SOILS AND FERTILIZERS
MODULE 2
PHYSICAL PROPERTIES OF SOILS

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1. General information
    a. A mineral soil is a porous mixture of inorganic particles, decaying organic matter, air, and water. Larger mineral fragments are sometimes <u>coated</u> with clay or organic matter.
    b. Where <u>larger</u> particles dominate the mineral fraction (as in southwest Florida soils), the soil is **sandy**; where the mineral <u>colloids</u> (small particles) dominate, the soil has **clayey** characteristics. All gradations in between are found in nature.
    c. Organic matter acts as a binding agent between individual particles, encouraging the formation of clumps or **aggregates**.
    d. Soil **texture** is concerned with the size of mineral particles in the soil (the relative proportions of particles of various sizes in a given soil); soil **structure** is the arrangement of soil particles into groups or aggregates. These properties help determine the nutrient, water, and air-supplying ability of the soil.
    e. The size of individual particles in a soil is not readily changed, thus texture is considered a basic property of soil. However, soil structure (soil aggregation) can be destroyed by excess tillage.
    f. Particle-size analysis can be done in a laboratory. It separates the particle sizes into convenient groupings. The USDA classification is:

< 0.002 mm	Clay
0.002-0.05 mm	Silt
0.05-0.10 mm	Very fine sand
0.10-0.25 mm	Fine sand
0.25-0.50 mm	Medium sand
0.50-1.0 mm	Coarse sand
1.0-2.0 mm	Very coarse sand

    g. Sandy soils are also known as <u>light</u> soils (easy to till or cultivate); clay soils are also known as <u>heavy</u> soils (difficult to till). The terms light and heavy refer to the ease of tillage or manipulation, not to soil weight. Actually, the dry weight of a unit volume of sand is heavier than that of clay.

2. Physical nature of soil size groupings
    a. Sand
        1. Rounded or irregular in shape.
        2. Not sticky when wet.
        3. Cannot be molded.
        4. Low water-holding capacity.

        5. High hydraulic conductivity (ease of water movement through it).
        6. Provides good drainage, but is drought-prone.

    b. Silt, Clay
        1. Smaller particles with large surface area (fine colloidal clay has about 10,000 times as much surface area as the same weight of medium-sized sand.

Particle size class	Specific surface area
Clay	10-1000 m^2 per gram
Fine silt	1 m^2 per gram
Fine sand	0.1 m^2 per gram

        2. Surface phenomena include absorption of water, nutrients, and gas, and the attraction of particles for each other.
        3. Sticky and easily molded when wet.
        4. Silt particles are really just smaller versions of sand particles; silts usually possess some plasticity, stickiness, and adsorptive capacity due to an adhering film of clay, but much less than clay itself.
        5. The presence of clay imparts fine texture and slow water and air movement, high water-holding capacity, and shrink-swell potential.

3. Soil textural classes
    a. Names give an idea of the textural make-up of a soil and an indication of its physical properties. Three fundamental groups of textural classes are recognized: sands, loams, and clays:
        1. To be called a **sand**: must have at least 70% sand and less than 15% clay
        2. To be called a **clay**: must have at least 35% clay, usually not less than 40%
        3. **Loams**: Somewhere in between sands and clays; about equal proportions of sand, silt, and clay.
    b. Specific textural classes:
        1. Sandy soils - sand, loamy sand
        2. Loamy soils - sandy loam, fine sandy loam, very fine sandy loam, loam, silt loam, silt, sandy clay loam, silty clay loam, clay loam
        3. Clayey soils - sandy clay, silty clay, clay

4. Soil structure
    a. Structure relates to the grouping or arrangement of soil particles into secondary groupings called aggregates or peds. Southwest Florida surface soils do not have much if any structure (they are called <u>structureless</u> or <u>single-grained</u> soils).

   b. Types of structure that can be found in soils include **platy**, **prismatic**, **columnar**, **blocky**, and **granular**. Can find weak granular structure in the surface horizons and stronger structure in the subsoil of southwest Florida soils.
   c. The only way to help granulate a sandy soil is to add organic matter. The organic matter would aid in the adsorption and retention of water and nutrients.

5. Particle density
   a. Particle density is the density of the solid particles making up the soil. It is defined as the mass of a unit volume of soil solids. Most mineral soils have a particle density between 2.60 and 2.75 grams per cm^3.
   b. The size of the particles of a given soil and the arrangement of the soils solids have nothing to do with the particle density, which depends on the type of mineral particles present. Organic matter will lower the average particle density slightly, since it weighs much less on a unit volume basis. Thus, the average particle density of surface soils is about 2.65 grams per cm^3.

6. Bulk density
   a. Bulk density is defined as the mass of a unit volume of dry soil (includes both solids and pore space).
   b. Bulk density is determined by the **volume of pore spaces** as well as soil solids. The larger the pore space, the lower the bulk density. Fine-textured soils such as the loams and clays generally have lower bulk density than sandy soils.

Soil texture	Bulk density
Fine	1.0-1.6 g/cm^3 (65-100 lbs/ft^3)
Coarse	1.2-1.8 g/cm^3 (75-110 lbs/ft^3)
Very compact	2.0 g/cm^3 (125 lbs/ft^3)

   c. Bulk density increases with depth in the soil, mainly due to lower organic matter content, less aggregation and root penetration, and compaction caused by the weight of the overlying layers. Soil management influences bulk density: addition of organic matter decreases it, increasing the intensity of cultivation increases it.
   d. Acre furrow-slice concept - the weight of soil in one acre to a depth of normal tillage operations (6 inches). For mineral soils, an acre furrow-slice weighs about 2 million lbs.

