E-1003

Oklahoma Homeowner's Handbook for Soil and Nutrient Management

3rd Edition

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Foreword

Caring for home landscapes and gardening can, and should, be an enjoyable and rewarding experience. The information in this handbook is intended to improve the chances of that happening. Many of the concepts and principles that are the foundation to interpreting and diagnosing the needs and problems encountered in the yard and garden, come from decades of research and its application in cultivated field crops.

The big, and exciting, difference between managing soils for cultivated crop production and the urban landscape is scale. Farmers typically manage 80 acre fields (average size wheat field in Oklahoma) and enterprises that total about 500 acres. In contrast, the average urban landscape is about 5,000 square feet, or 0.11 acres. Intensively managed areas, like a garden may be only 500 to 1,000 square feet or 0.01 to 0.02 acres. Selected, specialty areas in the landscape, like a flower bed for azaleas, may occupy no more than 50 to 60 square feet (3 feet x 20 feet), or only 0.001 acres. Management decisions that are feasible and appropriate for urban landscapes are neither feasible nor appropriate for the average farmer. For example, we may decide that the best approach for long-term, successful azalea growth is to remove a foot of existing clayey alkaline soil in a 50-square-foot area and replace it with a sandy, acidic soil mixture. The process will require a pick-up load of soil removed and a pick-up load of new soil material to replace it. Replacing the top foot of a farmer's 80 acre field would require 70,000 pick-up loads of soil. Obviously this is not feasible. While some of the fundamental concepts and principles learned from cultivated crop production research can be useful when transferred to managing the home landscape, the reverse is not always true. Thus, organic gardening can be easily implemented, but organic farming may be difficult because of a shortage of organic material for large scale field input.

Small scale management of homeowner landscapes not only makes some practices affordable, but also permits some unnecessary practices and mistakes that would not occur in larger scale situations. These, especially in the case of nutrient management, will be identified as practices that can be eliminated or modified to save small inputs of money and effort. Finally, the real value in acquiring new knowledge from reading and studying this handbook will come from an improved ability to manage on a cause-and-effect basis. That is, being able to recognize a dysfunction in the landscape that can be treated and how best to treat it. For example, yellowing in the lower leaves of a corn plant may be caused by several conditions. Being able to recognize the symptoms of nitrogen deficiency should eliminate the risk of treating the plants for disease or insects. Understanding the natural chemical and biological dynamics of nitrogen in the soil will identify several options for correcting nitrogen deficiency in corn. Adding nitrogen fertilizer is only one of those options.

The authors greatly appreciate the contribution from the two original authors: Dr. Gordon Johnson and Ms. Brenda Simons. Special thanks to Mr. Ray Ridlen and many other Extension educators for their inputs during the revision of this handbook. We are also grateful to Ms. Vickie Brake for redrawing most of the figures, Dr. Hailin Zhang for the photographs, and to Ms. Janelle Malone for editing.

Chapter 1
Composition and General Soil Management

What Makes Up Soils?

In the management of soils it is important to understand what makes up soils and how they are put together. A typical garden soil is made up of about half solids and half voids as illustrated in Figure. 1.1.

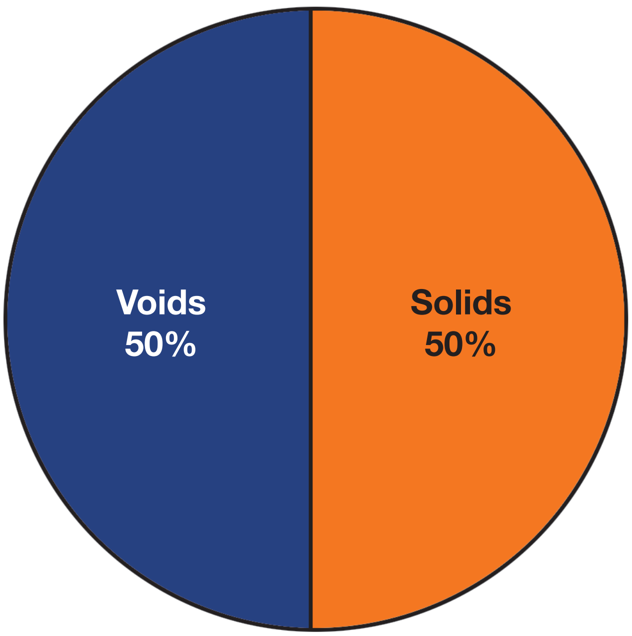

Figure 1.1. General composition of soils.

Closer examination of soil solids reveals they are mostly mineral, with only about 1 to 2 percent organic matter present. The mineral matter can be further categorized by particle size into sand, silt and clay materials. The voids in soil are filled with either air or water, and in a well drained soil, a day or so after irrigation or rainfall, half of the voids would be filled with air and half filled with water. A more complete description of the soil composition is illustrated in Figure 1.2.

The mineral and organic components provide a reservoir of nutrients for plants, which will be discussed in greater detail. The voids, or pores, holding water are usually an adequate supply to maintain the needs of plants for several days. Pores holding air are just as important to plants as those holding water because roots respire, as we do, taking in oxygen and giving off carbon dioxide. Large soil pores allow air exchange between the soil and the atmosphere, assuring oxygen for the roots to function normally.

