Chapter 2

Soils, Water, and Plant Nutrients

Contents

Soil is the primary source of water and nutrients for plants. It also provides the physical anchor that enables plants to stand upright. If the soil is managed well, the plants will be healthy and productive, and the quality and quantity of our water supplies will be better protected.

Texas has 1,411 types of soils, ranging from sugar sands to heavy clays. To produce healthy plants, gardeners must have a thorough knowledge of their soils' characteristics and manage their soil properly.

What is soil?

Soil is produced when a parent material—unweathered geologic material—in a given location is acted upon over time by climate and biological activity.

About 50 percent of bulk soil consists of weathered geologic material, or minerals, and the decaying remains of plants and animals, or organic matter. The other 50 percent of the bulk soil contains varying proportions of air and water, which occupy the spaces between the minerals and organic matter (Fig. 2.1). This space is called the pore space. Because air and water cannot occupy the same space, when one increases, the other must decrease.

The mineral component of soil usually consists of many kinds and sizes of particles, ranging from those easily visible to those so small that they can be seen only with the aid of a powerful electron microscope (Fig. 2.2). This mineral material comprises about 45 to 49 percent of the total volume.

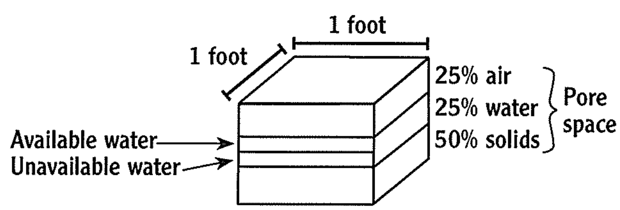


Figure 2.1. The most desirable soil content for most plants. The soil contains 25 percent water, 25 percent air, and 50 percent solids.

The remaining solid material consists of organic matter, which may contain both plant and animal remains in varying stages or degrees of decomposition. In Texas, organic matter makes up about 0.5 to 5 percent of the soil volume.

Under ideal moisture conditions for growing plants, the pore spaces contain 25 percent air and 25 percent water, based on total soil volume.

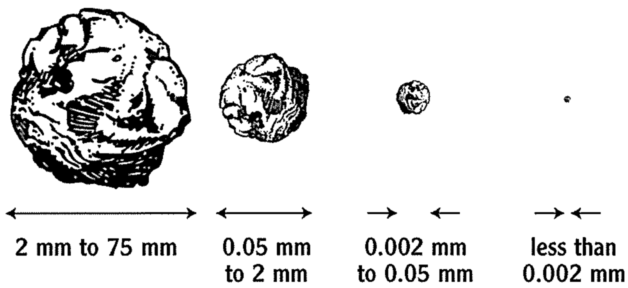


Figure 2.2. Relative sizes of mineral soil particles.

Texas has about 168 million acres made up of four natural geological regions: Mountains, High Plains, Rolling Plains and Coastal Plains. These regions have been divided into 16 Land Resource Areas (Fig. 2.3). The soils in these resource areas vary widely, as do their productivity levels and fertility recommendations.

More soil information for each county is available in Soil Survey Reports at http://websoilsurvey.nrcs.usda.gov/app/ or at the local office of the USDA Natural Resources Conservation Service (NRCS).

The percentage of mineral matter and organic matter in a cubic foot of soil varies from one soil to another and even within the same soil, depending on the kinds of plants grown in it and its frequency of cultivation, moisture content, and drainage.

Organic matter is usually highest in soils that have not been cultivated over long periods. Soils that are usually lowest in organic matter are those that are tilled often and contain relatively small amounts of plant residues. Tilling and plowing increases the amount of air in the soil, which enables the organic matter to decompose faster.

Soils with poor drainage or high water tables usually contain more organic matter than those that are well drained. This is because the water excludes air from the soil and prevents the organic matter from oxidizing—burning, composting, or decomposing. Generally, the hotter and drier the climate is, the less organic matter that the soil contains.

Because either air or water fills the pore spaces, the amount of air in a soil at a particular time depends on the amount of water there. Immediately after a rain, the pore spaces contain more water and less air. Conversely, in dry periods a soil contains more air and less water.

Adding organic matter usually increases a soil's capacity to hold water that is available for plant uptake. However, if large amounts of undecomposed organic materials are added to the soil, its water-holding capacity usually decreases until the material has decomposed partially.

Physical characteristics of soil

The physical properties of a soil are the characteristics that can be seen with the eye or felt between the thumb and fingers. They are the result of the soil's parent materials being acted upon by climatic factors such as precipitation, wind, and temperature. Over time, the physical properties of soil are also affected by:

- Topography, or the lay of the land, which includes its slope and direction
- The types and amount of vegetation, such as forest or grass, growing there
- Soil macroorganisms, such as ants and worms
- Soil microorganisms, such as fungi and bacteria

A change in any of these influences usually changes a soil's formation or development; this process is called weathering.

The important physical characteristics of a soil are color, texture, structure, drainage, and depth to the parent material, or unweathered geologic material.

The suitability of a soil for growing plants is largely determined by its physical properties, its chemical composition (fertility), and the surface features of the land (stoniness, slope, and erosion). Soil fertility governs to a limited extent the possible uses of the soil; to a larger extent, it determines expected yields.

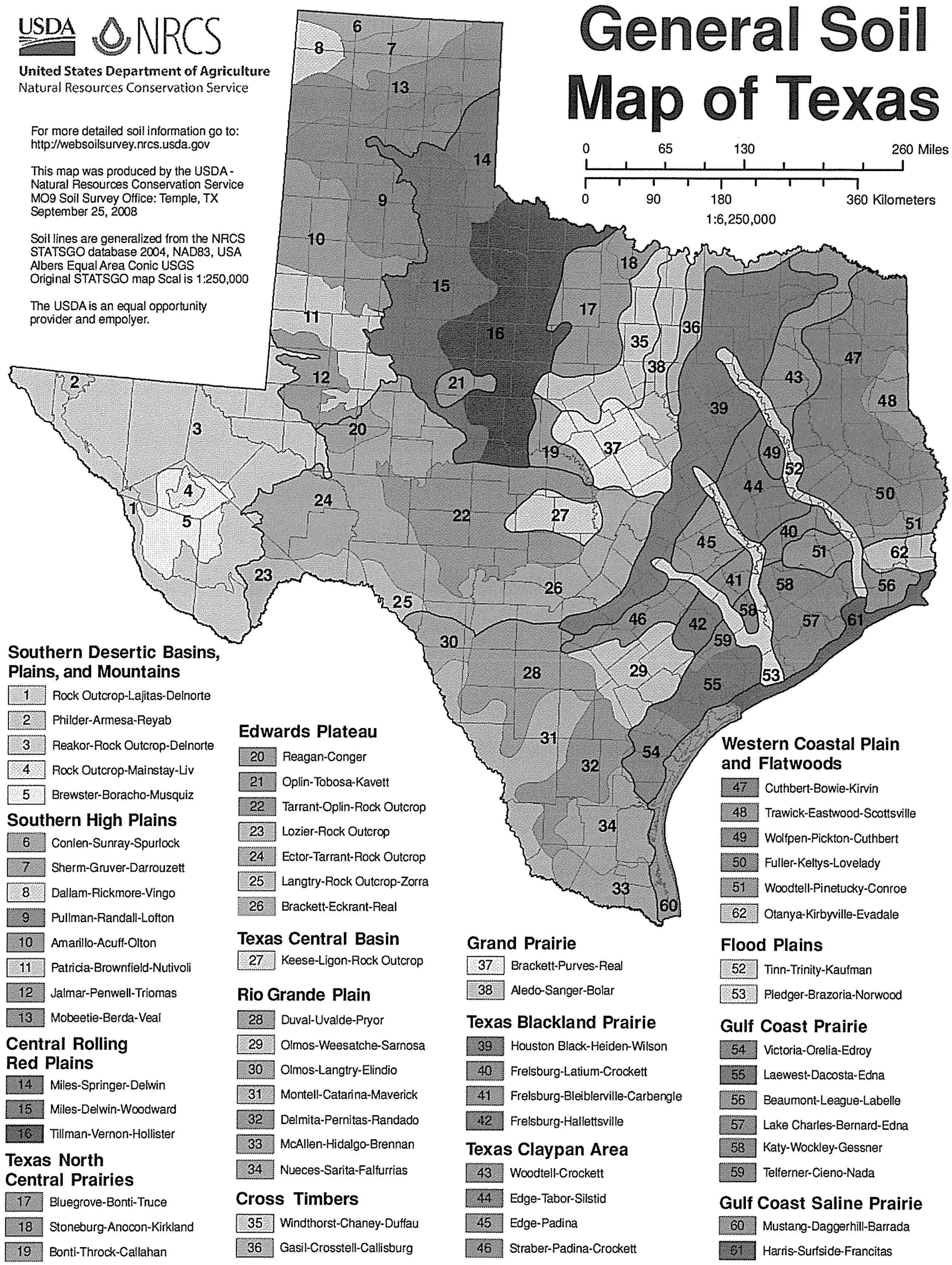


Figure 2.3. Map showing the soil types in the 16 Land Resource Areas of Texas.

However, fertility alone does not determine a soil's productive capacity. A soil's suitability as a growth medium is usually controlled by its physical properties. It is easier to adjust a soil's fertility levels than its physical properties.

Color

One of the first characteristics noticed about a soil is the color. In itself, color is of minor importance, but it indicates other soil conditions that are extremely important. In general, the color of a soil is determined by its organic matter content, the types and amounts of minerals in it, drainage conditions, and its degree of oxidation or extent of weathering.

Soils vary from almost white to shades of brown, red, yellow, gray, and black. Light colors indicate that the organic matter content is low. Light or pale colors in the surface soil are often associated with relatively coarse texture and highly leached conditions.

Dark colors can indicate high organic content. They also may result from poor drainage, low annual temperatures, or other influences that induce a high content of organic matter while slowing its oxidation.

Dark and light colors may also result from colors of the parent materials. Shades of red, yellow, or green indicate the presence of different kinds of iron oxides and hydroxides.

In general, subsoil colors indicate the relationships among air, water, and soil and the degree of oxidation of certain minerals in the soil. Red and brown subsoil colors indicate that the soil allows air and water to move relatively freely. The presence of these or other bright colors throughout the subsoil indicates favorable aeration. Some soils with mottled subsoils are also well aerated, especially if the colors are shades of red and brown.

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. In wet soils with low oxygen levels, the iron coatings are shades of green, gray, or black.

The darker the soil color is, the faster it warms up in the spring.

Texture

The relative amounts of differently sized soil particles, or the fineness or coarseness of the mineral particles in the soil, is referred to as texture. Texture depends on a soil's relative amounts of sand, silt, and clay. The proportions of sand, silt, and clay vary in each textural class (Fig. 2.4). Organic matter content has nothing to do with soil texture.

