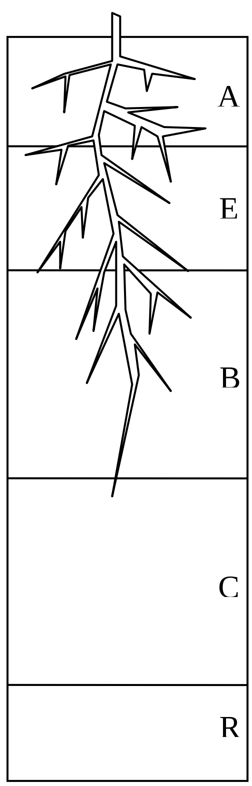
BOTANY, PLANT PHYSIOLOGY AND PLANT GROWTH
Lesson 10: SOILS

Segment One – Soil Horizons

Soil is primarily the result of parent materials (rocks) having been acted upon by climate and vegetation, over a period of time. It is weathered rock fragments with decaying remains of plants and animals (called organic matter). Soil also contains varying proportions of air, water and microorganisms. It furnishes mechanical support and nutrients for growing plants.

Most soils have distinct principal layers or horizons. Each layer can have two or more sub-horizons. The principal horizons (collectively called the soil profile) are: A or surface soil, E or subsurface layer, B or subsoil, and C or parent material. Beneath the soil profile lays the rock, similar to that from which the soil developed, usually referred to as the R layer. Horizons usually differ in color, texture, consistency and structure. In addition, there is usually considerable difference in chemical characteristics or composition.



Surface - Coarse - Surface soils that are highest in organic matter usually have the darkest colors. Has the greatest concentration of plant roots of any horizon of the soil. Plants obtain much of their nutrients and water from the surface soil.

Subsurface – Coarse - Shows depletion of organic matter.

Subsoil – Fine - Shows enrichment of clay material, iron, aluminum, or organic compounds.

Parent material – loosened or unconsolidated material. Decomposed rock.

Bedrock

Segment Two - Physical Properties of Soil

The physical properties of a soil are those characteristics that can be seen with the eye or felt between the thumb and fingers. They are the result of soil parent materials being acted upon by climatic factors (such as rainfall and temperature), relief (slope and direction or aspect) and vegetation (kind and amount, such as forest or grass) over a period of time. A change in any one of these influences usually results in a difference in the soil formed. Important physical properties of a soil are color, texture, structure, drainage and depth.

Fertility level alone is not indicative of its productive capacity, since soil physical properties usually control the suitability of the soil as a growth medium. Fertility is more easily changed than soil physical properties.

Color

When soil is examined, color is one of the first things noticed.

Surface soil colors vary from almost white, through shades of browns and grays, to black. Light colors indicate low organic matter content and dark colors can indicate high organic matter content. Light or pale colors in the surface soil are frequently associated with relatively coarse texture and highly leached conditions and occur in areas that have high annual temperatures. Dark colors may result from high water table conditions (poor drainage), low annual temperatures or other influences that induce high organic matter content and at the same time slow the oxidation (burning) of organic materials. Or they may result from colors imparted by the parent material. Shades of red or yellow, particularly where associated with relatively fine textures, usually indicate that subsoil material has been incorporated in the surface or plow layer.

Subsoil colors, in general, indicate air, water and soil relationships and the degree of oxidation of certain minerals in the soil. Red and brown subsoil colors indicate that the soil allows relatively free movement of air and water. The red to brown color of subsoils comes from iron coatings under well aerated conditions.

Soils with yellow-colored subsoils usually have some drainage impediment. Most soils that have mottling in the subsoil, especially where gray predominates, have too much water and too little air (oxygen) much of the time.

Texture

The relative amount of different size soil particles, or the fineness or coarseness of the mineral particles in the soil, is referred to as texture. Soil texture depends on the relative amounts of sand, silt and clay. In each texture class, there is a range in the amount of sand, silt and clay that class contains.

The coarser mineral particles of the soil are called sand. These particles vary in size. Most sand particles can be seen without a magnifying glass. All feel rough when rubbed between the thumb and fingers.

Relatively fine soil particles that feel smooth and floury are called silt. When wet, silt feels smooth but is not slick or sticky. When dry, it is smooth and if pressed between the thumb and finger will retain imprint. Silt particles are so fine that they cannot usually be seen by the unaided eye and are best seen with a microscope.

Clays are the finest soil particles. Clay particles can be seen only with the aid of a very powerful (electron) microscope. They feel extremely smooth when dry and become slick and sticky when wet. Clay will hold the form into which it is molded.

