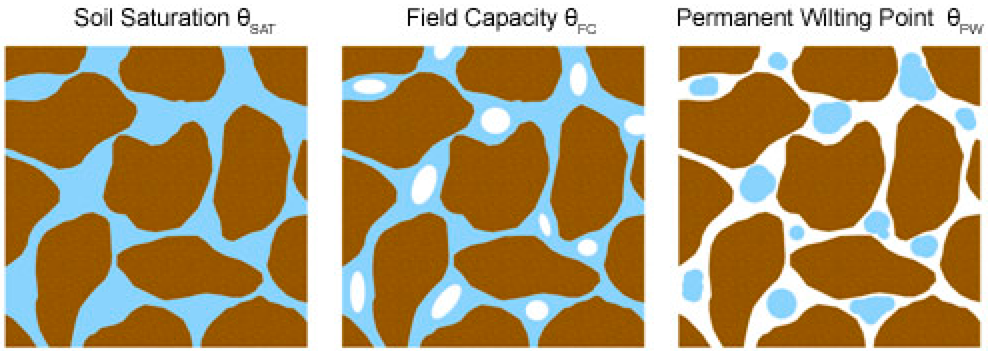
- Dig a hole about 1 foot deep.
- Fill with water and allow it to drain completely.
- Immediately refill the pit and measure the depth of the water with a ruler.
- Calculate how much water drains in an hour.

Test Your Drainage

- Less than 1 inch per hour— poor drainage
- 1 to 6 inches of drainage per hour is desirable.
- Faster than 6 inches per hour—excessive drainage

Soil Water

- **Saturation**--all pore spaces are filled with water
- **Field Capacity**—amount of water remaining in the soil a few days after having been wetted and after gravity no longer pulls down
- **Water available to plants**—"Baby bear"—just the right amount of water
- **Permanent Wilting Point**—water content of a soil when most plants growing in that soil wilt and fail to recover upon rewetting



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 (**NO_3^-**)
  - ammonium (**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**

What are three things that can happen to nitrogen?

- Uptaken by plants
- Leached or eroded
- 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
- Deficiency symptoms include stunting, yield reduction, darkening and purplish coloration of older foliage
- 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)**