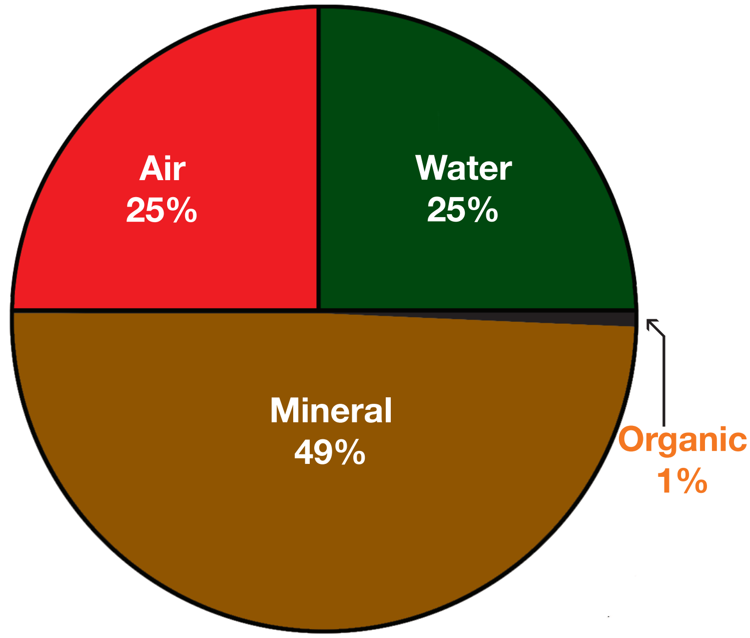

Figure 1.2. Distribution of air, water, mineral and organic matter in a soil.

Poor Physical Condition of Soil

Oklahoma spring gardening conditions often lead to a disruption of the normal, ideal soil condition. Avid gardeners delayed by frequent rainy weather in March and April, will decide to plant even when the soil is still wet or worse yet, when it is still raining. Owning one of those fancy garden tillers that thoroughly mix the soil while they walk alongside guiding it, they will attempt to prepare a seed bed when the soil is too wet. As a result, soil particles are packed close together, forcing out the air and water. Foot tracks often glisten from water forced to the soil surface because there are too few pores to contain the water present. This soil condition, compared to the normal soil is illustrated in Figure 1.3.

Compacting the soil by cultivating it when it is too wet redistributes the soil components, greatly reducing the amount of air and water the soil can hold. When the soil finally dries, it still retains the compacted condition (often it will be as hard as a brick) and now holds much less air and water. Consequently, the garden needs to be irrigated more frequently to supply enough water for the plants, and it is easy to over irrigate and not have enough air for the roots to breathe properly. The end result is a disappointing garden. This condition will persist until natural swelling and shrinking of the soil brought about by wetting and drying occurs, or the soil is cultivated when it is in a dry, crumbly condition.

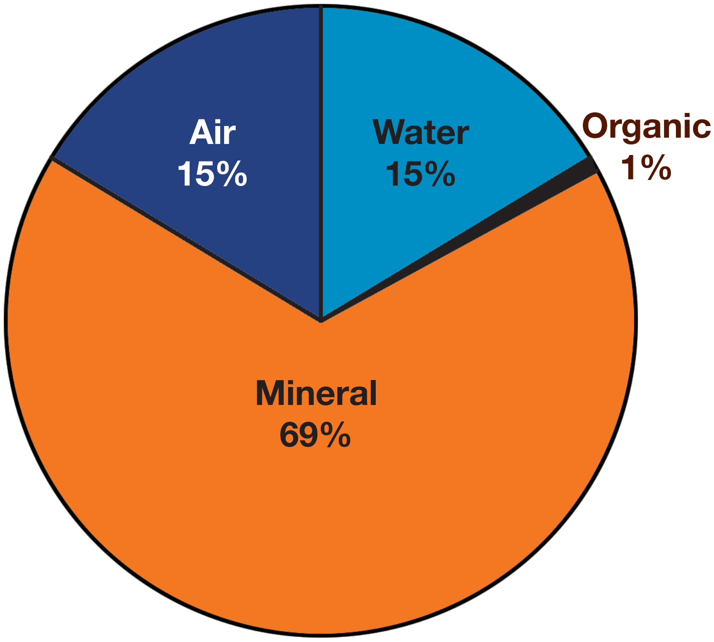

Figure 1.3. Distribution of solids, air and water in a compacted soil.

Improving Physical Condition of Soil

Avoiding tillage when soils are wet will help prevent the soil from becoming compacted and hard. To do this, it may be necessary to avoid tillage in the spring altogether. Eliminating tillage, especially if one has a relatively new, expensive garden tiller, can be a difficult change in management to implement. However, it is good to question the need for tillage and make sure there are good justifications for each operation (e.g. incorporate excess plant residue, soil amendments, pesticides, etc.). Most of the time, tillage causes a deterioration of soil structure.

Gypsum

It is a common myth among homeowners that adding gypsum to clayey soils, which is common in Oklahoma, will improve their physical condition, making them soft and easy to till. There is no scientific basis or research to support the claim that gypsum will soften hard, clayey soils. One can only guess at how this practice came to be. Perhaps an enthusiastic homeowner heard that some gypsum would be a good source of sulfur (it is) for plants. It would have been easy for the individual to have checked with a farm supply outlet for prices, and having found it available for a few dollars a ton, purchased a pick-up load of the off-white colored material for the garden. After spreading it, the gardener would have found it necessary to till it many times to get it thoroughly mixed and restore the soil to its original color. In the process, neighbors may have gathered wondering why it appeared to have snowed on this garden and not theirs. The gardener may have experienced the best garden crop in years and attributed this to the gypsum. More likely the garden benefited from the good deep tillage occasionally needed to break up hard pans or compacted layers of soil that form at the normal tillage depth. The high rate of gypsum served as a good marker, or indicator of when the job was done. Gypsum does have a place in the landscape as an amendment for correcting sodic or alkali soils, which will be further explained.

