SOILS AND FERTILIZERS
MODULE 4
BIOLOGICAL PROPERTIES OF SOILS

SOIL ORGANISMS

1. Introduction
   Soil organic matter (OM), or humus, is a product of degradation and synthesis. Living soil organisms, both animals and plants, are responsible for humus formation. These organisms cause biochemical changes as decay takes place, and also physically mix the OM with the soil. Vast numbers of organisms live in the soil, and by far the greatest proportion of these belong to plant life. Most soil organisms, both plant (flora) and animal (fauna), are so small that they can only be viewed with the aid of a microscope.

2. Organisms in Action
   a. Growing plants are subject to attack by soil organisms known as herbivores. Examples are parasitic nematodes, snails, slugs, and the larvae of some insects that attack plant roots. Soil-borne termites and beetle larvae devour above-ground woody material.
   b. Primary consumers: As soon as a plant part falls to the ground, it is attacked by microorganisms and by detrivores, animals that live on dead and decaying plant tissue. Bacteria and fungi initiate the attack if moisture is present. They are followed by attacks from mites, snails, beetles, worms, etc. The action of the microbes is chemical, while that of the animals is both physical and chemical (mixing is accomplished by the actions of chewing and/or burrowing animals).
   c. Secondary and tertiary consumers: The primary consumers themselves are food sources for predators and parasites in the soil. These are the higher-level consumers, including ants, spiders, centipedes, nematodes, termites, etc.
   d. Soil microorganisms are intimately involved in the decomposition of the OM which is deposited to the soil. In addition to their direct attack on plant tissue, they are active within the digestive tract of some of the animals. They also attack the finely shredded OM in animal feces and later decompose the bodies of dead animals. For this reason, soil microbes are referred to as the ultimate decomposers.

3. Organism Numbers - Factors affecting organism populations:
   a. Climate - Differences with respect to wet vs. dry areas (more moisture, more organisms).
   b. Vegetation - Differences with respect to forest vs. grass vs. cultivated field. (More diverse organisms under forest than under grass, but grassland organisms are more active and are present in greater total weight.) Compared with virgin areas, cultivated fields are generally lower in

numbers and weight of organisms, except where the soil in the virgin state was very acid and has since been well limed and fertilized.

c. The living soil organism population is dominated by the microorganisms, especially the microflora. It is estimated that 60-80% of the total soil metabolism is due to the microflora. End products of their activities include soil humus and plant-available nutrients.

4. Classes of Soil Organisms
    a. Soil macroanimals
        i. Earthworms - Not very prevalent in sandy soils.
        ii. Termites - Provide extensive mixing of soil materials and plant residues that they use for food. In cooperation with microbes, termites can rapidly break down woody materials.
    b. Soil microanimals
        i. Nematodes - Small worm-like organisms that cannot be seen without a microscope. Nematodes live on either decaying organic matter, other organisms such as bacteria, algae, or protozoa, or plant roots. The root-feeding group is the most important to growers, since they can become serious pests.
        ii. Protozoa - Single-celled animals that feed on bacteria.
    c. Soil algae
        i. Algae are chlorophyll-bearing organisms that are capable of photosynthesis.
        ii. They live at or near the soil surface due to their light requirement, and perform best under wet conditions.
    d. Soil fungi
        i. Fungi depend on the OM in the soil for their energy to live. Important types include the molds and mushrooms. Most fungi are found near the soil surface where the OM content is the highest and aeration is adequate. The type of OM available will influence the type of fungi that will grow. Fungi are very versatile in their ability to break down different kinds of OM. In affecting the processes of humus formation and soil aggregate stabilization, fungi are more important than soil bacteria.
        ii. **Mycorrhizae** is a class of fungi that are associated with plant roots. The association is important since it markedly increases the availability of several plant nutrients, especially from infertile soils. The relationship provides the fungi with plant root exudates for use as food; in return, the fungi enhance the availability of nutrients including phosphorus, zinc, copper, calcium, magnesium, manganese, and iron. The mycorrhizal fungi serve as an "extension" of the root system of the plant.
    e. Soil bacteria
        i. Bacteria are very simple, single-cell plant organisms. They can quickly reproduce to adjust their activity in response to changes in

their environment. They are slightly larger than the average clay particle.

ii. The greatest population of bacteria are found near the soil surface where temperature, moisture, aeration, and food supply (OM) are the highest. The conditions that favor the growth of higher plants also favor the growth of bacteria. Populations fluctuate with the seasons. Bacteria exist as colonies on and around soil particles wherever food and moisture are available. Many are capable of producing resistant bodies which can survive unfavorable conditions.

iii. Bacteria participate vigorously in all of the organic reactions that are vital to support higher plants. Three basic transformations are controlled by bacteria:
    1. Nitrification - The conversion of NH_4^+ to NO_3^-.
    2. Sulfur conversion - Breakdown of sulfur compounds.
    3. Nitrogen fixation - The conversion of N_2 gas to mineral nitrogen.