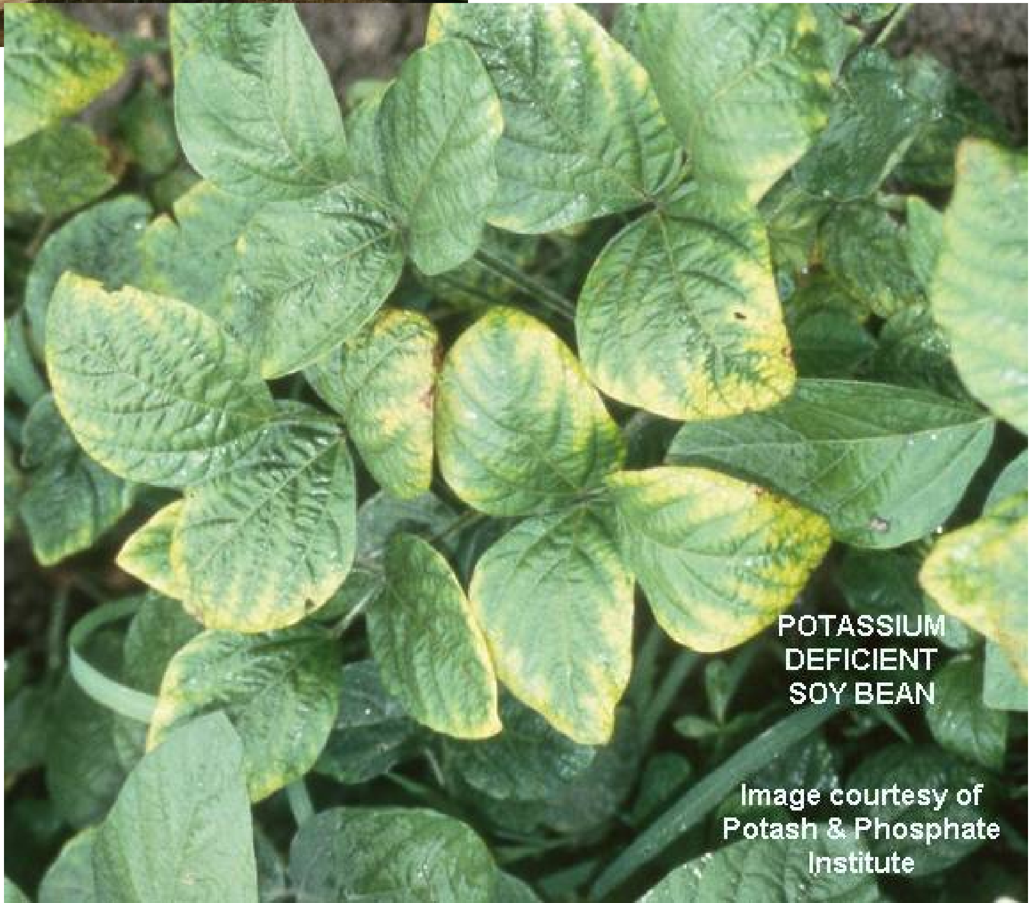

PHOSPHORUS
DEFICIENT
TOMATO
Photo
courtesy
of Ray Weil
University
of Maryland


PHOSPHORUS
DEFICIENT
GRAPE
Image courtesy of
Potash & Phosphate
Institute

Potassium (K)
Essential Macronutrient

- For cold hardiness, disease resistance, and general durability
- Deficiency symptoms may include leaf curling, marginal necrosis, weakened root and stem systems
- Readily leached from and fixed by soils
- In fertilizers as **K_2 O (potash)**


Normal
K deficient
POTASSIUM DEFICIENT
CORN LEAVES
Image courtesy of Ray Weil
University of Maryland


POTASSIUM
DEFICIENT
SOY BEAN
Image courtesy of
Potash & Phosphate
Institute

Calcium (Ca)
Essential secondary macronutrient

- An essential part of plant cell wall structure
- Provides for normal transport and retention of other elements
- If sufficient K and Mg, then don't need to amend for Ca
- Sources are **dolomitic lime, gypsum, and superphosphate**

Bitter pit of apple due to calcium deficiency

Caliche soil

Calcareous soils

- A quick home test to check for free calcium carbonate is to add vinegar to a soil sample. If 'fizzing' is seen, free calcium carbonate is present.


CALCIUM
DEFICIENT
TOMATO
(blossom end rot)
Image courtesy
of the Potash
& Phosphate Instit.

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
- May come in chelated form


