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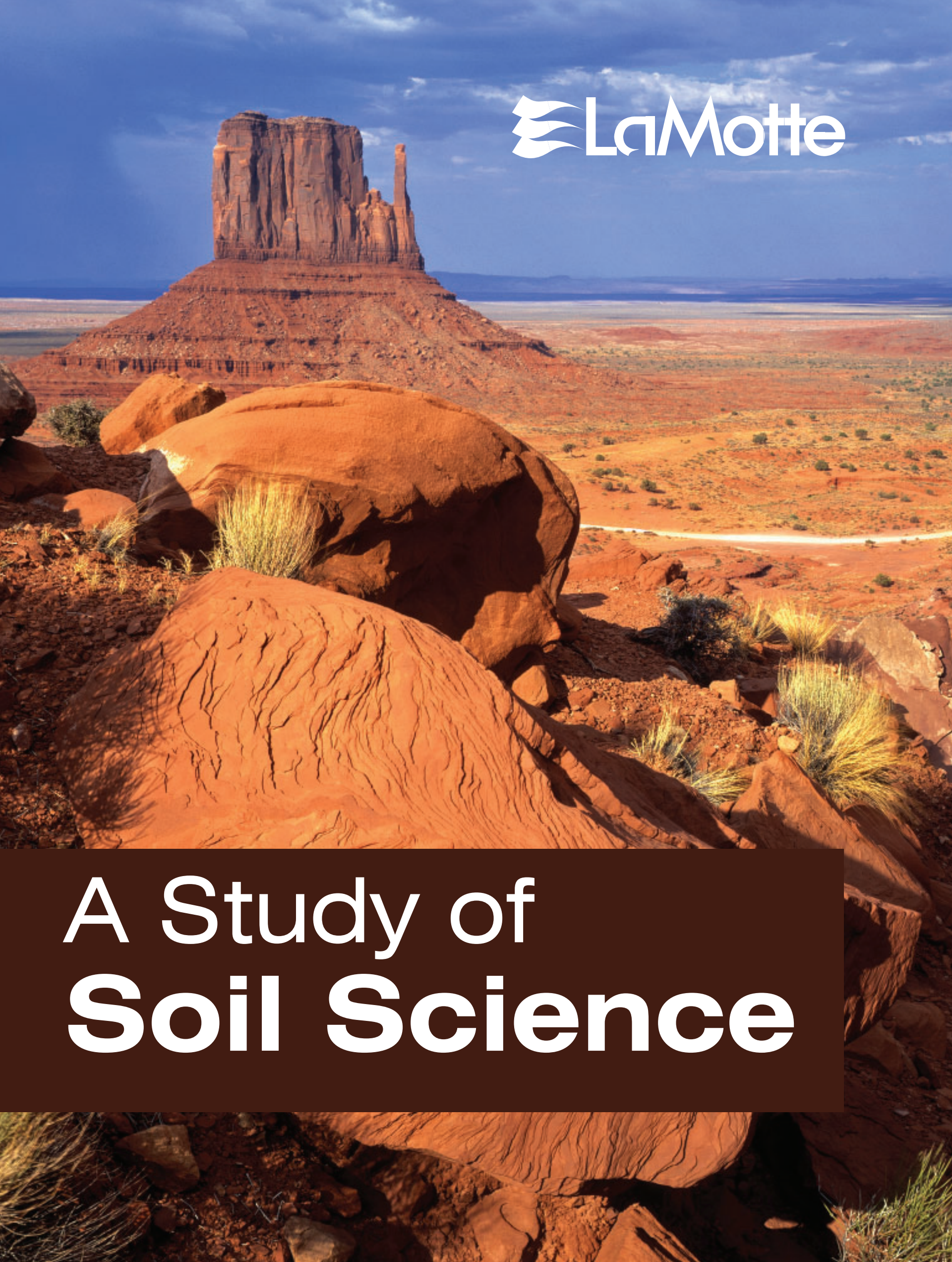

A Study of Soil Science

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The Expanded Second Edition

By Dr. Henry D. Foth

About the Author

This text has been prepared by Dr. Henry D. Foth, Professor of Soil Science, Michigan State University. Dr. Foth holds B.S. and M.S. degrees from the University of Wisconsin and received his Ph.D. from Iowa State University. Among the many organizations in which he has actively participated are the American Association for the Advancement of Science; Soil Science Society of America; American Association of University Professors; Soil Conservation Society of America; and the International Congress of Soil Science

Dr. Foth is co-author of *Fundamentals of Soil Science* (John Wiley and Company) and *Laboratory Manual for Introductory Soil Science* (W.C. Brown and Company). The author spent three summers working with the Earth Science Curriculum Project and is officially listed as a contributor to the text *Investigating the Earth*, a text developed by this project. Dr. Foth has also written numerous scientific articles for professional journals.

This text is distributed by the LaMotte Company, 802 Washington Avenue, Chestertown, Maryland 21620. We at LaMotte wish to express to Dr. Foth our deep appreciation for this splendid contribution to the study of soil science.

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Introduction

Soil makes up the “thin” layer of the earth where we live. The soil supports the plants that provide us with food, fiber, and forest products. Because the soil is located at the interface where the atmosphere and land meet, the soil acts like a policeman directing traffic by determining the amount of the rain that runs off and the amount of the rain that enters the soil. The soil stores and purifies water. Many waste products and chemical pesticides are destroyed by soil microorganisms. Soil that wanders about as sediment in waters or as dust in the air contributes to the pollution of our environment. Since the production of our food and the quality of our environment are so importantly related to the wise use of the soil, it is very important that all of us know some basic facts and ideas about the soil (Figure 1). The purpose of this booklet is to present some of these facts and ideas.

Fig. 1 Wise use of the soil helps to guarantee an abundance of food and a pleasant environment in which to live.

The Formation of Soil

Everywhere on the land surface there is either rock formation or soil exposed. When rocks that were formed deep in the earth are uplifted and exposed to the earth's atmosphere, the rocks adjust to the new environment. The chemical and physical changes that occur in the rock are called weathering. Weathering includes such physical processes as freezing, and thawing, and the action of wind, moving water and glacial ice. Chemically, minerals in the rock decompose. The loose mantle produced by weathering is soil (Figure 2).

A closer view of weathering and soil formation is presented in Figure 3. The weathered soil is about one foot thick. Depending on the chemical composition and hardness of the rock, the formation of a foot of soil could require as little as 100 years or as many as 100,000 years or more.

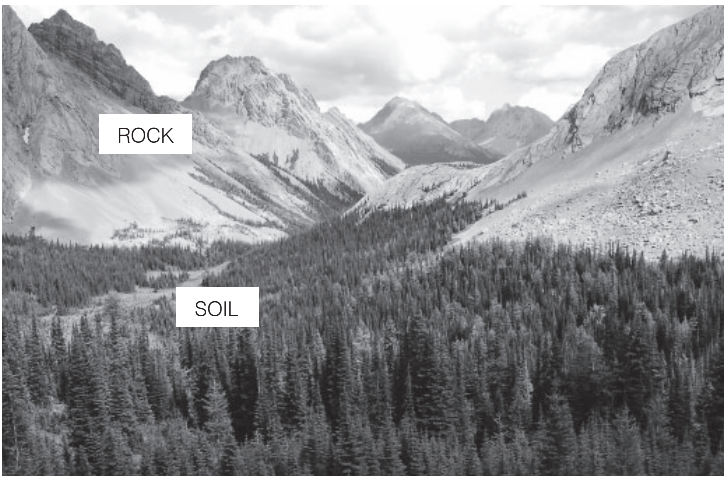


Fig. 2 When you climb to the upper end of a valley in the Rocky Mountains, you can get the feeling that you are seeing what the earth looked like soon after it cooled and rocks first weathered. Of course, at the time there were no plants or soils. Now, we see that trees quickly grow on the soil that is formed by weathering.

Fig. 3 A profile view of a soil formed directly from the weathering of bedrock. Thin soils like this one are best used for grazing animals or for forests.

We can also note that the soil in Figure 3 has a wide range in size of particles. Some particles are large rock fragments. Some particles are sand sized, like those in sand dunes. Particles of silt and clay size are usually so small they feel smooth and cannot be seen with the naked eye. Further, we see that plants are growing on the soil. The plants produce organic matter in the soil. Plant growth and weathering usually occur together in soil formation. In soil formation the plants roots excrete carbon dioxide that dissolves in the soil water and forms carbonic acid. This acid speeds up chemical weathering. Chemical weathering, on the other hand, causes elements that are essential to the growth of the plants to become soluble. In turn, chemical weathering contributes to the growth of the plants. Weathering and plant growth operate as a “team” in soil formation.