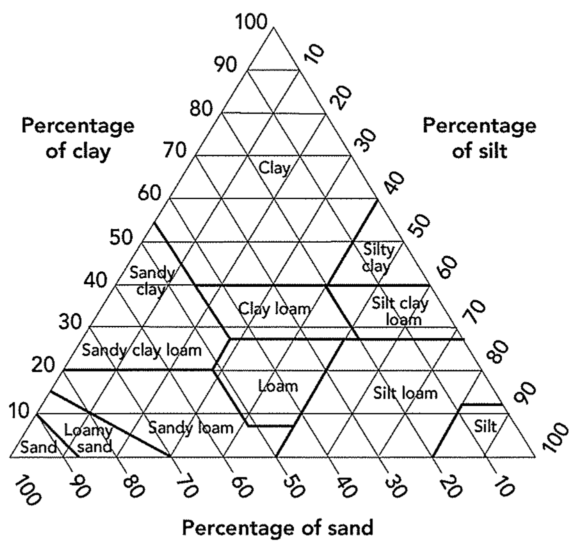


Figure 2.4. Soil textural triangle.

Sand consists of the coarser mineral particles of soil. These particles range in size from 0.05 to 2 millimeters (mm). Most sand particles can be seen without a magnifying glass. All feel rough when rubbed between the thumb and fingers. There is very little difference in the feel of sand when it is wet or dry.

Silt particles range from 0.002 to 0.05 mm and are so fine that a single particle is usually invisible to the unaided eye; these particles are best seen with the aid of a microscope. Silt consists of relatively fine soil particles that feel smooth and floury/powdery. When silt is wet, it feels smooth but not slick or sticky. It is also smooth when dry, and it is easily imprinted when pressed between the thumb and fingers.

Clays are the finest soil particles and decrease in size from 0.002 mm. Clay particles can be seen only with the aid of a powerful microscope. Aggregates of clay feel extremely hard and sharp when dry and become slick and sticky when wet. Clay will hold a molded form.

Texture is estimated in the field by the ribbon method, in which a ball of moist to wet soil is gently rubbed or stretched between the thumb and forefinger in an attempt to form a ribbon. Note how the soil feels, and assign a soil texture according to the descriptions below:

- **Sand:** Loose and single-grained; feels gritty, not sticky; does not form a ribbon
- **Sandy loam:** Feels gritty and slightly sticky; does not form a ribbon
- **Clay loam:** Forms short ribbons of less than 3 cm long
- **Clay:** Feels very sticky and plastic; easily forms a ribbon longer than 3 cm

Accurate results can be provided by a laboratory that separates a soil sample into clay, silt, and various sizes of sand groups, called separates. Regardless of the textural class, all soils in Texas contain sand, silt, and clay; however, a soil may have only a tiny amount of a particular particle size.

Although there are 12 general classes of soil texture, most soils in Texas fall into six general textural classes. Each class name indicates the size of the mineral particles that are dominant in the soil.

Principal soil textural classes in Texas

Following are the dominant soil textural classes in Texas. The list is not in order of land mass or importance.

Loamy sand feels very gritty or like sandpaper. It contains very little silt or clay, and it does not hold together very well when moist.

Loam feels as if it contains about equal proportions of sand, silt, and clay.

Sandy loam feels quite gritty 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 it is moist.

Silty clay loam is smooth to the touch when dry. When moist, it becomes somewhat slick, sticky, or both. Noticeable amounts of both silt and clay are present in silty clay loam, but the silt dominates.

Clay loam is dominated by clay. Clay loam is hard when dry, and slick and sticky when wet. Silt and sand are usually present in noticeable amounts in this soil texture, but they are overshadowed by the clay.

Clay overpowers sand or silt, even though it may contain up to 45 percent sand and/or 40 percent silt. The clay content is 40 percent or more. Clay is very hard when dry, and the small aggregates are difficult to impossible to break apart with a finger.

Texture influences many soil characteristics (Fig. 2.5). For example, compare sandy and clayey soils, assuming that they have the same structure:

- Sandy soils allow water to enter faster.
- Because sandy soils usually can hold relatively less water and more air, they warm up faster than do fine-textured soils of the same color. Air warms and cools faster than does water.
- Sandy soils are more easily tilled. They are best suited for the production of certain crops that grow in or on the soil, such as peanuts, potatoes, watermelons, and cantaloupes.

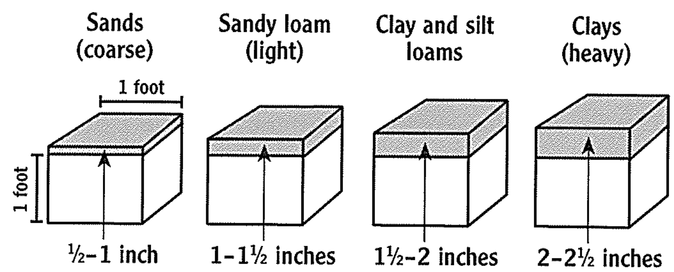


Figure 2.5. Effects of texture on the capacity of various textures of soils to hold water per foot of depth.

Soil horizons

Figure 2.6 depicts an example of a highly weathered Texas mineral soil showing the major soil horizons that could be found in lawns, gardens, and flower beds.

Typically, the **O,** or **organic, horizon** is not present in Texas soils except in some forested areas. However, it will develop where mulches, manures, lawn thatch, and plant residues are added to or left on the soil surface. Around homes it is usually less than 2 inches thick.

This horizon is typical in lawns, gardens, and flowerbeds that are mulched.

The **A horizon** is found in all soils except those eroded by wind or water or scraped off during home construction. It can also be buried under raised beds. This horizon usually has a dark color because of humus, which is completely decomposed organic material.

The A horizon is the most fertile and has the best structure of all soil horizons. It may be 2 to more than 12 inches thick.

The **E horizon** is the horizon of eluviation, which is the area from which materials have been transported out. The materials leaving this horizon include carbonates, humus, alumino-silicate clays, and iron and aluminum oxides.

The E horizon has a lighter, bleached color and coarser texture than the horizon above or below it. This horizon may or may not be present in soils, depending on the degree of weathering. It can be from 2 to more than 12 inches thick.

Soils in the eastern half of the state are more likely to have this horizon.

The **B horizon** is the horizon of alluviation, which is the area where materials have been transported. The materials entering this horizon include carbonates, humus, alumino-silicate clays, and iron and aluminum oxides.

Present in most Texas soils, the B horizon usually dictates the ability of water to move in the soil solum, which is the weathered zone composed of all soil horizons above the C or R horizon. The color of the soil in the B horizon varies, including browns, reds, blacks, yellows, grays, and greens. The depth of this horizon varies from 2 to more than 12 inches.

The **C** and **R horizons** are unweathered par-

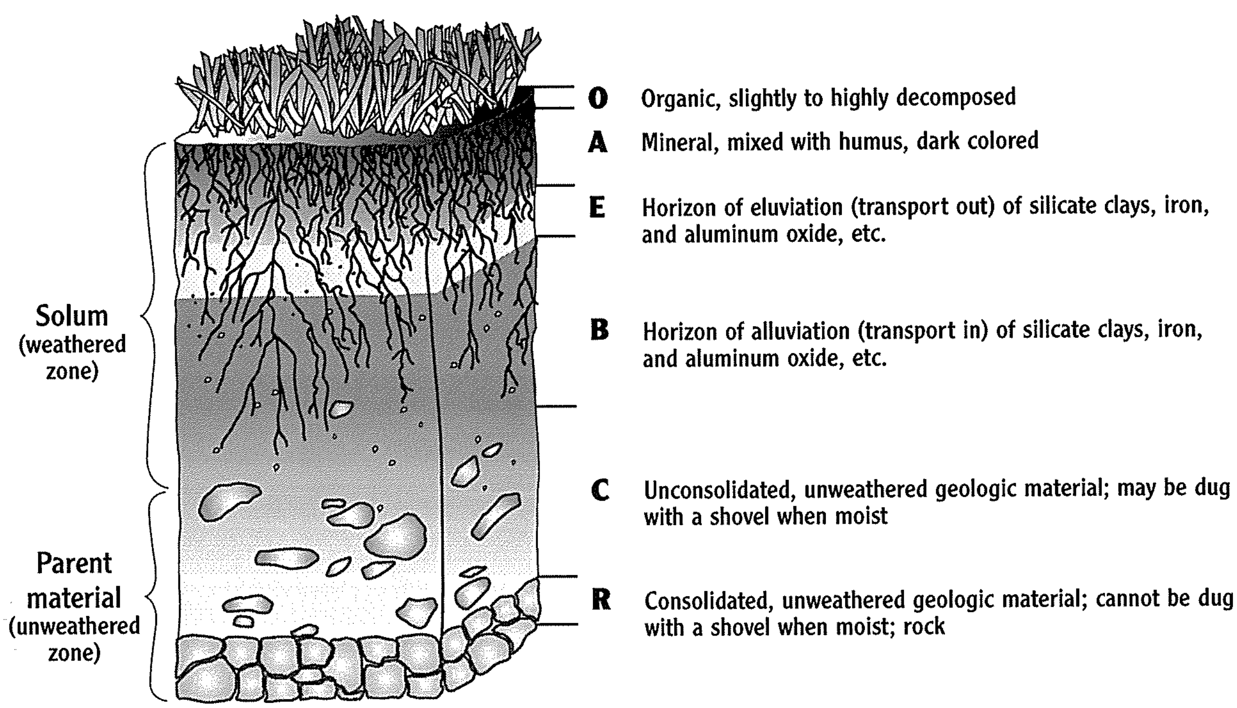


Figure 2.6. Soil horizons.

ent materials. The C horizon is parent material that is unconsolidated; when moist, it can be dug with a shovel. The R horizon is consolidated rock that cannot be dug with a shovel when moist.

Structure

During the soil formation process, soil particles are grouped together to form structural pieces called peds, or aggregates (Table 2.1). Soil structure varies widely, depending on the soil's content of clay and organic matter and the amount of cultivation, or tillage.

Soil aggregates are rounded or jagged and vary in size from a match head to a large pea. If the organic matter content is low and if the soil has been under continuous cultivation, the soil structure may be blocky.

Soil structure is closely related to air and water movement. Good structure allows air and water to move easily; poor structure slows this movement. Water can enter soil of a single-grain or granular structure faster than in soil of any other structure.

Because plant roots move through the same channels in the soil as do air and water, good structure allows the roots to develop extensively; poor structure discourages this development. Water, air, and plant roots move more freely through soils that have granular or blocky structure than those with platy structure.

Soil structure is almost always improved by adding organic matter and by working the soil when moisture conditions are favorable.

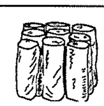
Growing plants also change the soil structure as they send their roots into the soil for mechanical support and for water and nutrient intake. As the roots grow, they tend to enlarge the openings in the soil. When they die and decay, they leave channels for air and water movement.

