Soil and Water

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Introduction to Soils

The importance of the soil cannot be overemphasized when trying to maintain plant health. Taking care of the environment in which the plant root system grows is essential to producing healthy plants and avoiding plant problems.

Soil is the primary source of water and nutrients for the plant. Soil also provides the physical anchor for the plant to stand upright. Managing soil and water properly and applying appropriate fertilizers at the right time are basic to producing healthy plants.

There are many different kinds of soils in New Mexico, from "sugar" sands to heavy clay and less prevalent loams. A thorough knowledge of soil characteristics is necessary to make proper decisions about vegetable gardening, fruit production and/or landscaping. This knowledge is fundamental to soil improvement, planting, watering, and fertilizing.

What is Soil?

Soil is produced when a parent material (rock) is acted upon by climate and vegetation over time. It consists of weathered rock fragments (minerals) and decaying remains of plants and animals (organic matter). Soil also contains varying proportions of air, water, and microorganisms. A soil in good condition for plant growth contains approximately 50 percent solid material and 50 percent open or pore space. Minerals and organic matter comprise the solid portion of the soil. The mineral component usually is made up of many different kinds and sizes of particles, ranging from those visible to the unaided eye to others so small that they can only be seen with the aid of a powerful electron microscope (fig. 1). This mineral material makes up about 45 to 48 percent of the total volume. The remaining solid material consists of organic matter, which in New Mexico makes up about 0.5 to 3 percent of the soil mass and is usually considered a stable soil component. However, some measures of organic matter include both plant and animal remains in varying stages or degrees of decomposition. Under ideal moisture conditions for growing plants, soil openings or pore spaces contain 25 percent air and 25 percent water based on total soil volume. Micro- and macro-organisms are complementary to soils. Without them, most soils would be "dead" and would not contain the organic matter that is so prized in Southwestern soil.

The percentage of mineral matter and organic matter in a cubic foot of soil varies from one soil type to another and even within the same soil, depending on the plants grown, cultivation frequency, soil moisture, and drainage of the soil. Organic matter will usually be highest in native soils that have not been cultivated over long periods of time and have developed where rain has promoted plant growth. Cultivated soils that have been tilled frequently and have relatively small amounts of plant residues left over after harvest are usually lowest in organic matter. Tillage increases the amount of air in the soil, which also increases the rate of organic matter decomposition. Soils with poor drainage or high water tables usually have a higher organic matter content than those that are well-drained, because the water excludes air from the soil mass and prevents oxidation of organic matter. Generally, the hotter and drier the climate, the lower the organic matter content will be in the soil.

Since either air or water fills pore spaces, the amount of air in soil at a particular time depends on the amount of water present in the pore spaces. Immediately after a rain, more water and less air are present in the pore spaces. Conversely, in dry periods, a soil contains more air and less water. Increasing organic

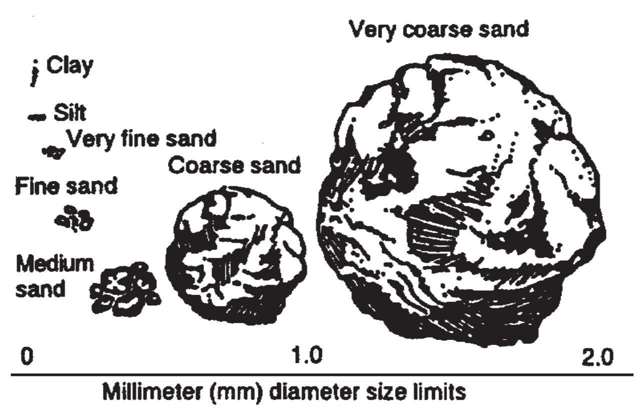


Figure 1. Relative sizes of mineral soil particles.

matter content usually increases water-holding capacity, but the addition of large amounts of undecomposed organic material can reduce water capacity until the material has been decomposed.

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 (rainfall and temperature) and affected by relief (slope and direction or aspect) and vegetation (kind and amount, such as forest or grass) over time. A change in any one of these factors usually results in a difference in soil formation or development. The important physical properties of a soil are color, texture, structure, drainage, and depth.

Soil physical properties (texture, structure, drainage, and depth), chemical composition (fertility), and surface features (stoniness, slope, and erosion) largely determine the soil's suitability. Soil fertility, to a limited extent, governs what it may be used for. To a larger extent, it determines expected yields. However, soil fertility alone is not indicative of a soil's productive capacity. The physical properties of soil usually control its suitability as a growth medium. It is easier to adjust soil fertility than it is to change the soil's physical properties.