Raised Beds

Mounding soil in rows a foot or two above drainageways between plantings improves the drainage of excess rain from the soil and allows easy access to plants growing on the mounds. If an inch of sand followed by about two inches of straw is placed in the drainageways, they will be easy to walk in and weed or harvest portions of the garden when it would otherwise be too wet. At the end of the season, the sand and straw can be incorporated into the raised bed to improve soil, and new layers of sand and straw placed in the drainageway the following year. Raised beds make it easier to manage poorly drained soils during rainy seasons (Figure 1.4).

Figure 1.4. The effective use of raised beds in a garden setting.

Organic Material

The best soil amendment to reduce the risk of soil compaction and soil crusting is the addition and maintenance of high levels of organic matter. Good supporting evidence for this practice comes from observing characteristics of soils with extremely different organic matter contents. Soils of the Desert Southwest U.S. are hard when dry, sticky when wet and form crusts impenetrable to the germinating seeds of lettuce and carrots. These soils characteristically have less than 1 percent organic matter in the surface layer. In contrast, soils developed in cooler climates of the upper Midwest typically contain 3 to 5 percent organic matter and are less likely to be sticky when wet, hard when dry or form a crust that small-seeded plants cannot penetrate when they germinate. The key is lots of organic matter in the soil. The greatest benefit of organic gardening is the improved ease with which soils can be managed. The greatest drawbacks are finding enough organic matter and managing it in such a way that other problems are not caused. Soil organic matter maintenance will be considered in later chapters.

Life in the Soil

In addition to knowing the general make up of soils, proper management of the soil involves understanding how the soil lives and how it responds to changes. Most of this soil life is a result of chemical and biological activity in the soil that is closely linked to the amount of organic matter and clay present (Figure 1.5). Although much of the soil is composed of sand and silt particles, they are rather inert or inactive in terms of soil life.

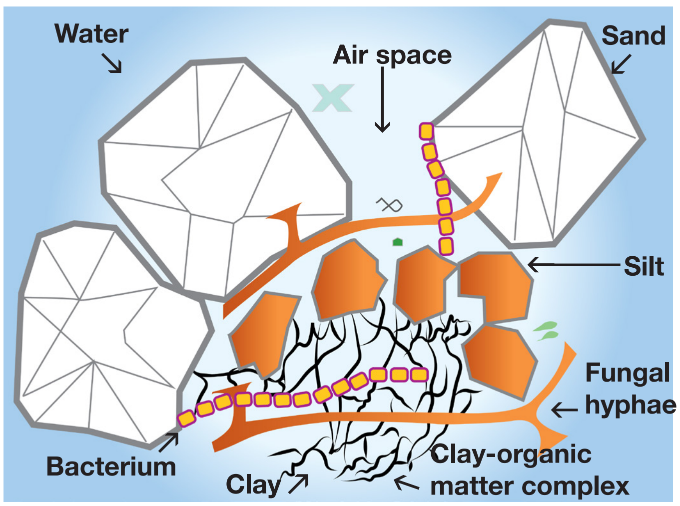

Figure 1.5. Illustration of soil minerals (sand, silt, and clay); organic matter; pore space; and microorganisms (from Scheyer and Hipple, 2005 Urban Soil Primer).

Clay

Clays are a unique and critical component of soils because of their size, shape and electrical charge. Clay particles are so small they can only be seen through an electron microscope and belong to the category of particles called colloids. These particles are small enough to be suspended in fluids almost indefinitely. A common example is milk. The solids remain suspended until the milk sours, causing the particles to coagulate, or come together in large groups that settle to the bottom of the container. The solids in smoke are colloidal, allowing dense smoke to be seen and easily moved by wind, as the solids are suspended in air. Clay is easily suspended in clean water. The suspension of clay from the erosion of Permian Red Bed geological material (parent material for many soils) in Oklahoma is likely the reason the river between Texas and Oklahoma was named the Red River.

Clay particles usually have a thin, irregular shape, sometimes referred to as platey. This shape and small size is responsible for their tremendous adsorptive properties. Clay (and organic matter) gives soils the capacity to store water and nutrients for plants. Because of how they were formed, clays have an internal electrical charge imbalance that causes them to act like the negative (-) pole of a magnet. This characteristic adds to their adsorptive properties, especially for chemical elements in the soil that are present as positively charged ions, or cations. Some of these are essential elements that plants require as nutrients. The plate-like shape of clay particles can be envisioned as shown in Figure 1.6.

Figure 1.6. Negative charges on clay or organic colloids attract cations to their negative charges.

Here Comes the Gypsum

It may seem like this discussion is wandering away from worthwhile applications of information to help the garden or lawn, but there is a point to it all. There are situations in the urban landscape when gypsum additions are beneficial to the soil. These situations are a result of the soil receiving excess sodium (chemical symbol Na) caused by salt water spilling onto the soil (recent or past), potassium (K) from excessive dumping of fireplace ashes in an area or as a result of irrigating with high sodium water. When this happens, because Na and K are positively charged ions (Na^+ and K^+) that have a thick shell of water around them, they can not get close enough to the clay to effectively neutralize the negative charge on the clay. As a result, the clay particles are said to be dispersed, that is, they are no longer grouped together in aggregates, and are free to float about and plug up the small pores in soil responsible for water infiltration and drainage. When this happens, we observe water puddles after only a small amount of rain or irrigation. Because the soil pores provided by sand and soil aggregates are plugged, water does not reach the roots and plants die of drought even though the surface soil is very wet. This condition is referred to as a sodic or alkali soil.