In addition to the visible plants, soils also contain bacteria, molds, and other tiny plants that can be seen only with the aid of a microscope. Even these plants enrich the soil as they die.

Drainage

Soil drainage is the rate and extent of water movement in the soil. This includes movement across the surface of soil, or infiltration, as well as downward through the soil, or percolation.

Table 2.1. Soil structural terminology and characteristics.

Name	Shape	Description	Common location 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	A horizons with some organic matter
Platy		Aggregates that have a thin vertical dimension compared to the lateral dimensions	Compacted layers and sometimes E horizons
Blocky		Roughly equidimensional peds usually higher in clay than other structural aggregates	B horizons with clay
Prismatic		Structural aggregates that have a much greater vertical than lateral dimension	Some B horizons
Massive		No definite structure or shape; usually hard	C horizons or compact transported material

A vital factor in soil drainage is slope or lack of slope. Other factors include texture, structure, and the physical condition of surface soil and subsoil layers.

Low-lying areas within a field or landscape receive runoff water as well as precipitation. The water from these areas often must escape by infiltration and percolation through the soil or by evaporation from the surface. Poor structure and other physical influences such as soil compaction restrict drainage through the soil.

Too much and too little water in the soil are equally undesirable. If the soil has too much water, most plants will suffocate because they cannot take up oxygen. But if there is too little water, the plants will wilt and eventually die.

Depth

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

Several terms are used to express the effective soil depth to a layer that retards root development:

- **Very shallow:** The soil extends less than 10 inches deep.
- **Shallow:** The soil extends 10 to 20 inches deep.
- **Moderately deep:** The soil extends 20 to 39 inches deep.
- **Deep:** The soil extends 39 to 59 inches deep.
- **Very deep:** The soil extends 59 inches or more deep.

Soils that are deep and well drained and have desirable texture and structure are suitable for the production of most crops, especially fruit and nut trees. Deep soils can hold much more water and plant nutrients than can shallow soils with similar textures. Soil depth and its capacity for nutrients and water often determine the yield from a crop, particularly from annual crops grown through the summer.

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

Organic matter

Although traditional soil textbooks seldom include organic matter under a discussion of the physical properties of soil, the current emphasis on composting and use of organic matter in home gardens and landscape provides ample rationale for doing so. Furthermore, organic matter greatly affects the structural characteristic of soils.

When a soil's temperature and moisture conditions are favorable, earthworms, insects, bacteria, fungi, and other types of plants and animals use the organic matter as food. They break it down into inorganic soil nutrients and humus.

This decomposition process releases most of the carbon in the organic material back into the atmosphere as carbon dioxide; only about 10 to 20 percent remains in the soil. Through this process, nutrients (except potassium, because it is not associated with the organic molecule available when a plant or animal dies) are mineralized and made available for use as the inorganic form of nutrients for growing plants. This process of converting organic nutrients into plant-available nutrients (inorganic) is called mineralization.

The decomposing organic material also helps develop better relationships between air and water in the soil by:

- **Slowing drainage in sandy soils:** The organic material increases a sandy soil's water-holding capacity by occupying some of the space between the sand grains and binding them together.
- **Speeding drainage in clayey soils:** The organic material enables excess water to drain faster and oxygen to move into clayey or fine-textured soil more easily.

It does this by grouping the soil particles into small pieces, which also makes the soil easier to work.

The amount of organic matter in a soil depends primarily on the kinds of plants that have been growing there as well as on temperature, drainage, and long-term management practices. Soils covered with native grass for long periods usually have higher organic matter content and deeper A horizons. Soils that have native forest cover usually have lower organic matter content and shallower A horizons (Fig. 2.6). These soils often have O horizons because of leaf litter.

In both cases, the soil usually contains more organic matter if it is well-drained than if it drains poorly. This is because well-drained soil has more available oxygen and other substances needed by the organisms that decompose the organic material.

Soils in cold climates usually have more organic matter than those in warm climates. Most Texas soils have 0.5 to 1.0 percent organic matter, with some as high as 5 percent. Therefore, a primary key to successful gardening in Texas is the addition of organic materials—such as composted manures, yard clippings, and wood products—to the soil.

Improving soil structure

In special cases, expanded shale, vermiculite, and perlite are added to heavy clays to help improve soil aeration. However, to do any good, these inert materials are generally needed in large amounts at considerable expense and labor.

Play sand, such as from sandboxes, should not be added because its particles are too small to help with aeration and it is very difficult to incorporate into a clay soil. In some cases, it can make the situation worse by causing the clay to "set up" like concrete.

Compost, manures, and other organic amendments are usually more effective and economical in modifying soil structure. Be sure to account for the nutrients in the organic amendments and reduce the amount of fertilizer or other sources of nutrients accordingly.

Additions of organic matter

Organic matter is an excellent soil enhancer for both clayey and sandy soils. Good sources of undecomposed organic matter include manures, leaf mold, sawdust, and straw, which can be decomposed in the soil by soil organisms.

The rate of decomposition is affected by various factors, including moisture, temperature, and nitrogen availability, through their effects on these organisms. Adequate water must be present, and warm weather will increase the rate at which the microbes work.

For rapid decomposition, the amount of carbon and nitrogen in the material must be balanced. If the compost contains large amounts of undecomposed, high-carbon substances—such as dried leaves, straw, or sawdust—inorganic nitrogen may need to be added. Fresh green wastes such as grass clippings are slightly higher in nitrogen than are dry materials, and leaves or blades are higher in nitrogen than are stems.

Organic matter can also be added to the soil in the form of compost. The use of compost is one way to avoid tying up nitrogen during decomposition. Compost can be made from plant wastes. For more information on composting, see Chapter 3.

Growing cover crops

Another source of inexpensive organic matter for soil is a cover crop. Also known as green manures, cover crops are usually grasses or legumes that are planted in the garden in autumn and incorporated into the soil in the spring. Examples of cover crops are annual rye, perennial ryegrass, and 'Elbon' cereal rye.

Cover cropping provides additional organic matter and helps reduce erosion. 'Elbon' rye is also a trap crop for nematodes; the nematodes enter the roots of the rye and cannot escape, so they die, reducing the infestation.

Legume cover crops can increase the amount of nitrogen in the soil and reduce additional nutrient needs. Allowing a deep-rooted cover crop to grow for a season in a problem soil can help break up a hardpan, (hard, unbroken ground) and greatly improve the suitability for growing healthy plants.

For best results, sow the seed just before the first killing frost. In a fall garden, plant the cover crops between the rows and in any cleared areas.

In the spring, incorporate the green manures at least 2 weeks before planting vegetables. Do not allow them to go to seed.

Soil microorganisms and macroorganisms

Plants and animals that have died are degraded by soil microorganisms and macroorganisms

Soil microorganisms: Soil microorganisms are microscopic plants and animals living in the soil. They include actinomycetes, algae, bacteria, fungi, nematodes (roundworms), protozoa, viruses, and yeast. One tablespoon of soil holds about 1 billion microbes, and each pound of healthy soil contains 1 trillion microorganisms.

A typical soil may contain these estimated numbers of organisms in each gram:

- Bacteria: 10^8 to 10^9
- Actinomycetes: 10^7 to 10^8
- Fungi: 10^5 to 10^6
- Protozoa: 10^4 to 10^5
- Algae: 10^4 to 10^5
- Nematodes: 10 to 10^2

Note: 1 gram is about the weight of a standard paper clip.

The microorganisms' primary job is to break down all dead plants and animals, first into organic matter, then humus, then humic acid, and ultimately into basic elements. Microbes must have a constant supply of organic matter, or their numbers will be reduced.

Some microorganisms can fix—or convert into a useful compound for plants—nitrogen from the air. As microbes are constantly being born, feeding, and dying, they make nutrients from the soil's organic matter available for plant food. Their dead bodies are an important source of not only nutrients but also organic matter.

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

Water is vital to the health of microorganisms. Beneficial microbes thrive in soil that is neither dry nor soggy—about as wet as a squeezed-out sponge. Soil with at least 1 percent organic matter is easier to keep at the proper moisture level than is soil with less organic matter.

The number of microbes in the soil is directly proportional to the amount of organic matter there. In general, microbe populations can be increased markedly by adding organic amendments. Green manures must have this increase of soil microbes to be effective.

Macroorganisms: Earthworms are macroorganisms that till and enrich the soil. An earthworm consists mainly of an alimentary canal (digestive tract), which continually ingests, decomposes, and deposits casts (wastes) during the earthworm's active periods.

As soil or organic matter is passed through an earthworm's digestive system, it is broken up and neutralized by secretions of calcium carbonate from calciferous glands near the worm's gizzard. Once in the gizzard, material is finely ground before 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 of all humus materials. Fresh casts are substantially higher in bacteria, organic material, available nitrogen, phosphorus, calcium, magnesium, and potassium than is the soil itself.

Earthworms thrive on compost and contribute to its quality through both physical and chemical processes, and they reproduce readily in a well-managed pile. Because earthworms play such a large part in making compost, wise gardeners adjust their composting methods to take full advantage of the earthworm's contributions.

Mulching

Mulching is simply placing a layer of organic or inorganic material on top of the soil. It is a standard practice in many vegetable gardens, in flower and shrub beds, and around fruit and ornamental trees.

Organic mulches, such as shredded pine bark or compost, can reduce extreme fluctuations in soil temperatures and moisture levels. They also can control weeds. Each of these benefits enhances the soil structure, improves the infiltration of irrigation and rainfall, softens hard clay soils, and reduces the water requirements of sandy soils.

Most garden and landscape plants benefit from the addition of about 2 inches of organic materials once a year. After the mulch decomposes, it can be incorporated into the garden soil, further improving the soil structure. Again, take into account the nutrients in the mulch, and reduce the added sources of nutrients appropriately.

If added regularly, manures, compost, cover crops, mulches, and other organic materials can raise the soil nutrient level and enhance its physical structure to a point that the need for added nutrients is greatly reduced. These highly desirable soil qualities do not come with a single or even several additions of organic material; instead, they require a serious soil-building program. A major step toward such a program is building a home compost pile.

Soil water

As mentioned previously, a soil's capacity for storing water is affected by its physical properties of texture, structure, and drainage, and by its mineral and organic composition.

Terms

The principal forces that move and hold water in the soil are gravitational, capillary, and hygroscopic forces.

Gravitational water moves in response to gravity, usually under saturated conditions (Fig. 2.7a). This water drains downward, leaving only a short period for plants to access it.

Capillary water is held against gravity in the pore spaces of the soil. This force is the most important for plant growth.

Hygroscopic water is held so tightly by individual soil particles that roots cannot extract it. This water is associated with the soil moisture content at and below the wilting point (Fig. 2.7c) and is referred to as unavailable water.