Color

When soil is examined, color is one of the first things noticed. In itself, color is of minor importance, but it indicates or reflects other soil conditions that are extremely important. In general, color is determined by organic matter content, drainage conditions, and degree of oxidation or extent of weathering.

Soil colors vary from almost white to shades of brown, gray, and black. Light colors indicate low organic matter content, while dark colors can indicate higher organic content. Light or pale colors in the surface soil frequently are associated with relatively coarse texture and highly leached conditions. These colors 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 while slowing the oxidation (burning) of organic materials. Dark colors also may result from colors imparted by the parent material.

Shades of red or yellow, particularly when associated with relatively fine textures, usually indicate that subsoil material has been incorporated in the surface or plow layer. In general, subsoil colors 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. If these or other bright colors persist throughout the subsoil, it indicates favorable aeration. Some subsoils with a mottled appearance, especially when the colors are shades of red and brown, also are well-aerated.

Soils with yellow 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. The red-to-brown color of subsoils comes from iron coatings under well-aerated conditions. In wet soils with low oxygen levels, the iron coatings are removed chemically and biologically, leaving the gray color of background soil minerals.

Texture

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. The proportions of sand, silt, and clay vary in each texture class (fig. 2).

Sands are the soil's coarsest mineral particles. These particles vary in size, but most sand particles can be

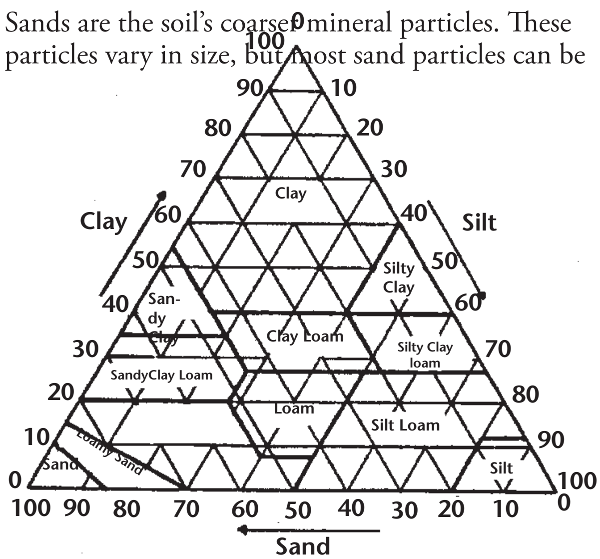


Figure 2. Soil textural triangle.

seen without a magnifying glass. All feel rough when rubbed between the thumb and fingers.

Silt consists of relatively fine soil particles that feel smooth and floury. When wet, silt feels smooth but not slick or sticky. It also is smooth when dry, and it is easily imprinted when pressed between the thumb and fingers. Silt particles are so fine that they are usually invisible to 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 powerful microscope. They feel extremely smooth when dry and become slick and sticky when wet. Clay will hold a molded form. Clays also are responsible for most of the chemical reactions and inherent fertility of a soil.

Loam is a textural class of soils that has moderate amounts of sand, silt, and clay. A true loam soil contains approximately 7 to 27 percent clay, 28 to 50 percent silt, and approximately 50 percent sand. Loam strictly refers to particle size distribution and does not refer to the amount of organic matter in the soil. A soil with more than 50 percent sand can become a sandy loam. Loam soils with a higher percentage silt are classified as silt loam. Loam soils with more clay are classified as clay loam.

Although there are about 20 kinds or classes of soil texture, most soils fall into six general textural classes. Each class name indicates the size of the mineral particles that are dominant in the soil. Texture is estimated in the field by rubbing or feeling moist to wet soil between the thumb and fingers. Laboratories can accurately assess soil texture with mechanical analysis that separates the soil into sand, silt, and clay of various sizes (called separates). Regardless of textural class, all soils contain sand, silt, and clay, although the amount of a particular particle size may be small.

Principle Soil Classes

Loam

When rubbed between the thumb and fingers, the proportions of sand, silt, and clay feel approximately equal.

Sandy loam

Sandy loam varies from very fine loam to very coarse. The feel is quite sandy or rough, but contains some silt and a small amount of clay. The amounts of silt and clay are sufficient to hold the soil together when moist.

Silt loam

Silt is the dominant size particle in silt loam and feels quite smooth or floury when rubbed between the thumb and fingers.

Silty clay loam

Silty clay loam is 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 usually are present in noticeable amounts in this soil texture, but they are overshadowed by clay.

Clay

Clay has a fine texture with the absence of sand or silt. Clay holds its form when wet, and when pressed between the thumb and middle of the forefinger a ribbon forms that can be several inches long. Clays are very hard when dry.