In most climates, water movement through the soil transports very small sized mineral particles, such as clay particles. The clay particles tend to be moved downward out of the topsoil and deposited in the subsoil layer. This causes subsoils to be enriched with clay particles and have a higher clay content than the surface soil. The soil profile in Figure 4 shows this feature which is very common in soils.

The Components of Soil

We have just seen that weathering and plant growth usually occur together during soil formation. Thus, soils are usually a mixture of both mineral matter and organic matter. Further, we can observe in Figure 3 that weathering of hard, dense rocks produces smaller particles which have spaces between them. Thus soils have pore space. The various components of the soil and their relationship to plant growth are summarized in Figure 5. Perhaps you would be surprised to see that a soil in a park, garden or in a lawn at your school may be about half pore space.

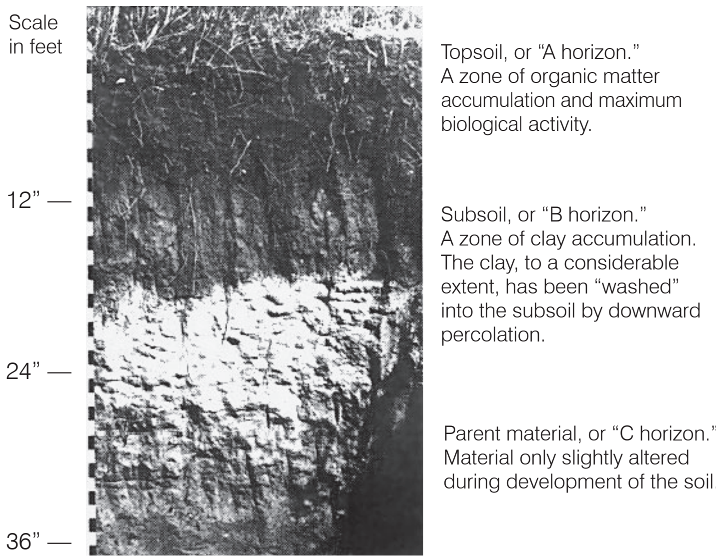


Fig. 4 A soil profile formed directly in a thick sediment. Plant roots and water readily penetrate the soil so that development of soil horizons is not directly dependent on weathering of bedrock. The dark-colored topsoil is indicative of a soil developed under Prairie grasses and well suited for agriculture. Compare this soil with the one in Fig. 3.

Mineral Particles

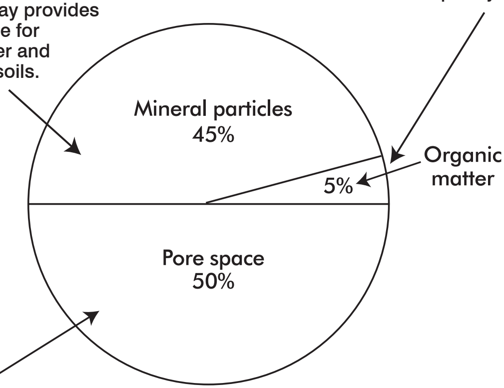
1. Sand and silt particles weather and essential plant nutrients become soluble for plants.

2. Clay particles are formed during weathering, and are very fine-sized. Clay provides most of the surface for absorption of water and nutrients in most soils.

Organic Matter

1. Provides essential nutrients for plants when decomposed. Very important for nitrogen.

2. Acts to make soils friable, easy to cultivate, and able to absorb water quickly.



Pore Space

1. Plant root live in pore spaces.
2. Some water is stored in pores.
3. Pores also contain oxygen needed for root respiration.
4. Pores allow oxygen to diffuse into soil and excess water to drain away.

Fig. 5 The components of a typical topsoil and their relationship to plant growth.

In relation to the overall size of the planet, the topsoil and subsoil layers of the earth are quite thin - so thin in fact that there are many areas where the soil layers have been eroded by water and wind, to expose parent rock formations. Other areas that have not been subjected to serious erosion may have apparently deep layers of soil; however, these thicker layers are only equivalent to one one-millionth of the earth's diameter.

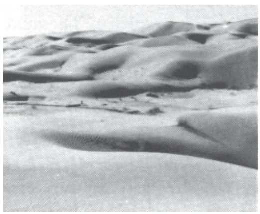
Imagine a gigantic apple that has a diameter of 200 feet. The skin on this gigantic apple is the same thickness as the skin on an ordinary apple. The relationship of the relatively thin skin to the gigantic apple is the same relationship that exits between the combined top and subsoil layers of soil on the earth's surface to the size of the earth itself.

From this brief study of soil formation, we can see that only an infinitesimal part of the earth's mass is available for the organized cultivation of crops.

Of the surface of this planet, approximately seventy-five percent is covered with water and the remaining twenty-five percent is land area (Figure 6). Of the land area, approximately three-fifths is either desert, frozen wasteland or too mountainous to support the cultivation of plant life. This leaves approximately one-tenth of the earth's surface available for growing the plants we need for food (vegetables and grains), for clothing (cotton), for shelter (timber), and for industrial raw materials (rubber, bean oils, etc.).

Oceans, seas, and lakes cover 75% of the earth's surface.

Deserts, polar ice caps, and mountains cover another 15% (right). Only 10% of the earth's surface is suitable for agriculture (bottom).



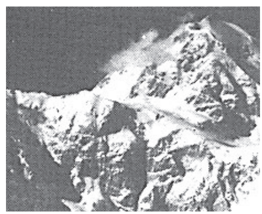


Fig. 6 The extent of the earth's surface that has soil suitable for agriculture is very limited.

Soil Particles Support Plant Life

Let us consider that plant life has its beginning in the seed that contains a dormant miniature plant (Figure 7). When a plant seed falls to the warm, moist soil, several interesting things begin to happen. First the seed absorbs water and swells. The dormant miniature plant in the seed embryo "comes to life." Respiration increases and food stored in the seed is digested. Soon, the seed bursts open and the top and root portions of the embryo emerge from the seed. This "borning" of a plant is called germination. Soon tender leaves emerge from the soil (Figure 8), then turn green and the plant begins to manufacture its own food. Food is what the plant manufactures in photosynthesis, for instance carbohydrates. Nutrients are absorbed from the soil or obtained from the air and water. Examples are carbon, nitrogen, iron, calcium. The food that was stored in the original seed is largely exhausted. The plant is now on its own, dependent on the air of the

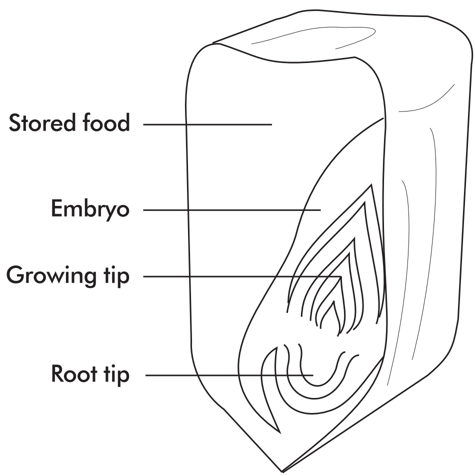


Fig. 7 A sketch illustrating the relationship of the miniture plant in the embryo and the food stored in a corn seed as seen under a microscope. After germination, the growing tip emerges from the ground and becomes the top of the plant and the root tip developes into the primary root system.

Fig. 8 Tender plant leaves emerge through well-cultivated soil. The leaves will manufacture food by photosynthesis and the roots will absorb water and nutrients.

atmosphere and water in the soil for the carbon, hydrogen and oxygen used to manufacture food by photosynthesis. The plant is dependent on the soil for the remaining thirteen essential elements that it needs. Very frequently one of the thirteen nutrients supplied from the soil particles limits the growth of plants. For this reason we need to look closely at how soil particles support plant life.

The chemical weathering of mineral soil particles is a very important source of plant nutrients. An illustration of a reaction is as follows:

$$\underset{CaCO_3}{\text{Calcite}} + \underset{H_2CO_3}{\text{Carbonic Acid}} \xrightarrow[\text{weathering}]{\text{chemical}} \underset{Ca^{++}}{\text{Calcium ion}} + \underset{2HCO_3^{--}}{\text{Bicarbonate ions}}$$

The calcite decomposed (or weathered) and calcium and bicarbonate ions were formed. Ions are positive or negatively charges atoms (Ca^{++}) or groups of atoms (HCO^{-}).