Two other important water terms are field capacity and available water. Field capacity is the amount of water that a soil will hold against gravity when allowed to drain freely for 24 hours (Fig. 2.7b). Available water is the capillary and gravitational water that can be used by plants.

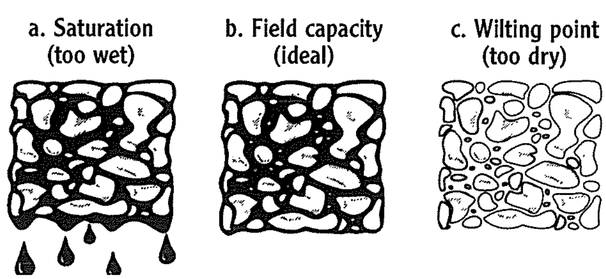


Figure 2.7. Three important soil moisture conditions.

Available soil water

Plants must use energy to get water from the soil. A measurement of that energy, or the force in which water is held by the soil, is known as soil moisture tension; it is expressed in units of pressure.

A plant can readily extract water from the soil when the soil water level is at field capacity and the soil moisture tension is low. As the soil moisture levels drop, the soil moisture tension increases, and it becomes increasingly difficult for the plant to extract water.

Even at the permanent wilting point, a soil contains some moisture; however, this water is held so tightly by the soil that the plants cannot extract any of it.

Soil moisture storage

The size and total volume of pore space are affected by a soil's texture and structure. Clay soils can hold much water because of the relatively large surface areas of individual clay particles and the large number of very small pores.

In contrast, sand particles have relatively small surface areas, and sandy soils contain fewer, larger pores than do clay soils. Water drains more easily from these larger pores because of gravity.

Figure 2.8 illustrates the relationship between soil texture and the amount of water held in the soil. The amounts of available and unavailable water increase as the clay content of the soil increases up to the silt loam texture. At this point, the available water starts to decrease slightly. Thus, sands have a much lower water-holding capacity than do silt loam soils, and clay soils can hold slightly less than can silt loam soils.

Knowing the water-holding capacity of a soil can help a gardener determine how much and how often to water. Soils with low water-holding capacity must be watered more often with smaller amounts of water than soils that can hold more water.

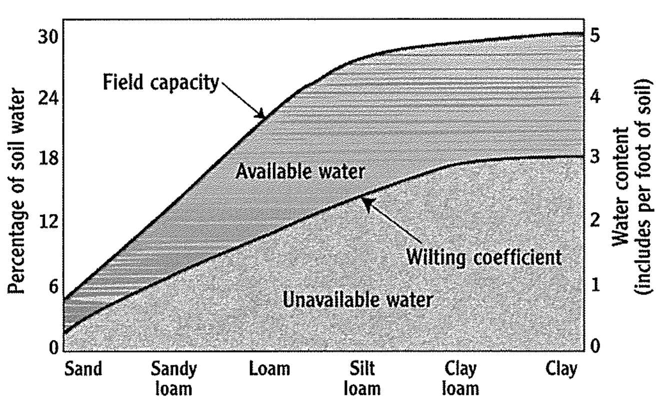


Figure 2.8. The relationship between soil texture and soil moisture content.

Water is returned to the atmosphere through evaporation and transpiration, which is the release of water through plant leaves. The sum of evaporation and transpiration is known as evapotranspiration (ET).

Across Texas during the growing season, about 1.0 to 1.5 inches of water is lost each week from the soil and from plants through evapotranspiration. Thus, when a soil's available water gets low, the water should be replenished at about 1.0 to 1.5 inches of water.

If soils have a low water-holding capacity (very well drained), adding 0.5 to 0.75 inches every 4 days may be appropriate. If soils have a higher water-holding capacity (moderately to slowly drained), adding 1 to 1.5 inches every 6 or 7 days will be appropriate.

It is best to irrigate at night, with the last drop of water being applied at sunrise. This reduces the amount of water lost through evaporation. Watering deep and infrequently at night will not cause disease problems. Always calibrate the irrigation system to apply the correct amount and to avoid runoff.

The ET Network at http://texaset.tamu.edu/ lists the ET rates at various sites in Texas. If you are located close to one of those sites, use that information to estimate the local evapotranspiration rate and the amount of water that needs to be applied.

Take into consideration whether the soil has been modified significantly. Additions of organic matter can dramatically increase a soil's water-holding capacity. Properly improved garden and flowerbed soils generally hold more available moisture and need to be watered less often.

Philosophy of irrigation

The soil serves as a "bank account" of water for plants. As discussed previously, each soil type can hold a specific amount of water (Fig. 2.8). A proper irrigation schedule completely refills the bank account of water at every irrigation and keeps the bank account at acceptable levels for the plant to withdraw needed water.

In Central and East Texas, irrigation should be considered a supplement to natural rainfall. If no rains fall, the landscapes, vegetable gardens, and fruit orchards need to be irrigated. However, in arid areas of the state, rainfall may be only a supplement to irrigation. Residents in all areas of Texas must use water effectively, efficiently, and conservatively.

Specific recommendations for scheduling irrigation and soil improvements are discussed in the chapters on home fruit production (Chapter 5), vegetable gardening (Chapter 6), landscape horticulture (Chapter 7), and lawn care (Chapter 8).

Plant nutrients and soil pH

Plants need 16 essential elements for normal growth. Four of those elements—carbon, hydrogen, oxygen, and nitrogen—make up 95 percent of plant solids. Carbon, hydrogen, and oxygen come from air and water. Even though the air is 78 percent nitrogen, nitrogen and the other essential elements must be taken up by the plant roots from the soil.

The other 12 essential elements for all plants are boron, calcium, chlorine, copper, iron, magnesium, manganese, molybdenum, phosphorus, potassium, sulfur, and zinc. These elements come from the soil. Except for nitrogen, calcium, magnesium, phosphorus and potassium, the soil usually contains enough of these elements for most plants.

Some types of plants also need five additional elements: cobalt, nickel, silicon, sodium, and vanadium.

Soil pH greatly affects the solubility of almost all nutrients. For optimum growth, the pH for some plants must be acidic; for some plants, it must be neutral; and for some, it must be alkaline.

Soil pH

A measurement of the hydrogen ion activity of soil or growth media is called pH. This measurement expresses the degree of acidity or alkalinity of a substance (Table 2.2). The pH scale contains 14 levels known as pH units. The scale is centered on pH 7, which is neutral. Values below 7 constitute the acid range of the scale, and values above 7 make up the alkaline range.

Table 2.2. Descriptive terms for ranges in soil pH and selected common compounds.

Soil descriptive term	pH	Common range compounds
	0	
	1	Battery acid
	2	Lime and lemon juice, vinegar, apple cider
Ultra acid	<3.5	
Extremely acid	3.5–4.4	Tomato juice
Very strongly acid	4.5–5.0	
Strongly acid	5.1–5.5	
	≤5.6	"Acid" rain
	5.6–5.7	"Pure" rain, distilled water
Moderately acid	5.6–6.0	
Slightly acid	6.1–6.5	Cow's milk, coffee
Neutral	6.6–7.3	
Slightly alkaline	7.4–7.8	
Moderately alkaline	7.9–8.4	Baking soda
Strongly alkaline	8.5–9.0	
Very strongly alkaline	>9.0	
	10–11	
	12	Ammonia
	13	Lye
	14	

The measurement is not a linear scale but a logarithmic scale. For example, 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.

For most plants, the ideal soil pH is near neutral or slightly acid. Although some types of plant growth can occur in a pH range of 3.5 to 10.0, the optimum range for mineral soils is about 6 to 7; for organic soils or growing media, it is 5.5 to 6.5.

Extremes in pH affect the availability of plant nutrients and the concentration of the toxic minerals in the soil (Fig. 2.9). In highly acidic soils (low pH), manganese and aluminum can concentrate at toxic levels. Low pH values also make calcium, phosphorus, and magnesium less available. At pH 7 and above, phosphorus, iron, copper, zinc, boron, and manganese become less available for plant use.

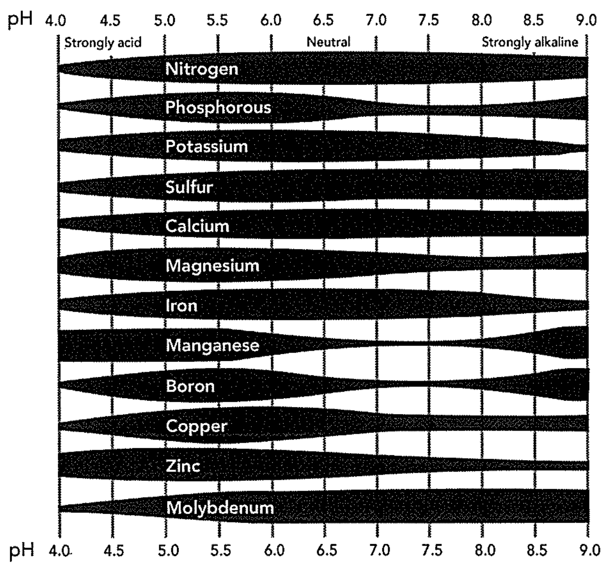


Figure 2.9. The effect of pH on plant nutrient availability.

Soil pH can be adjusted by applying certain materials to the soil. Soils can be made less acidic by applying a form of limestone. The type used most often is ground agricultural limestone. The finer the grind, the more rapidly it becomes effective. Different soils require different amounts of limestone to adjust the reaction to the proper range.

When adjusting the pH, take into consideration the soil's texture and organic matter content and the crop to be grown. For example, to make the same pH change in soils that are low in organic matter and/or clay, much less limestone is required than in soils that are high in those materials. In Texas, it is the clay the makes most of the difference because most of our soils are low in organic matter.

Wood ashes can also be used to raise soil pH. Wood ashes contain potash (potassium), phosphate, boron, and other elements.

Apply twice as much ash as limestone for about the same effect. Do not allow the ashes to contact germinating seedlings or plant roots because they may damage the roots. Spread on a thin layer during the winter and incorporate it into the soil.

If wood ashes are used, check the pH yearly. Do not use coal ashes or large amounts of wood ash (more than 20 pounds per 1,000 square feet), as they may cause toxicity problems. Never use charcoal ashes because they contain other chemicals that can affect the soil.

To reduce alkalinity, add elemental sulfur, concentrated sulfuric acid, or aluminum sulfate to the soil. Be careful when adding compounds to reduce the alkalinity: If too much is added, the pH may drop to as low as 2 to 3 instead of the desired level of about 7.

Many ornamental plants require slightly to strongly acid soil. When grown in soils in the alkaline range, these species develop iron chlorosis, which causes yellowing of new leaves. Iron chlorosis is often confused with nitrogen deficiency, which causes yellowing of older leaves. Although these conditions look similar, they occur in different locations on a plant.