We may picture the sodic soil condition much as what would happen if we filled a bath tub full of water and then threw playing cards, one by one, into the tub. As they settled to the bottom, some would slide over the drain hole and restrict or prevent water from leaving the tub. The cards would plug the bathtub drain in much the same way clay particles in a sodic soil would plug soil pores. However, if we put a rubber band around the deck of cards and then threw them into the tub, it is unlikely the drain would get plugged. In fact, we could throw many decks of cards into the tub, if the cards of each deck were bound by a rubber band, the tub would still drain. Dispersed clay in a sodic soil can be brought back to normal from a liberal application of gypsum (50 to 100 pounds per 1,000 square feet) if good internal soil drainage is provided. The calcium (Ca) in gypsum (calcium sulfate) will dissolve in the soil slowly, and because the calcium ion has two positive charges (Ca^{2+}) compared to only one for either sodium or potassium, calcium will bump sodium off the clay and effectively neutralize the negative clay charges allowing the separated clay particles to come back together in groups or packs. The process is much the same as gathering the individual cards in the tub into decks and putting a rubber band around them. Doing so would allow the tub to drain freely, provided the water had somewhere to go. Similarly, good soil drainage is necessary so the excess sodium can be washed out of the soil (Figure 1.7).

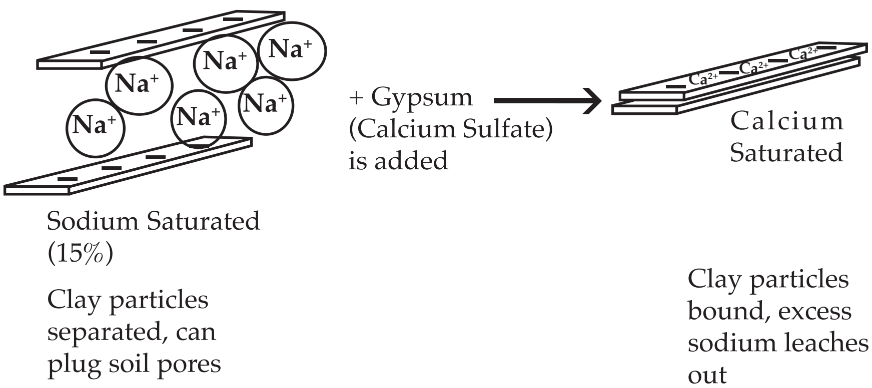

Figure 1.7. The action of gypsum to restore dispersed sodic soil to more aggregated normal soil.

Soil Organic Matter

As soil clay is usually the focal point of soil chemical activity, soil organic matter is usually the focal point for soil biological activity. This biological activity results from the action of microorganisms, mainly bacteria, fungi and actinomycetes that are present in virtually all soils. These microorganisms are micro or small organisms. They have many of the same requirements for growth as the plants we are trying to grow in the garden or lawn. They need water, heat (warm temperature) and most of the mineral elements of higher plants. Additionally, most of them need organic material as a source of carbon and energy. These microorganisms decay plant residue and convert it to humus. Most of them are aerobic — they require oxygen from soil air.

Organic matter management, used in organic gardening, depends on the balance between how much organic matter is added and how much is lost. Roots and above ground plant parts are a natural input of organic material to the soil. If the garden is cultivated, however, these additions are inadequate to raise, or even maintain, soil organic matter levels because the decay and loss of organic matter (even humus) promoted by cultivation will outweigh the input from plants grown in the garden. Organic gardeners realize that if they cultivate the soil frequently, they must bring more organic material (grass clippings, compost, etc.) from other sources to maintain a suitably high humus level in the soil.

Increasing the organic matter from the 1 percent level common in cultivated Oklahoma soils, to 3 to 5 percent will cause clayey and sandy soils to act more like loam textured soils. The clayey soils will not crust and get hard when dry, the sandy soils will be able to store more water and nutrients if an adequate amount of organic matter is present in the soil.

An question often asked by gardeners is how much and what types of organic matter are good. Specific, quantitative answers to these questions are difficult to make. Generally, it is good to use a variety of organic sources and add them in moderation (another nonspecific term). Moderation, in this use of the term, means do not add more organic material at any one time than you can physically incorporate (spade or till) and still end up with a surface that looks more like the soil than the organic material just added. Adding a variety of sources means just that. Almost anything organic can be added, including shredded newspaper, table scraps, plant trimmings from flower beds and shrubbery, grass clippings, animal waste, compost, etc. The two cautions in good management are 1) do not use just one material, and 2) do not try to convert a soil with 1 percent organic matter to one with 5 percent organic matter overnight (do not try to create an instant organic garden). Too much compost or animal manure applied to the soil may result in high soil salinity or too many nutrients that may impact plant growth.

Having just moved from Michigan to Arizona (Tucson), a new homeowner decided to improve the existing rock yard and develop a garden. Believing in the value of soil organic matter, and knowing the pale, mineral desert soils of Arizona would be incapable of providing the good foundation for new plantings, the homeowner purchased two pick-up loads of bagged steer manure and spread it on the small garden-to-be area. Much to his dismay, the homeowner could not grow anything in the garden for a year because he had added so much steer manure to the small area that it responded more like a compost pile than a garden. Whenever it was moist enough, the high desert temperature caused very active microbial decay of the steer manure. This in turn created more heat in the soil-steer manure mixture and it released more available nitrogen than plants could use.

Chapter 5 will examine the importance of organic matter maintenance in relation to nitrogen management.