Microorganisms, primarily bacteria and fungi, decompose organic matter in the soil and nutrients are also released as ions. Organic matter is singularly important in supplying nitrogen for plants. Its preservation in the soil is of the utmost importance. A simple chemical test has been developed to determine if organic matter of humus is present in the soil.

Nutrients are usually absorbed through plant roots as ions and not as molecules or as discrete soil particles (Figure 9). About 150 years ago it was generally believed that small soil particles were absorbed by the roots of plants. The soil particles were believed to be digested in the plant like food is digested in the stomach. No wonder a great debate occurred when Liebig proposed the ionic theory of plant nutrition

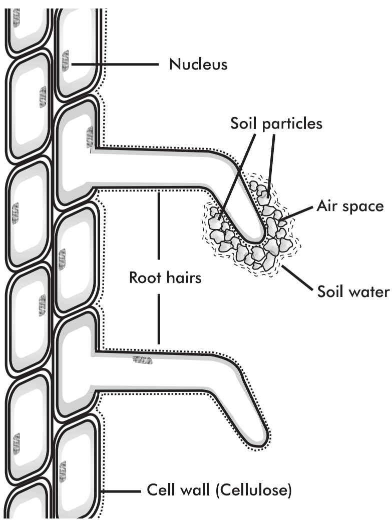
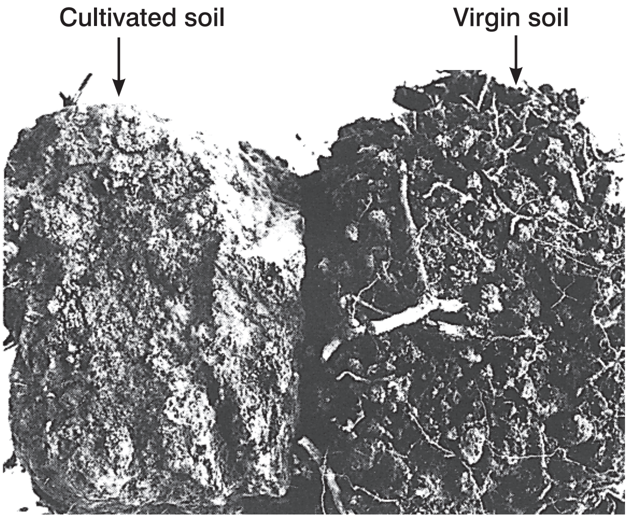


Fig. 9 The diagram shows the structure of root hairs extending out from the primary root. Note that these are surface cells and that they penetrate the air spaces in the soil. Soil water containing dissolved nutrients diffuses through the walls of these cells and is transported to all parts of the plant. Nutrients are usually absorbed through the roots as ions and not as molecules or as discrete soil particles.

about 1840. Now we know that soil particles are important because they are a source of essential elements required in the nutrition of the plant. We can consider that the soil, with its processes for weathering and decomposition, serves as a digestive system for the plant.



These two samples of soil were taken only 25 feet apart. The one on the left came from a cultivated field, and the one on the right from a virgin fence row. Note that the virgin soil is porous, full of roots, and has a great deal of organic matter.

Essential Plant Nutrients

If almost all types of soil can mechanically support plant life with equal ease, why are are some lawns greener than others, why do some gardens produce larger flowers or vegetables than others and why do certain farms produce higher yields than others? It is the presence of available plant nutrients that may determine if the plant will grow to a lush, full maturity or whether the plant will develop as a stunted, off-color miniature of what it should be. A fertile soil is one that is able to supply the complete dietary needs of the growing plant. You know the importance of well-balanced meals in your own welfare.

The same balance of proper nutrients is also very important to the healthy growth of plants. This means that a wide variety of ions must be available to the plant's root system and these ions must be available in correct proportions. Each nutrient has a specific function to perform in the life of the growing plant. If some essential nutrients are absent, the plant will show some characteristic signs of deficiency in its development. To the trained botanist or the experienced farmer the visible evidences of plant nutrient deficiencies are know as "hunger signs" (Figure 10). A chemical examination of the soil will provide information that can be used to determine what essential nutrient is needed and how much fertilizer should be applied.

Plants are capable of absorbing and assimilating as many as forty or fifty different chemical elements. Sixteen of these chemical elements have been found to be essential to the growth of most plants.

What are the names of these essential nutrients and what is the principal characteristic of each?

Fig. 10 Manganese-deficient plants usually develop yellow-colored leaves that have dark green veins. Such symptoms are seen on the upper leaves of this bean plant.

Nitrogen is the element which stimulates above-ground growth and produces the rich green color that is characteristic of a healthy plant. It also influences the quality of the plant's fruit and it increases the fruit's protein content. The plant's utilization of other major elements is stimulated by the presence of nitrogen in the plant.

Phosphorus is abundant in the fruits of plants and seeds and also in the parts of the root which are involved in the rapid uptake of water and nutrients, such as the root hair section. Phosphorus plays a major role in plants in those processes requiring a transfer of energy. An example of the need of the plant for energy is the formation of fats. Energy is also utilized by the plant to translocate food from one part of the plant to the other.

Potassium has much to do with the vigor and vitality of the plant, encouraging the development of a healthy root system and offsetting the harmful effect of excessive nitrogen. Potassium also tends to counteract a delay in ripening and thereby exerts a balancing effect on excessive nitrogen levels. Potassium appears to play a role in the synthesis of starch and the translocation of carbohydrates within the plant.

Calcium forms a structural part of the walls of plant cells. It gives rigidity or stiffness to plant stems in the same way that calcium in our bones makes them rigid. It also neutralizes acids that are formed within the plant.

Magnesium might be considered as a companion to calcium, for it is similar in many of its characteristics and usually occurs in nature along with calcium. In plant nutrition, however, magnesium is a working companion of phosphorus and stimulates the utilization of phosphorus by the plant. It is essential in the formation of chlorophyll, contributing largely to the healthy green quality of vegetation around us.

Sulfur is a constituent of plant proteins and some plant hormones. The element sulfur also appears to influence photosynthesis and protein synthesis.

Other elements required by plants include iron, manganese, boron, copper, zinc, molybdenum, and chlorine. The amounts of these required by the plant are very small and these serve largely in the enzyme systems of the plants. It is interesting that boron is needed by plants by not by animals. On the other hand, animals need sodium and iodine and plants do not.

The essential elements considered thus far are those that are supplied to the plant primarily from the soil particles and likely to be needed in fertilizers. The plant also requires large amounts of carbon, oxygen and hydrogen, in fact these three elements account for about 90 percent of the total. These last three, however, the plant generally obtains from carbon dioxide and water and, thus, in most cases are not as limiting to plant growth as the others. Many tests of soil are used for the purposes of determining the presence of the major plant nutrients (major elements).

Soil Reaction

When we asked the question "What is the reaction of a soil?" we mean is the soil acid (giving an acid reaction), or is it neutral (giving a neutral reaction), or is it alkaline (giving an alkaline reaction)? All soils fall into one of these three categories. Soils that give an acid reaction are sometimes called "sour" soils. Soils that give an alkaline reaction are sometimes called "sweet" soils.

To measure the soil reaction, an arbitrary scale is used. This same idea was used earlier in science so that man could read temperatures. A man named Fahrenheit developed a scale where 32° was the point at which water would freeze and 212° was the point at which water would boil. The Fahrenheit scale permitted readings to be made between these two extremes. The scale designed for reading levels of acidity or alkalinity was created with 0 being a very acid reading and 14 being a very alkaline point. The midpoint on the scale is 7 and this represents the neutral point. This scale is called a pH scale (always written with a small "p" and a capital "H"). This same scale is used to express the acid-alkaline nature or "pH factor" of water, food, paper, food products, laundry solutions, metal plating baths and many, many other liquids, gases and solids as well as soil (Figure 11).

