Soils and Fertilizer

Function of Soil in the Landscape and Why We Care:

- Supports the roots and anchors the above ground plant material
- Provides the essential elements for uptake by trees and plants
- Holds and supplies water and essential elements to the plants
- Releases water vapor into the air, potentially creating a cooler microclimate

Knowing the characteristics of the soil on a particular job site can be the difference between success and failure.

Soil isn’t “Just Dirt”! It is the ecosystem that supports our landscape plants. What we do to it matters.

Arizona Desert Soils

- Mineral
- Alkaline
- Arid
- Probably some caliche
- May be rocky and shallow, particularly in foothills
- May be saline
- May be heavy

Ideal Soil Composition

Desert soils have significantly less than 5% organic matter. Why?
In general, our desert, urban soils have low organic matter and less pore space.

Soil quality directly impacts plant life:
- Establishment
- Growth
- Health
- Longevity

Establishment/Growth/Health/Longevity

Organic Matter

- Group of carbon containing compounds
- Originated from living material and have been deposited on or within earth's structural components
- Contains minerals and trace elements

Benefits of Organic Matter

- Helps strengthen soil aggregates, thus improving soil structure
- Improve aeration and water infiltration
- Increases water-holding capacity
- Provides significant amounts of cation exchange capacity

- What do we do with organic matter in the landscape? Blow it, bag it and cart it away.
- Mulching grass clippings and leaving some leaf litter as a natural mulch can increase the organic matter content of the soil over time.

Soil Texture

Refers to the size of particles that make up the soil: sand, silt and clay

- Sand (0.01 - 0.1 mm)
- Silt (0.01 mm - 0.002 mm)
- Clay (< 0.002 mm)

Heavy, Light or Just Right?

Clay
- “Heavy”
- Slow infiltration
- High water-holding capacity
- High nutrient-holding capacity

Sand
- “Light”
- Fast infiltration
- Low water-holding capacity
- Low nutrient-holding capacity

Soil Texture Triangle

- 68% sand
- 18% silt
- 14% clay

International Society of Arboriculture, Bugwood.org
Can you alter soil texture?

- “You get what you get and you don’t throw a fit!”
- Not practical to try to alter on a large scale
- Not financially feasible on a large scale
- Better to focus on selecting plants that are more tolerant of current site conditions

Soil Structure:

*Arrangement of soil particles into groups called soil aggregates.*

*Impacts water infiltration*

pH

pH is a measure of acidity/alkalinity. Desert soils tend to be high in pH.
Salinity

Sodium (Na), Calcium (Ca), Potassium (K) and salts accumulate in soils

Peeling of the soil surface is a sign of poorly drained, salty soil and remediation is required for plants to grow.

How does soil become saline?

- Shallow watering
- Fertilizers
- Irrigation water quality
- Application of other salty substances to soil

Frequent, shallow irrigation is the leading cause of salt build up. Watering more deeply and less frequently helps flush salts out of the root zone of plants.

Cation Exchange Capacity (CEC)

The total number of cations a soil can hold—or its total negative charge—is the soil’s cation exchange capacity. The higher the CEC, the higher the negative charge and the more cations that can be held.

Cations held on the clay and organic matter particles in soils can be replaced by other cations; thus, they are exchangeable. For instance, potassium can be replaced by cations such as calcium or hydrogen, and vice versa.

Cation Exchange Capacity

Cations:
- $\text{NH}_4^+$, $\text{K}^+$, $\text{Fe}^{2+}$, $\text{Ca}^{2+}$

Anions:
- $\text{NO}_3^-$, $\text{SO}_4^{2-}$

Humus and clay carry a negative charge, and so attract positively charged cations.
Cation Exchange Video

* https://www.youtube.com/watch?v=HmEyymSXOfI&feature=youtu.be

**Sodium Adsorption Ratio (SAR)**

The ratio of ‘bad’ to ‘good’ flocculators gives an indication of the relative status of these cations:

Mathematically, this is expressed as the ‘sodium adsorption ratio’ or SAR:

\[
\text{SAR} = \frac{[\text{Na}^+]}{\sqrt{[\text{Ca}^{2+}] + [\text{Mg}^{2+}]} \div 2}
\]

where concentrations are expressed in mmoles/L.