Soil texture influences many different characteristics. A brief comparison between sandy and clay soils will highlight these points. Coarse-textured or sandy soils allow water to enter at a faster rate than fine-textured or clay-dominant soils. In addition, the relatively low water holding capacity and the large amount of air present in sandy soils allows them to warm up faster than fine-textured soils. Sandy soils also are more easily tilled. They are best suited for producing special crops, such as potatoes, peanuts, and certain fruits.

Structure

Table 1. Soil structure terminology and characteristics.

Name	Shape	Description	Where Commonly Found in Soils
Single grain		Usually individual sand grains not held together	Sandy or loamy textures
Granular		Porous granules held together by organic matter and some clay	Top 4 to 12 inches of soil with some organic matter
Platy		Aggregates that have a thin vertical dimension with respect to lateral dimensions	Compacted layers
Blocky		Roughly equidimensional usually higher in clay than other structural aggregates	Usually a foot or two into a soil that contains clay
Prismatic		Structural aggregates that have a much greater vertical than lateral dimension	Some layers in the soil 1-2 feet from the surface
Massive		No definite structure or shape; usually hard	Usually found 3 feet from the surface soil but can be deeper or more shallow

Soil particles are grouped together in the formation processes to form structural pieces called peds or aggregates (table 1). Soil structure usually will be granular unless it is disrupted. The soil aggregates will be rounded and will vary in size from very small pellets to a large pea. If organic matter content is low and the soil has been under continuous cultivation, the soil structure may be quite indistinct or massive. If the soil is fine-textured with high organic content, it may have a blocky structure. Organic matter plays an important role in soil physical characteristics.

Soil structure is closely related to air and water movement within it. Good structure allows favorable movement of air and water, while poor structure slows down this movement. Water can enter a soil with granular structure more rapidly than it can enter one with 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. Water, air, and plant roots move more freely through soils that have blocky structure than those with platy or flaky horizontal structure. Good soil structure is almost always promoted by adding organic matter and by working the soil when it is not so wet that large clods form.

Growing plants also change the soil structure as they send their roots down for mechanical support and to gather water and food. As plant roots grow, they tend to enlarge the openings in the soil. When they die and decay, they leave channels for movement of air and water. In addition to visible plants, there are bacteria molds and other very small plants growing in the soil that can only be seen with the aid of a microscope. Even these plants enrich the soil as they die.

Drainage

Soil drainage is defined as the rate and extent of water movement in the soil. This includes 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 soil and subsoil layers. Soil drainage often is indicated by soil color. Clear, bright colors indicate well-drained conditions. Mixed, drab, and dominantly gray colors indicate imperfection in drainage. Low lying areas within a field or landscape receive runoff water as well as precipitation. Frequently, the water from these areas must escape by lateral movement through the soil or by evaporation from the surface, as poor structure and other physical influences do not allow drainage through the soil.

Too much or too little water in the soil is equally undesirable (fig. 3). With too much water, most plants will suffocate. However, when there is too little water, plants will wilt and eventually die. For most plants, the most desirable soil moisture situation is one in which approximately half of the soil pore space is occupied by water.

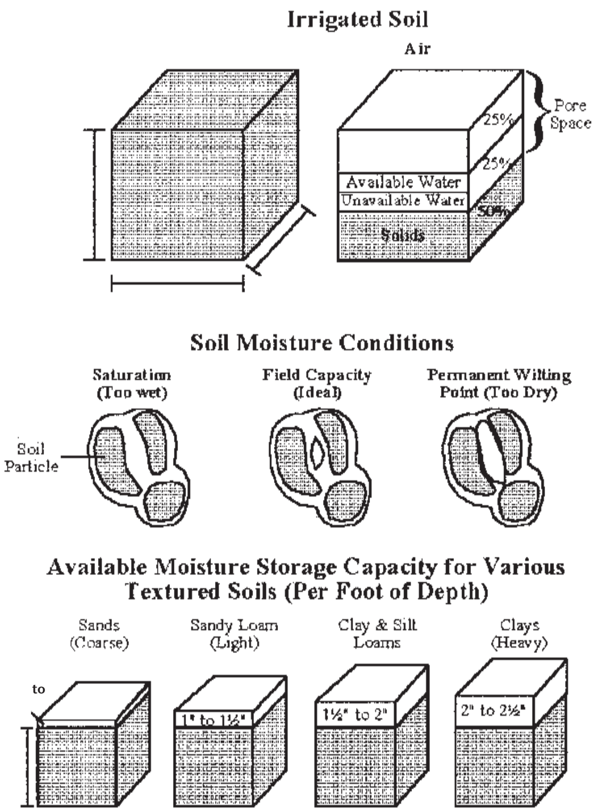


Figure 3. Effects of texture on capacity of soils to hold water.