The proper soil reaction or soil pH factor is extremely important to plants because it directly affects the availability of the plant food

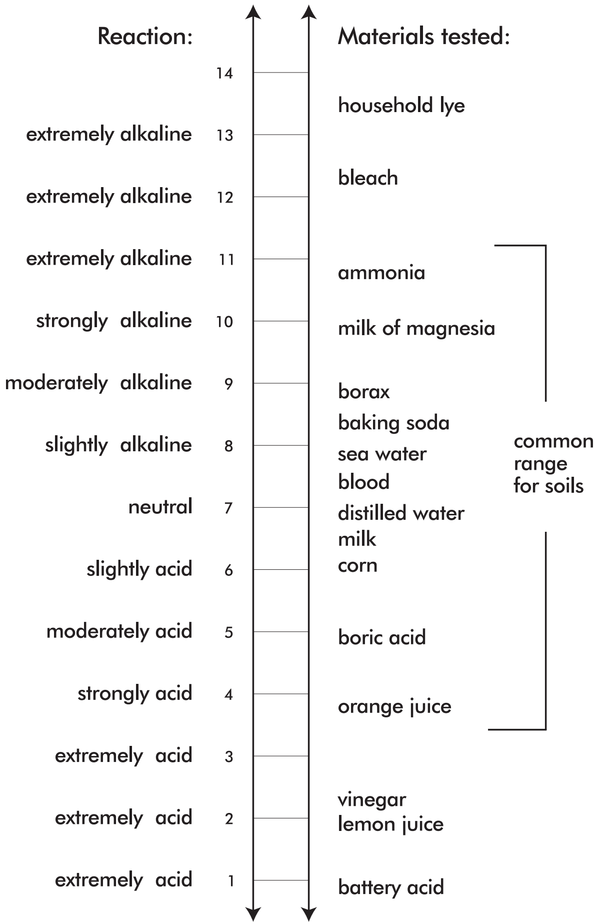


Fig. 11 The approximate pH values of some common substances, including soil.

nutrients which the plants need for efficient growth. Soils that are too acid or too alkaline will not favor the solution of compounds, and restrict the presence of ions of essential plant nutrients, as many of these elements do not dissolve easily in these extreme soil conditions. Because of this, most plants prefer a soil reaction that is neutral or near the neutral point. Soils in the pH range of 6.0 to 8.0 are generally satisfactory except for certain acid-loving plants that grow best in soils that have pH values in the range of pH 4.0 to 5.0. The pH value of a soil sample indicates the "chemical climate" of the soil. The manganese deficiency shown in Figure 10 resulted from the low solubility of manganese in an alkaline soil.

The chemical characteristics of a soil are dependent in part upon the nature of the rock from which the soil formed. The weathering of granite and many sandstones produces acid soils. The weathering of limestone commonly results in alkaline soils. In the humid regions, however, part of the rain water that falls on the land moves through the soil and carries away the most soluble constituents. Thus, in time, a soil formed from limestone can become acid after the lime has been removed.

Edmund Ruffin discovered this to be the case in Virginia. He wrote in 1832, "and what will be deemed incredible by some, for the greater part of the rich limestone soils between Blue Ridge and Allegheny are (equally) destitute of calcareous earth (lime)." Ruffin was not only one of the most famous early American soil scientists but Ruffin is one of several persons believed to have fired the first shot at Fort Sumter in 1861 that started the Civil War. Generally, then, in the humid regions soils are acidic in reaction and neutral or alkaline in reaction in subhumid and arid regions. A general distribution of these soils is given in Figure 12.

The soil reaction or pH of a soil can be changed by adding chemicals to the soil. If it should be necessary to increase the pH (make it less acid or to make it alkaline), calcium in the form of limestone is added to the soil. In the event it is desirable to decrease the pH (make it less alkaline or to make it acid), commercial alum or sulfur is added.

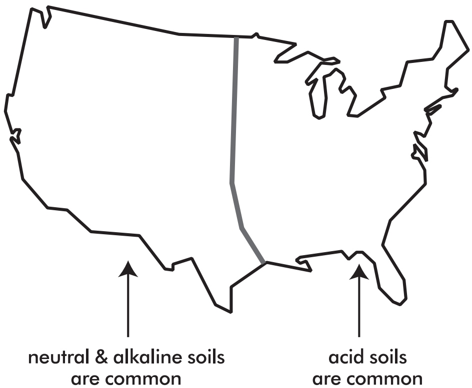


Fig. 12 General distribution of soils in the continental United States in relation to soil reaction.

A simple chemical test has been developed to determine the soil reaction or pH value of soil. The test can easily be made in the field.

Chemical Tests for Soil

Knowledge of the chemical characteristics of soil is essential to the successful growth of all plant life. This is true whether it is the professional raising of crops for commercial purposes or an amateur enterprise such as the raising of a lawn, shrubbery or a garden for decorative purposes. Soils are tested to determine if essential plant nutrients are present and if the soil reaction or pH value is correct for raising the desired plants. If the correct conditions do not exist, the soil tests tell what must be done to provide the correct balance of the necessary nutrients and to provide the proper soil reaction.

Since certain known plant nutrients are essential, why is it not reasonable to add the essential plant nutrients automatically so that you will know that there will be sufficient amounts of these plant nutrients present? First, this would be an extremely costly method of soil treatment, particularly in farming operations. Secondly, it is possible to have too much of a certain plant nutrient so that it causes an imbalance in feeding. For example, a great abundance of one plant nutrient may cause the plant to ignore a second plant nutrient that is present in sufficient quantities under normal conditions. The key that unlocks the door to successful plant culture is in the "balanced" abundance of essential plant nutrients.

Collecting and Preparing Soil Samples

Follow carefully the rules given here for collecting and preparing soil samples. When taking a soil sample in a lawn, a person should take a sample from the upper two or three inches of soil. In the case of garden and farm crops, the sample should be taken from the upper six to eight inches of soil. When analyzing a specific area of soil (a lawn, a garden or field) take the samples from several different locations within the area and mix them together. The resulting sample will provide an average value that will be representative of the entire area.

1. A clean trowel, spoon or knife can be used to obtain the samples.
2. Collect four or five heaping teaspoons of soil.
3. Place the soil samples in the plastic sampling bag.
4. The soil should not be touched with the hands any more than is absolutely necessary.
5. After the sample is collected, it should be placed on a piece of clean paper or plastic. The soil should be allowed to dry in the air for several hours or overnight. Do not bake the soil to accelerate drying.
6. All foreign matter (leaves, roots, stones, etc.) should be removed.
7. All lumps should be crushed until the largest clumps are not larger than ⅛ inch diameter.

The soil sample is now ready for use in the chemical testing procedures.

The soil sampling tube at left is used to obtain accurate soil samples without disturbing the terrain, except for the one-inch diameter core that is removed. The tube is pressed into the soil to the desired depth. The sawtoothed cutting edge is tapered so that the core is removed from the ground when the tube is extracted. The cutaway side serves two purposes: it permits the study of the topsoil-subsoil profile; and it allows the operator to select soil for analysis from the desired depth from the surface.

General classification of soils by texture can be made by liquid separation of the sand, silt and clay fractions based on their settling time, as seen at right. A measured amount of soil is shaken in water. The sand fraction will settle out quickly. The intermediate particle size of the silt causes it to settle out prior to the finely divided clay particles. The amounts of sand, silt and clay present in the soil sample are measured in graduated conical tubes.

Soil as a Water Reservoir

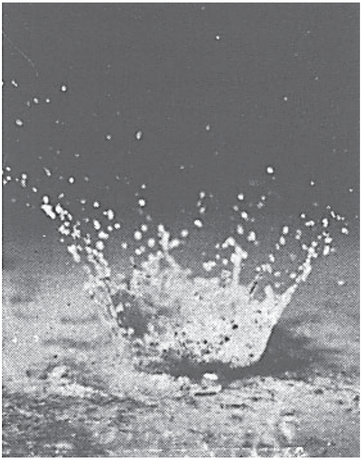
Millions of gallons of water land on the earth each second as rainfall. The soil, which is located at the air-earth interface, acts as a traffic director—directing the disposal of the rainfall that falls on the land. Approximately one-fourth of the rainfall runs off the land into streams, lakes and rivers. Most of the water, however, about 75 percent, enters the soil. The attraction between water and soil, being similar to that between water and glass, causes water to be absorbed on the surfaces of soil particles and retained in capillary-sized pores. Plants use this water in large quantities, requiring about 500 pounds of water for each pound of plant growth. The large water demands of plants and the large water storage capacity of the soil result in about two-thirds of the precipitation being disposed of through evapotranspiration (evaporation from plant leaves and the soil). Plant roots tend to be very well distributed through the soil and as a result, plants can effectively remove water throughout the root-zone.

Have you ever wondered how much water you use in a day? It will surprise you. On the average day, just for your household and general needs, each of us uses about 150 gallons. That is about 1200 pounds of water a day. If, on the other hand, we consider the water needed to produce our food, the figure increases many times. Consider the amount of water used to produce a loaf of bread. To do this we need to make a few assumptions that appear entirely justified. Plants use about 500 pounds of water to produce a pound of plant dry matter and a typical grain plant is about one half grain. This means that the remainder of the plant, consisting of the stalk, leaf and root makes of about half of the weight of the plant. Thus if one pound of wheat grain is required to make a loaf of bread, 1000 (500 x 2) pounds of water would be transpired to produce the grain to make the flour for a loaf of bread weighing about one pound. If wheat is eaten by a steer, about eight pounds of grain are required to produce one pound of beef. A large serving of meat, considered to be about a quarter of a pound, would require water transpired by plants to produce the grain that was fed to the steer equal to (¼ x 8 x 1000) 2000 pounds.