**Exchangeable Sodium Percentage (ESP)**

Mathematically, this is expressed as the percentage of the CEC (cation exchange capacity) that is filled with sodium in units of charge per mass (cmol/kg)

An alternative to SAR is ESP (Exchangeable Sodium Percentage)

SAR and ESP are approximately equal numerically

\[
\text{ESP} = \frac{[\text{Na}^+]}{\text{Cation Exchange Capacity}}
\]

**Salt-affected Soil Classification**

<table>
<thead>
<tr>
<th>pH</th>
<th>EC (dS/m)</th>
<th>ESP</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5-7.2</td>
<td>&lt;4</td>
<td>&lt;15</td>
</tr>
<tr>
<td>&lt;6.5</td>
<td>&lt;4</td>
<td>&lt;15</td>
</tr>
<tr>
<td>&lt;8.5</td>
<td>&gt;4</td>
<td>&lt;15</td>
</tr>
<tr>
<td>&gt;8.5</td>
<td>&lt;4</td>
<td>&gt;15</td>
</tr>
</tbody>
</table>

**Test soil to determine sodium level**

Soil sodium tests:

SAR - sodium adsorption ratio
ESP - exchangeable sodium percentage

If SAR or ESP are ≥ 10 the soil is likely to disperse.
You should consider treating the soil.

Lower ESP and SAR numbers are **always** good
Plant Salinity Tolerance

Managing Salt

• Apply extra water to prevent excessive salt buildup
  • The amount of extra water needed is called the leaching requirement (LR)
    • LR is higher when using salty irrigation water
    • LR is higher when growing salt-sensitive plants
  • You can save water and prevent salt buildup by using adapted plant species

Salty Soil – Saline or Sodic?

Why does it matter? The treatment is different!

• Saline
  • Non-sodic soil containing sufficient soluble salt to adversely affect the growth of most crop plants with a lower limit of electrical conductivity of the saturated extract \( EC_e \) being 4 decisiemens / meter (dS/m), which is equivalent to a value of 4 mmhos/cm

• Sodic
  • Non-saline soil containing sufficient exchangeable sodium (Na) to adversely affect crop production and soil structure under most conditions of soil and plant type. The sodium adsorption ratio of the saturation extract \( SARE \) is at least 13

Salty Soil Treatments

• Sodic soils
  • Gypsum applications (replaces Na with Ca)
  • Leaching program

• Saline soils
  • Leaching program (best way)
  • Elemental sulfur applications (soil incorporation is best)

• Sodic-saline soils
  • Gypsum applications
  • Leaching program

Caliche

• Layer of soil where soil particles have been cemented together by lime (calcium carbonate, \( \text{CaCO}_3 \))
• Common in arid areas due to low precipitation
• Light in color
• Thickness of layers vary, few inches to several feet thick
• May be more than one layer of caliche in the soil profile

Caliche

• Reduces water movement through soil profile
• Restricts root growth to upper levels of soil (may reduce growth)
• Leads to salt accumulation and reduced aeration in soil
• High pH can cause nutrient deficiencies in plants, especially iron
Caliche Management

• Keep roots out of the caliche zone
• Physically remove caliche layers if possible to allow for water drainage out of root zone
• Check drainage on property prior to planting by performing a percolation test
  • Dig plant hole, fill with water and confirm drainage is at rate of 4” per 4 hours
• Utilize chimney drainage holes to provide drainage

Soil Amendments

Used to modify soil chemistry in our region

• **Gypsum** (Calcium sulfate)
  • temporarily removes Na from soil, helps break apart hardened soils
• **Soil sulfur**
  • may eventually reduce pH after repeated applications
• **Organic matter**
  • Microbial degradation and production of organic acids
  • Large amounts are required
• **Fertilizers**
  • Ammonium products (especially ammonium sulfate)

How do you know if you need to apply gypsum?