Soil Depth

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

Terms that are used to express effective soil depth include the following:

Very Shallow

Soil extends less than 10 inches to a layer that retards root development.

Shallow

Soil extends 10 to 20 inches to a layer that retards root development.

Moderately Deep

Soil extends 20 to 36 inches to a layer that retards root development.

Deep

Soil extends 36 to 60 inches to a layer that retards root development.

Very Deep

Soil extends 60 inches or more to a layer that retards root development.

Soils that are deep, well-drained and have desirable texture and structure are suitable for producing most crops, especially fruit and nut trees. Deep soils can hold much more plant nutrients and water than shallow soils with similar textures. Frequently, soil depth and its capacity for nutrients and water determine the crop yield, particularly for annual crops grown throughout the summer.

Plants growing in shallow soils also have less mechanical support than those growing in deep soils. For example, trees growing in shallow soils are blown over by wind more frequently than those growing in deep soils.

Soil Organic Matter

Although older soils textbooks would seldom include organic matter under a discussion of physical properties of soil, the current literature emphasizes the importance of organic matter to the soil's structural properties. Home gardeners and landscapers who use compost and other organic matter may have realized this over the years as they improved their soils.

Soil organic matter 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. They break it down into humus (the portion of organic matter that remains after most decomposition has taken place) and soil nutrients. Through this process, nutrients are made available for use as food by growing plants.

The digested and decomposing organic material also helps develop good air-water relationships. In sandy soil, organic material occupies some of the space between the sand grains, binding them together and increasing water-holding capacity. In a fine-textured or clay soil, organic material creates aggregates of the fine soil particles, allowing excess water to drain more rapidly and oxygen to move into the soil more easily. This grouping of the soil particles into small pieces (aggregates or peds) causes the soil to feel mellow and makes it easier to work. It is defined as soil tilth and does not make a soil a loam. Many gardeners try to change a soils texture by bringing in sand for clay soils and clay for sandy soils. A better way to improve soil is to promote a steady increase in soil organic matter to about 3 or 4 percent.

Organic matter content primarily depends on the kinds of plants that have been growing on a soil, long-term management practices, temperature, and drainage. Soils that had native grass cover for long periods usually have higher organic matter content. Likewise, those soils that have native forest cover may have lower organic matter content depending on the amount of under-story growth. In either case, if plants have grown on soil that is poorly drained, the organic matter content is usually higher than if the same plant is grown on well-drained soil. This is because of differences in available oxygen and other substances in well-drained soil that are needed by the organisms that attack and decompose the organic material. Soils in cold climates usually have more organic matter than those in warm climates. Most native New Mexico soils have less than 1 percent organic matter. Thus, adding organic matter (composted manures, vegetables, and grass) to the soil is a key to successful gardening in New Mexico. Remember, you are amending a soil that took hundreds of thousands of years to form, so don't expect it to change in one growing season.

Improving Soil Structure

In special cases, coarse sand, vermiculite, and perlite are added to heavy clays to help improve soil texture or structure. However, these inert materials generally are needed in large quantities (at considerable expense and labor) to do any good. In some cases, they can make the situation worse by causing clays to "set up" similar to adobe (concrete). Compost, manures and other organic amendments usually are more effective and economical for modifying soil structure.

Additions of Organic Matter

Organic matter is a great soil amendment for both clay and sandy soils. Good sources of undecomposed organic matter include manures, leaf mold, sawdust, and straw. These materials can then be decomposed in the soil by soil organisms. Various factors, such as moisture, temperature, and nitrogen availability, determine the decomposition rate 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 is necessary if large amounts of undecomposed, 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 and additional nitrogen is not needed. Nitrogen is required by soil microbes as part of their metabolism and structure. Microbes can consume all the readily available nitrogen in the soil, so that the organic carbon and nitrogen present in the amendment can be decomposed into humus. Organic matter also can be added to the soil in the form of compost. The use of compost is one way to avoid tying up so much nitrogen during decomposition, depending on compost quality. Gardeners can either purchase compos or make it from plant waste from the garden.