Although we need to drink only a pint or a quart of water a day to stay alive, each of us uses tons of water every day to supply our daily food and general living needs. As a collector and storer of water, the soil plays a vital role in our lives.

When rain occurs frequently, as during a rainy season, the soil absorbs water faster than plants can use it. The excess water percolates down below the root zones and contributes to the underground water supply. About eleven percent of the rainfall is disposed of in this manner. This water, however, is very important for providing a continuous supply of water for rivers and lakes and for contributing to the underground water reservoir. We remove much of this water in order to supply our daily water requirements. Obviously, the quality of the

Soil tests for plant nutrients can be made by extracting the nutrient material from the soil by means of an extraction solution. A sample of the soil and the extraction solution are shaken together in a test tube for a specified period of time. The extraction solution will remove a representative amount of the nutrient(s) from the soil. The liquid is then filtered and the chemical analysis is conducted on the extract. The composition of the extraction solution may be varied depending upon the type of soil being analized and upon the nutrient material being investigated.



Left: The stroboscopic camera has caught the impact and explosive burst of a raindrop falling upon bare, moist soil. The photo at right shows the effect of ground cover in breaking the driving impact of raindrops that first strike the plant leaves and then drop gently to the ground.

water that we pump out of the earth will be influenced by the kind of soil the water percolated through on its way to the underground water reservoir.

Life in the Soil

A handful of moist, fertile soil contains more organisms than there are people on the earth. The most numerous organisms are single-celled bacteria. Bacteria and fungi are non-chlorophyllous plants. Some specialized bacteria play an important role in removing nitrogen from the air and combining it into a form higher plants can use. This process is called nitrogen fixation.

Protozoa are single-celled animals that are a little more than masses of protoplasm with an appendage for locomotion. Protozoa feed on bacteria. Larger macro soil animals include worms, mites, centipedes, snails, ants, termites, gophers and badgers. Some animals, such as worms, infect plant foots and are harmful. Earthworms are beneficial by loosening the soil. Termites and ants are active in mixing the soil by bringing soil from deeper layers and depositing it on the surface. Many of these smaller macro organisms can be removed from the soil with a Berlese funnel as shown in Figure 13. The light is left on for about a day. As the heat from the light bulb dries out the soil, the soil animals are driven out of the soil and into the collecting bottle. A moist surface soil containing lots of organic matter, as found in a forest, is an ideal kind of soil for study.

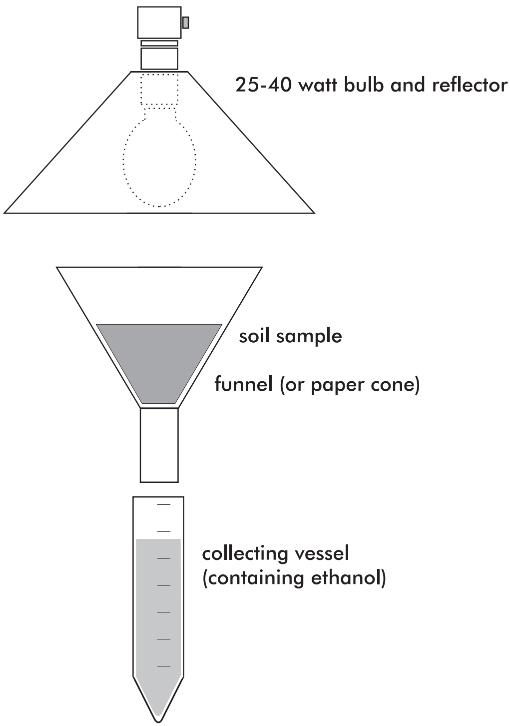


Fig. 13 The Berlese funnel is used for collecting small soil animals. The light bulb is suspended about 4 inches above the soil.

Life in the soil includes both plants and animals in as great a diversity as plants and animals living above the surface of the ground. In addition, the total weight of living matter, including plant roots, may equal or exceed the weight of life above the ground. Many of the activities of the organisms in the soil are beneficial, but others, as disease producing organisms, are harmful.

Role of Organisms in Chemical and Water Disposal

Man has developed chemicals that serve useful purposes. Some of these chemicals, however, are foreign to the soil. To prevent excessive pollution of the environment with harmful chemicals, we have restricted the use of persistent chemicals like DDT and use chemicals the soil organisms can decompose or detoxify soon after the chemicals have served their purpose.

Suburban and country homes use septic tanks for digestion of sewage and filter fields for the disposal of the septic tank effluent (Figure 15). The sewage effluent water is purified as it percolates through the soil.

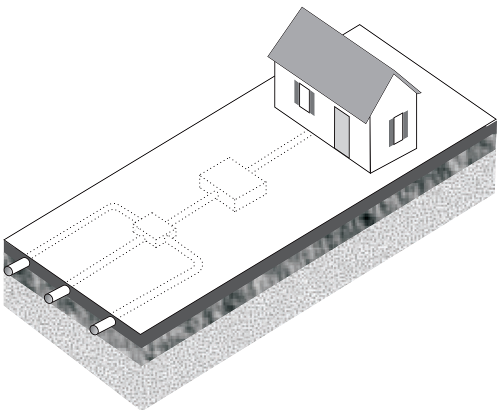


Fig. 15 Many homes in suburbs and rural areas are too far from city sewer lines to use city sewage disposal systems. These homes use septic tanks for digestion of sewage and filter fields for the disposal of the sewage effluent (water).

The effluent eventually helps to recharge the underground water reservoir. Soil organisms also destroy disease organisms and decompose many of the waste materials still remaining in the septic tank effluent water.

Permeable soils are required for filter fields; otherwise, the effluent may naturally saturate the soil with polluted water. Unfiltered effluent would become a health hazard wherever it seeps or flows. Soil permeability can be determined by digging a hole as deep as the filter field bed will be located. The bottom of the hole is covered with gravel and then filled partially with water. A measuring stick is used to determine how rapidly the water infiltrated into the ground. Soils with permeability rates less than an inch per hour are likely to be too impermeable for use as filter beds. One soil property that can be studied easily and is related to permeability is texture. In general the more clay in the soil, the more impermeable the soil; the more sand the more permeable.

Septic system filter field installed in soil. This part of the septic system disposes of the septic tank effluent. The sewage effluent water is purified as it percolates through the soil.

Glossary of Terms

A definition of commonly used terms relating to soil and plant management.

Absorption: Assimilation of molecules or other substances into the physical structure of a liquid or solid without chemical reaction.

Acid soils: Soils having a pH below 7.0 or neutral. Soils may be naturally acid from their rocky origin, by leaching, or may become acid from decaying leaves or from soil additives such as alum. Acid soils can be neutralized by the addition of lime products.

Acid-loving plants: Some plants thrive in acid soils and some are damaged by neutral or alkaline soil reactions. A few of these are:

Andromeda	Heath
Azalea	Heather
Blueberry	Mountain Laurel
Calla	Orchid
Camellia	Rhododendron
Galax	Trailing Arbutus

Adsorption: Physical adhesion of molecules to the surface of solids without chemical reaction.

Aeration: The circulation of air within the soil. Plant life requires oxygen in the root zone as well as the leaf area. Compacted soil, where air cannot travel freely, should be broken up by spading or aerating equipment which perforates the soil.

Agronomy: A specialization of agriculture concerned with the theory and practice of field crop production and soil management. The scientific management of land.

Alkaline soils: Soils having a pH reading above 7.0-opposite of acid soils. Alkaline soils are usually caused by native limestone or other alkaline materials. However, they can be caused in garden soils by over-liming. While acid-loving plants will become stunted and sickly in alkaline soils, there are some plants that thrive on neutral or slightly alkaline soils. A few of these are:

Asparagus	Lilac
Bean	Pansy
Begonia	Pea
Canna	Phlox
Dahlia	Sweet Pea
Lettuce	Turnip

Alum: The common name for Aluminum Sulfate, a chemical used to acidify neutral or alkaline soils. Applied in powder or solution form, the amount added should be dictated by a pH soil test.

Aluminum sulfate: Technical name for Alum.

Anion: A negatively charged ion resulting from the dissociation of molecules in solution.

Assimilation: The taking up of plant nutrients and transforming them into actual plant tissues.

Available: Referring to plant nutrients, it means that they are capable of being assimilated by growing plants.

