Soils and Fertilizers

Leo Espinoza
Soils Specialist
What is soil?

A collection of organic and inorganic bodies on the earth’s surface, modified by the surrounding environment or even made by humans, with characteristic chemical, physical and biological properties...
Major Soil Components

 Minerals
Mineral soils <20% OM by weight.

 Organic matter
Organic soils >20% OM by weight; 50% by volume.

 Air

 Water
Major Land Resources in Arkansas

49 soil associations
Pedon, Polypedon, and Soil Horizons

Factors that Distinguish Soil Horizons:
- Color
- Texture
- Structure
- Consistence
- Porosity
- Mineral Content
- Moisture
- Chemical Processes

Eluviation or Dissolution:
- O, A, E horizons

Illuviation or Deposition:
- B Horizon

Figure 18-1 The Pedon, the soil sampling and mapping unit.
Major Soil Properties

- **Soil Physical Properties**
  - Color, Texture, Structure, Density, Water holding capacity, Aeration.

- **Soil Chemical Properties**
  - pH, Mineralogy, Clay chemistry, Cation Exchange Capacity, Base Saturation.

- **Soil Biological Properties**
  - Organic matter, Organisms
Soil Texture

Size distribution of primary soil particles. The amount of sand, silt, and clay a soil contains.

Three large groups by texture are sands, loams, and clays
Relative Size of Soil Particles

- Clay: <0.002 mm
- Silt: 0.05-0.002 mm
- Sand: 2-0.05 mm
Soil Pore Space

- Sandy soils 35-50% pore space
- Clayey soils 40-60% pore space.
- Very compacted zones 25-30%.
Texture Triangle

Silt  30%
Sand  40%
Clay  30%

Physical properties
Soil Properties - Structure

Figure 18-5: Types of Soil Structure.
Significance of Structure

�认为

Soil structure influences:

a.) water conductivity
b.) root penetration
c.) air movement
Soil Water

- Requirements for crop growth.
- The solvent from which plants absorb nutrients.
- Influences soil aeration and temperature.
- Influences erosion.
Soil Moisture “Terms”

Maximum Retention Capacity  
(Gravitational Water)

Field Capacity (Available Water)

Wilting Coefficient (Permanent Wilting Point)

Hygroscopic Coefficient (Hygroscopic Water)
Terms to Describe Soil Moisture

Saturation

Field Capacity

Wilting Point

Inches / ft
Sand: 1 - 1.4
Silt: 2.5 - 2.9
Clay: 3.5 - 3.9

Inch / ft
Sand: 0.2 - 0.4
Silt: 0.9 - 1.1
Clay: 1.5 - 1.7
Major Soil Properties

 DisplayName

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Soil pH

Soil pH is a measure of the H+ ion activity or concentration in soil solution.
Soil pH Classification

Soils with pH < 5.0:
- Strongly acid -- corrective treatment is needed immediately for most crop production.

Soils with pH between 5.0 and 5.5:
- Moderate acid -- need corrective treatment, but crops will grow.

Soils with pH between 5.5 and 6.5:
- Optimum for most crops

Soils with a pH range of 6.5 to 7.0:
- Near neutral

Soils with a pH > 7.0:
- Neutral to alkaline.
The pH Scale

Optimum for Most Crops

1  2  3  4  5  6  7  8  9  10  11  12  13  14

Increasing Acidity

Increasing Alkalinity
Soil pH and Micronutrient Availability

- pH
- Fe, Mn
- Mo
- Cu
- B
- Zn
How do we correct soil pH problems?

**Acidic pHs (< 5.5):**
Lime is applied to raise the pH to optimum levels.

**Alkaline pHs (>7.5):**
Sulfur can be used.
Acid forming fertilizers may help lower the pH, but most alkaline soils resist any changes in pH.
How do we correct acidic soil pH problems?
Several materials are available, with each material being compared to calcium carbonate.

Calcium carbonate is assigned a value of 100.
<table>
<thead>
<tr>
<th>Material</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure CaCO₃</td>
<td>100</td>
</tr>
<tr>
<td>Ag Lime</td>
<td>90-100</td>
</tr>
<tr>
<td>Dolomitic lime</td>
<td>95-108</td>
</tr>
<tr>
<td>Burned lime</td>
<td>150 – 175 (Toxic)</td>
</tr>
<tr>
<td>Boiler wood ash</td>
<td>30 - 60</td>
</tr>
</tbody>
</table>
Fineness Factor

- Will react slowly with soil particles.
- Will react fast with soil particles.
Cation Exchange Capacity (CEC)

- The ability of a soil to retain positively charged ions (cations).