Correct iron chlorosis by applying chelated iron to the soil or by spraying the plants—just wet the leaves—with a 2 percent iron solution. If the iron is applied to the leaves, iron sulfate can also be used.

Buy solution that contains only iron and not a mixture of iron with other micronutrients. Many of these mixtures contain too much copper. If applied at sufficient rates to meet the iron needs, too much copper may be applied, causing copper toxicity to the plants.

Fertilizers

Of the 16 elements essential for plant growth, nitrogen, phosphorus, and potassium are considered fertilizer macronutrients because plants require more of them for maximum growth.

Calcium, magnesium, and sulfur are secondary macronutrients; usually they are either present in sufficient quantities or are added coincidentally with other materials such as limestone or other fertilizers.

The other essential elements, called micronutrients, are just as important but are required in smaller amounts. If plants lack any of these elements, they exhibit signs of nutrient deficiency. Chapter 1 provides an outline of macro- and micronutrients and lists some of the symptoms of nutrient deficiency.

Overapplication of nutrients can cause toxicities or salt effects that hamper plant growth.

Fertilizer analysis

The fertilizer analysis on the bag refers to the amount of an element it contains based on percentage of weight. All fertilizers are labeled with at least three numbers that give the percentage by weight of nitrogen (N), phosphate (P_2O_5), and potash (K_2O). Often, to simplify matters, these numbers are said to represent nitrogen, phosphorus, and potassium, or N-P-K.

Remember that it is not N-P-K but N-P_2O_5-K_2O represented in the bag. For example, if a 100-pound bag of fertilizer is labeled 10-10-10, it contains 10 pounds of N, 10 pounds of phosphorus as P_2O_5, and 10 pounds of potassium as K_2O. To convert the P_2O_5 to actual phosphorus, multiply it by 0.44; to convert K_2O to actual potassium, multiply it by 0.83.

The other 70 pounds may be filler, carrier, or pure compounds mixed together to get that blend of nutrients. In the case of pure compounds, the other materials in the bag are other elements such as oxygen, hydrogen, or sulfur. Filler or carrier helps to spread the fertilizer evenly and avoids burning the plants with too much fertilizer.

For example: A 100-pound bag of fertilizer labeled 0-20-10 contains 0 pounds of N, 20 pounds of P_2O_5, 10 pounds of K_2O, and 70 pounds of filler, carrier, or other elements of the pure compounds.

Another example: A 100-pound bag of 21-0-0 fertilizer contains 21 pounds of N, 0 pounds of P_2O_5 and 0 pounds of K_2O. This is ammonium sulfate. The other 79 pounds in the bag are hydrogen, oxygen, and sulfur. There is no filler or carrier.

Several states, including Texas, have adopted a model label law for classifying fertilizers. The law establishes minimum levels of nutrients allowable and provides specific labeling requirements.

To date, not all states have enacted model label legislation, so there are still differences from state to state as to what constitutes a fertilizer and what types of information are required on the label. Even so, the information contained on fertilizer labels has been standardized, and the consumer is protected by state laws requiring manufacturers to guarantee the claimed nutrients.

Because the law requires only that the manufacturer guarantees what is claimed on the label, a fertilizer will in some cases contain secondary nutrients or micronutrients that are not listed on the label. This is because the manufacturer does not want to guarantee the exact amounts of those nutrients. However, the gardener/consumer can be assured that the nutrients listed on the label are actually contained in the fertilizer.

Complete and incomplete fertilizers

A fertilizer is said to be complete when it contains nitrogen, phosphorus, and potassium. An incomplete fertilizer is missing one of the major components. Examples of incomplete fertilizers are listed in Table 2.3.

Incomplete fertilizers are blended to make complete fertilizers. Example 1 shows that if 100 pounds of urea (46-0-0) were combined with 100 pounds of triple super phosphate (0-46-0), and 100 pounds of muriate of potash (0-0-60), a fertilizer grade of 15-15-20 would result.

Table 2.3. Common incomplete fertilizers or farm-type fertilizers.

Compound	% Nitrogen	% P_2O_5	% K_2O
Ammonium nitrate	34	0	0
Ammonium sulfate	21	0	0
Urea	46	0	0
Monoammonium phosphate	11	48	0
Diammonium phosphate	18	46	0
Super phosphate	0	20	0
Triple super phosphate	0	46	0
Muriate of potash (potassium chloride)	0	0	60
Potassium sulfate	0	0	52
Slow-release			
Urea formaldehyde	38	0	0
Sulfur coated urea	17–22	0	0
IBDU	31	0	0

In Example 1, the 100 pounds of the urea fertilizer contains 46 pounds of N; triple super phosphate has 46 pounds of P_2O_5; and muriate of potash has 60 pounds of K_2O. When these three quantities are combined, each quantity is diluted by the other two by one-third, provided that each bag is of equal weight.

Example 1. The amounts of three types of incomplete fertilizer needed to produce 300 pounds of a complete 15-15-20 fertilizer grade.

Fertilizer	Formulation	Amount
Urea	46-0-0	100 lb
Triple super phosphate	0-46-0	100 lb
Muriate of potash	0-0-60	100 lb

46 x 100 ÷ 300 = 15 for the urea and triple super phosphate

60 x 100 ÷ 300 = 20 for the muriate of potash

The specific fertilizer ratio needed depends on the soil nutrient level. For example, a 1-1-1 ratio (such as 8-8-8, 13-13-13, or 20-20-20) is widely used when lawns are first established. Established lawns generally respond better to fertilizer ratios that are higher in nitrogen than in phosphate and potash. Suggested ratios after lawn establishment are 3-1-2 or 4-1-3.

For best results, have the soil tested every 1 to 3 years and follow the recommendations.

Special-purpose fertilizers

Some fertilizers in stores are packaged for certain uses or types of plants, such as camellia food, rhododendron and azalea food, or rose food. The camellia and rhododendron or azalea fertilizers belong to an old, established group, the acid plant foods. Some of the compounds used in these fertilizers are chosen because they have an acid reaction; they are especially beneficial to acid-loving plants.

The other fertilizers packaged for certain plants do not have as valid a research background. Compare, for example, the fertilizer ratios of three different brands of rose food on any garden center shelf.

Other special-purpose fertilizers that are marketed extensively claim to promote increased blooming of vegetable and ornamental plants. These fertilizers contain high amounts of phosphorus. **Although phosphorus is a macronutrient and needed by the plant for proper blooming and root growth, adding high doses of phosphorus does not guarantee increased blooming and can lead to problems in surface water quality.**

Many Texas soils contain enough phosphorus and potassium for normal home usage, and occasional additions of a complete lawn or garden fertilizer are generally adequate.

Choosing fertilizer

To choose the best fertilizer analysis, consider the soil's structure and chemistry, the nutrients needed, and the method of applying the fertilizer. Have a soil test performed before buying any source of nutrients, especially expensive, special-purpose fertilizers.

It is not possible to make a blanket statement that one fertilizer is best for every area of the state. Although it is true that different plants use different nutrients at different rates, what is unknown is the reserve of nutrients already in the soil. The nutrient concentrations change with every soil series, every management practice, and every location.

Slow-release fertilizers

Because plants can take up fertilizers continuously, they benefit from receiving a balance of nutrients throughout their growth. The most efficient way to achieve this continuous balance may be to apply a slow-release fertilizer, which is designed to release nutrients at the same rate they are taken up by the plants. Slow-release fertilizers contain one or more essential elements. These elements are released or made available to the plant over an extended period.

Example 2. The amount of ammonium sulfate needed for a 5,000-square-foot lawn requiring 1 pound of nitrogen per 1,000 square feet.

Lawn: 5,000 square feet
Fertilizer: Ammonium sulfate (21-0-0)
Rate: 1 pound of nitrogen per 1,000 square feet

$$\text{Total fertilizer needed} = \frac{\text{N application rate (lb/1,000 ft}^2\text{)}}{\text{\% N content of fertilizer as decimal}} \times \frac{\text{Lawn size (ft}^2\text{)}}{1{,}000}$$

$$= \frac{1}{0.21} \times \frac{5{,}000}{1{,}000} = \frac{5}{0.21} = 24 \text{ lb fertilizer}$$

Example 3. The amount of 20-10-5 fertilizer that should be applied to get 2 pounds of P205 per 1,000 square feet in a garden that measures 20 X 10 feet.

Garden: 20 X 10 = 200 ft²
Fertilizer: 20-10-5 = 10% P_2O_5
Rate: 2 lb P_2O_5 per 1,000 ft²

$$\text{Total fertilizer needed} = \frac{P_2O_5 \text{ application rate (lb/1,0000 ft}^2\text{)}}{\text{\% } P_2O_5 \text{ content of fertilizer as decimal}} \times \frac{\text{Lawn size (ft}^2\text{)}}{1{,}000}$$

$$\text{Total } P_2O_5 \text{ needed} = \frac{2}{0.10} \times \frac{200}{1{,}000} = 20 \times 0.20 = 4 \text{ lb per 200 ft}^2 \text{ of 20-10-5}$$

Converting this to 1,000 square feet: 20 pounds of 20-10-5 are needed for every 1,000 square feet.

How much nitrogen and potassium are applied with that 20 pounds?

Amount of fertilizer applied x concentration of the nutrient = 20 lb x 0.2 = 4 lb nitrogen; and 20 x 0.05 = 1 lb potash (K_2O)

There are three major types of slow-release fertilizers, according to the way in which the fertilizer is released. A slow-release fertilizer may contain:

- Materials that dissolve slowly
- Materials from which the nitrogen is released by microorganisms
- Granular materials covered with resin or sulfur that controls the rate that the nutrients in the granules are released into the soil

These nutrient-release systems may be used in combination with one another.

Sulfur-coated urea is a slow-release fertilizer with a covering of sulfur around each urea particle. The particles are coated with different thicknesses of sulfur, which controls the release rate of nitrogen. The release rate speeds up as the temperature increases. Watering does not affect its release rate.

Sulfur-coated urea releases more slowly when it is applied to the soil surface than when incorporated into the soil. This material generally costs less than other slow-release fertilizers and also supplies the essential element sulfur.

When fertilizer products coated with multiple layers of resin come into contact with water, the layers swell and increase the pore size in the resin, enabling the dissolved fertilizer to move into the soil. The release rate depends on the thickness of the coating and the temperature and water content of the soil.

A large amount of fertilizer is often released during the first 2 or 3 days after application. Depending on the coating, release timing can extend up to 12 months. Based on research from many parts of Texas, the slow-release fertilizers release faster here than in other parts of the United States because of the warm temperatures and, in about half of Texas, higher water contents of the soil. Thus, slow-release fertilizers in Texas are released over days and weeks rather than weeks and months.

Although slow-release fertilizers are generally more expensive than are the other types, they do not need to be applied as often as do conventional fertilizers. Also, higher amounts of slow-release fertilizers can be applied without danger of burning.

