Soil Science for Master Gardeners

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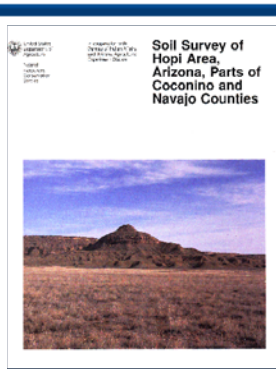
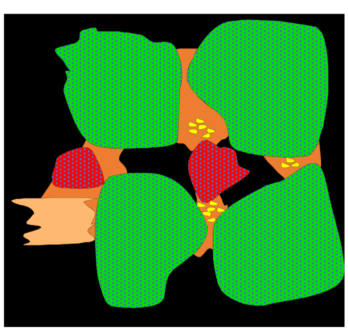
Soil Information Sources



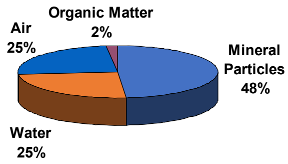
Soil Components

- Mineral Particles
  - sand
  - silt
  - clay
- Open Spaces (pores)
  - air
  - water
- Organic Materials
  - carbon-based



Composition of Soil by Volume

Pores can be filled with either air or water



Parent Materials

- Residual
  - rock weathered in place
  - organic deposits at soil surface
- Transported
  - gravity: colluvial
  - water: alluvial, marine, lacustrine
  - wind: eolian (loess)
  - ice: glacial

Factors of Soil Formation

- Parent materials (geological or organic soil precursors)
- Climate (especially rainfall and temperature)
- Biota (living organisms - vegetation, microbes, soil animals, human beings)
- Topography (configuration of soil surface)
- Time parent materials are subjected to soil formation processes

Weathering

- Physical weathering (disintegration)
  - heating/cooling
  - water, ice, wind abrasion
  - plants and animals
- Chemical weathering (chemical alteration)
  - hydrolysis (splitting by water)
  - hydration (combining with water)
  - acid weathering
  - oxidation

Soil Formation in Moist Environments

Water

Water transports clay particles, organic matter, salts

Water, Salts

Soil Formation in Arid Environments

Water

Water transports salts

Water, Salts

Soil Horizons

Soils develop horizontal layers, or horizons, as materials move through the soil profile



Soil Horizons

- A horizon
  - dark layer, high in organic matter
- E horizon
  - layer of leaching
  - depletion of organic matter, clays, iron & aluminum oxides
- B horizon
  - zone of accumulation
  - enrichment of organic matter, clays, iron & aluminum oxides
- C horizon
  - parent material

Soil Horizons

A

E

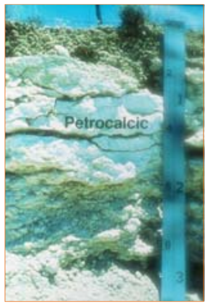
B

C

Arid Soil Horizons

Sodium chloride

Calcium carbonate (Caliche)



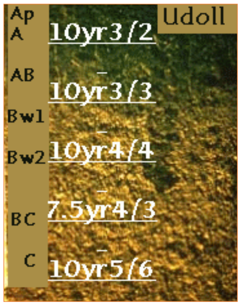
Soil Physical Properties

- Color
- Texture
- Structure
- Drainage
- Depth
- Surface features

Soil Color

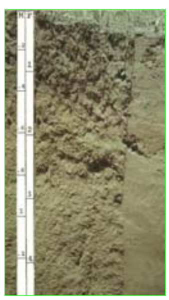
- Organic matter:
  - dark brown — High organic matter content
- Drainage conditions and degree of oxidation (weathering):
  - red-brown — Good drainage
  - yellow — Moderate drainage
  - gray — Poor drainage

Soil Color



Soil Color

Organic soil

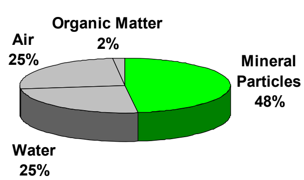


Young soil

Highly weathered soil

Mineral Particles

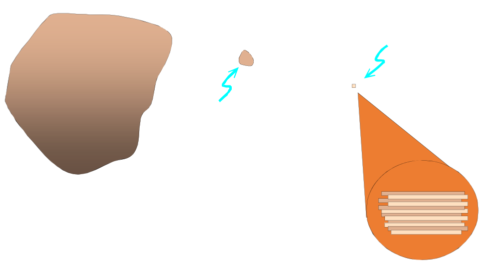
- Mineral Particles
  - sand
  - silt
  - clay
- Pore Spaces
- Organic Matter