Growing Cover Crops

Cover crops are another source of inexpensive organic matter for soil improvement. Also known as green manures, cover crops (annual rye, perennial ryegrass, "Elbon" cereal ryegrass, and hairy vetch) are planted in the garden in fall and are incorporated in spring. For best results, seed should be sown a little before the first killing frost. In a fall garden, plant cover crops between the rows and in any cleared areas. Cover cropping provides additional organic matter and helps reduce erosion and topsoil loss. "Elbon" cereal ryegrass also is known to help control nematodes and is referred to as a trap crop. Legume cover crops can supply 50 to 100 percent of all the nitrogen needs of subsequent crops such as tomatoes. Legumes help reduce synthetic fertilizer needs. A deep-rooted cover crop allowed to grow for a season in problem soil can help break up a hardpan and greatly improve tilth. A rule of thumb is to incorporate green manures a minimum of two weeks before planting vegetables. Another method is to track soil temperature and incorporate the cover crop once the top four inches of soil reaches 50°F. Cover crops should not be allowed to go to seed.

Soil Microorganisms and =

Soil would actually be considered "dead" without the presence and activity of micro- and macroorganisms. Soil health often is judged for by the presence of microbial activity and earthworms. Plant life would suffer without the activity of these organisms.

Soil Microorganisms

Soil microorganisms are microscopic plants and animals living in the soil. They include bacteria, fungi, actinomycetes, algae, protozoa, yeast, virus, and nematodes. There are about 50 billion microbes in 1 tablespoon of soil, and 900 billion microorganisms per pound of healthy soil. Typically, 1 gram (approximate weight of a standard paper clip) of soil may contain:

3 million to 50 million bacteria

1 million to 20 million actinomycetes

5,000 to 1 million fungi

1,000 to 1 million yeast

1,000 to 500,000 protozoa

1,000 to 500,000 algae

10 to 5,000 nematodes

The microorganisms' primary job is to break down the organic matter, first into humus, then humic acid, and ultimately into basic elements. Microbes must have a constant supply of organic matter or their numbers decrease. In addition, certain microorganisms also have the ability to fix nitrogen from the air. Nutrients from the soil's organic matter are made available for plant food through microbial feeding, as microbes are constantly being born and dying. Their dead bodies actually are an important source not only of nutrients but also of organic matter.

The primary environmental factors affecting microbial populations are moisture, organic matter, aeration, temperature, pH, and inorganic nutrient supply.

Soil moisture is important to the health of microorganisms. Beneficial microbes thrive in soil that is neither dry nor soggy but rather about as wet as a squeezed damp sponge. Soil with at least 1 percent organic matter is easier to keep at the proper moisture level than soil with no additional organic matter.

Soil microbial populations are directly proportional to the organic matter content. Organic amendments generally increase this population markedly. Green manures depend on this increase of soil microbes for effectiveness.

Earthworms

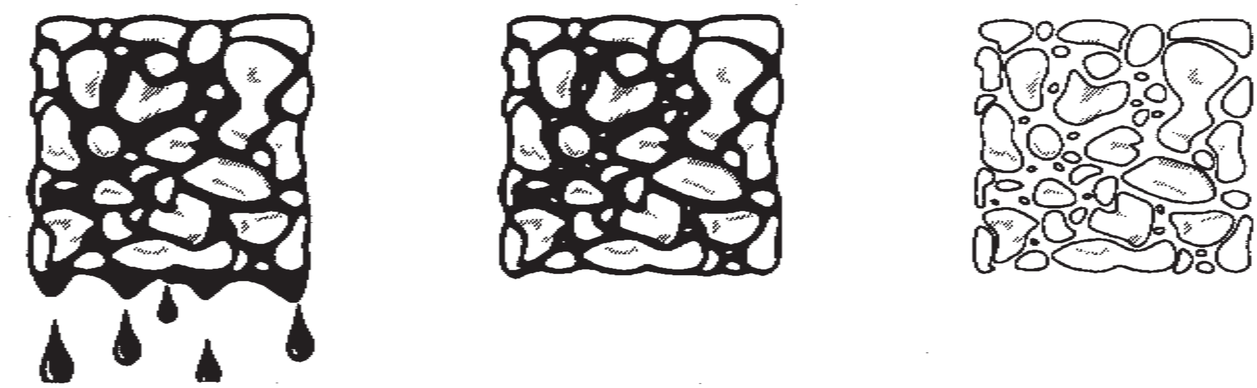
If bacteria are the champion microscopic decomposers, then the heavyweight champion is undoubtedly the earthworm. The earthworm has been praised for spending most of its time tilling and enriching the soil. The great English naturalist, Charles Darwin, was the first to suggest that all the fertile areas of this planet have at least once passed through the bodies of earthworms.

The earthworm consists mainly of an alimentary canal, which continually ingests, decomposes and deposits casts during active periods. As soil or organic matter is passed through an earthworm's digestive system, it is broken up and neutralized by calcium carbonate secretions from calciferous glands near the worm's gizzard. Once in the gizzard, material is finely ground prior to digestion. Digestive intestinal juices rich in hormones, enzymes and other fermenting substances continue the breakdown process. The matter passes out of the worm's body in the form of casts, which are the richest and finest quality of all humus material. Fresh casts are markedly higher than soil itself in bacteria, organic material, available nitrogen, calcium, magnesium, and available phosphorus, and potassium.