Observe the soil:

• Soil cracks when dry
• Soil won’t absorb water
• Rainwater soaks in more slowly than irrigation water

Soil Amendments

Elemental Sulfur

• Slow reaction- may take many months to change pH
• Dependent on microbial action (*Thiobacillus*)
• Soil incorporation is necessary
• Sulfur neutralizes the free calcium carbonate
• Not practical to change soil pH over large areas, but may be appropriate for directed applications to specific plants
• Monitor results with soil sample to confirm desired pH is achieved

Sulfur is oxidized by bacteria to form sulfuric acid

\[
S + O_2 + H_2O = H_2SO_4
\]

(elemental S + oxygen + water + soil microorganisms + time = sulfuric acid)

Soil Texture Affects Water Movement
Capillary Action

- Cohesion – “like sticking to like”
- Water molecules stick together
- Adhesion – “sticking to unlike”
- Water molecules stick to certain surfaces
- Capillary action – drawing of water in a narrow tube

Water Infiltration

*Rate which water enters the soil surface*

Soil Compaction

*Increased density of soil by packing the soil particles closer together causing a reduction in the volume of air.*

Compaction reduces pore space:

- Restricts H₂O and O₂
- Poor root development

Soil Percolation

*Movement of water through the soil profile*

Soil Moisture Levels

- Saturated soil: all pores are filled
- Field capacity: about 20% of pores are filled
- Wilting point: plants can’t extract the remaining water

Sweet spot
Evapotranspiration (Et)

Evaporation + Transpiration = Evapotranspiration

Factors that Affect ET

- Temperature
- Relative humidity
- Wind speed
- Light intensity
- Type of plant

Stomata

Factors affecting opening and closing:
- Light, especially blue light
- Water
- Temperature
- CO₂

1-2-3 Rule of Irrigation

Watering depth
1 ft - Flowers, vegetables and other small annuals
2 ft – Shrubs
3 ft – Trees

Essential Plant Elements

Macronutrients
- Needed in larger amounts
- Primary macronutrients
  - Nitrogen (N)
  - Phosphorus (P)
  - Potassium (K)
- Secondary macronutrients
  - Calcium
  - Sulfur
  - Magnesium

Micronutrients
- Needed in smaller amounts
  - Iron
  - Boron
  - Manganese
  - Zinc
  - Copper
  - Chlorine
  - Molybdenum
  - Nickel*
- Other essential plant elements include Hydrogen, Carbon & Oxygen

FERTILIZING
Essential and Beneficial Elements for Plants

<table>
<thead>
<tr>
<th>Essential and Beneficial Elements in Higher Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential Mineral Element</td>
</tr>
<tr>
<td>Essential Non-mineral Element</td>
</tr>
<tr>
<td>Beneficial Mineral Element</td>
</tr>
<tr>
<td>Optional Non-beneficial Element</td>
</tr>
<tr>
<td>Essential Trace Elements</td>
</tr>
</tbody>
</table>

- Li, Be, B, N, O, F, Ne, He
- K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr
- Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe
- Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn
- Fr, Ra, Ac, Rf, Db, Sg, Bh, Hs, Mt,Ds, Rg, Cn, Nh, Fl, Mc, Lv, Ts, Og
- Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr

Soil Testing

- **Find a local, reliable lab** – see AZ Cooperative Extension Publication AZ1111 in the resources
- **Collect a representative sample** – ask your lab for specifics or see AZ Coop Ext Publication AZ1412
- **Make decisions based on the results** - pay extra for the recommendations – worth it unless you are very experienced

Nitrogen (N)

- Originates from decomposing organic material, from rainfall and from nitrogen-fixing bacteria
- Generally, in short supply in western (desert) soils
- Required in large amounts by plants
- Readily lost through leaching & microbe activity

To get quick ‘greening’, use a fertilizer with nitrogen in the ammonic form

Examples: Ammonium Sulfate (21-0-0) Ammonium Nitrate (33-0-0)

Ammonium Nitrite Nitrate

Nitrogen Deficiency

- Nitrogen (N)
  - Yellowing of older leaves, bottom of plant
  - Rest of the plant is often light green
  - Stunted growth
  - Foliage may drop early in fall
  - Mobile in plants so overwatering can cause deficiency

- Treatment
  - Ammonium, Urea, Nitrate, manures, blood meal
Nitrogen-Fixing Bacteria on the roots of Acacia

Phosphorus Deficiency
- Phosphorus (P)
  - Leaf tips look burnt
  - Older leaves turning a dark green or reddish purple
  - Stunting
  - Loss of lower leaves
  - Poor root growth
  - Mobile in plants
- Treatment
  - Phosphate products
  - Bone meal
  - Greensand