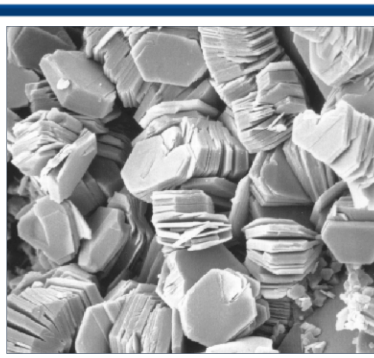
Soil Texture

- Soil texture is determined by the amount of sand, silt, and clay
  - excludes
    - organic matter
    - large particles (larger than 2 mm)
- Size of mineral particles
  - sand 2 to 0.05 mm
  - silt 0.05 to 0.002 mm
  - clay less than 0.002 mm

Relative Size of Soil Particles



Structure of Clay Particles



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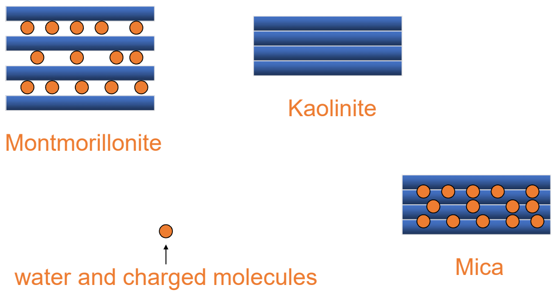


Specific Surface Area

Area per weight (square meters per gram)

- 1 gram sand ~ 0.1 square meter
- 1 gram silt ~ 1 square meter
- 1 gram clay ~ 10 to 1,000 square meters

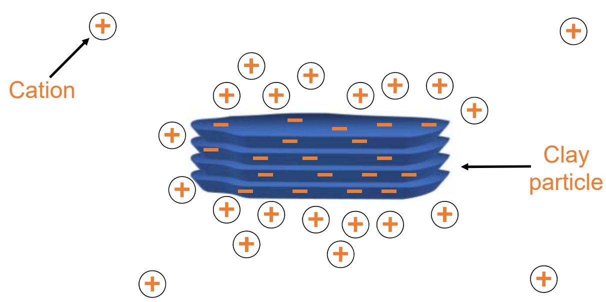
Particle Surfaces are Important

- Coated with water
- Electrically charged
- Sites for microbial growth
- Sites of chemical reactions
  - weathering
  - adsorption of chemicals
  - retention of nutrients
  - soil aggregate formation

Clay Particles have Electrical Charge

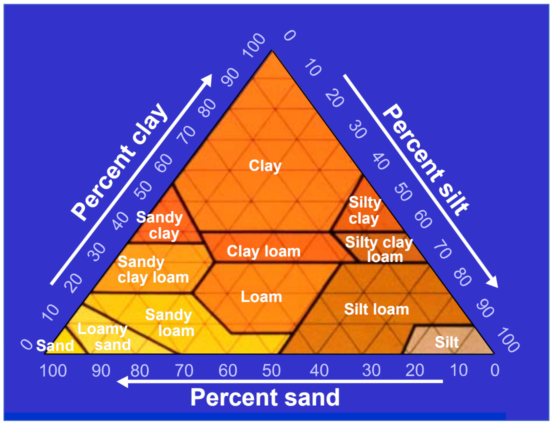
- Most clay particles are negatively charged
- Ions (charged molecules)
  - cations are positively charged ions
  - anions are negatively charged ions
- Cations are attracted to negatively charged clays
  - these cations are loosely held or exchangeable
  - this process is called cation exchange

Cation Exchange



Cation Exchange

- Exchangeable soil cations include
  - calcium, magnesium, potassium, ammonium, sodium
  - hydrogen, aluminum in acid soils
- Exchangeable cations can replace one another
- Exchangeable cations are available to plants, microbes, etc.
- The amount of exchange in a soil is called the Cation Exchange Capacity (CEC)