Chapter 2
Acid and Basic Soils: pH

What is pH?

Good nutrient and soil management often involves obtaining a representative soil sample and submitting it to a laboratory for testing. A common soil property tested by labs is the soil pH. It is an invention of chemists, and it is a useful indicator of whether the soil is acidic or basic/alkaline. To understand this, consider the following.

Most everyone is familiar with the chemical notation for water, H_2O, said H-2-O. This designates that water is made up of two hydrogen ions (H^+) and one oxygen ion (O^{-2}). Water could also be correctly written as HOH (there would still be two Hs and one O). When pure water is closely examined, it is found that a small amount of it has broken apart (chemists call it disassociated) into pieces of hydrogen and oxygen that have positive and negative charges on them. This breaking apart can be expressed as

$$HOH \rightarrow H^+ + OH^-$$

When substances containing water have a lot of either H^+ or OH^- in them, they are found to be more reactive. For example, water that has more than the normal amount of either H^+ or OH^- will corrode metals more than would pure water. Solutions containing more than normal amounts of H^+ (compared to pure water) are said to be acidic or acid, and if they contain less than normal amounts of H^+ they are called basic or alkaline. Pure water, because it contains the normal amount of H^+, is neither acidic nor basic and is called neutral.

The amount of H^+ present in pure water is only 0.0000001 moles per liter, a unit used by chemists. This, and similar measures of the H^+ present, are cumbersome to communicate. An easier way to express the value is as a power of ten, as done when 10 x 10 is expressed as 10^2 or 10 squared. The value of 0.0000001 could be written as 10^{-7}. This was soon shortened to just writing the number to which 10 was raised (7) and indicating that it was a negative value by using the small letter p. Since H^+ was being measured (or expressed), pH came to mean the negative power to which 10 is raised to express the H^+ concentration. The scale of pH is from 0 to 14. For pure water then, the pH is 7. When the pH is less than 7, it is acidic; greater than 7, it is basic or alkaline. It is important to realize that a pH of 5 is 10 times more acidic than a pH of 6, and 100 times more acidic than a pH of 7. Knowing this helps us understand why soil pH does not change rapidly from one year to the next, unless we add a large amount of a basic material, like lime, or an acidic or acid-producing material, like sulfur.

Normal Occurrence of Acid and Alkaline Soils

Whether soils are naturally acidic or alkaline is related to annual rainfall more than any other single factor. In central and eastern Oklahoma, which receive more than 30 inches of rainfall annually, soils are commonly acidic. In western Oklahoma, where annual rainfall averages 20 inches or less, soils are normally neutral or alkaline (pH 7 or greater). Soils are neutral or alkaline when the basic, or lime-like, materials from which they develop are not washed out by high rainfall. In some western soils, there is just enough rainfall to cause the parent material to chemically weather (gradually dissolve in water), but not enough rainfall to wash the products away. Accumulation of these products results in western soils containing gypsum (calcium sulfate) and lime (calcium carbonate) at or near the soil surface. Even under intensive gardening, and soil management practices that promote increased soil acidity, these soils will remain neutral or basic in pH for several generations. Typical soil pH and associated descriptive terms are shown in Figure 2.1.

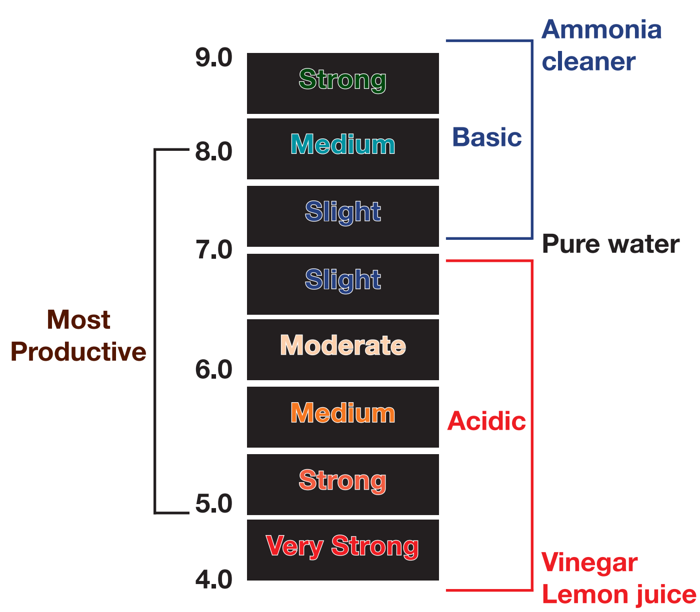

Figure 2.1. Typical pH found in soils and terms used to describe them.

Changing Soil pH

Acid Soils

Sometimes the soil is too acidic for normal growth of landscape or garden plants (Figure 2.2). In these cases, lime can be added to neutralize some of the acidity and make a more favorable environment for the plants. Most plants will not do well when the soil pH is less than 5.5, and they do poorly when the pH is less than 5.0. Some exceptions are acid-loving plants (more appropriately termed acid tolerant) like blueberries, azaleas, pin oak and fescue.

Figure 2.2. This is the impact of low soil pH on canola. The foreground is more acidic than the background.

Once a soil test identifies a soil as too acidic for normal plant growth, the next step is to decide how much lime to apply. Most soil tests will report a buffer index (BI), or some measure of the soils capacity to hold acidic and basic materials. Because both acidic and basic materials held in the soil exist as cations, which are chemical elements that have a positive charge like H^+, the ability or capacity of the soil to hold these substances is directly related to the amount of negative charges in the soil. Recalling from Chapter 1 that clay particles have an internal negative charge, clays then serve as a reservoir for holding acidic and basic material in soil. Additionally, since humus also has negative charges at the surface of particles, the humus content of soil also contributes to how much acidic and basic material the soil can hold.