Because the nitrogen in slow-release fertilizers is being released continually over a longer period than in conventional fertilizers, the plants may use the slowly released nitrogen more efficiently than that in other forms.

Urea formaldehyde and sulfur coated urea have been used to fertilize turf; resin-coated fertilizers are more often used for container-grown plants.

Be careful when applying slow-release fertilizers around trees or shrubs in the summer, as they may keep the plant growing late in the summer. Late-season growth may not allow the trees and shrubs to harden off completely, which exposes them to excessive winter damage.

Table 2.4 compares slow-release with conventional fertilizers.

On fertilizer labels, the initials or designations W.I.N. and W.S.N. stand for water-insoluble nitrogen and water-soluble nitrogen, respectively. Water-soluble nitrogen dissolves readily and is usually in a very simple form such as ammonia-nitrogen or nitrate-nitrogen. That fertilizer may also contain nitrogen in other forms that do not dissolve readily. These are usually organic forms of nitrogen (with the exception of urea) that must be broken down into simpler forms before it can be used.

Water-insoluble nitrogen is a slow-release nitrogen source that delivers nitrogen at different rates according to the amount and kind of material in its composition.

Organic fertilizers

When applied to fertilizers or to soil amendments that are used as sources of nutrients, the word *organic* simply means that the nutrients contained in the product are derived solely from the remains (or a byproduct) of a once-living organism.

Table 2.4. Comparison of slow-release and conventional fertilizers.

Type of fertilizer	Advantages	Disadvantages
Slow-release	• Fewer applications • Low burn potential • Release rates vary depending on fertilizer characteristics	• Unit cost is high • Availability limited • Release rate governed by factors other than plant need and climatic conditions • Comparatively slow release rate • Most are acid forming
Conventional	• Fast acting • Low cost	• Greater burn potential • Solidifies in the bag when wet • Nitrogen leaches readily
Manures or sewage sludge	• Low burn potential • Relatively slow release • Contains all nutrients • Conditions soil	• Salt may be a problem • Bulky; difficult to handle • Odor • Weed seeds a problem (manure)

A list of selected organic sources of nutrients is given in Table 2.5. All of these products packaged as fertilizers in Texas have the nutrient percentages stated on the package labels. If no numbers are on the bag, the product is considered a soil amendment and there is no guarantee as to the contents of the bag.

Some organic materials, particularly composted manures and sludges, are sold as soil amendments and do not have a nutrient guarantee, even though small amounts of nutrients are present. Most of the materials not containing manures are high in one of the three major nutrients and low or zero in the other two. Some may be fortified with nitrogen, phosphorus, or potassium for a higher analysis. Many are low in all three.

In general, organic materials release nutrients over a fairly long period. The potential drawback is that they may not release enough of their principal nutrient at the proper time to give the plant what it needs for optimum growth.

Because organic sources of nutrients depend on soil organisms to break them down and release nutrients, most of them are effective only when the soil is moist and warm enough for the soil organisms to be active. In most of Texas, the microorganisms are active most if not all of the time.

When using organic nutrient sources, apply the organic material to the soil at least 4 to 6 weeks before planting. This gives the microorganisms time to mineralize the nutrients so enough are available for plant uptake when needed.

Examples of organic sources of nutrients are cottonseed meal, blood meal, fish emulsion, and all manures and composts. Bone meal and hoof and horn meal are also considered organic fertilizers. Urea is a synthetic organic fertilizer, an organic substance manufactured from inorganic materials

Cottonseed meal is a byproduct of cotton manufacturing. As a source of nutrients, it is somewhat acidic. Formulas vary slightly, but they generally contain 7 percent N, 3 percent P_2O_5, and 2 percent K_2O.

Cottonseed meal is available to plants more readily in warm soils, and there is little danger of burn. For general garden use, apply 55 to 60 pounds per 1,000 square feet to deliver about 4 pounds of N for the growing season. This will also deliver about 2 pounds of P_2O_5 and 1 pound of K_2O.

Cottonseed meal is often used to fertilize acid-loving plants such as azaleas, camellias, and rhododendrons.

Blood meal is dried, powdered blood collected from cattle slaughterhouses. It is a rich source of nitrogen—so rich, in fact, that it may do harm if used in excess. Be careful not to exceed the amount recommended on the label.

To add 4 pounds of nitrogen for the growing season, add 40 pounds of blood meal per 1,000 square feet. In addition to nitrogen, blood meal supplies small amounts of phosphorus and some essential trace elements, including iron.

Fish emulsion, a well-rounded fertilizer, is a partially decomposed blend of finely pulverized fish. Although the odor is intense no matter how little is used, it dissipates within a day or two. Fish emulsion is high in nitrogen and is a source of several trace elements.

In late spring when garden plants have sprouted, an application of fish emulsion followed by

Table 2.5. Common organic sources of nutrients and their estimated nutrient content.

Source	% N	% P_2O_5	% K_2O	Remarks
Blood	10	1.5	0	A rapidly available source of nutrients
Fish scrap	9	7	0	Do not confuse with fish emulsives, which are generally quite low in nutrient content.
Guano, bat	6	9	3	Partially decomposed bat manure from caves
Guano, bird	13	11	3	Partially decomposed bird manure from islands
Kelp or seaweed	1	0.5	9	
Meal				
Bone, raw	4	22	0	Main value is nitrogen; phosphorus is slowly available on acid soils
Bone, steamed	2	27	0	As a result of steaming under pressure, some nitrogen is lost, but more phosphorus is plant available.
Cotton seed	6.0	2.5	2.2	Generally very acid; useful in alkaline soils
Cocoa shell	2.5	1	3	Use as mulch.
Hoof and horn	14	0	0	The steam-treated and ground material is a rather quickly available source of nitrogen.
Manure				Although manures are generally low in nutrients, when used in relatively large amounts to improve soil structure, they may cause damage because of too much salt. **These values are based on first-year mineralization rates. If applied yearly, after 3 years divide N by 0.5 and P_2O_5 by 0.8. The K_2O will remain the same.**
Dairy	0.6	0.3	0.6	
Cattle	0.6	0.4	0.7	
Chicken	1.4	2.8	2.2	
Horse	0.6	0.3	0.7	
Sheep	0.9	0.5	0.9	
Swine	0.6	0.4	0.6	
Mushroom compost, spent	1.0	1.0	2.3	
Oyster shell	0.2	0.3	0	Because of their alkalinity, oyster shells are best suited for raising pH rather than as a source of nutrients.
Peat (reed or sedge)	2	0.3	0.3	Best used as a soil conditioner rather than as a source of nutrients; breaks down too rapidly
Rice hulls, ground	0.5	.02	0.5	Degrade slowly
Sewage sludge, Class A	6.0	3.0	0.0	Examples of Class A sludges are Milorganite (Milwaukee, WI), Hu-Acinite (Houston), Chicagrow (Chicago, IL), Nitroganic (Pasadena, CA) and Dillo Dirt (Austin).
Wood ashes	0	2	6	Quite alkaline; do not use on high-pH soils

deep watering will boost the plant's early growth spurt. Contrary to popular belief, too strong a solution of fish emulsion can burn plants, particularly those in containers.

Manure is a complete source of nutrients, but it is low in the amounts of nutrients it can supply. Manures vary in nutrient content according to the type of animal and the feed it has been eating; however, a nutrient ratio of 1-1-1 is typical. Manures are good soil conditioners as well as sources of nutrients.

Commonly available manures include those from horses, cattle, pigs, poultry, and sheep. The actual nutrient content varies widely; the concentration of nutrients is highest when the manures are fresh.

As manure is aged, leached, or composted, its nutrient content may be reduced, especially that of nitrogen. However, in the composting process, most nutrients except nitrogen will increase. This is because nitrogen is lost as ammonia in the composting process and the other nutrients are not; thus, as the weight of the compost pile decreases, the other nutrients appear to increase. The nitrogen concentration will be about the same per weight of compost pile.

Even though fresh manures have the highest amount of nutrients, most gardeners use composted forms of manure to ensure that they contain smaller amount of salts, thereby reducing the chance of burning plants. Do not use fresh manure if it will contact tender plant roots.

Typical rates of manure applications vary from a moderate 100 pounds per 1,000 square feet to as much as 400 pounds per 1,000 square feet. Reduce the rate by 50 percent when using saline irrigation water.

Sewage sludge is a recycled product of municipal sewage treatment plants. The only type available for homeowners is Class A biosolids. It is an activated sludge that is free of pathogens, or disease-causing organisms.

The concentration of nutrients in activated sludge is about 6-3-0. It contains about 0.6 to 0.9 percent K_2O, but it is not guaranteed as are the nitrogen and phosphate rates.

Questions have arisen in the past about the long-term effects of using sewage sludge products in the garden, particularly around edible crops. Heavy metals, such as cadmium, have previously been present in the sludge and could have built up in the soil. Because industrial and municipal (human manure) wastes are now separated, heavy metals are no longer a problem. However, if there is a concern, have the sludge tested for heavy metals.

Table 2.6 shows the approximate nutrient content of manures and the suggested rates of application per 1,000 square feet of garden area every 3 to 4 years. Apply a source of nitrogen between manure applications. The rates given are for materials used singly; if combinations of two or more materials are used, reduce the rate accordingly.

Compared to synthetic fertilizer formulations, organic sources of nutrients contain relatively low concentrations of actual nutrients. However, they may perform other important functions that the synthetic formulations do not,

Table 2.6. Estimated range of nutrient contents in manure.

Type of manure	% N	% P_2O_5%	% K_2O	Suggested rates per 1,000 sq ft of bed area*
Chicken manure, dry	2.0–3.6	2.0–5.5	1.7–3.1	100
Steer manure, dry	0.6–1.4	0.3–1.2	0.5–1.8	300
Dairy manure, dry	0.6–1.4	0.6–1.4	0.5–1.1	300

*Cut rates by 50% if soils are saline or water has a medium to high salinity hazard.

Source: Extension publications from the Texas AgriLife Extension Service and from Clemson University, Michigan State University, the University of Minnesota, and Purdue University.

such as increasing the soil's organic content, improving its physical structure, and improving air and water movement in the soil.

Lawn fertilizers combined with herbicides or insecticides

The major reason for buying a lawn fertilizer combined with a herbicide and/or an insecticide is convenience. A drawback to using the fertilizer-insecticide combination is that the broad-spectrum insecticide used in it may kill many beneficial insects and not the target insect.

As for the "weed and feed" fertilizers, some of the broad-spectrum herbicides in them can also harm or kill the trees, shrubs, and other nontarget plants in the lawn area. And they may sometimes actually fertilize the weeds targeted for control.

It is always best to use an appropriate herbicide to kill the target plants and an insecticide to kill the target insects. Always apply the herbicides and insecticides according to the instructions on the label.

Some organic compounds can be used as herbicides or insecticides. Seek Extension recommendations for the specific compound and rate of application.