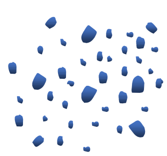


Soil Structure

- Soil particles are grouped in aggregates
- Aggregates
  - vary in size, shape, and strength
  - are promoted by
    - organic matter
    - calcium and other ‘flocculating’ cations
  - can be destroyed by tillage and traffic
  - allow movement of air, water, roots

Soil Aggregates

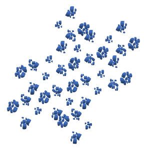
Single Grain



Individual grains not held together - common in sands

Soil Aggregates

Granular



Porous granules held together by organic matter and clay
- common in A horizons

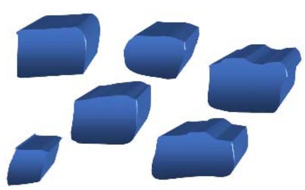
Soil Aggregates

Platy

Flat aggregates
- found in compacted layers and E horizons

Soil Aggregates

Blocky



Roughly equidimensional aggregates
- found in clayey B horizons

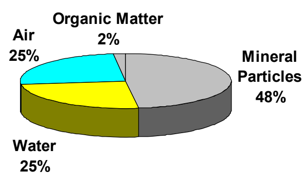
Soil Aggregates

Columnar
and
Prismatic

Vertical aggregates
- found in some B horizons

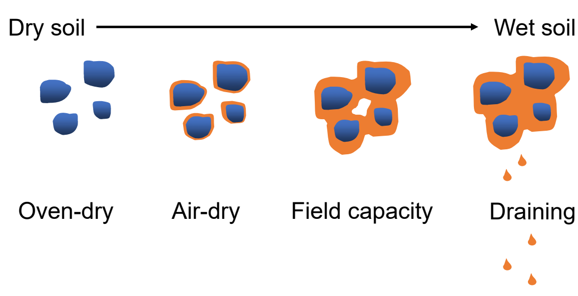
Soil Pores

- Mineral Particles
- Pore Spaces
  - water
  - air
- Organic Matter

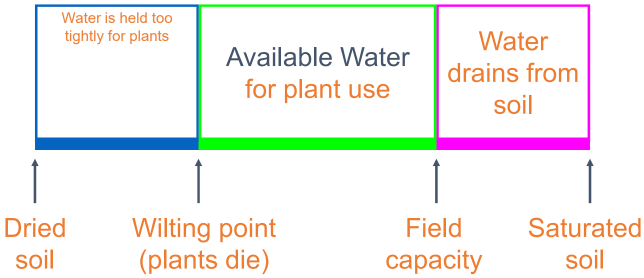


Soil Water

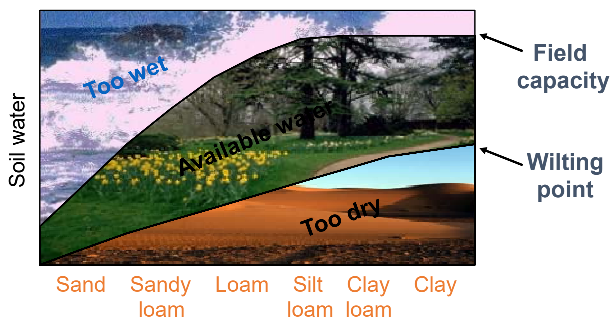
Water is attracted to particle surfaces



Available Soil Water

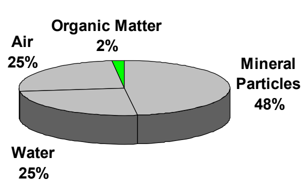


Soil Water



Organic Matter

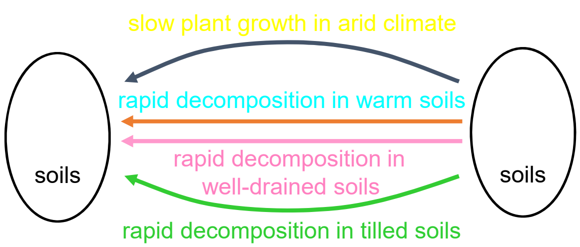
- Mineral Particles
- Pore Spaces
- Organic Matter
  - biological remains
  - less than1% to over 20%
    - most AZ soils have < 2%
  - energy-rich material
  - broken down by organisms to form
    - humus (improves structure and water-holding capacity)
    - soluble nutrients