Bacteria: Microscopic single-celled organisms vitally helpful in increasing soil fertility and plant life. They break down complex substances in soil, fertilizer and vegetable matter and convert them to simpler forms which are available for plant assimilation.They are also capable of taking free nitrogen from the air and making it available to plants. Bacterial action is the basis of composting.

Bedrock: The solid rock underlying soils.

Biological function: The role played by a chemical compound or a system of chemical compounds in living organisms.

Buffer: A substance which tends to resist changes in the pH of a solution

Burning: Concentrated commercial fertilizers may cause burning as they become soluble in soil moisture. The resulting solution is so concentrated that it reverses the natural flow of sap up from the root hairs. The sap is drawn out of the plan cells by the abnormal action and the affected plant tissue.

Calcium: One of the major plant nutrients, it forms the structural part of the walls of plant cells. It is generally applied to soil in the form of calcium carbonate (limestone) or as an ingredient in commercial fertilizers.

Carbon: An important element in the structure of all plants, it makes up about one half of their dry weight. It is obtained primarily from the carbon dioxide in the air.

Cation: A positively charged ion resulting from the dissociation of molecules in solution

Chlorophyll: The pigment responsible for the green color of plants. It is important in photosynthesis in plants, the process by which sugar is manufactured.

Chlorosis: The reduction of the amount of chlorophyll in plants that causes discoloration of the foliage. Lack of nitrogen, magnesium, sulfur or iron in the soil, excessive soil alkalinity or virus diseases may cause chlorosis. Chlorosis is comparable to anemia in animals.

Clay soil: (Clay particles are mineral particles <0.002 mm in diameter). In the grading of soils by texture, clay is the extreme of fineness. Clay soil has the tendency to become sticky or greasy to the touch and when dry it becomes extremely hard and brick-like. Inexpensive test equipment is available for determining if soil is clay, sand or loam. Clay soils require larger amounts of lime or alum to bring about desired changes in soil pH than do sandy or loam soils.

Colloidal: Matter of very fine particle size.

Color chart: A series of printed colors that represent various degrees of abundance or deficiency of plant nutrients or soil reaction in soil samples. In soil tests, the color that results from the addition of the test reagent is compared with the color chart and the results are read directly from the chart.

Color standards: Printed overlays or glass tubes that contain a series of colored solutions that are used in the same manner as the color charts above.

Compaction: A state of the soil where it has been pressed together, either by nature or by heavy construction or farm equipment. Special sampling tubes are available where a cross-section of the soil can be removed and the layer of compaction determined. This compacted layer should be broken up to allow the proper circulation of air and water through the soil.

Compost: A mixture of soils and organic matter made up of fermenting or decomposed materials such as leaves, grass, straw or garden wastes. This rich soil preparation supplies both humus and plant nutrients in a safe, convenient form. This material is developed by a means of a compost heap which consists of alternating layers of vegetable matter, manure and a mixture of soil, limestone, and commercial fertilizer. The pile should be kept moist and should be spaded over and re-piled periodically.

Deficiencies: The total lack or insufficient presence of the necessary plant nutrients in soils or in plant tissues. The deficiencies are determined by means of soil and plant tissue testing sets.

Depletion: The removal of plant nutrients from the soil by leaching of rain water and by plant growth, particularly those plants or crops that are harvested. The rate of depletion can be determined by periodic soil tests. The depleted plant nutrients must be replaced by humus or commercial fertilizers from successful growth of the future plants.

Drainage: The removal of excess water, both surface and subsurface, from plants. All plants, except aquatic, will die if exposed to an excess of water. To overcome this condition holes are placed in the bottom of flower pots and cinder, gravel, or other granular materials are placed in layers beneath beds that do not drain naturally.

Earthing-up: Mounding or hilling up of soil around the roots of plants. The purpose may be to increase root-hold, to cover tubers of potatoes, etc. or to protect semi-hardy plants during the winter

Ecology: The science that deals with the interrelations of organisms and their environment.

Environment: All external conditions that may act upon a soil or organism to influence its development. Such factors may include sunlight, temperature, moisture, chemical pollutants and various organisms.

Equivalent, chemical: The weight in grams of a substance which combines with or displaces one gram of hydrogen, obtained by dividing the formula weight by the valence. Thus for Potassium with an atomic weight of 39.1 and valence of 1, the chemical equivalent is 39.1 grams, whereas for aluminum with atomic weight 26.98 and valence of 3, the chemical equivalent is 8.99 grams.

Erosion: The detachment and transport of soil particles by the action of wind and water. This great destructive force can be combated by cover crops, contour planting or terracing, gully control or wind breaks.

Eutrophic: Having concentrations of nutrients in solution optimal for plant or animal growth.

Exchange capacity (cation): The exchange capacity of a soil depends upon the amount of clay and organic matter capable of adsorbing cations. Adsorption of an added cation results in the release of an equivalent amount of some other cation from the soil. Usually expressed as meq/100 g of soil.

Extracting solution: A solution used in soil testing for removing elements from the soil for test purposes. The soil is shaken in a tube with the extracting solution and then filtered. The resulting mixture is then tested for the presence of plant nutrients.

Fertilizer: Any natural or manufactured material added to the soil in order to supply one or more plant nutrients. Fertilizers can be obtained as separate plant nutrients, but most often they are sold as a mixture of nitrogen, phosphorus, and potassium. On each bag of mixed fertilizer will appear the analysis of the ingredients in a standard formula. For example, a fertilizer with a 5-10-5 formula means that the contents are guaranteed to be 5% Nitrogen - 10% P_20_5 (4.4% phosphorus), 5% K_20 (4.15% Potassium).

Filtrate: The liquid which has passed through a filter.

Fixation (in soil): The conversion of a soluble material, such as a plant nutrient like phosphorus, from a soluble or exchangeable form to a relatively insoluble (unavailable) form.

Food, plant: The organic compounds made by a plant within its cells. (Sometimes used loosely for plant nutrients).

Friable: Refers to a soil that is rich, light and easily worked with the fingers.

Germination: The beginning of plant growth from a seed. When a seed is planted water is absorbed, the seed coat is ruptured and the root growth begins.

Gibberellins: A group of growth-regulating substances that are produced by a certain species of fungi of the genus "Gibberella."

Green manure: Growing plant material, while green or soon after maturity, is mixed with soil, thereby increasing the organic content of the soil.

Ground water: That portion of the total precipitation which at any particular time is either passing through or standing in the soil and the underlying strata and is free to move under the influence of gravity.

Gypsum: The common name for calcium sulfate. It is not considered to be of much value as a fertilizer. It is sometimes used as a filler for other commercial fertilizers.

Heaving: The lifting action exerted by the soil during the alternating freezing and thawing of winter. Sandy soils heave very little, while heavier clay soils can lift roots completely out of the ground.

Humus: The well-decomposed vegetable and animal material which is capable of holding large amounts of plant nutrients and moisture. See composting.

Hydrated lime: A calcium compound in the hydroxide form used as a soil additive for reducing acidity and as a source of calcium, an essential plant nutrient. It is also know as slaked lime and is a product of quick-lime treated with steam or water.

Hydroponics: The practice of growing plants in tanks of nutrient solutions. It differs from chemical gardening only in that it does not employ a supporting medium such as gravel, sand, etc., but merely a screen to support the plants.

Igneous rock: Rock formed from the cooling and solidification of magma, and that has not changed appreciable since its formation.

Indicator solution: A chemical reagent used in soil testing to determine the pH or degree of acidity or alkalinity in a soil sample. Generally a single wide range indicator solution is used, however, for extremely accurate readings a series of short range indications is used.

Inorganic: Non-living matter, such as rock, clay or sand as contrasted with organic or living matter such as plants and animals. The mineral fraction of soil is inorganic.

Insoluble: Will not dissolve easily in water

Ion: Atoms, groups of atoms, or compounds which are electrically charged as a result of the loss of electrons (cations) or the gain of electrons (anions).

Iron: One of the elements essential to plant growth, it is found in sufficient quantity in practically all soils. Iron becomes insoluble (unavailable) when the soils become alkaline (above pH 7.0) and plants grown therein may sometimes exhibit chlorosis

Irrigation: The artificial application of water to the soil for the benefit of growing crops.

Land classification: The arrangement of land units into various categories based upon the properties of the land and its suitability for some particular purpose.

Leaching: The removal of soluble chemical elements by the passage of water through the soil.

Lime: A chemical compound containing calcium that is used as a soil adjustment material and also as a source of calcium as a plant nutrient. Limestone is calcium carbonate, quick lime is calcium oxide, and slaked or hydrated lime is calcium hydroxide. Besides its neutralizing effect and nutrient properties, it also has a beneficial effect on the structure of the soil. The amount of lime needed is determined by a simple soil pH or acidity test.