- Clays and soils are generally negatively charged and attract cations (K, Ca, Mg...).
Organic matter increases significantly the Cation Exchange Capacity of a soil.
Percent Base Saturation

- The ratio of “basic” cations to the total soil cations. (i.e., $H^+$ and $Al^{+3}$)

Generally, as %BS increases, pH increases for a soil, and over a large number of soils.

A base saturation $>15\%$ is ideal.
Major Soil Properties

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Major Soil Microorganisms

- **Fungi**
  - (yeasts, molds, mycorhizae, mushrooms)

- **Algae**
  - (Green, Cyanobacteria)

- **Actinomycetes**

- **Bacteria**
  - (aerobic, anaerobic, facultative)
## Soil Microflora Per Gram Soil

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Bacteria</th>
<th>Actinomycetes</th>
<th>Fungi</th>
<th>Algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-8</td>
<td>9.8 mill</td>
<td>2.1 mill</td>
<td>119,000</td>
<td>25,000</td>
</tr>
<tr>
<td>20-25</td>
<td>2.2 mill</td>
<td>245,000</td>
<td>50,000</td>
<td>5,000</td>
</tr>
<tr>
<td>35-40</td>
<td>570,000</td>
<td>49,000</td>
<td>14,000</td>
<td>500</td>
</tr>
</tbody>
</table>

*Biological properties*
Important Bacterial-Driven Processes

- $\text{N}_2$ fixation by Legumes
- Sulfur oxidation
- Nitrification (N Mineralization)
Soil Organic Matter
Influence of SOM on Soil Physical and Chemical Characteristics

- **Color**: The dark color is the result of SOM for most soils (but may also be related to manganese)
- **Granulation**: SOM increases granular structure
- **Cation Exchange Capacity**: SOM increases CEC
Influence of SOM on Soil Physical and Chemical Characteristics

Nutrient Supply:
- Exchangeable cations
- N,P,S, and micronutrients in organic forms released through mineralization
- Acidity from SOM dissolves primary minerals releasing nutrients e.g. K from feldspars, Ca from limestone

Aggregate Stability: SOM increases aggregate stability

Water Holding Capacity: SOM increases water-holding capacity
General Plant Nutrition
General Plant Nutrition

**Essential element:** A chemical element necessary for the normal growth of plants

**Categories of essential elements:**

1. Macronutrients
   a. Secondary
2. Micronutrients
Nutrients Required for Plant Growth

**MACRONUTRIENTS**

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Carbon (C)
- Hydrogen (H)
- Oxygen ($O_2$)

**Secondary**

- Calcium (Ca)
- Magnesium (Mg)
- Sulfur (S)

**MICRONUTRIENTS**

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

“Plant production can be no greater than that allowed by the growth factor present in the lowest amount relative to the optimum amount for that factor”.

Growth factors may include:
- essential nutrients
- Water
- oxygen/carbon dioxide
- Temperature
- others
Role of Nutrients in Plants

Nitrogen is a major part of all amino acids, which are the building blocks of proteins. N is the nutrient used in largest amounts by plants, providing plants a deep green color.
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**P** Phosphorus is an essential component of ATP, the energy currency of cells. This is the energy that regulates most enzymes in plants and animals. P is also a component of DNA.

**K** Potassium activates many enzymes inside plants. A good supply of K is important for drought conditions. Winter hardiness.
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Role of Nutrients in Plants

Ca  Component of cell walls, plays a role in the permeability of membranes.

Mg  Constituent of Chlorophyll and enzyme activator.

S   Constituent of some plant proteins.

Micronutrients

In general, micronutrients are involved in the activation of enzymes within a plant. Enzymes regulate most reactions in plants.
How are fertilizer recommendations made?

1. A representative soil sample is collected, with the recommendation being as good as the quality of the sample collected.

2. The soil sample is analyzed for available nutrients following standard procedures.

3. The soil test is analyzed and a fertilizer recommendation is generated. Recommendations are based on research conducted under variable weather and soil conditions.
Collecting a representative soil sample...
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Different soil test laboratories may recommend different amounts of fertilizer for the same soil and crop.

Labs may use different extractant solutions. Labs may follow different philosophies.
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Philosophies of Soil Testing

“Fertilize the crop”: Apply only enough fertilizer to produce optimum yields for the current year and no additional amounts for maintenance or increasing soil fertility.

“Fertilize the soil”: Apply enough fertilizer to produce optimum yields for the current year but also add an additional amount for maintenance or increasing soil fertility.
Units and Conversions

- **ppm** = parts per million (soil analysis)
- **mg/l** = miligrams per liter (water analysis)
- **lb/A** = pound per acre (soil analysis)

1 ppm = 1 mg/l

1 ppm ~ 2 lb/A

If a soil test reports 10 ppm K, this is equivalent to Approx 20 lb/A
A soil test is an index of the availability of nutrients for plant uptake. A routine soil test measures only a portion of the total pool of nutrients in the soil. The release of native nutrients and the “tie-up” of nutrients added from manures, fertilizers, compost and plant residues involve complex soil chemical and microbiological processes. This explains why the soil test will not normally reflect a “pound-for-pound” increase with addition of a nutrient. For example, a 5-10-10 package of fertilizer might only increase levels of the soil type or cation exchange capacity of the soil, the crop and yield expected, the time of year and the cultural and other practices to be followed.