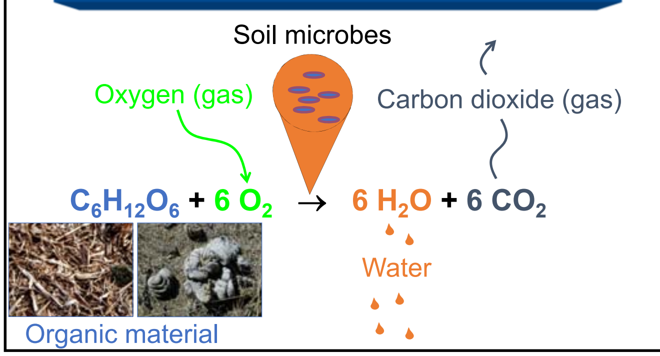
Organic Matter (OM)

- Soil structure
  - aggregate formation promoted by OM
  - OM increases water infiltration & water holding capacity
- OM increases cation exchange capacity
- OM can increase microbial activity
- Nutrients
  - OM provides a nutrient source
  - OM helps keep some nutrients available
- OM can retain pesticides

Organic Matter Content



Aerobic Respiration



Organic Materials in Soil

- Organic materials are decomposed by soil microbes
  - carbon (C) in organics used for substrate and energy
  - nitrogen is also required
    - about $^1/_{10}$ as much N as C is needed
    - C:N ratio of 10:1
- Organics with C:N ratios greater than about 10:1 require additional N

C:N of Some Organic Materials

Material	C:N ratio

Managing Organic Amendments

- High C:N ratio organics
  - add adequate N during soil application
  - compost
    - to reduce C:N ratio
    - to eliminate weed seeds
- Low C:N ratio organics
  - add directly to soil
  - watch for "burning" by high N organics
- High O_2 consumption
  - anaerobic conditions in poorly aerated soils

Plant Nutrients

What's in a plant?

- Carbon (C) 45%
- Hydrogen (H) 6%
- Oxygen (O) 43%

- Nitrogen (N) 1 to 6%
- Phosphorus (P) 0.1 to 1%
- Potassium (K) 1 to 6%
- Calcium (Ca) 0.1 to 4%
- Magnesium (Mg) 0.1 to 2%
- Sulfur (S) 0.1 to 1.5%

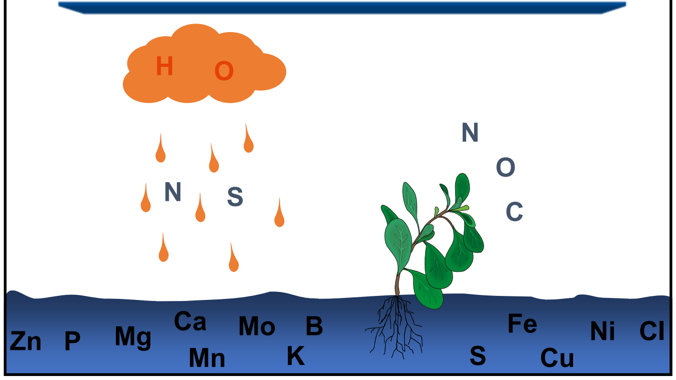
These are called *Macronutrients* because plants need relatively large amounts of them

Plant Nutrients

Micronutrients (measured in parts per million or ppm)

- Iron (Fe) 10 to 1000
- Manganese (Mn) 10 to 1000
- Molybdenum (Mo) 0.1 to 10
- Chlorine (Cl) 100 to 30,000
- Copper (Cu) 2 to 50
- Boron (B) 2 to 75
- Zinc (Zn) 10 to 100
- Nickel (Ni) 0.1 to 1