Applying fertilizer

Computing the amount of fertilizer needed for a given area can be tricky at first, but becomes easier with practice.

Recommendations for fertilizing vegetables and annual flowers are usually stated something like: "Apply 3 to 4 pounds of 15-5-10 fertilizer per 100 square feet of garden space." This is fine as long as the formula, 15-5-10, is used. If the fertilizer to be used has a different formula, perhaps with a fertilizer that has a higher nitrogen content as indicated by the first number in the formula, the rate of application should be reduced to avoid nitrogen burn.

Table 2.7 shows how the amount to be applied decreases as its percentage of nitrogen increases. The percentage of nitrogen is indicated by the first number in each series. If the soil test indicates high levels of phosphorus, use sources of nutrients that are low in or contain no phosphorus, the second number.

Table 2.7. Nitrogen rates to apply 1 pound of nitrogen per 100 square feet.

Formula	Pounds per 100 sq ft
30-2-5	0.3
20-27-5	0.5
15-5-10	0.6
8-8-8	1.2
6-3-0 (Hu-Acinite)	2.0

Soluble salts

Applied correctly, fertilizers and other sources of nutrients do not burn or damage plants. Fertilizers are salts much like table salt, except that they contain various plant nutrients.

When a fertilizer (salt) is applied to soil, the water nearby begins to gradually move toward the application area. The fertilizer salts begin to diffuse, or move away from the place where they were applied. This dilutes the fertilizer and distributes it throughout a much larger area.

If tender plant roots are close to the placement of fertilizer, water leaves these roots as well as from the surrounding soil. The more salt or fertilizer applied, the more water is drawn from the nearby roots. As water is drawn from the roots, the plant cells begin to dehydrate and collapse, and the plant roots may burn or dehydrate to a point beyond recovery. If soil moisture is limited, most of the water drawn toward the salt will come from plant roots, severely damaging the plant.

Keep two rules in mind when applying a fertilizer during hot weather when soil moisture is limited:

- Do not overapply commercial inorganic or organic fertilizers.

- Make sure adequate moisture is present after applying sources of nutrients high in salts.

Table 2.8 lists commonly used garden commercial fertilizers that are high in salt content or burn potential. The last column is the practical measure of relative salinity. The higher the number, the greater the salt content.

Table 2.8. High-salt-content fertilizers.

Material	Nutrient content	Salt index per unit
Nitrogen sources		
Ammonium nitrate	33% N	2.99
Ammonium sulfate	21% N	3.25
Monoammonium phosphate	12% N	2.45
Diammonium phosphate	21% N	1.61
Potassium nitrate	14% N	5.34
Urea	46% N	1.62
Phosphate sources		
Monoammonium phosphate	52% P_2O_5	0.48
Diammonium phosphate	54% P_2O_5	0.64
Superphosphate	20% P_2O_5	0.39
Potassium sources		
Potassium nitrate	47% K_2O	1.58
Potassium chloride (potash)	60% K_2O	2.19
Potassium sulfate	54% K_2O	0.85
Manure salts	20% K_2O	5.64
Sulfur sources		
Gypsum	24% S	0.11
Epsom salt	27% S	1.15

In a container, the soluble salts will accumulate on top of the soil and form a yellow or white crust. A ring of salt deposits may form around the pot at the soil line or around the drainage hole. Salts will also build up on the outside of clay pots.

Soluble salts build up when sources of nutrients are applied repeatedly without enough water to leach or wash the old salts through the soil. It also occurs when water evaporates from the soil, leaving the minerals or salts behind. As the salts in the soil become more and more concentrated, plants find it harder and harder to take up water. If the salts build up to an extremely high level, water can be taken out of the root tips, causing them to die.

Soluble salt problems are common on plants grown in containers but rare in the garden. The best way to avoid soluble salt injury is to water correctly, preventing the salts from accumulating.

When applying water, allow some of it to drain through, then empty the drip plate. Allow an amount of water equal to one-tenth of the volume of the pot to drain through each time water is applied.

Do not allow the pot to sit in water. If the drained water is allowed to be absorbed by the soil, the salts that were washed out will be taken back into the soil. Salts can be reabsorbed through the drainage hole or directly through a clay pot.

Container plants should be leached every 2 to 4 months. Leaching is done by pouring a large amount of water on the soil and letting it drain completely. Leach a plant before fertilizing to avoid washing away all of the newly added nutrients.

The amount of water used for leaching should equal twice the volume of the pot. A 6-inch pot will hold 10 cups of water, so use 20 cups of water to leach a plant in a 6-inch pot. Keep the water running through the soil to wash out the salts.

If a layer of salts has formed a crust on the soil, remove the salt crust before leaching. Do not remove more than ¼ inch of soil. Do not add more soil to the top of the pot. If the soluble salt level is extremely high or if the pot has no drainage, repot the plant.

The level of salts that causes injury varies with the type of plant and the growing conditions. A plant grown in the home may be injured by salts at a concentration as low as 200 parts per million (ppm). If the same plant is in a greenhouse where light and drainage are good, it will grow with salts 10 times that level, or 2,000 ppm.

Some nurseries and plant shops leach plants to remove the excess salts before the plant is sold. If you are not sure if leaching has been done, leach a newly purchased plant the first time you water it.

Timing of fertilizer application

Besides soil texture, other factors affecting the frequency of fertilizer application include the type and expected use of the plant, the amount of organic matter in the soil, the frequency and amount of nitrogen or water applied, and the type of fertilizer and its release rate.

Type and use of plants: Some plants feed more heavily on some nutrients than on others. Generally, nitrogen is added for leafy top growth; phosphorus encourages root and fruit production; and potassium is for cold hardiness, disease resistance, and general durability.

For example, in a vegetable garden, root crops require less nitrogen than do leafy crops. Corn feeds heavily on nitrogen, but most trees and shrubs are generally light feeders. Corn may require nitrogen fertilization every 4 weeks; most trees and shrubs perform well with a single, well-placed application every year.

Turfgrasses are medium to heavy feeders of nitrogen, requiring at least two applications per year at 1 pound per 1,000 square feet. If the lawn clippings are mulched, over the years it may be sufficient to add up to 1 pound per 1,000 square feet per year.

Do not fertilize trees or shrubs after August 1. Late fertilization can cause new flushes of growth on woody plants that would normally be adjusting for the coming winter. This may delay dormancy and cause severe winter dieback of new growth.

Table 2.9 suggests general nutritional needs for groups of garden plants. Individual species within these groups vary considerably.

Table 2.9. Primary nutrient needs of common landscape plants.

Plants	Nutrient needs
Flowers, annual	Medium
Flowers, perennial	Low to medium
Fruits	Medium
Herbs	Low to medium
Shrubs, deciduous	Low to medium
Shrubs, evergreen	Low
Trees, shade	Low to medium
Turfgrass	Medium to high
Vegetables	High

Application methods

Fertilizer can be applied using different methods, depending on the fertilizer formulation and the plant requirements. Methods include broadcasting, banding, using starter solutions, side dressing, and foliar feeding.

Broadcasting: Fertilizer is spread at the recommended rate over the growing area; it is either left there to filter into the soil or is incorporated into the soil with a rototiller or spade.

The broadcast method is used over large garden areas, on lawn areas, or when time or labor is limited.

Banding: Narrow bands of fertilizer are applied in furrows 2 to 3 inches from vegetable garden seeds and 1 to 2 inches deeper than the seeds or plants that are to be planted. If the fertilizer band is placed too close to the seeds, it could burn the seedling roots or kill the seed.

The best technique is to stretch a string where the seed row is to be planted. Using the corner of a hoe, dig a furrow 3 inches deep and 3 inches to one side of and parallel to the string. Spread the fertilizer in the furrow and cover it with soil. Repeat the banding operation on the other side of the string, then sow the seeds under the string.

For widely spaced plants such as tomatoes, fertilizers can be placed in bands 6 inches long for each plant or in circles around the plants. Place the bands 4 inches from the plant base. If the fertilizer is placed in the hole itself, put it at the bottom of the hole. Work it into the soil with a layer of soil about 2 inches deep over the fertilized soil; then put the plant in the hole.

Banding is one way to satisfy the need of many plants—especially tomatoes—for phosphorus as the first roots develop. When fertilizer is broadcast and worked into soil, much of the phosphorus is locked up by the soil and is not as available to the plant. By concentrating the phosphorus in a band, the plant is given what it needs even though much of the phosphorus stays in the soil.

Starter solutions: Another way to satisfy the need for phosphorus when setting out transplants of cabbages, eggplants, onions, peppers, or tomatoes is to use a liquid fertilizer that is high in phosphorus as a starter solution. Follow the directions on the product label.

Side dressing: Dry fertilizer is applied along the side of the row after the plants are up and growing. Scatter the fertilizer on both sides of the row 6 to 8 inches from the plants. Rake it into the soil and water thoroughly.

Foliar feeding: In most situations, nutrients should not be applied to the leaves. The plant leaf was not designed to take up nutrients except for carbon and oxygen; the roots were designed to take up all other nutrients.

Foliar feeding may be used when micronutrients, such as iron or zinc, are locked in the soil. Nitrogen can also be foliarly applied to salvage a crop, especially if organic sources of nutrients are applied too late for sufficient mineralization to occur and release nutrients for plant growth. Absorption begins within minutes after application and is completed within 1 to 2 days.

Foliar application can be a supplement to plant nutrition at a critical time for the plant, but it is not a substitute.

Soil testing

The purpose of a soil test is to supply information that will enable a homeowner to wisely choose and apply soil amendments and sources of nutrients. A soil test conducted by the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory will provide information on soil pH, salt content, and available nitrogen, phosphorus, potassium, calcium, magnesium, sodium, and sulfur. Upon request, it will include information about the micronutrients copper, iron, manganese, and zinc. Other tests are also available if nutrient or salt problems are present.

The results of the soil test are mailed to the homeowner with recommendations as to which nutrients and how much of each should be applied to healthy plants in the landscape, vegetable garden, or fruit orchard.

Soil sample bags and information sheets are available from your county Extension office. The information sheets and soil test information are available on the Web at http://soiltesting.tamu.edu.

Have the soil tested if it has never been tested before. Otherwise, have it tested every 3 years, unless management has changed.

If you want to send the soil sample to a commercial laboratory instead of the one at Texas AgriLife Extension Service, use an agronomic soil testing laboratory, not an environmental soil testing laboratory. Most environmental laboratories are unfamiliar with agronomic soil testing and therefore do not make nutrient recommendations.

The accuracy of a soil test is a reflection of the quality of the sample taken. Be sure the sample is representative of the area to be treated. For a good, representative sampling, follow these steps:

1. Use a clean shovel or other sampling tool to sample the soil from 10 random areas in the lawn to a depth of 6 inches. Avoid sampling unusual areas such as under eaves or near gravel roads, brush piles, or manure or compost piles.