Loam: A class or texture of soil that contains moderate amounts of sand, silt, and clay. Soils that are predominantly sandy but contain silt and clay fractions are called sandy loams. Soils having a large proportion of clay, but with some sand or silt present are called clay loams or clays.

Magnesium: One of the important plant nutrients. it is known to stimulate the assimilation of the key plant nutrient: phosphorus.

Manure: Manure is the animal waste from stables and barnyards used to enrich the soil. Manures are extremely valuable as they provide both plant nutrients and organic matter for soils.

Marl: An earthy deposit consisting mainly of calcium carbonate, usually mixed with clay. Marl is used for liming acid soils. It is slower-acting than most lime products used for this purpose.

Marsh: Periodically wet or continually flooded areas with the surface not deeply submerged. Covered dominantly with sedges, cattails, rushes, or other water plants.

Micro-nutrients: See Trace Elements.

Metamorphic rock: A rock that has been greatly altered from its previous condition through the combined action of heat and pressure. For example, marble is a metamorphic rock produced from limestone, gneiss is produced from granite, and slate is produced from shale.

Micro-organisms: Forms of life that are made up of organisms too small to be clearly distinguished without the use of a microscope.

Milliequivalent (meq): A milliequivalent is 1/1000 of an equivalent. Examples: meq for Aluminum is 8.99 milligrams and for Potassium 39.1 milligrams.

Mineral soil: A general term for a soil composed chiefly of inorganic mineral matter, in contrast to an organic soil which is composed chiefly of organic matter.

Muck: A type of soil consisting of highly decomposed organic material. It has undergone a more complete decomposition than peat and has higher mineral content than peat. It is dark brown or black in color and its nutrient are very slowly available to plants

Mulch: A natural or artificial material applied in layers on the surface of the soil and around outdoor plants for the purpose of conserving moisture and controlling extremes in temperature. Compost, straw, leaves, sawdust and paper are commonly used mulching materials.

Neutral soil: A soil that is neither acid nor alkaline, but having a pH of 7.0. Few soils are exactly neutral for they tend to become acid with moisture and alkaline with extreme dryness. Acid soils are made neutral by the addition of lime while alkaline soils are made neutral by the addition of alum, sulfur, or tannic acid.

Nitrate: (see Nitrogen) A form of nitrogen that is readily available to plants. Ammonium nitrate is widely used as a nitrogen fertilizer.

Nitrogen: One of the key elements essential to plant life. It stimulates above-ground growth and produces the rich green color characteristic of a healthy plant. Soils are usually low in nitrates due to the ease with which it is leached out of the soil and because it is consumed in volume by living plants. The nitrogen concentration is represented in the first figure of a fertilizer formula.

Nutrient, plant: Any element taken in by a plant, essential to its growth and used by it to produce its food or tissue.

Organic: This term generally refers to material derived from plants or animals. Humus and compost are examples of organic materials.

Organic fertilizer: Any product having value as a plant nutrient that derives its being from an animal or vegetable source. Such materials as barnyard manure, compost, leaf mold, green manure are considered organic fertilizers. Generally the term fertilizers refers to chemical plant nutrients which are manufactured or processed and not considered organic materials.

Organic matter: That fraction of soils which results from the decomposition of vegetable and animal matter though the action of bacteria. It is one of the important constituents of soil because it provides a natural home for the bacterial action necessary for plant life. Organic matter in soils can be increased by the addition of manure, compost and activated peat moss. Soils rich in organic matter have high water-retaining capacity and are usually well-aerated.

Osmosis: The movement of a liquid across a membrane from a region of high concentration to a region of low concentration. Water and nutrients move into roots independently.

Peat or Peat moss: Obtained from deposits of partly decomposed plant life, peat moss has become widely used as a mulching material, rooting medium and a source of organic matter. It has very little value as a plant nutrient, however it is extremely helpful in importing the water retention and aeration properties of soils.

Percolation: The downward movement of water through soil.

Permeability, soil: The property of the soil that enables water, air or roots to move through it. A heavily compacted soil restricts such movements.

pH: The degree of acidity or alkalinity of the soil. Also referred to as soil reaction, this measurement is based on the pH scale where 7.0 is neutral —values from 0.0 to 7.0 are acid and values from 7.0 to 14.0 are alkaline. The pH of soil is determined by a simple chemical test where a sensitive indicator solution is added directly to a soil sample in a test tube.

Phosphate: A general term for a compound of phosphorus which is one of three most essential plant nutrients. Bonemeal is a source of phosphates. Most phosphate fertilizers are either natural phosphate rock or phosphate rock treated with sulfuric acid - super phosphates. It is used in rather large amounts an is a major component of most mixed fertilizers.

Phosphate rock: Also rock phosphate. A natural deposit of rock containing one or more calcium phosphate minerals of such purity as to permit its use in the manufacture of commercial fertilizers.

Phosphorus: One of the big three in plant nutrients (along with nitrogen and potassium) of utmost importance in plant life. Phosphorus stimulates early root formation, gives a rapid and vigorous start to plants, hastens maturity, stimulates blooming and acid in seed formation. The concentration of phosphorous in mixed fertilizers is denoted by the middle figure in the fertilizer formula. Super phosphate is sometimes given the formula 0-45-0 which denotes the fertilizer is 45% available phosphate expressed as P_20_5.

Photosynthesis: The process by which green leaves of plants, in the presence of sunlight, manufacture their own needed materials from carbon dioxide in the air and water and minerals taken from the soil.

Pipet: A plastic or glass tube used for the transfer of a measured amount of liquid.

Pore space: That part of the soil that is not occupied by solid particles.

Potash: A common name for a compound containing potassium, one of the primary plant nutrients, the oxide of potassium.

Potassium: A primary plant nutrient of great importance, it imparts increased vigor and disease resistance to plants. It is responsible for producing strong, stiff stalks, increased plumpness in grain and seeds, and is essential in the development of chlorophyll. In mixed fertilizers, its concentration is denoted by the third figure given. For example, a formula of 6-10-8 contains potassium equivalent to 8% K_2O potassium. The presence or absence of available potassium in soil can be determined by a simple soil test using a very small sample of the soil in question.

Potting soil: A good potting soil is light, well supplied with humus, sand, and plant nutrients, well sifted and uniformly mixed. It should be damp but not wet.

Precipitate: An insoluble compound formed by chemical reaction between two or more normally soluble compounds in solution.

Primary elements: Nitrogen, phosphorus and potassium are considered the primary plant nutrients. Their absence or presence in the soil is determined by simple soil tests and in plants by tests that are similar to soil tests, but called plant tissue tests. Other elements required for plant life are classified as either secondary or trace elements.

Productive soil: A soil in which the chemical, physical and biological conditions are favorable for the economic production of crops suited to a particular area.

Quicklime: A common name for calcium oxide, a fast-acting product added to the soil for decreasing acidity and to provide calcium as a plant nutrient.

Reagents: The chemicals, each with a specific purpose, used in the analysis of soil and plant tissues.

Rock-phosphate: See Phosphate Rock.

Root: The descending portion of a plant whose purpose is to penetrate the soil, absorb moisture and nutritional elements that will be converted into food by the leaves.

Root zone: The area of the soil where the roots of a particular plant will have their greatest concentration. The root zone varies for each plant. It is all-important that both plant nutrients and moisture reach the root zone for the beneficial effects to be realized.

Runoff: That portion of the precipitation on an area which is discharged from the area through stream channels. That which is lost without entering the soil is called "surface runoff" and that which enters the soil before reaching the stream is called "ground water runoff" or "seepage flow" from ground water.

Sand: Minute rock fragments that make up the mineral portion of soil. Sands are formed though erosion of native rock material.

Sandy soil: Technically a soil that contains 70% or more of sand and 15% or less of clay. A simple soil texture test has been developed to determine if soils are sand, silt or clay.

Sap: The aqueous fluids in plants which contain and transport the material necessary for plant growth. Sap is motivated in its travel by variation of root pressure.

Secondary element: Calcium, sulfur, magnesium, and iron. These plant nutrients are required in smaller quantities than the primary elements, nevertheless they must be considered in soil management. These materials are generally found in abundance, however, proper pH control must be maintained to assure their availability.

Seedlings: The first visual evidence of the successful germination of a seed. The seedling comes into being when the food stored in the seed pod has been used up. Its primary roots grow long, branch roots develop and the first leaves unfold and expand.