Sources of Plant Nutrients



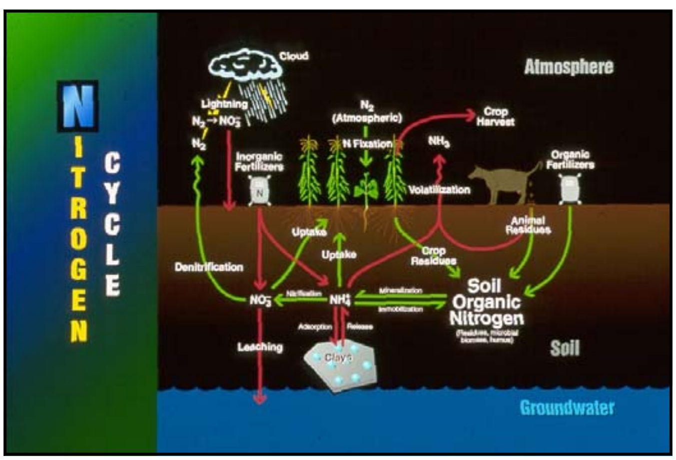
Primary Nutrients

- The three nutrients that most often limit plant growth
  - nitrogen (N)
  - phosphorus (P)
  - potassium (K)

Nitrogen

- Nitrogen deficiency symptoms

- yellow or reddish leaves
- leaf tips & margins yellow and die starting with oldest leaves
- stunted plants



Phosphorus

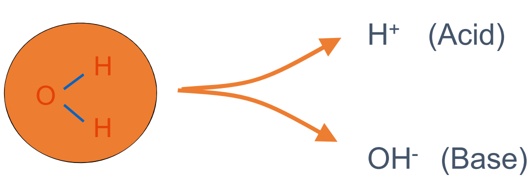
- Phosphorus deficiency symptoms
  - purplish foliage - oldest leaves first
  - slow growth, stunted plants
  - dark green coloration
  - delayed maturity

Potassium

- Potassium deficiency symptoms

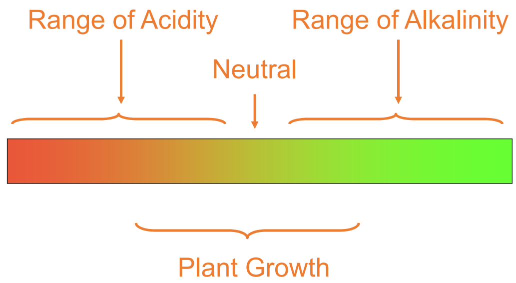
- leaf tips and margins ‘burn’ - oldest leaves first
- plants have weak stalks
- small fruit or shriveled seeds
- slow growth

Acidity

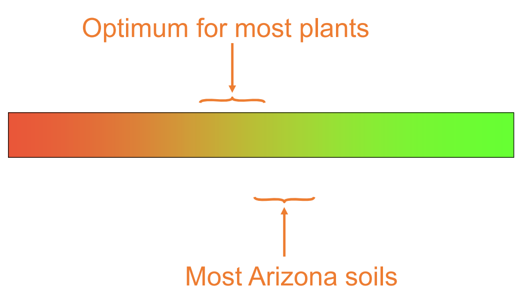


The pH scale

Each pH unit is 10 times more acid or alkaline than the next unit



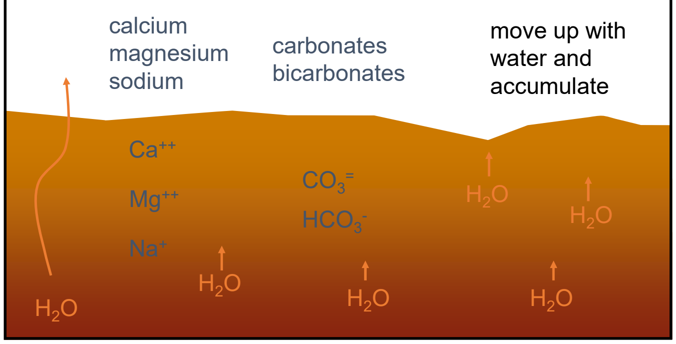
Soil pH



Soil pH

- Alters nutrient availability
- Affects microbial activity
  - Can affect disease susceptibility