The following discussions should help you understand your soil test report. The interpretations provided apply only to routine tests conducted by the University of Arkansas soil testing laboratory and should not be used to interpret information provided by other laboratories. See...
Fertilize Your Lawn – Keep It Green and Growing

Stanley L. Chapman
Extension Soils Specialist

Timely fertilization helps keep lawn grasses green and growing. Weeds in lawns are one result of sparse, unfertilized turf. For the average lawn, you need to buy at least 150 pounds of mixed fertilizer and about 100 pounds of ammonium nitrate or urea yearly. In so doing, you can make your lawn a source of pride for the entire family and also enhance your community environment. Keep your lawn well fed by following these simple instructions.

composting them before returning to the lawn. Requirements for phosphate and potash may be reduced after several years of returning clippings to the soil. Nitrogen needs may also be reduced, but probably not to the same extent as phosphorus and potassium.

If possible, fertilizer and lime recommendations should be based on a soil test. In lieu of a soil test, fertilize according to the following guidelines.
# Soil Analysis Report

**UNIVERSITY OF ARKANSAS**

Cooperative Extension Service

Soil Testing And Research Laboratory

Marianna, Arkansas 72360

http://www.uark.edu/depts/soiltest

**Lab No:** 4560  
**Sample No:** 333401  
**County:** Dallas  
**Date Processed:** 1/24/02  
**Soil Association:** 42  
**Acres in Field:** 1  
**Soil Texture:** Sand  
**Irrigation:**  
**Field ID:** GARDEN

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.8</td>
</tr>
<tr>
<td>salinity-EC</td>
<td>60</td>
</tr>
<tr>
<td>OM</td>
<td>11</td>
</tr>
<tr>
<td>CEC</td>
<td>81.9</td>
</tr>
<tr>
<td>K sat</td>
<td>2.7</td>
</tr>
<tr>
<td>Mg sat</td>
<td>6.1</td>
</tr>
<tr>
<td>Na sat</td>
<td>0.6</td>
</tr>
<tr>
<td>P</td>
<td>128</td>
</tr>
<tr>
<td>K</td>
<td>230</td>
</tr>
<tr>
<td>Ca</td>
<td>3210</td>
</tr>
<tr>
<td>Mg</td>
<td>162</td>
</tr>
<tr>
<td>Na</td>
<td>31</td>
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<tr>
<td>Fe</td>
<td>129</td>
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<td>NOS-N</td>
<td>15</td>
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<td>SO4-S</td>
<td>114</td>
</tr>
<tr>
<td>Cu</td>
<td>1.6</td>
</tr>
<tr>
<td>Zn</td>
<td>11.8</td>
</tr>
<tr>
<td>B</td>
<td>0.1</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Last Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>GARDEN GROUP 2: SOUTHERN PEAS, PEANUTS, SWEET POT., ALL BEANS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>0 lb</td>
</tr>
<tr>
<td>P2O5/A</td>
<td>0 lb</td>
</tr>
<tr>
<td>K2O/A</td>
<td>0 lb</td>
</tr>
<tr>
<td>Lime/A</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**110240** Mix into the soil 6 lbs. (3 quarts) of 12-12-24 or equivalent per 1000 sq. ft. at early seedbed preparation; or 2 lbs. (4 cups) per 100 ft. of row at planting.
Crop 1  |  GARDEN GROUP2: SOUTHERN PEAS, PEANUTS, SWEET POT., ALL BEANS
--- | ---
**Recommendation** | 352 | 0 | lb N/A | 0 | lb P2O5/A | 0 | lb K2O/A | 0.0 | ton Lime/A

110240 Mix into the soil 6 lbs. (3 quarts) of 12-12-24 or equivalent per 1000 sq. ft. at early seedbed preparation; or 2 lbs. (1 cup) per 100 ft. of row at planting.

110250 Sidedress Irish Potatoes and beans with 0.5 lbs. (1 cup) of ammonium nitrate or equivalent per 100 ft. of row after stand is established.

110016 Use the appropriate seed inoculant at planting if no legume has been previously grown on this site.

Enclosure Note: H007, FSA7510

---

Crop 2  |  GENERAL GARDEN - ALL CROPS (EXCEPT LEGUMES & SWEET POTATOES
--- | ---
**Recommendation** | 353 | 0 | lb N/A | 0 | lb P2O5/A | 0 | lb K2O/A | 0.0 | ton Lime/A

110140 Mix into the soil 12 lbs. (6 quarts) of 12-12-24 or equivalent per 1000 sq. ft. at early seedbed preparation; or 3.5 lbs. (7 cups) per 100 ft. of row at planting.