IRON
DEFICIENT
ROSE
Photo
courtesy of
Ray Weil
University
of Maryland


+Fe
-Fe
IRON
DEFICIENT
AZALEA
Photo
courtesy of
Ray Weil
University
of Maryland

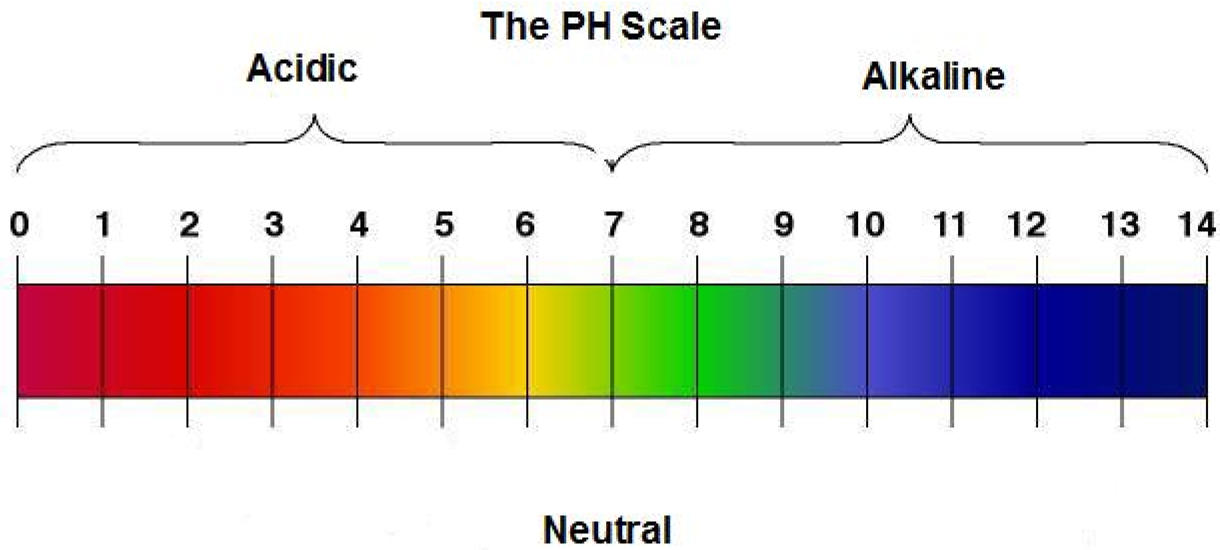
Cu vat for pickling

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–Soil Reaction

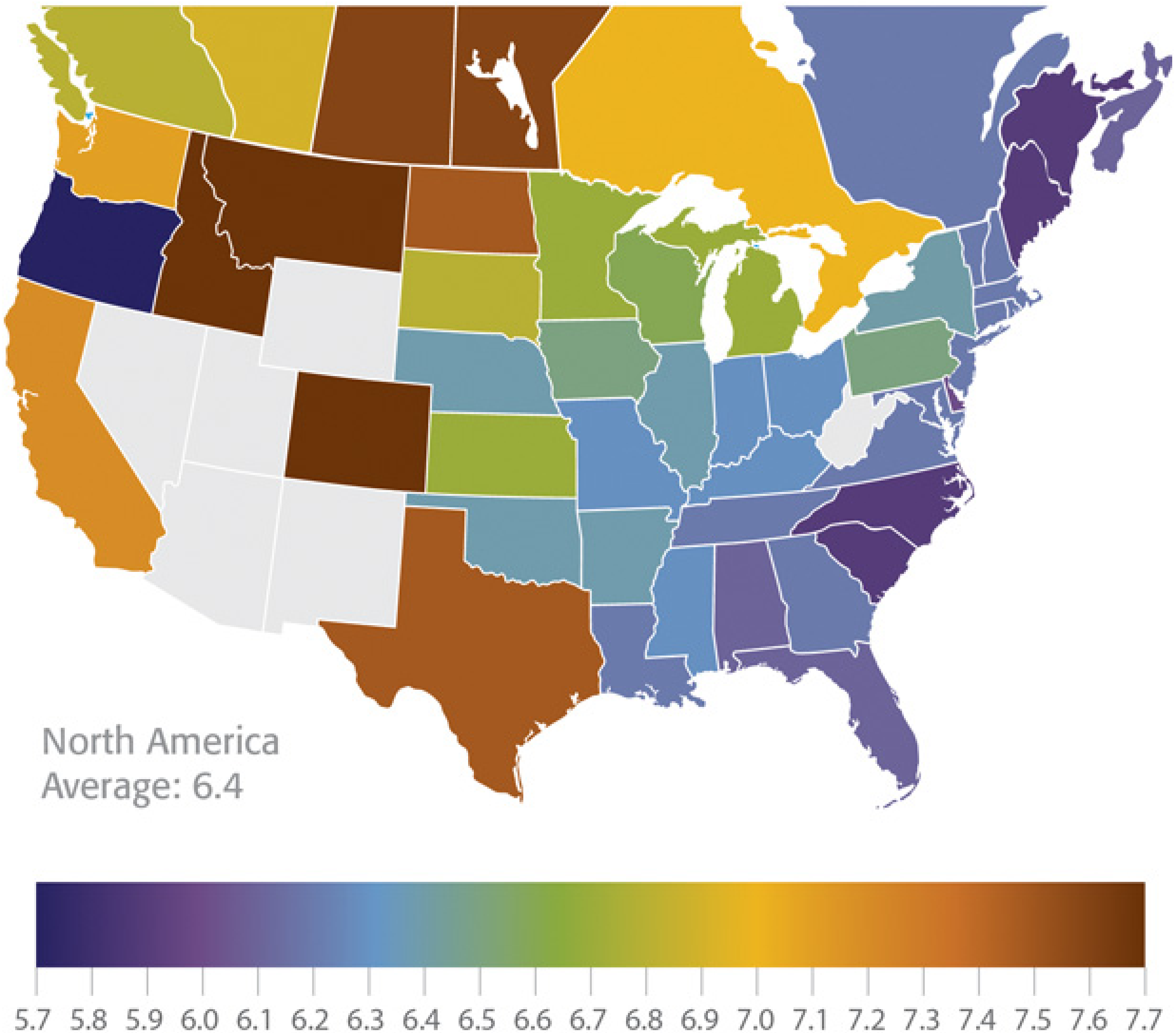
- pH is a measure of free hydrogen ions **H^+**
- Logarithmic scale (factor of 10)
- pH regulates nutrient availability
- Fungi tend to prefer acidic conditions 4 - 5
- Aluminum is a problem in very acidic soils