Silt: A type of soil that falls in between sand and clay in texture. It is usually found in combination with one or the other of these soil fractions.

Slaked lime: See Hydrated Lime.

Soil chemistry: A division of soil science concerned with the chemical constitution, the chemical properties and the chemical reaction of soils.

Soil horizon: A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil-forming processes. These characteristics form the basis for systematic classification of soils.

Soil profile: A vertical section of the soil through all its horizons and extending into the parent material.

Soil reaction: The soil reaction of a sample is the pH value or degree of acidity or alkalinity of the soil. This determination is made by means of a simple pH test. The reaction of the soil dictates the amount of lime or alum needed to bring the soil to the desirable level.

Soil salinity: The amount of soluble salts in a soil, expressed in terms of percentage, parts per million or other convenient terms.

Soil sampling tube: A device for conveniently removing a sample of soil from the earth without disturbing the surrounding area. These tubes are used for getting sub-surface samples and some penetrate to a depth of six feet. A special "cut away" model has been devised for locating compacted layers in the soil.

Soil science: That science dealing with soils as a natural resource. It includes the study of soil formation, classification and mapping, and the physical, chemical, and biological properties of soils and their relationship to crop production.

Soluble: Will dissolve easily in water.

Sour: Acid soils are sometimes referred to as “sour” soils. Sour soils fall within the pH range of 4.0 and 6.0

Sub-soil: The layer of soil normally found beneath the top soil. It is often more compacted than the top soil and contains less organic matter.

Sulfur: One of the secondary elements essential for plant growth, it is utilized by the plant in the production of proteins, vitamins, etc., and is important in the manufacture of chlorophyll. Lack of sufficient sulfur results in chlorosis. Super phosphate sulfur is found in most commercial fertilizer mixtures. Sulfur is sometimes used to acidify alkaline or neutral soils.

Super phosphate: A fertilizer product containing approximately 20% or more available phosphorus as P_2O_5. It is formed by treating phosphate rock with sulfuric acid. Double or triple super phosphate contains 40% to 50% available P_2O_5.

Sweet: Alkaline soils are sometimes referred to as “sweet” soils. They have a soil reaction (pH reading) above 7.0 as determined by a simple soil pH test.

Test plate: A specially designed plate used in the analysis of soils. In some tests the soil itself is placed directly on the plate and in other tests solutions are placed on the plate for color development.

Test tube: A plastic or glass tube, especially marked and graduated, used in the analysis of soils.

Tidal flats: Areas of nearly flat, barren mud periodically covered by tidal waters. Normally these materials have an excess of soluble salts.

Tile drain: Concrete, ceramic or plastic pipe placed at suitable depths and spacings in the soil or subsoil to provide water outlets from the soil.

Tilth: The physical condition of soil as related to its ease of tillage, fitness as a seedbed, and its effect upon seedling emergence and root penetration.

Tissue testing: The analysis of the leaves and living tissues of plants for the purpose of determining the presence or absence of necessary plant nutrients. Often the soil may contain an adequate supply of plant nutrients, but the plant itself is unable to utilize it. This may be due to plant disease, dry soil or damage to the root system. Tissue tests are performed in the same manner as soil tests, using the same reagents and equipment.

Trace elements: Those elements essential to plant life that are required in extremely small quantities. The trace elements are: Manganese, Boron, Zinc, Copper, Cobalt, Aluminum and Molybdenum. The presence of these elements not only benefits the plant nutritionally, but also prevents numerous plant diseases. Excesses of trace elements have a toxic effect on plants and the addition of them should only be made following a soil analysis and careful study.

Turbidity: The reduction of transparency of a liquid due to the scattering effect of light by suspended particles.

Underground runoff (seepage): Water flowing toward stream channels after infiltration into the ground.

Wasteland: Land not suitable for, or capable of, producing materials or services of value.

Weathering: All physical and chemical changes produced in rocks, at or near the earth's surface, by atmospheric agents.

Soil Science in Earth Science Studies

As Earth Science studies now appear on virtually all secondary school curriculums, the attention given Soil Science has increased dramatically. The subject of Soil Science presents opportunities for classroom studies, laboratory activities and field trip experiences. Academically, this study brings together the classical geologic science with the present day concern for our immediate environment. In the concept of time, soil science studies are at the immediate focus between the historical origin of the earth's formation and the future potential of the productiveness of the earth's thin veneer of tillable soil. Accurate measurement of soil is a vital engineering challenge for those responsible for providing the food and fiber for the exciting world of tomorrow.

Other LaMotte Science Handbooks

A Study of Water Quality by Dr. Charles E. Renn, Professor of Environmental Engineering Science, Johns Hopkins University.

This text covers the factors that determine the quality of water. It studies the "life cycle" of water, beginning with water in its purest form found in nature, observing it as it is altered by its contact with the atmosphere and the earth and continuing the study through the basic treatments involved in the production of high quality water suitable for use in industry and in the home. The problems of scale formation, corrosion, and staining are discussed as are the objectionable characteristics of taste, odor, color and turbidity in water. Order by Code Number 1532.

Our Environment Battles Water Pollution by Dr. Charles E. Renn, Professor Environmental Engineering Science, John Hopkins University

The author identifies flowing water as a living, changing environment and explains the changes that take place and why these changes come about. The text traces a theoretical river from its origin as a mountain brook, detailing the biological and chemical changes that take place as the stream grows in volume and gains a more complex composition, until it finally discharges into a marine estuary. Some of the subjects covered are natural mechanisms that purify water, the reaction of fish to various water conditions, the differences between water in motion and water impounded, the relationship between air pollution and water pollution and the detection and reporting of water pollution factors. Order by Code Number 1592.

Limnology : An Introduction to the Fresh Water Environment, by William H. Amos, Chairman, Science Department, St. Andrew's School

This text is an authoritative booklet written expressly for instructors and students interested in studying fresh water supplies. The information is presented in a straightforward manner and there is an abundance of photographs and diagrams that illustrate the essential areas of investigation. The text discusses the basic chemical and physical characteristics of water, stream dynamics, plant zonation, the succession of ponds, the energy cycle of ponds and the adaptation of plants and animals to various aquatic conditions. The biological environments of ponds, lakes, swamps, streams, and rivers are discussed. Order by Code Number 1593.

pH, Buffers and Acid-Base Titrations by Staff, LaMotte Company

This booklet deals with the practical applications of pH control by employing pH indicators with color standards or buffer reagents as reference points. Considerable emphasis is put upon both the theoretical as well as the practical application of acids and bases in chemical testing. Among the tables given is a graph of a typical acid-base titration. Order by Code Number 1595.

Environmental Science Testing Products Catalog

LaMotte Company offers a free Environmental Science Education catalog (code 1590) which contains practical, "hands-on" test equipment for air, soil and water chemistry students in elementary, secondary, vocational, outdoor and college science programs.

For those interested in further investigations in Soil Science the following publications are recommended:

Kellogg, Charles E., *The Soils That Support Us*. The Macmillan Company, New York, 1971.

McGraw-Hill Encyclopedia of Science and Technology. McGraw-Hill Book Company, New York, 1960. Volume 12, "Soil", and Volume 14, "Weathering"

United States Department of Agriculture, "Soil," 1957, and "Land," 1958. United States Government Printing Office.

Kellogg, Charles E., "Soil." Scientific American, July, 1950 (also Scientific American Offprint No. 821)

"Soil and Water Conservation Activities for Boy Scouts," United States Department of Agriculture Bulletin PA-348, 1964.

"Soils Suitable for Septic Tank Filter Fields," United States Department of Agriculture Information Bulletin 243, 1961. (Gives interaction for percolation test.)

Miller, C.E., Turk, L.M. and Foth, Henry D.; *Fundamentals of Soil Science*, John Wiley and Company, New York, 1965.

See local county Soil Conservation Agent for pamphlets on local soil situations.

Photo Credits

Fig. 1. U.S. Department of Agriculture; Figs. 3-4. H.D. Foth; Figs. 6, 8. H. Armstrong Roberts; Fig. 10. Soil Conservation Service, U.S.D.A.; Fig. 11. H. D. Foth; Fig. 15, 16. U.S. Department of Agriculture

All other photographs: LaMotte Company

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This illustrated booklet deals with the subjects of soil formation, variations in soil composition, the plant life cycle, soil reaction (pH), and the major, minor, and trace elements. It discusses the importance of humus or organic matter in soils, and stresses the importance of a balanced nutrient program for plants. This expanded edition includes sections on soil as a water reservoir, soil as a filter media for groundwater, and the role of soil organisms in treating chemical contaminants such as pesticides. A glossary of soil science terms is included.

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