7. Pore space
   a. **Pore space** is defined as **that portion of the soil volume occupied by air and water**. The amount of pore space is determined by the arrangement of the soil particles. If they lie close together as in sands or compact subsoils, total porosity is low. If they are arranged in porous

aggregates, as is often the case in medium-textured soils high in organic matter, the pore space per unit volume will be high.

Percent pore space = 100 - ((Bulk density/Particle density) x 100)

b. Sandy soils normally have 35-50% pore space, while medium to fine-textured soils have 40-60% pore space, or even more in cases of high organic matter and granulated structure. Pore space decreases with soil depth.

8. Pore size
    a. **Pore size** is defined as the **cross-sectional area of a pore**. Two general classes of pore size occur in soils: **macro** and **micro**. There is no sharp cutoff point, but pores smaller than about 0.06 mm in diameter are considered micropores, and those larger as macropores.
        1. Macropores allow easy movement of air and water.
        2. Micropores are usually filled with water in field soils and do not permit much air movement into or out of the soil. The water movement is restricted to slow capillary movement. Thus, in a sandy soil, although total porosity is lower, the movement of water is rapid because of the dominance of macropores.
    b. Fine-textured soils without stable granular structure allow relatively slow air and water movement despite the unusually large volume of total pore space. The dominating micropores often stay full of water. Aeration, especially in the subsoil, is frequently inadequate for satisfactory root development and desirable microbial activity. **Therefore, the size (diameter) of the individual pore spaces rather than their combined volume is the important consideration**.
    c. Large diameter pores can conduct more water, more rapidly than small diameter pores, and exert a smaller **suction** on water than small pores. Suction is a measure of the energy required to remove water from a given pore. Therefore, it is easier to remove water from a large pore than from a small pore. Tensiometers can provide a measure of the suction with which soil water is held.

9. Capillary fundamentals and soil water
    a. Capillarity is a familiar phenomenon, a typical example being the movement of water up a wick when the lower end is immersed in water. Capillarity is caused by the attractive force of water for the walls of the channels through which it moves (adhesion), and the surface tension of water, which is largely due to the attraction of water molecules for each other (cohesion). Capillarity can be demonstrated by placing one end of a fine glass tube in water. The water rises in the tube, and the smaller the tube bore, the higher the water rises.
    b. Capillary forces are at work in all moist soils. However, the rate of movement and the rise in height are less than one would expect on the

basis of soil pore size. One reason is that soil pores are not straight like glass tubes, but are crooked (tortuous). Also, some soil pores are filled with air, which may be entrapped, slowing down or preventing the movement of water by capillarity.

10. Retention of water in soil
    a. The pore space in soil is usually at least partially filled with water. When all pores are filled, the soil is <u>saturated</u>. Under unsaturated conditions, water is present only in the smaller pores while the larger pores are air-filled.
    b. As a soil dries out through drainage, evaporation, or plant water use, water leaves some of the pores, which then become air-filled. Because water is removed easiest from large pores, they empty first. The smaller the pore, the greater the **suction** with which the water is held. It is more difficult to remove water from the smaller pores, thus they remain water-filled until the soil dries out further. The suction with which a soil holds water at any given time governs the availability of water to plants.
    c. Soil suction is best measured by tensiometers, which in its simplest form consists of a water-filled porous cup that is in contact with the soil at one end, and a suction gauge at the other end. The two are connected by a water-filled tube. Water inside the tensiometer is drawn out through the cup into the soil until the suction inside the tensiometer equals that of the soil. The gauge measures the magnitude of the suction. The drier the soil, the greater the suction, and the higher the tensiometer gauge reading. A saturated soil will register no soil suction, with a tensiometer reading of zero.

11. Movement of water in soil
    a. Two factors cause water to move in soil:
        1. Gravity
        2. The soil suction due to capillary forces. The <u>hydraulic head</u> at a given point in the soil is equal to the potential for gravity to move water plus the potential for suction to move water. The direction and rate of water flow depend on differences in hydraulic head between different points in the soil.

12. Field soil moisture terminology
    a. Saturation - all pores filled with water.
    b. Field capacity - after rain or irrigation has stopped, there will be a continued relatively rapid downward movement of water due to gravity. After a period of time, downward movement will become negligible. With respect to the water that is left, the soil is said to be at **field capacity**. At this time, water has moved out of the macropores, and its place has been taken by air. The smaller pores are still water-filled and can supply plants with needed moisture. It takes about 1 day to reach field capacity in freely-draining sandy soils. The tensiometer reading at field capacity is about 10 cb.

   c. Flatwoods soils may be greatly slowed in reaching field capacity due to the presence of a shallow water table. If this situation exists, true field capacity may never be reached due to upward water movement from the water table caused by capillarity. A quasi-equilibrium state may be reached where partial drainage has taken place, which could be interpreted as a form of field capacity. Tensiometer readings in this instance would be in the range of 5 to 9 centibars.

13. How soil physical properties relate to citrus growth and production
   a. Low soil water-holding capacity due to dominance of macropores caused by sandy texture. Implications - Soils can by droughty; during dry periods, irrigations need to be scheduled more frequently with smaller volume per application; soil water suction can be measured with tensiometers; this measurement can be used as a guide to help schedule irrigations.
   b. Water can move upward from a water table into the root zone via capillary forces if the water table is close enough. Implication - Irrigation may be delayed because of contributions of water from the water table.
   c. Good drainage due to dominance of macropores. Implications - Once land is elevated by bedding, movement of excess water (e.g. from heavy rains) through the soil is usually not a problem due to high conductivity.
   d. Soil compaction is not a potential problem which could decrease the effective rooting zone.
   e. Little soil chemical activity occurs on mineral soil particle surfaces due to large particles made of inert material (e.g. quartz sand).