Iron Deficiency
- Iron (Fe)
  - Interverinal chlorosis (yellowing leaf with green veins)
  - Found on newer growth
  - Leaves may be small
  - Immobile in plants
- Treatment
  - Iron chelates
  - Ferrous sulfate

Zinc Deficiency
- Zinc (Zn)
  - New leaves interveinal chlorosis, thicker green pattern around veins
  - Necrotic spots on margins or tips
  - Dwarfed new leaves, cupped upward or distorted

Zn deficiency
Fe deficiency

Deficiency on citrus, normal leaf on right
Other Micronutrient Deficiencies

- Micronutrient deficiencies may be caused by multiple minerals lacking
- Application of micronutrient packages will help broaden the spectrum
- Foliar testing to confirm mineral deficiency

Zinc (Z) Deficiency
Manganese (Mn) Deficiency
Magnesium (Mg) Deficiency

Micronutrient deficiencies may be caused by multiple minerals lacking. Application of micronutrient packages will help broaden the spectrum. Foliar testing to confirm mineral deficiency.

pH is a measure of acidity/alkalinity

Understanding Soil pH

Understanding Soil pH

https://www.youtube.com/watch?v=7Z15h189LCc

Nutrient Availability and pH

Treating Plants in Alkaline Soils

- Metal nutrients are insoluble in alkaline soils (iron, manganese, zinc)
- Apply nutrients directly to plant foliage
  - use sulfate salts
  - iron sulfate
  - copper sulfate
  - zinc sulfate
- Use chelated forms
  - more soluble than un-chelated forms
  - stay in solution longer
  - more available to plants
  - EDTA
  - DTPA
  - others

Chelates

Chelated Iron Fe -EDTA
Other Factors Affecting Uptake

<table>
<thead>
<tr>
<th>Raises Fertility</th>
<th>Lowers Fertility</th>
</tr>
</thead>
<tbody>
<tr>
<td>High clay content</td>
<td>High sand content</td>
</tr>
<tr>
<td>High humus content</td>
<td>Loss of organic matter</td>
</tr>
<tr>
<td>Good structure</td>
<td>Compaction</td>
</tr>
<tr>
<td>Warm soil</td>
<td>Cold soil</td>
</tr>
<tr>
<td>Deep soil</td>
<td>Shallow soil</td>
</tr>
<tr>
<td>Moist soil</td>
<td>Dry or wet soil</td>
</tr>
<tr>
<td>Good drainage</td>
<td>Excess irrigation or drainage</td>
</tr>
<tr>
<td>Fertilization</td>
<td>Erosion</td>
</tr>
<tr>
<td>Desirable microbes</td>
<td>Root damaging pests</td>
</tr>
<tr>
<td>Near neutral pH</td>
<td>pH too acid or alkaline</td>
</tr>
</tbody>
</table>

Fertilizer analysis
N-P₂O₅-K₂O
(nitrogen-phosphate-potash)

- **Complete** fertilizer
  - 21-7-14 (contains N-P-K)
- **Incomplete** fertilizer
  - 21-0-0 (contains only N)
- **Slow release** fertilizers
  - Coated to promote slow release of minerals

Organic vs. Chemical Fertilizers

**Organic**
- Manure
- Compost
- Fish emulsion
- Guano
- Milorganite
- Bone meal, blood meal
- Cottonseed meal

**Chemical/ Inorganic**
- Ammonium nitrate
- Ammonium sulfate
- Urea
- Superphosphate
- Potassium nitrate
- Calcium nitrate

- Add nutrients to the soil
- Organic and inorganic forms
- Usually salts
- Can burn plants
- Must be watered in

Organic vs. Chemical Fertilizers

**Organic**
- Often recycle waste materials
- May be resource intensive
- Can be bulky, heavy
- Micronutrients
- May contain pathogens, weeds
- Salt
- Requires more fertilizer to get the same amount of N as chemical fertilizer
- Generally slow-release
- Can improve soil structure as they break down

**Chemical (Inorganic)**
- Can be energy intensive to make
- Lighter weight
- Less material required
- Minerals in formulations readily available for plants
- Must be purchased
- Salt
- May provide more predictable results
- More risk of over fertilization
Fertilizer Application Methods