SOIL ORGANIC MATTER

1. Introduction
   Organic matter influences soil physical and chemical properties far out of proportion to the small quantities present. It commonly accounts for at least 50% of the CEC of surface soils (probably over 90% in southwest Florida soils), and is responsible for any aggregate stability that might occur. It also supplies energy for the soil microorganisms that were just discussed.

2. Sources of Organic Matter
   The original source of OM is plant tissue, such as the tops and roots of trees, shrubs, grasses, and other native plants. As these materials are decomposed by soil organisms, they become part of the underlying horizons by infiltration or physical incorporation.

3. Composition of Plant Residues
   The moisture content of plant residues varies from 60 to 90%. Dry matter is mostly carbon and oxygen, with less than 10% each of hydrogen and inorganic elements (ash). The most significant inorganic elements include nitrogen, sulfur, phosphorus, and potassium. The general composition of OM includes the following groups of compounds: carbohydrates (sugars, cellulose), fats, oils, lignin, and proteins.

4. Decomposition of Organic Compounds
   When organic tissue is added to soil, three general reactions take place:
    a. The bulk of the material is broken down or altered, with CO_2, H_2O, energy, and heat as major products.

b. The essential elements N, P, and S, are released to the soil and/or immobilized by a series of reactions.
c. Compounds resistant to further breakdown by microbes are formed.

5. Humus - Genesis and Definition
    a. The formation of humus, although a complicated process, can be simply described. As organic tissue is incorporated into a moist, warm soil, it is immediately attacked by a variety of different soil organisms. The easily-decomposed compounds are quickly consumed, first yielding intermediate substances and finally simple, water-soluble products.
    b. As this decomposition occurs, two major kinds of organic compounds tend to be stabilized in the soil. First are the microbial-resistant compounds which have come from the dead plant material itself (such as lignin), and second are new compounds which are synthesized by microbes and held as part of their tissue.
    c. The resultant mixture of **humic substances**, or newly-formed **humus**, is quite resistant to further microbial attack. Nitrogen and other essential elements within the humus are protected from ready solubility and dissipation. Humus, therefore, is a mixture of complex compounds, not a single material, which are resistant to microbial degradation.

6. Nature and Characteristics of Humus:
    a. Black in color.
    b. Colloidal-sized particles of organic material.
    c. High surface area (even more than colloidal clay).
    d. The surfaces are negatively-charged.
    e. The CEC of humus far exceeds that of clay.
    f. The water-holding capacity of humus is 4-5 times that of clay**.**
    g. Helps form soil aggregates.

7. Regulation of Soil Organic Matter
    The inherent capacity of soils to produce crops is closely related to their organic matter and nitrogen content. The satisfactory level of these two constituents is difficult to maintain in the majority of farm soils. In southwest Florida especially, the methods of OM additions and upkeep should receive priority consideration in all soil management programs.
    Sources of supply:
    a. Green-manuring - The plowing under of crops when in an immature, succulent stage (rye, cowpea, sorghum-sudangrass, millet, etc.).
    b. Farm manure applications.
    c. Non-farm organic wastes, such as biosolids and municipal wastes.
    d. In citrus groves, sources include dead leaves, wood, roots, and fallen fruit from the trees, plus that obtained from the plant material growing in the row middles.

8. How Biological Properties Relate to Citrus Growth and Production
    a. Soil organisms, especially microorganisms, are very numerous in southwest Florida soils due to high temperature and moisture conditions. Thus, breakdown of OM is rapid and maintenance of high quantities is difficult. Harmful organisms such as some nematodes and fungi also flourish under these conditions, causing economic damage in some cases. Growers need to be aware of the symptoms of injury so that appropriate action can be taken when necessary.
    b. When fertilizer containing ammonium is added to the soil, bacteria convert the ammonium-N to nitrate-N in a matter of weeks. This changes the N form from one that can be adsorbed to one that cannot. When elemental sulfur is applied to the soil, bacteria convert it to sulfuric acid, which lowers soil pH.
    c. Almost all of the CEC in southwest Florida soils is due to organic matter. Since the higher the CEC, the better the nutrient-holding capacity of the soil, it is desirable to maintain as high an OM content as possible. This objective can best be accomplished through regular OM addition to the soil.