Certain worms thrive on compost and contribute to its quality through both physical and chemical processes, and they reproduce readily in the well-managed pile. Wise gardeners adjust their composting methods to take full advantage of worm talents, since worms can take on such a large role in compost making.

Mulching

Mulching is a standard practice in many vegetable gardens, flower and shrub beds and around fruit and ornamental trees. Although mulching, by definition, is simply placing a layer of organic or inorganic material on top of the soil, the benefits to the internal soil structure seem miraculous. Organic mulches, such



a. Saturation b. Field Capacity c. Wilting Point

Figure 4. Three important soil moisture conditions. At the wilting point, plants can extract very little soil moisture.

as shredded pine bark or compost, reduce extreme fluctuations in soil temperatures and moisture levels. Weeds also can be controlled with mulches. These benefits all seem to have an enhancing effect on soil structure, improving irrigation and rain infiltration, softening hard clay soils and reducing the water requirements of sandy soils. Mulching with 2 to 4 inches of organic material twice a year is recommended for most garden and landscape plants. After the mulch decomposes, it can be turned in the garden soil, further improving soil structure.

Regularly adding manures, compost, cover crops, mulches, and other organic materials can raise the soil nutrient level and enhance the physical structure so that the need for synthetic fertilizers is reduced greatly. These highly desirable soil qualities, however, do not come with one single or even several additions of organic material; they require a serious soil-building program. The key is building a home compost pile.

Soil Water

As mentioned previously, a soil's physical properties (texture, structure, drainage) and solid material composition (mineral and organic) affects its water-storing capabilities. Understanding the basic principles associated with soil water storage is essential to proper irrigation of vegetable gardens, fruit orchards, lawns, and landscapes.

Soil Water Terms

Various terms are used to describe soil water content and the forces that move and hold water in the soil. Three classes of soil water describe the principal forces at work: gravitational, capillary, and hygroscopic. Gravitational water moves in response to gravity, usually under saturated conditions (fig. 4a). This water drains downward, leaving plants only a short time for access. Capillary water is held against gravity in the soil's pore spaces and is the most important for plant growth. Field capacity is the amount of water a soil will hold against gravity when allowed to drain freely (fig. 4b). Capillary and gravitational water that plants can use is known as available water. Hygroscopic water is held so tightly by individual soil particles that roots cannot easily extract it. This water is associated with the soil moisture content at and below the wilting point (fig. 4c) and is referred to as unavailable water.

Available Soil Water

Soil moisture tension is a measure of the energy or the force with which water is held by the soil and is expressed in units of pressure (suction). The plant must use energy to get water from the soil. When soil water is at field capacity and soil moisture tension is low, the plant can readily extract water. As the soil moisture is depleted, the soil moisture tension increases, mak-

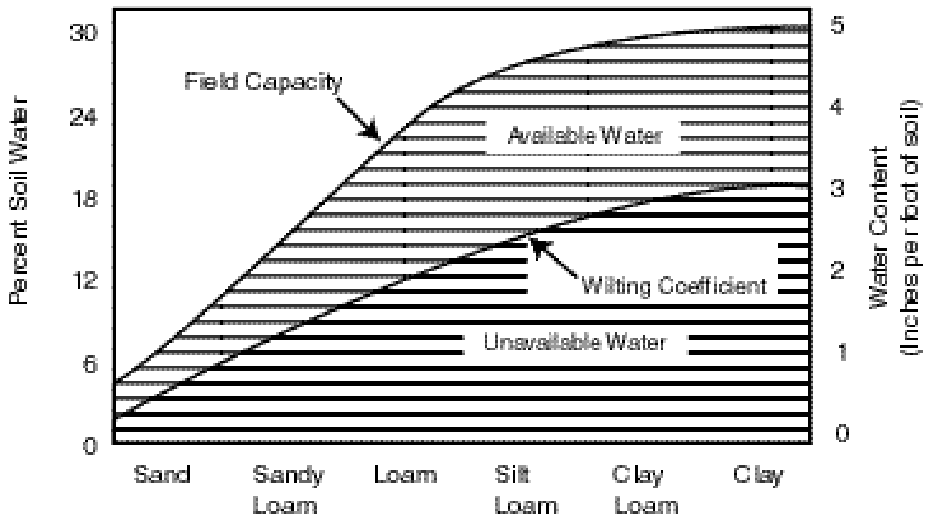


Figure 5. Relationship between soil texture and soil water holding capacity expressed as percent by volume water and inches per foot of soil.

ing it more difficult for the plant to extract water. At the permanent wilting point, the soil still contains some moisture. This moisture is so tightly held that the plant cannot use any of it. Most plants will not recover from this level of stress.