The soil's ability to resist change in pH is often referred to as its buffer capacity. The more clay and humus in the soil, the greater its buffer capacity. Sandy soils take only small amounts of lime to neutralize the acidity present, whereas clayey soils containing a lot of organic matter may take two to three times more. Figure 2.3 illustrates the relationship between soil pH and buffer index. The buffer capacity of the soil is depicted as a large reservoir that holds basic, lime-like material that is connected by a small conduit or pipe to a small reservoir where pH is measured. When pH is measured, it identifies the level of acidity in both the small and large reservoirs (since they are connected). Buffer index gives an indication of

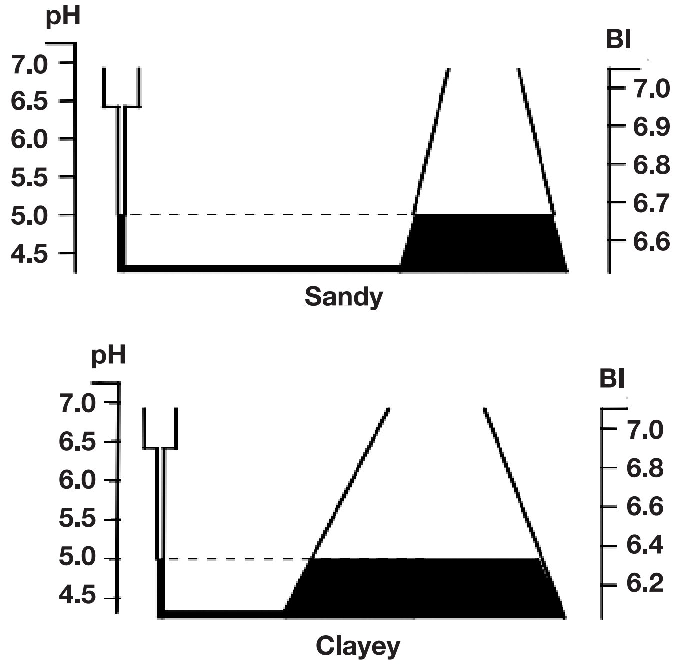

Figure 2.3. Relationship between soil pH and buffer index for sandy and clayey soils.

the size of the large reservoir and how much lime is necessary to fill it up to where it will change the pH to the desired value.

When managing acid soils, soil pH is used to decide whether or not to lime; buffer index is used as a guide for how much lime to add. For this reason, when soil pH is 6.3 or higher, buffer index is not measured because these soils should not be limed for most plants.

Table 2.1 shows the relationship between soil buffer index and lime requirement, for lime that is about 100 percent active ingredient. Typical aglime may only have 60 percent active ingredient; therefore, more may be needed if the lime used is less than 100 percent. Additional lime may be added the following year after a new soil test indicates the soil is still too acidic.

Table 2.1. Calibrated relationship between soil buffer index (BI) and lime requirement.

Buffer Index	Lime Needed lbs/1,000 sq ft	Lime Needed tons/acre
7.1 or greater	23	0.5
7.0	32	0.7
6.9	46	1.0
6.8	55	1.2
6.7	64	1.4
6.6	87	1.9
6.5	115	2.5
6.4	142	3.1
6.3	170	3.7
6.2	193	4.2

Because acid is held on the exchange sites, or the negatively charged surface of clay and humus particles, lime must be mixed well into the soil to effectively neutralize soil acidity. The mixing is best accomplished when both the lime and soil are dry and in a powdery state.

This condition is not usually possible (and making the soil into a powdery condition is not usually desirable), but good mixing will hasten the reaction of lime and soil. For established lawns, mixing is not possible, but liming after aeration will help the lime penetrate the rooting zone. Once liming has been done and the soil pH is raised to a more desirable level, it should not be necessary to lime again for several years.

Basic or Alkaline Soils

When soils are developed from basic parent material (limestone) or in low rainfall climates, the pH is usually above 7. Although it is usually too expensive for farmers to amend their fields to lower pH, homeowners can consider this as an option to allow acid loving plants in the landscape. For small areas, like portions of flower beds or gardens, the first approach should be to remove the existing soil, unless it is already very sandy. It is only necessary to remove existing soil to a depth of about a foot for most plantings, because the top foot of soil is where most active roots will reside (slightly greater depth is desirable for trees). Once existing soil is removed, it should be replaced with top soils with desirable properties. If the pH is not acidic enough, yellow sulfur can be added to further acidify the soil (see Table 2.2). The yellow sulfur is oxidized to sulfuric acid (battery acid) by existing soil microorganisms, but will take several weeks to complete. It will usually be best to add small amounts of sulfur and periodically check the pH to gradually develop the desired soil pH, avoiding the risk of adding an estimated large amount of sulfur and ending up with a soil pH too acidic to grow anything in, then having to lime the soil. The difficulty with making the soil more acidic is that the materials we use do not have a desirable end-point pH, which is when the material is done reacting. Thus, while excess lime is usually not harmful and would result in the pH going up to only about 7.5, excess sulfur could bring the pH down below 4.0.

Table 2.2. Estimated amounts of sulfur required to acidify alkaline soils.