pH

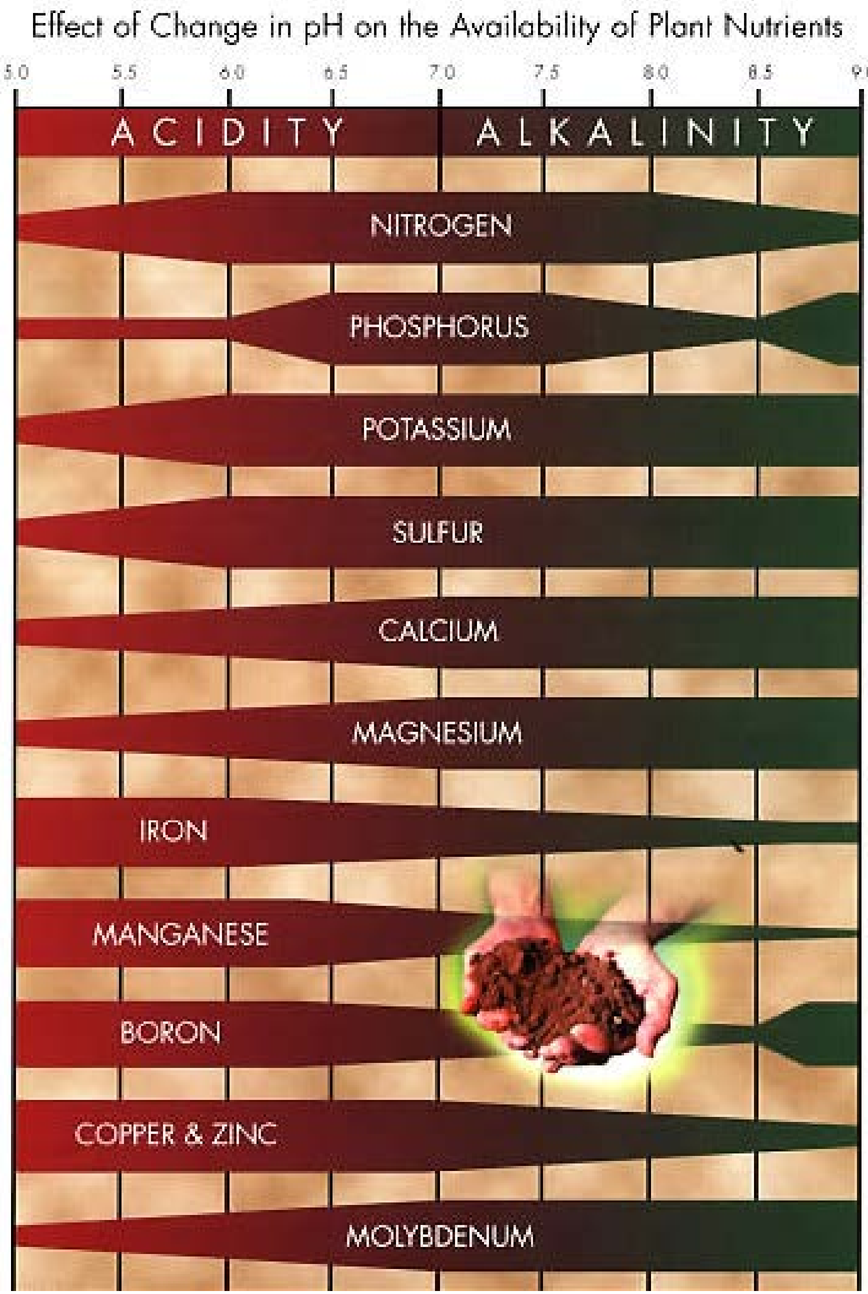
- Acid soils—high annual rainfall
- Adding limestone ($CaCO_3$) increases pH
- Adding sulfur or aluminum sulfate decreases pH
- Poor rainfall increases soil pH
- Most N fertilizers decrease pH
  - ammonium (NH_4^+) decreases pH
  - urea decreases pH (from ammonia and carbon dioxide)
  - nitrate (NO_3^-) increases pH
- **pH is very difficult to change**

MEDIAN SOIL pH



Values calculated in 2010 from 4.3 million samples.

Mosaic Co. Crop Nutrition

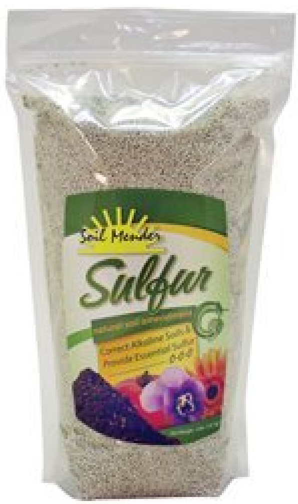

Effect of Change in pH on the Availability of Plant Nutrients
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
ACIDITY
ALKALINITY
NITROGEN
PHOSPHORUS
POTASSIUM
SULFUR
CALCIUM
MAGNESIUM
IRON
MANGANESE
BORON
COPPER & ZINC
MOLYBDENUM

Different forms of lime

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

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.