Soil Moisture Storage

As previously mentioned, soils are made up of mineral matter, organic matter, water, and air. Mineral and organic matter are the solids in soil, and many occupy 35 to 75 percent of the total soil volume. The remaining volume, or pore space, is occupied by air and water. A medium-textured soil typically contains about 50 percent solid material and 50 percent pore space.

The size and total volume of pore space are a function of both the soil's texture and structure. Clay soils can hold a significant amount of water because of the relatively large surface areas of individual clay particles and the large number of very small pores. Sand particles, on the other hand, have relatively small surface areas, and sandy soils contain a smaller number of pores that are larger in size. Water drains more easily from these larger pores because of gravity. Figure 5 illustrates the relationship between soil texture and the amount of water held in the soil. Both the amounts of available and unavailable water increase as the soil's clay content increases. Thus, sands have a much lower water-holding capacity than clay soils.

Knowing a soil's water-holding capacity is important in determining both the amount and frequency of irrigation. Soils with low water-holding capacity must be irrigated more frequently with smaller amounts of water than soils with higher water-holding capacity. Water-holding capacities range from 1 inch per foot of soil for sands to 3.9 inches for clays (table 2). These values can be used as a general guide in the absence of specific field data. A good source of specific soils information is contained in the county soil survey reports published by the Soil Conservation Service.

It also must be noted that many garden soils have been modified significantly. Additions of organic matter, such as compost, shredded pine bark, and other soil amendments, can dramatically increase soil water-holding capacity. Although amending garden soils is generally recommended, be aware that the values shown in table 2 may vary significantly from improved garden soils. Properly improved garden soils generally will hold more available moisture, thus they require less frequent irrigations of increased amounts.

Philosophy of Irrigation

The soil serves as a "bank account" of water for plants. Each soil type can hold a specific amount of water. A proper irrigation schedule refills the bank account of water completely at every irrigation and keeps the bank account at acceptable levels for the plant to withdraw needed water.

Table 2. Approximate water-holding capacity of soils given in inches of water per foot of soil (in/ft).

Soil Texture	Moisture Held at Field Capacity	Moisture Held at Permanent Wilting Point	Available Moisture	Water to be Replaced at Irrigation*
Sand	1.0–1.4	.2–.4	.8–1.0	.5–.8
Sandy loam	1.9–2.3	.6–.8	1.3–1.5	.8–1.2
Loam	2.5–2.9	.9–1.1	1.6–1.8	1.1–1.3
Silt loam	2.7–3.1	1.0–1.2	1.7–1.9	1.2–1.5
Clay loam	3.0–3.4	1.1–1.3	1.9–2.1	1.3–1.7
Clay	3.5–3.9	1.5–1.7	2.0–2.2	1.4–1.8

*Based on application of irrigation water when 50 to 60 percent of the available water in the root zone has been depleted and assuming 75 percent irrigation application efficiency.

In New Mexico, rain is considered a supplement to irrigation. Most landscapes in New Mexico are considered xeric and can not support orchards, grass, or vegetables. In some areas of the state, there is sufficient rain such that irrigation only supplements what comes from the sky. Nevertheless, effective and efficient use of water resources should remain a primary concern for home gardeners.

Specific recommendations for scheduling irrigations and soil improvements will be discussed in subsequent chapters on vegetable gardening, home fruit production, lawn care, and landscape horticulture.

Plant Nutrients and Soil pH

Plants need 16 elements for normal growth. Carbon, hydrogen, oxygen, nitrogen, and potassium make up 95 percent of plant solids. Carbon, hydrogen, and oxygen come from air and water. Although the air is 78 percent nitrogen, plants must acquire nitrogen and the other essential elements from the soil. Legumes, however, can use nitrogen from the air with help from a symbiotic bacteria.

The other 11 essential elements are iron, calcium, phosphorus, copper, sulphur, magnesium, manganese, zinc, boron, chlorine and molybdenum. These elements come from the soil. With the exception of nitrogen, calcium, magnesium, phosphorus, and potassium, there usually is enough of these elements in the soil for most plants. Other elements also associated with plant growth are cobalt, silica, and selenium.

To understand why plant nutrients need to be added to a soil, an understanding of soil pH is crucial.