Loam is a textural class of soils that has moderate amounts of sand, silts and clay. Loam contains approximately 7-27% clay, 28-50% silt and approximately 50% sand.

Although there are about 20 kinds or classes of soil texture, most surface soils in Minnesota fall into five general textural classes.

Principal Surface Soil Classes Found in Minnesota:

- **Loam** - When rubbed between the thumb and fingers approximately equal influence of sand, silt and clay is felt.
- **Sandy Loam** - Varies from very fine loam to very coarse. Feels quite sandy or rough, but contains some silt and a small amount of clay. The amount of silt and clay is sufficient to hold the soil together when moist.
- **Silt Loam** - Silt is the dominant size particle in silt loam, which feels quite smooth or floury when rubbed between the thumb and fingers.
- **Silty Clay Loam** - Smooth to the touch when dry. When moist it becomes somewhat slick or sticky, or both. Noticeable amounts of both silt and clay are present in silty clay loam, but silt is a dominant part of the soil.
- **Clay Loam** - Clay dominates a clay loam, which is smooth when dry and slick and sticky when wet. Silt and sand are usually present in noticeable amounts in this texture of soil but are overshadowed by clay.

Structure

Soil particles are grouped together in the formation processes to form structural pieces called peds or aggregates. In surface soil the structure will usually be granular unless it is disrupted. The soil aggregates will be rounded and vary in size from very small shot to large pea. If organic matter content is low and if the soil has been under continuous cultivation, the soil structure may be quite indistinct. If the soil is fine-textured with high organic matter content, it may have a blocky-surface structure.

Structure of the soil is closely related to air and water movement within it. Good structure allows favorable movement of air and water, while poor or no structure slows down this movement. Water can enter a surface soil that has granular structure more rapidly than one that has little structure. Since plant roots move through the same channels in the soil as air and water, good structure allows extensive root development while poor structure discourages it. Good structure of the surface soil is promoted by an adequate supply of organic matter and by only working the soil when its moisture conditions are correct.

Improving Soil Structure:
Organic matter is a great soil ameliorator for both clay and sandy soils. Good sources of organic matter include composted manure, leaf mold, bark, peat, sawdust and straw. These materials are decomposed in the soil by soil organisms. Various factors, such as moisture, temperature and nitrogen availability determine the rate of decomposition through their effects on these organisms. Adequate water must be present and warm temperatures will increase the rate at which the microbes work. The proper balance of carbon and nitrogen in the material is needed for rapid decomposition. The addition of nitrogen may be necessary if large amounts of non-decomposed high-carbon substances such as dried leaves, straw or sawdust are used. Fresh green wastes, such as grass clippings are higher in nitrogen than dry material. Nitrogen is used by the microbes in the process of breaking down the organic matter and may cause a nitrogen deficiency in the plants by using up the available nitrogen, if it is not present in sufficient amounts.

Drainage

Soil drainage is defined as rate and extent of water movement in the soil. Included is movement across the surface as well as downward through the soil. Slope or lack of slope is a very important factor in soil drainage. Other factors include texture, structure and physical condition of surface and subsoil layers. Soil drainage is indicated by soil color. Clear, bright colors indicate well-drained conditions. Mixed, drab and predominantly gray colors indicate imperfection in drainage.

Too much or too little water in the soil is equally undesirable. With too much water, most plants will suffocate. Where there is too little water, plants will wilt and eventually die. The most desirable soil moisture situation is one in which approximately one-half of the pore space of the surface soil is occupied by water.

Soil Depth

The effective depth of a soil for plant growth is the vertical distance into the soil from the surface to a layer that essentially stops the downward growth of plant roots. The barrier layer may be rock, sand, gravel, heavy clay or a partially cemented layer. Terms that are used to express effective depth of soil are:

- VERY SHALLOW - soil is less than 10" to a layer that retards root development.
- SHALLOW - soil is 10 - 20" to a layer that retards root development.
- MODERATELY DEEP - soil is 20-36" to a layer that retards root development.
- DEEP - soil is 36-60" to a layer that retards root development.
- VERY DEEP - soil is 60" or more to a layer that retards root development.

Soils that are deep, well-drained, and have desirable texture and structure are suitable for the production of most crops. Deep soils can hold much more plant nutrients and water than shallow soils with similar textures. Depth of soil and its capacity for nutrients and water frequently determine the yield from a crop, particularly annual crops grown through the summer months.