110190 Sidedress with 0.75 lbs. (1.5 cups) of ammonium nitrate per 100 ft. of row 3 weeks after planting or at flowering for cucurbits.

110016 Use the appropriate seed inoculant at planting if no legume has been previously grown on this site.
What is in a Fertilizer Label?

Fertilizer Classification

Fertilizers are classified according to the presence of nitrogen, phosphorus, and potassium.
What is in a Fertilizer Label?

8 – 8 – 5

8 lb $\text{N}$ per 100 lb of material
8 lb $\text{P}_2\text{O}_5$ per 100 lb of material
5 lb $\text{K}_2\text{O}$ per 100 lb of material
Chemical sources:

Complete formulas: 12-24-12
13-13-13

Single element 0-0-60

Organic sources:

Compost
Poultry litter
Manure
Sewage Sludge
What is the difference between chemical and organic sources?

Organic sources release nutrients slowly.

Chemical sources are readily available for plant roots.

We can make our own organic fertilizer by Composting food “leftovers.”
## Composting

### Typical Composition of Municipal Waste Compost

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic-N</td>
<td>1.2%</td>
<td>P</td>
<td>0.7%</td>
</tr>
<tr>
<td>K</td>
<td>0.5%</td>
<td>Ca</td>
<td>3.5%</td>
</tr>
<tr>
<td>Mg</td>
<td>0.5%</td>
<td>Fe</td>
<td>1.8%</td>
</tr>
</tbody>
</table>
An example...
How Much Fertilizer to Apply?

- Lawn is 4000 square feet
- Need to apply 1 lb of nitrogen per 1000 square feet
- Fertilizer that will be used is (13-13-13)
Applying Fertilizer (continued)

- 100 lb of material contain 13 lb of N
- Therefore, @ 8 lb of material supplies about 1 lb of actual nitrogen
- Rate is 1 lb per 1,000 square feet
- 8 lb 13-13-13 per 1000 ft
- 32 lb 13-13-13 per 4000 square
Amount of nitrogen fertilizers needed to supply 4, 2, and 1 lb. of actual nitrogen per 4000 square feet.

<table>
<thead>
<tr>
<th></th>
<th>4 lb</th>
<th>2 lb</th>
<th>1 lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea (45-0-0)</td>
<td>32</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Ammonium nitrate (33-0-0)</td>
<td>48</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Ammonium sulfate (21-0-0)</td>
<td>80</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>10-10-10</td>
<td>160</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>13-13-13</td>
<td>128</td>
<td>64</td>
<td>32</td>
</tr>
</tbody>
</table>
What is wrong with this picture?
Mineralization/Immobilization

**Immobilization** The conversion of an element from the inorganic form to the organic form in microbial tissues, thus rendering the element temporarily unavailable to plants or other organisms.

**Mineralization** Process of conversion of organic materials to inorganic materials, thus rendering the element available to plants or other organisms.

**Major Nutrients Involved:** N, P, S
## Mineral Soil Particles

<table>
<thead>
<tr>
<th>Particle Size</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>&gt; 2.0</td>
</tr>
<tr>
<td>Sand</td>
<td>2.0 - 0.05</td>
</tr>
<tr>
<td>Silt</td>
<td>0.05 - 0.002</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt; 0.002</td>
</tr>
</tbody>
</table>
Most C and N in soils is associated with SOM. The amount of decomposition and subsequent N released will depend upon the C/N ratio of the residue or the soil.

Soils usually have C/N between 8:1 and 15:1.

Plant tissues/residues have high C/N ratios:
- Legumes 20:1 to 30:1
- Straw (wheat, rice, etc.) 100:1
- Woodchips, sawdust, etc. 400:1
What is in a Fertilizer Label? Cont...

However,

Fertilizer is not sold as N, P$_2$O$_5$, or K$_2$O,

Instead they are sold as:

- Nitrate and Ammonium for N
- Phosphates for P
- Typically as KCl for K
Composting

Composting is the biological decomposition of organic matter.

Microorganisms, worms and insects break organic materials into compost.

Compost contains nutrients that, when returned to the soil, are used by plants. This is nature’s way of recycling.
Compost improves the structure of soils, especially soils high in clay, by adding organic matter.

Compost is a soil conditioner. It slowly releases plant nutrients.

Compost improves soil health by promoting the growth of beneficial microorganisms.

Compost conserves water by increasing the ability of a soil to hold water, and reducing soil lost by erosion.

Arkansas Act 479 of 1993 prohibits the disposal of yard waste in landfills.