Existing pH	lbs sulfur/100 sq ft
7 to 8	2
8.1 to 8.5	4
8.6 or above	6

Chapter 3
Growth Requirements for Landscape Plants

Plants and their Environment: Plant Growth Factors

General Considerations

There are several aspects of the landscape environment that influence how well plants grow. The most obvious of these are light, heat, moisture and nutrients.

Plantings are sometimes made because of their tolerance or need for light or shade and sometimes the light condition is modified to create a better light condition than exists. For example, fescue turf is planted in shade where bermudagrass does poorly. As already discussed in Chapter 1, the moisture supply to plants can be adversely influenced if the soil is compacted, but usually improved by increasing the humus content. Heat, moisture and nutrients for plants can all be influenced by the landscape and soil management. When the landscape is not flat, subtle differences in relief can cause big differences in how plants respond. For example, soil on slopes usually will be drier than soil in level areas above and below the slope. Soil at the bottom of the slope may be wet for longer periods of time than that on the slope or above the slope as illustrated in Figure 3.1.

Figure 3.1. General relationship of landscape position and soil moisture.

Because water is a good conductor of heat, but requires more energy to warm up than does dry soil, wet soils tend to be the latest to warm up in the spring, compared to moist or dry soils. Improving the drainage of soils at the bottom of slopes can help them warm up at the same time as the rest of the landscape. New home sites are sometimes leveled by cutting earth away from the high points and using it to fill the low points on the lot, as shown in Figure 3.2. This can be drastic in some cases and result in the new surface soil being quite different.

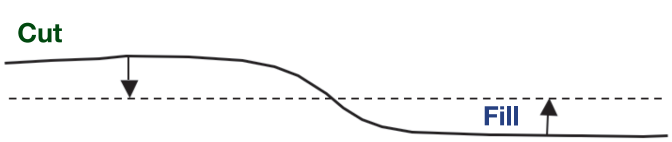

Figure 3.2. Areas of cut and fill for reshaping landscape.

Usually the area that was cut will have a shallow surface soil the contractor brought in, underlain by compacted, infertile subsoil. It will be difficult to grow anything deeper rooting than turf on the cut area. When plants do not grow well, it is often enlightening to dig or probe into the soil to determine if adequate subsoil depth exists. Occasionally, the restrictive layer is a buried piece of plywood.

The growth factor easiest to manage is that of the nutrient supply for plants. For this reason, the remainder of this handbook will be devoted to that topic.

Essential Elements for Plants

Plants differ in growth habit, morphological features and benefit or purpose they serve the homeowner, however, all plants require 16 chemical elements (Figure 3.3) to survive and reproduce.

The names of the 16 essential elements and their chemical symbol (often used in trade magazines and product information) are listed in Table 3.1. While it is important to recognize that only 16 elements have been identified by modern science as essential for plants, most of them are well supplied in the growth environment and only a few require our management. Based on the amount needed, those nutrients are grouped in macronutrients, secondary nutrients and micronutrients.

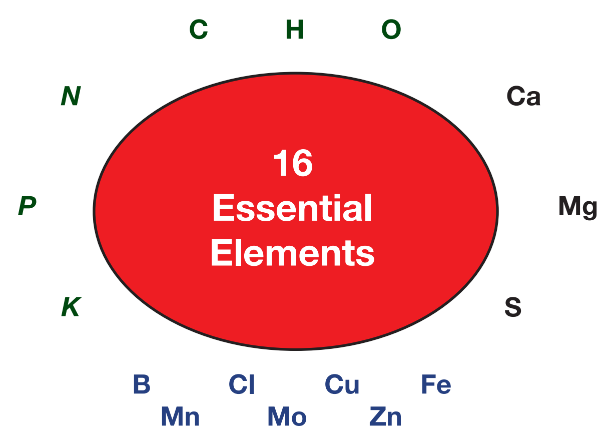

Figure 3.3. Essential nutrients needed by plants.

Macronutrients

Carbon (C), Hydrogen (H) and Oxygen (O)

Higher plants get their C from carbon dioxide (CO_2) in the atmosphere. Most of the H and O for plants is supplied by water (H_2O) and air (O_2). Timely irrigation and managing soil to maintain or improve infiltration and internal

Table 3.1. Essential nutrients required by plants.

Element Name	Element Symbol	Soil Mobility*
Macroutrients		
Carbon	C	
Hydrogen	H	
Oxygen	O	
Nitrogen	*N*	*M*
Phosphorus	*P*	*I*
Potassium	*K*	*I*
Secondary Nutrients		
Calcium	Ca	I
Magnesium	Mg	I
Sulfur	S	M
Micronutrients		
Iron	Fe	I
Manganese	Mn	I
Copper	Cu	I
Zinc	Zn	I
Boron	B	M
Chlorine	Cl	M
Molybdenum	Mo	I

* M means the nutrient is mobile and will move with water in the soil; I means the nutrient is relatively immobile and does not move with water in the soil readily.

drainage (as discussed in Chapter 1) can be important to meeting plant needs for these elements. In many home landscapes, perennial plants have been wisely selected to thrive in the natural climate and soil of the site. When this is done, little added management is necessary.

Nitrogen (N), Phosphorus (P) and Potassium (K)

Macronutrients are three nutrients required in large amounts by plants. They are nitrogen, phosphorus and potassium. Because these nutrients are primarily supplied from the soil, they were the first elements to become depleted under intensive cropping systems that resulted in high yields of produce being hauled off the fields to market. In response to widespread soil depletion, the fertilizer industry was born. Subsequently, soil supplies have been replenished by addition of mined natural deposits or synthetically prepared soluble forms of these three nutrients.