Plants growing on shallow soils also have less mechanical support than those growing in deep soils. Trees growing in shallow soils are more frequently blown over by wind than those growing in deep soils.

Erosion:

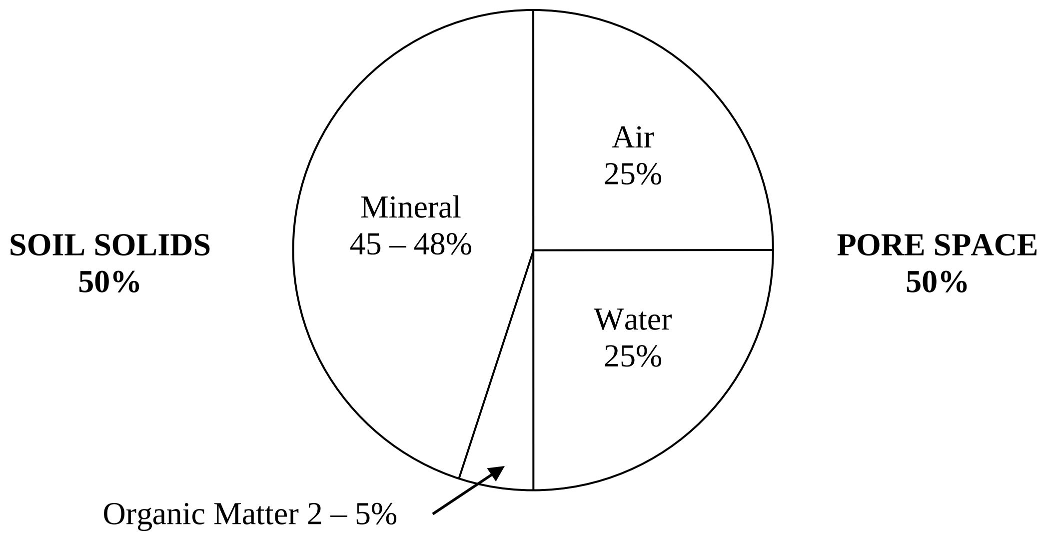
Some of the principal reasons for soil erosion in Minnesota are: insufficient vegetative cover, overexposure through the use of cultivated crops on soils not suited to cultivation, and use of improper equipment and methods in preparation and tillage of the soil.

Segment Three – Components of Soil

A desirable surface soil in good condition for plant growth contains approximately 50% solid material and 50% open or pore space.

- The mineral component is usually made up of many different sizes of particles, ranging from those visible to the unaided eye to particles so small that they can only be seen with the aid of a very powerful microscope. This mineral material is about 45 to 48% of the total volume.
- Organic material makes up about 2 to 5% of the volume and may contain both plant and animal material in varying stages or degrees of decomposition.

- Pore space, or open space, under ideal conditions for growing plants, contains about 25% air and 25% water based on total volume of soil. When water occupies one half or less of the pore space, sufficient oxygen is supplied for biological activities such as root growth.



Soil Organic Matter

Organic matter in soil consists of the remains of plants and animals. When temperature and moisture conditions are favorable in the soil, earthworms, insects, bacteria, fungi and other types of plants and animals use the organic matter as food, breaking it down into humus (the portion of organic matter that remains after most decomposition has taken place) and soil nutrients. Through this process, materials are made available for use as nutrients by growing plants.

The digested and decomposing organic material also helps develop good air-water relations. In sandy soil, organic material occupies some of the space between the sand grains, thus binding these together and increasing water-holding capacity. In a fine textured or clay soil, organic matter creates aggregates of the fine soil particles, allowing water to move more rapidly. This grouping of the soil particles into small pieces (aggregates or peds) causes it to feel crumbly and makes it easy to work.

Water and Air In The Soil

When organic matter decomposes in the soil, it gives off carbon dioxide. This carbon dioxide replaces some of the oxygen of the air in the soil. As a result, soil air contains less oxygen and more carbon dioxide than the air above the surface of the soil.

Carbon dioxide is dissolved by water in the soil to form a weak acid. This solution reacts with the minerals in the soil to form compounds that can be taken up and used as nutrients by the plants.