Soil pH

A measurement of the hydrogen (acidic) ion activity of soil or growth media is called pH. The reading is a scaled measurement, which expresses the degree of acidity or alkalinity in terms of pH values, very much like heat and cold are expressed in degrees Celsius or Fahrenheit. The Celsius temperature scale is centered around zero degrees or water's freezing point; thermometers measure intensities of heat and cold above and below this point. The scale for measuring acidity contains 14 levels known as pH units (fig. 6). A pH of 7 is considered neutral and is the scale's midpoint. Values below 7 constitute the acid range, and values above 7 make up the alkaline or basic range.

The pH scale is not linear but rather logarithmic. That is, a soil with a pH of 9.5 is 10 times more alkaline than a soil with a pH of 8.5, and 100 times more alkaline than a soil with a pH of 7.5.

A soil's pH is a major characteristic that affects the quality of plant growth. A nearly neutral or slightly acid soil generally is considered ideal for most plants because most of the plant nutrients are readily available in this range. Plant growth can occur anywhere in a 3.5

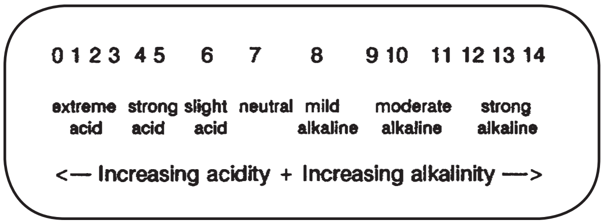


Figure 6. pH values.

to 10.0 pH range. A soil pH of 6.0 to 7.0 requires no special cultural practices to improve plant growth.

Extremes in soil pH have an impact on plant growth by affecting the availability of plant nutrients (fig 7.) and the concentration of minerals toxic to plants. In highly acidic soils, manganese and aluminum can concentrate at toxic levels. At low pH values, calcium, phosphorus, and magnesium are less available. At pH 7 and above, phosphorus, iron, copper, zinc, boron, and manganese become less available.

By applying certain materials to the soil, adjustments can be made in pH values. Soils can be made less acidic by applying a form of lime; ground agricultural limestone is used most frequently. The finer the grind, the more rapidly it becomes effective. Different soils will require a different amount of lime. Soil texture, organic matter content, the crop to be grown, and soil type are all factors to consider in adjusting pH. For example, soils low in organic matter require much less lime than soils high in organic matter to make the same pH change. Soil testing can be done to calculate how much lime is needed to raise pH.

If pH is too high, elemental sulfur, or aluminum sulfate can be added to the soil to reduce alkalinity. Many ornamental plants require slightly to strongly acidic soil. These species develop iron chlorosis when grown in soils in the alkaline range. Iron chlorosis can be confused with nitrogen deficiency, since both cause a yellowing of the leaves. Nitrogen deficiencies show up in old growth, while iron deficiencies show up in the new growth first. This problem can be corrected by applying chelated iron or iron sulfate to the soil to reduce the alkalinity and add iron. Which product is best for your area depends on the amount of free lime already present in the soil.

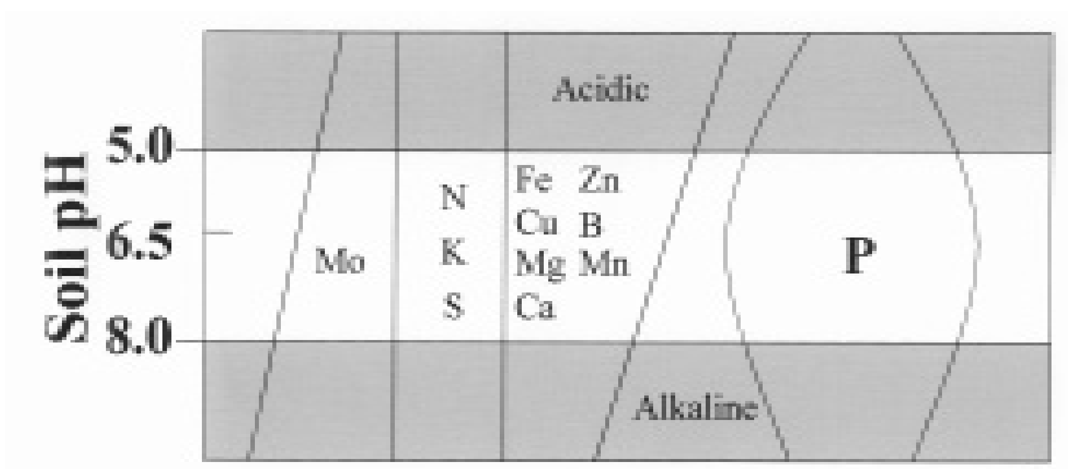


Figure 7. The effect of pH on plant nutrient availability.

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