**Solid**
- Broadcast
- Placement

**Liquid**
- Foliar
- Soak
- Fertigation

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**Determining the amount of a fertilizer for a given area**

1. Take the measurements (in feet) of the area in question
2. Multiply the length by the width; this gives you the area in square feet (sq ft.)
3. Read the label. Determine how much product is required per 1000 sq ft. Measure the amount fertilizer needed
4. Calibrate your spreader, load and distribute

---

**Example #1**

*A lawn is 100 by 50 ft. How much fertilizer is necessary if the label states that you need 1 lb. of the product per 1000 square feet?*

Determine the area. 100 ft. X 50 ft. = 5000 sq. ft.

Since you need 1 lb. of fertilizer/ 1000 sq. ft. Divide 5000 sq.ft. by 1000

This tells you how many 1000 sq. ft. units there are in the lawn. This is 5.

\[ 5 \times 1 \text{ lb/1000} = 5 \text{ lbs per 5000 sq.ft} \]

Answer is 5 lbs.

---

**Example #2**

*How many lbs. of 16-20-0, applied to a 50’ by 20’ lawn, requiring 1 lb. of nitrogen per 1000 sq. ft.?*

**Step 1:** Determine the area
50’ X 20’ = 1000 sq. ft.

**Step 2:** Calculate how many pounds of 16-20-0 it takes to get one pound of nitrogen (N)

\[ \frac{100 \text{ by 16 (10/1.6 or 1/0.16 same results)}}{100 \div 16 = 6.25 \text{ lbs. of 16-20-0}} \]

---

**Step 3:** Since you have 1000 sq. ft., you’ll need

**6.25 lbs. of 16-20-0 for the lawn**
Example 3:

How many pounds of 16-20-0 should be applied to a lawn measuring 50’ by 40’ that requires 2 lbs of phosphorus per 1000 sq. ft.?

Step 1: Determine the area.
50 ft. X 40 ft. = 2000 sq. ft.

Step 2: Determine the number of lbs. of 16-20-0 to get 1 lb of Phosphorous. 100 divided by 20 = 5 lbs.
(5 lbs of 16-20-0 has 1 lb of Phosphorus)

Step 3: Calculate the number of lbs of 16-20-0 that supplies the rate of 2 lbs. of phosphorus per 1000 sq. ft.

Remember that 5 lbs of 16-20-0 has 1 lb of phosphate

2 x 5 lbs = 10 lbs of ammonium phosphate

Your rate of 16-20-0 is:
10 lbs/1000 sq ft to apply 2 lbs of P per 1000 sq ft

Please ask questions! Then go calibrate your equipment and get the job done!

https://www.youtube.com/watch?v=BT4kzNq7750
You can apply these principals to calibrating a drop spreader and handheld belly-grinder.

Resources

- Laboratories Conducting Soil, Plant, Feed, or Water Testing
  https://extension.arizona.edu/pubs/laboratories-conducting-soil-plant-feed-or-water-testing
- Fertilizing Home Gardens in Arizona
  http://extension.arizona.edu/pubs/fertilizing-home-gardens-arizona
- Soil Sampling and Analysis
  http://extension.arizona.edu/pubs/soil-sampling-and-analysis
- Using Gypsum and Other Calcium Amendments in Southwestern Soils
  https://extension.arizona.edu/pubs/using-gypsum-other-calcium-amendments-southwestern-soils
- Diagnosing Nutrient Deficiencies Quick-Reference
  https://extension.arizona.edu/pubs/diagnosing-nutrient-deficiencies-quick-reference
- Nitrogen in Soil and the Environment
  https://extension.arizona.edu/pubs/nitrogen-soil-and-environment
- Recognizing and Treating Iron Deficiency in the Home Yard
  https://extension.arizona.edu/pubs/recognizing-treating-iron-deficiency-home-yard
- University of Arizona publication search
  https://extension.arizona.edu/pubs

Soil Testing Laboratories

Local
IAS Laboratories 602-273-7248
2515 E. University Dr. Phoenix, AZ

Motzz Laboratory, Inc. 602-454-2376
3540 E. Corona Ave. Phoenix, AZ

National
AgSource/ Harris Labs 402-476-0300
harrislabs.agsource.com
harrislabs@agsource.com
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