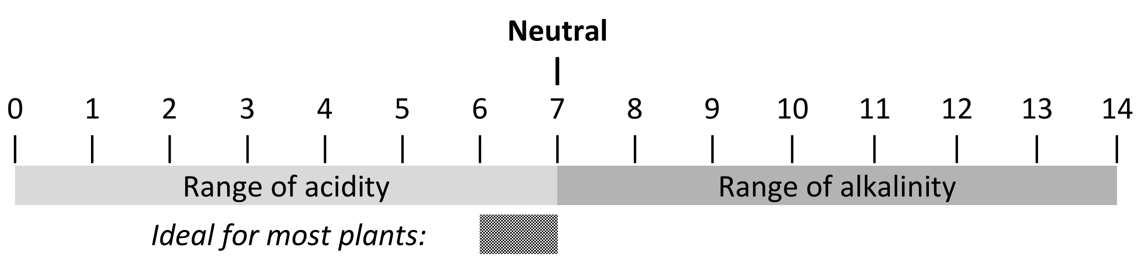
Plant Nutrients in the Soil

Plants need 17 elements for normal growth. Carbon, hydrogen and oxygen (which come from air and water) and nitrogen (which is in the soil) are the 4 elements that make up 95% of plant solids. Although the atmosphere is 78% nitrogen, it is unavailable for plant use. However, certain bacteria that live in nodules on the roots of legumes are able to fix nitrogen from the air into a form available to plants.

The other 13 essential elements are iron, calcium, phosphorus, potassium, copper, sulfur, magnesium, manganese, zinc, boron, chlorine, cobalt and molybdenum. These elements come from the soil. With the exception of calcium, magnesium, phosphorus, and potassium, there are usually enough of these elements in the soil for cultivation of crops.

Segment Four – Soil pH

A pH is a reading taken from a scale that measures the hydrogen (acid forming) ion activity of soil or growth media. The reading expresses the degree of acidity or alkalinity in terms of pH values, very much like heat and cold are expressed in degrees Centigrade or Fahrenheit. The Centigrade temperature scale is centered around zero degrees or the freezing point of water and thermometers are used to measure intensities of heat and cold above and below this point. The scale for measuring acidity or alkalinity contains 14 divisions known as pH units. It is centered on pH 7 which is neutral. Values below 7 constitute the acid range of the scale and values above 7 make up the alkaline range.



The measurement scale is not a linear scale but a logarithmic scale. That is, a soil with a pH of 8.5 is ten times more alkaline than a soil with a pH of 7.5, and a soil with a pH of 4.5 is ten times more acid than a soil with a pH of 5.5.

The pH condition of soil is one of a number of environmental conditions that affect the quality of plant growth. A near neutral or slightly acid soil is generally considered ideal for most plants. Some type of plant growth can occur anywhere in a 3.5 to 10.0 range. With some notable exceptions, most plants grow well in a soil pH range of 6.0 to 7.0.

The major impact that extremes in pH have on plant growth is related to the availability of plant nutrients and the soil concentration of the plant-toxic minerals. In highly acid soils, manganese can concentrate at toxic levels. Also at low pH values, calcium, phosphorous and magnesium become tied up and unavailable to the plant. At pH values of 7 and above, phosphorus, iron, copper, zinc, boron and manganese become less available to the plant.

By the application of certain materials to the soil, adjustments can be made in pH values.

- To make soils less acid apply a material that contains some form of lime. Ground agricultural limestone is the most frequently used. The finer the grind the more rapidly it becomes effective.
- If pH is too high, elemental sulfur, iron sulfate or aluminum sulfate can be added to the soil to reduce alkalinity. Most ornamental plants require slightly to strongly acid soil. These species develop iron chlorosis when grown in soils in the alkaline range. Iron chlorosis is often confused with nitrogen deficiency since the symptoms (a definite yellowing of the leaves) are similar. This problem can be corrected by applying chelated iron sulfate to the soil to reduce the alkalinity and add iron.

Soil Testing

The purpose of a soil test is to supply the homeowner with enough information to make a wise fertilizer purchase. According to the University of Minnesota Soil Testing Laboratory website; “soil texture, organic matter, pH, buffer index, phosphorus, and potassium are part of the Regular Soil Test Series and are the usual categories tested. The University of Minnesota Soil Test Report is focused on describing the fertility status of your soil and providing information that will help improve the mineral nutrition of your plants.” The results of the soil test are sent to the homeowner to aid in determining what kind of fertilizer should be applied for economical growth of the desired crop. Soil tests should be performed if such tests have never been done before. A soil test need not be performed more often than every 3 to 4 years. The sample should be submitted in the fall prior to planting or tilling so that needed lime can be changing the pH over the winter. Fertilizers should be incorporated the next spring.

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