Alkalinity in Arid Soils



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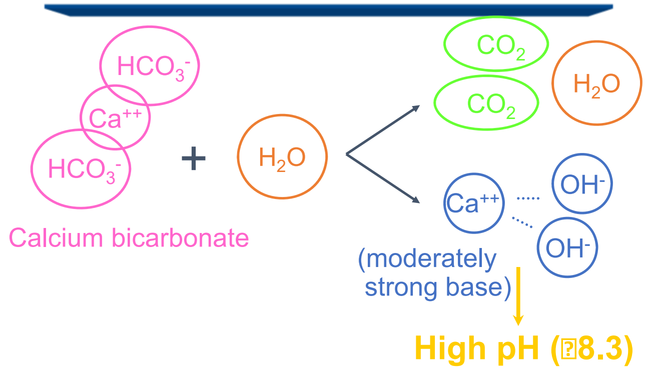
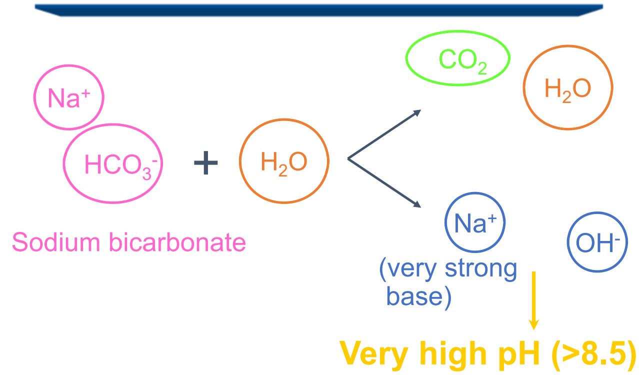
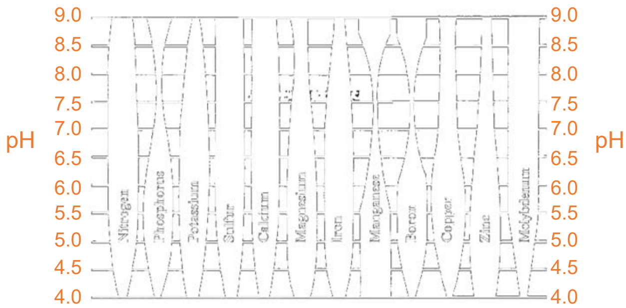


Alkalinity in Sodic Soils



Effects of pH on Nutrient Availability

The thicker the bar, the more available the nutrient



Iron Chlorosis

Iron deficiency appears on youngest leaves of plants growing in alkaline soils

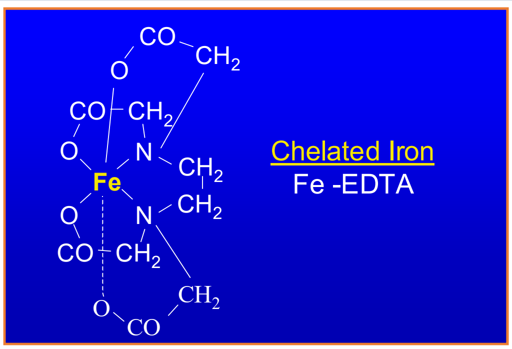
Treating Soil Alkalinity

- Acidify the soil
  1) sulfuric acid
     H_2SO_4
  2) sulfur (biological reaction)
     $2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4$
  3) aluminum sulfate:
     $Al_2(SO_4)_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2SO_4$
- NOTE: gypsum ($CaSO_4$) is NOT an acidifying compound and will not lower pH of most soils!

Fertilizing Alkaline Soils

- Apply nutrients to high pH soils
- Metal nutrients are insoluble in alkaline soils
  - iron, manganese, zinc
- Use chelated forms
  - more soluble than unchelated forms
  - stay in solution longer
  - more available to plants

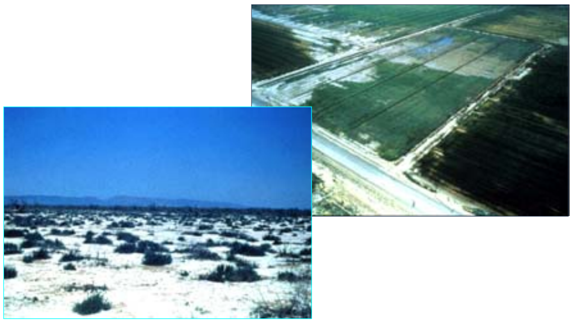
Chelates



Treating Plants in Alkaline Soils

- Apply nutrients directly to plant foliage
  - Iron, Copper, Zinc
    - use sulfate salts
      - iron sulfate
      - copper sulfate
      - zinc sulfate
    - use chelated forms
      - EDTA
      - DTPA
      - others