2. Place the samples in a clean plastic bucket or similar plastic container and thoroughly mix them.
3. Place about a pint of the mixed soil in the container provided by your local county agent, fill out the form, and send it to the indicated address. If you cannot obtain a soil sample bag, use a zipper-lock sandwich bag and double-bag the sample.

Follow the same procedure for gardens and flowerbeds. If your garden and flower beds are small, take three to five random samples instead of 10. Label each sample bag twice so that if one label rubs off during transportation, the other one is still there. Send the sample(s) to the laboratory of your choice that day or the next.

Do not dry the soil samples in an oven or microwave because this changes the potassium chemistry in the soil. If the soil sample is wet, place it on clean white paper in your home or garage, turn it morning and evening until it is air dry, then ship it to the laboratory that day or the next.

An example of the soil test report form is shown in Figure 2.10. Always make sure the correct recommendation has been sent to you by checking the "Customer Sample ID" and "Crop Grown" lines on the report form. These two lines should match the recommendation that you requested, such as lawn establishment and lawn.

The report is normally mailed within 2 to 3 days after the sample is received. The report form in Figure 2.10 lists the following information:

- Column 1 lists most requested analyses.
- Column 2 lists the results of the analyses requested by the homeowner. The analyses shown in this example are the routine analyses that include pH, conductivity (the amount of salts in the soil), nitrate-nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and sodium.
- Sodium is not required by most plants; in fact, too much sodium harms most plants. The reason that sodium is reported is to determine if there is a potential problem with sodium. Thus, if there are no notes related to sodium, the sodium content is acceptable.
- Column 3 lists the critical limit for each nutrient and pH.
- Column 4 lists the units of each of the parameters measured.
- The middle portion of the report is a graph of the soil sample analyses that compares them relative to the critical limit. If the analyses are greater than the critical limit, no additional nutrient will be recommended.
- The last column lists the recommended nutrients per 1,000 square feet.
- In the bottom quarter of the page will usually be notes on management practices for the entire growing season for the crop specified. In this example soil test report are additional recommendations for N depending on the type of grass in the lawn.

Environmental issues

Since the mid 1990s, city dwellers have been encouraged to adopt management practices to reduce fertilizer runoff and conserve water. Nutrients must be managed properly to sustain and improve the quality of surface water supplies.

Proper fertilizer use: For many years, fertilizers with 1-1-1 ratios such as 8-8-8 or 13-13-13 were used to fertilize lawns, gardens, and flowerbeds. Manures and composted manures also have about 1-1-1 ratios. However, research has shown that most plants use N-P_2O_5-K_2O in ratios more similar to 3-1-2 or 4-1-3.

Therefore, by applying the 1-1-1 ratio fertilizers to meet the nitrogen needs, homeowners have overapplied the phosphorus by three to four times with each application. Research in the late 1990s and early 2000s has shown that large amounts of phosphorus are washed from recently fertilized grass sod, regardless of the type of fertilizer, and the phosphorus in the runoff is contributing to the potential of eutrophication. Eutrophication is the natural weathering process of a surface water body.

AgriLIFE EXTENSION
Texas A&M System

Soil Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
345 Heep Center, 2474 TAMU
College Station, TX 77843-2474
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Report generated for:
0
FALSE
FALSE
FALSE
FALSE
Brazos County

Laboratory Number: 241209
Customer Sample ID: Lawn Establishment
Crop Grown: LAWN

Sample received on: 3/31/2008
Printed on: 9/4/2008
Area Represented: 43560 sqft

Analysis	Results	CL*	Units	ExLow VLow Low Mod High VHigh Excess.	Fertilizer Recommended
pH	6.0	(6.2)	-	Mod. Acid	
Conductivity	133	(-)	umho/cm	None	
Nitrate-N	2	(-)	ppm		0.9 lbs N/1000sqft
Phosphorus	15	(50)	ppm		2.1 lbs P2O5/1000sqft
Potassium	50	(175)	ppm		2.1 lbs K20/1000sqft
Calcium	1,802	(180)	ppm		0 lbs Ca/1000sqft
Magnesium	221	(50)	ppm		0 lbs Mg/1000sqft
Sulfur	15	(13)	ppm		0 lbs S/1000sqft
Sodium	144	(-)	ppm		
Iron					
Zinc					
Manganese					
Copper					
Boron					
Limestone Requirement					10.00 lbs/1000sqft

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended.

Nitrogen Apply an additional 1 lb N/1000 sqft during late summer (St. Augustine grass), mid-summer and early fall (common bermuda grass and zoysia grass) and every 6-8 weeks for hybrid bermuda grass.

Methods: pH and conductivity 2:1; nitrate-N/Cd-red.; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP; and B/hotwater by ICP.

Figure 2.10. Example of a soil analysis report from Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory.

The eutrophication process speeds up when dissolved nutrients such as phosphates and nitrates are added to the water, either naturally or by pollution. If this occurs, the water becomes deficient in dissolved oxygen, especially if the water body is shallow.

As the nutrients—especially nitrate-nitrogen and phosphorus—become more concentrated than normal, algal blooms occur. The algae die and other organisms consume them. During this growth and consumption, the microorganisms use oxygen.

When a microorganism competes with fish for oxygen, the microorganism always wins. Thus, the oxygen in the water becomes reduced or depleted, leading to "stinky" water and possibly fish kills.

The best way to manage nutrients is to follow the soil test nutrient recommendations and apply the appropriate amount of nutrients at the right time. Remember: Inorganic fertilizers are soluble salts, and organic fertilizers contain salts. Thus, overapplying inorganic or organic sources of nutrients can cause problems with salt in the lawn as well as in water resources.

Also, overapplying nitrogen can cause many plants to grow vegetatively and not produce fruiting bodies. Therefore, the best way to manage nutrients is to apply the right amount, regardless of the source.

Proper water use: Water quality and quantity are becoming more of an issue each year because of increased population and potential drought conditions. Manage irrigation amounts and frequency both for quality and quantity.

In areas where the water quality is marginal, homeowners must manage salts and/or sodium. If the water is high in salts and/or sodium, use some type of drip irrigation in the flowerbeds and gardens. Lawn grasses are usually more tolerant of salt and sodium and can be watered with sprinkler systems.

However, the salts and/or sodium may need to be corrected periodically, and the process for salts is different from that for sodium. Start with a soil test to identify the problem and degree of severity so the proper remediation can be recommended and carried out.

The Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory can test water quality for irrigation purposes. For submittal forms and instructions for collecting the water sample, visit http://soiltesting.tamu.edu .

An example of a water test report for the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory is shown in Figure 2.11. Ensure that you are getting the right interpretation of the water sample by checking the information given in "Water Source" and "Water Use" areas. This should be what you requested.

The report form in Figure 2.11 lists the following information:

- Column 1 lists the analyses that are available.
- Column 2 lists the results of the test requested. In this report, the routine water report was requested. Notice at the bottom of this column is a number beside "Charge Balance." This is the ratio of cations to anions analyzed in the sample. The closer this number is to 100, the more the analysis represents all of the major cations and anions in the water. If the water sample has a lot of organic material in it, giving it an iced tea or coffee color, this number will probably not be very close to 100. This is because of the presence of organic anions and cations that are not measured in the analyses.
- Column 3 lists the units of each of the parameters that were determined.
- Column 4 lists the method used to determine that parameter.
- The last third of the report is a graph indicating the potential limitations of the water. Parameters in the acceptable range are appropriate for all uses. Parameters in the very limiting range may cause problems for plants that are sensitive to that parameter.

AgriLIFE EXTENSION
Texas A&M System

Water Analysis Report
Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
345 Heep Center, 2474 TAMU
College Station, TX 77843-2474
979-845-4816

Visit our website:
http://soiltesting.tamu.edu

Format based on publication SCS-2002-12

Report generated for:
0
0
#VALUE!

Laboratory#:	13778
Customer Sample ID:	1
Date Processed:	8/12/2008
Sample from Brazos County	
Water Source =Well	**Water Use =Irrigation**

Parameter analyzed		Results	Units	Method	V. Limiting	Limiting	Acceptable
Calcium (Ca)	<	1	ppm	ICP			*****
Magnesium (Mg)	<	1	ppm	ICP			*****
Sodium (Na)		170	ppm	ICP			*****
Potassium (K)		2	ppm	ICP			*****
Boron (B)		1.76	ppm	ICP		*****	
Carbonate (CO_3)		13	ppm	Titr.			*****
Bicarbonate (HCO_3)		372	ppm	Titr.			*****
Sulfate (SO_4 =calculated from total s)	<	3	ppm	ICP			*****
Chloride (Cl-)		40	ppm	Titr.			*****
Nitrate-N (NO_3-N)		0.05	ppm	Cd-red.			*****
Phosphorus (P)		1.62	ppm	ICP			*****
pH		8.20		ISE			*****
Conductivity		631	umhos/cm	Cond.			*****
Hardness		0	grains CaCO3/gallon	Calc.			*****
Hardness		7	ppm CaC03	Calc.			*****
Alkalinity		327	ppm CaC03	Calc.		*****	
Total Dissolved Salts (TDS)		606	ppm	Calc.		*****	
SAR		34.3		Calc.	*****		
Iron (Fe)							
Zinc (Zn)							
Copper (Cu)							
Manganese (Mn)							
Arsenic (As)							
Barium (Ba)							
Nickel (Ni)							
Cadmium (Cd)							
Lead (Pb)							
Chromium (Cr)							
Flouride (F)							
Charge Balance (cation/anion*100)		96		Calc.			

ppm=parts per million=milligrams per liter
N/A, not applicable for this water use

Descriptions of each water parameter, potential use issues and target levels are provided in publication SCS-2002-10, Description of Water Analysis Parameters.

ICP, Inductively coupled plasma; Titr., titration; ISE, ion selective electrode; Cd-red., cadmium reduction; cond., conductivity; calc., calculated

Figure 2.11. Example of a water analysis report from Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory.

The amount and frequency of watering lawns, gardens, and flowerbeds depend on soil conditions and the types of plants. Generally, lawns should be watered as needed with about 1.0 to 1.5 inches of water per week. Water every 4 to 7 days, depending on how fast the water drains in the soil.

For example, if the soil is sandy and well drained, it may need a application of 0.5 inch of water every 3 to 4 days to apply the 1.0 inch per week. Calibrate the irrigation system to ensure that the appropriate amount of water per week is applied. Water at night or early morning, with the last drop of water being applied at dawn to reduce evaporation and ensure maximum infiltration.

Also, if applying 1 inch of water in a single application causes runoff, use split irrigations to achieve the 1-inch total. For example, if the sprinkler system applies 1 inch per hour and water begins running off at 20 minutes, split the applications to 15 minutes and cycle the sprinkler system four times. These measures ensure water conservation and maximum use of water.

Notes