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.

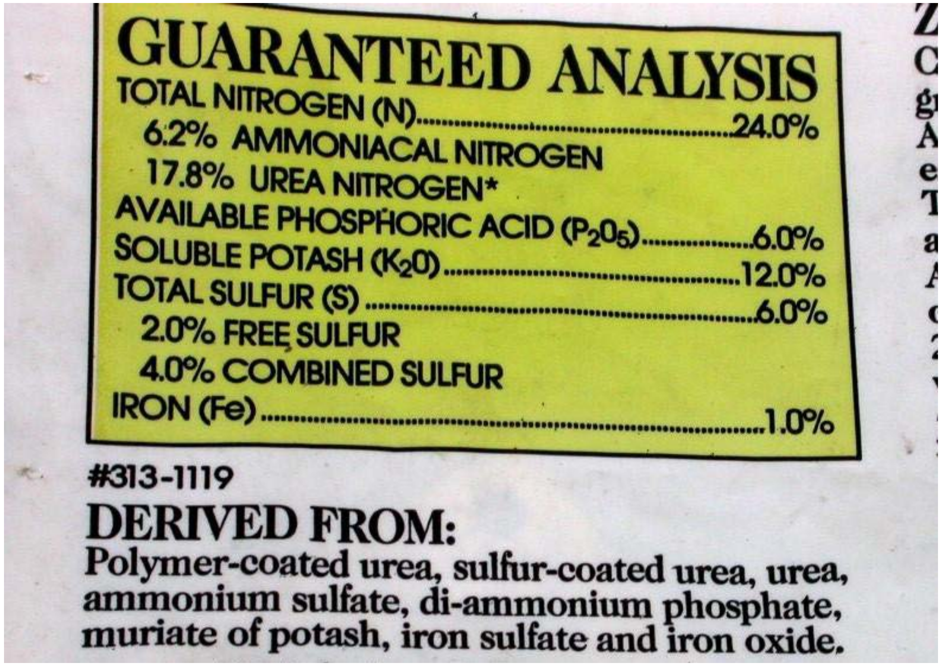
Inorganic Fertilizers

- 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

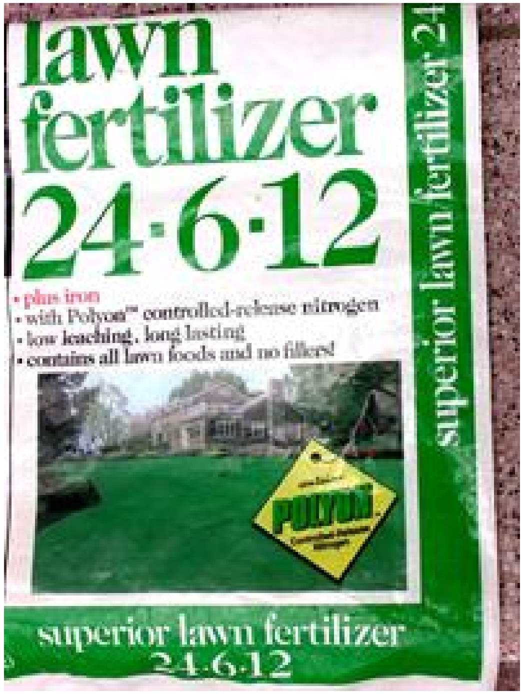


Fertilizer Nomenclature

- Fertilizer Analysis
  - N is NO_3^- or NH_4^+ (100%)
  - P is P_2O_5 (.49)
  - K is K_2O (.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 …

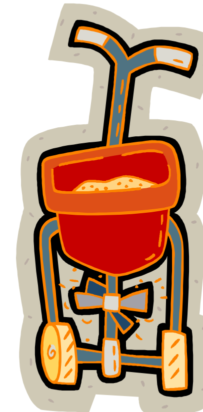
1. What is the analysis?
2. What is the ratio?
3. 8.2% ammoniacal N—change to pH?
4. 5.8% nitrate—change to pH?
5. 2% urea—change to pH?
6. Overall change to pH?
7. If the bag weighs 40 pounds, then how much actual N is in the bag?

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 X .16 = 6.4 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 = length X width
  - Triangle: A = (base X height) ÷ 2
  - Circle: $A = \pi r^2$

SAMPLE HISTORY

Sample ID	Field ID	LAST CROP Name	LAST CROP Yield	LAST LIME APPLICATION Months Prev.	LAST LIME APPLICATION Tons/Acre	SOIL INFORMATION 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

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 X 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 X 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