Salts and Soil



Salt-Affected Soils

- Salt-affected soils
  - Occur naturally in arid climates
  - Can be formed by addition of salts in irrigation water

Water Transports Salts

Salt-Affected Soils

Saline - excess salts
good structure
moderate pH

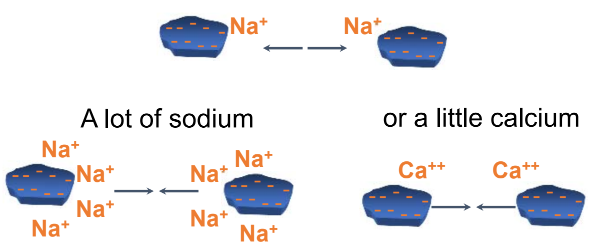
Saline-sodic
excess salts
excess Na
good structure
high pH

Sodic - excess Na
poor structure
high pH (>8.5)

Salts Affect Soil Structure

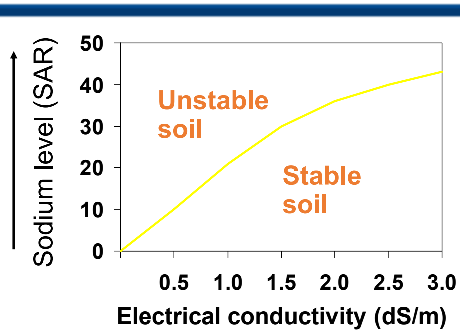
A little sodium makes particles repel one another.

A lot of sodium or a little calcium



make particles attract one another.

Salts Affect Soil Structure



Tests for Soil Salts

- Measuring total soil salts
  - EC - electrical conductivity
- Measures of the amount of sodium
  - SAR - sodium adsorption ratio
  - ESP - exchangeable sodium percentage

Classifying Salt-Affected Soils

Measurement	Normal	Saline	Sodic	Saline-Sodic
EC (dS/m)	<4	>4	<4	>4
ESP	<15	<15	>15	>15
SAR	<13	<13	>13	>13

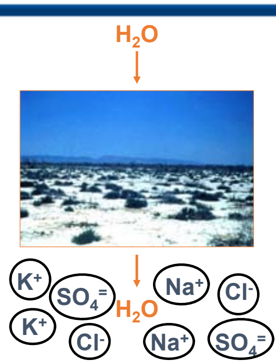
Electrical Conductivity (EC)

EC (dS/m)	Plant response

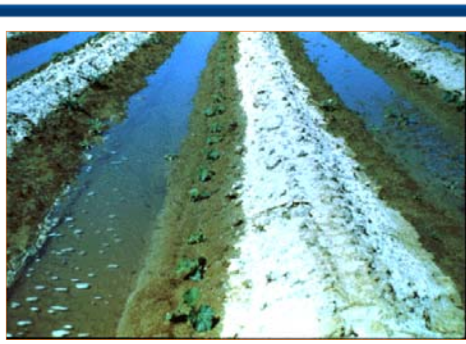
Salt-Affected Soils

- Plant age affects tolerance to salts
  - Seedlings are most sensitive
  - Mature plants are least sensitive
- Different plant parts may be variably affected
  - Seeds
  - Vegetation
- Plant species vary in salt tolerance

Managing Non-Sodic Saline Soils



Avoiding Salts



Sodium-Affected Soils

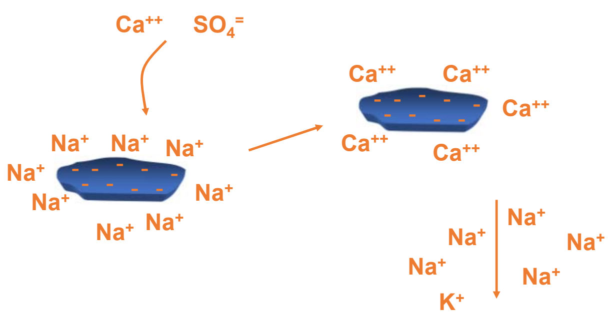
- Poor structure
- Poor drainage
- May have surface cracking when dry
- Very high pH (>8.5)

Managing Sodic Soils

1. Stabilize structure by adding gypsum ($CaSO_4$) to replace Na^+ with Ca^{2+}
2. Reduce salt level by flushing with water to wash out Na^+ and excess gypsum*

*may be very difficult in soils with poor structure!

Managing Sodic Soils

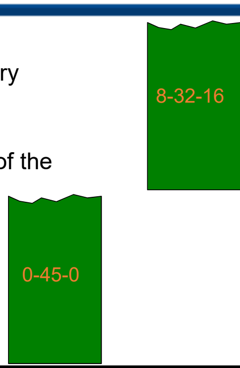


Fertilizers

- Label must contain percent (by weight) of
  - total nitrogen (N)
  - available phosphate (as P_2O_5)
    - P_2O_5 times 0.43 = P
  - soluble potash (as K_2O)
    - K_2O times 0.83 = K
- Other nutrients may be specified

Types of Fertilizer

- Complete
  - contains all three primary nutrients (N, P and K)
- Incomplete
  - is missing at least one of the primary nutrients



Common incomplete fertilizers

Fertilizer	N	P_2O_5	K_2O

Slow-release fertilizers

- Release nutrients (usually nitrogen) over a long period of time
  - slowly soluble materials
    - urea formaldehyde
  - granules coated with resins or sulfur
    - sulfur-coated urea
    - Osmocote®
  - materials that must decompose to release nutrients
    - organic fertilizers

Organic fertilizers

- Remains or by-products of plants or animals
  - cottonseed meal
  - blood meal
  - fish meal
  - manures
- Relatively low nutrient contents
- Contain micronutrients
- Slow release
- Low burn potential
- Condition soil by adding organic matter

Typical composition of organic fertilizers

	% Moisture	N	P	K
		(% of dry weight)		
Chicken				
Cattle				
Hog				
Horse				
Sheep				
Municipal solid waste compost				
Sewage sludge				

Fertilizer formulations

- Fertilizers can be combined with herbicides
  - common in turf formulations
- Fertilizers
  - granular solids
  - slow-release granules
  - liquids/water soluble powders
  - slow-release spikes/tablets

Fertilizers are salts

Material	Nutrient level	Relative saltiness
Ammonium nitrate		
Ammonium sulfate		
Potassium nitrate		
Urea formaldehyde		
Urea		
Single superphosphate		
Potassium chloride		
Potassium sulfate		
Epsom salts		

Avoiding fertilizer burn

- Do not over-apply fertilizers
  - particularly nitrogen fertilizers
- Make sure adequate moisture is present after applying fertilizer
- Periodically flush soluble salts from soil
  - make sure adequate drainage is available
  - irrigate 2 to 3 times as long as normal every 6 to 8 weeks to flush salts from soil

Soil Testing

Available nutrients
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Nitrogen
- Sulfur
- Micronutrients

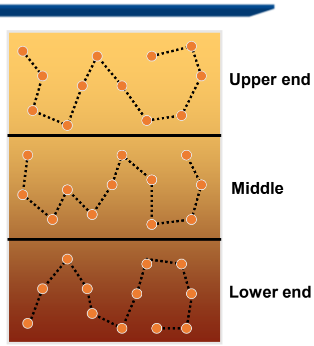
Soil properties
- Texture
- pH
- Cation Exchange Capacity (CEC)
- Electrical Conductivity (EC)
- Sodium Adsorption Ratio (SAR) or Exchangeable Sodium Percentage (ESP)

Soil Sampling

- Obtaining a representative sample is the critical step in soil analysis
  - A 1 cup sample from a 1,000 square foot field is 1/100,000 of the field!
- A good soil sample
  - made up of 15 to 25 cores or subsamples
  - never take less than 5 subsamples

Soil Sampling

- Divide fields into uniform areas for sampling
  - soil type
  - slope
  - degree of erosion
  - cropping/use history
  - growth differences



Soil Sampling

- Sample to the proper depth
  - usually eight inches
- Make sure soil cores represent sampled area
  - mix individual cores thoroughly to make sample
- Time of sampling
  - depends on analyses, field operations, etc.
- Sampling tools
  - soil probe or sampling tube is best

Soil, Water and
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