Plant growth and yield are strongly influenced by the supply of N. Of all the nutrients, N is most commonly deficient, especially when plant vegetation is removed from the area where it grew (bagging lawn clippings). Because nitrogen is bound organically in amino acids and plant proteins, when plants die, much of the N in the dead tissue remains bound in these organic forms. As plant residue decays and becomes soil organic matter (humus), most N remains organically bound and becomes an important reservoir of slow-release N. Nitrogen in humus cannot be absorbed by plants until it is released by soil microorganisms and is then available in an inorganic form as either ammonium (NH_4^+) or nitrate (NO_3^-). Clearly, nitrogen management must involve organic matter management. Understanding this is especially important for organic gardeners and will be dealt with in greater detail in later chapters.

Phosphorus deficiency in mature lawns and gardens is uncommon because plants use only about an eighth as much phosphorus as they do nitrogen and many homeowners apply as much phosphorus back to the soil in the form of compost and fertilizers as they do nitrogen. Since phosphorus is immobile in the soil, it accumulates and will be adequately supplied by soils that have a history of annual inputs of phosphorus. Phosphorus may be deficient in soil that was previously farmed and received little or no phosphorus input. Phosphorus will most commonly be deficient in recently modified landscapes (such as the cut area illustrated in Figure 3.2) where surface soil has been removed and the P deficient subsoil is being used as a growing medium.

Potassium deficiency is common in high rainfall (greater than 35 inches annually) regions, such as eastern Oklahoma. Soils that naturally have a near neutral or higher pH (7 or above) will usually be rich in available potassium (western Oklahoma) because they have developed in arid and semi-arid climates without enough rainfall to leach potassium from the soils.

Secondary Nutrients

Calcium (Ca), Magnesium (Mg) and Sulfur (S)

These elements are seldom deficient in the urban landscape (Figure 3.4). Calcium and magnesium are the main elements responsible for keeping the soil pH from becoming too acidic. Before supplies for plants become deficient, the soil pH is too acid for plants to grow and lime must be added to raise the pH back to a suitable level. Because lime is mostly calcium carbonate (usually some magnesium carbonate), liming to keep the pH desirable also maintains good supplies of calcium and magnesium for plants.

Rainfall in Oklahoma adds about 6 pounds of sulfur per acre per year. While this may not seem like much, plants only require about one-twentieth as much sulfur as nitrogen. One way to appreciate how much sulfur is in rainfall, consider the likelihood of needing fertilizer nitrogen if we received 120 pounds per acre of nitrogen each year in rainfall. This would be equivalent to about 3 pounds of nitrogen per 1,000 square feet, more than enough to support summer growth of a lawn. If sulfur is needed, gypsum (calcium sulfate) would be a good, inexpensive source.

Figure 3.4. Example of a properly nourished and maintained landscape.

Micronutrients

Molybdenum (Mo), Manganese (Mn) and Copper (Cu)

These elements have not been found to be deficient in Oklahoma soils, and are unlikely to be deficient in landscape plants grown in soil or soil mixes.

Chlorine (Cl) and Boron (B)

Chlorine deficiency has only been documented once by OSU research. This occurred near Perkins, in wheat on a deep, sandy soil following an unusually wet year (chlorine likely leached out of the soil). Boron deficiency also occurs in deep, sandy soils and has only been reported in peanut production in Oklahoma. It is unlikely homeowners will experience deficiencies of either of these nutrients in their landscapes.

Iron (Fe) and Zinc (Zn)

Deficiencies of iron and zinc are limited to specific soil-plant conditions or situations. The plants most susceptible to zinc deficiency in Oklahoma are pecans. Commercial growers routinely apply foliar zinc fertilizers to avoid the problem. Deficiency shows up as a shortening of internodes (space along stem between nodes or leaves) called rosetting, which causes the leaves or branches of new growth to appear as if they are all growing out of the same point on the main stalk. Corn is the second most susceptible plant to zinc deficiency. Most soils in Oklahoma are adequately supplied with Zn.

Most soils contain 50,000 to 60,000 pounds per acre of iron. However, most of this iron is in an oxide form, like rust, that plants are unable to use directly. Iron deficiency in plants is limited to high pH soils (central and western Oklahoma) and in plants that do not have an effective mechanism for extracting iron from soil. These plants are unable to acidify soil next to their roots, thereby increasing availability of iron, and may be termed acid loving. Susceptible plants may also lack the ability to produce compounds from their roots capable of chelating Fe to improve its availability. Chelate comes from a Greek word meaning claw. A metal ion is bound with parts of a large organic molecule, where individual bonds between each part of the organic molecule and the metal cause the metal to be held as if it were in the grip of a claw. Pin oaks are an example of plants that do poorly in neutral and high pH soils, and they are not recommended for parts of central and western Oklahoma for that reason. Most garden plants are effective in obtaining adequate iron from soils and iron deficiency is not common (Figure 3.5).

Figure 3.5. Example of crepe myrtles that are not exhibiting any micronutrient deficiencies.

When iron deficiency does occur, it will appear as interveinal chlorosis (yellowing between the veins) in the newest leaves because iron is not translocated well from old leaves to new leaves, as are N, P and K. Deficiencies can be corrected by foliar application of a 1 percent solution of iron sulfate, iron-ammonium sulfate (ferrous or ferric ammonium sulfate) or other fertilizers containing Fe. However, if the supply of iron from the soil to the plant is not improved, chlorosis will again develop on new growth because iron is not translocated from old, well fed tissue, to new deficient tissue. Soil organic matter helps to naturally chelate iron and improve its availability to plants. Improving and maintaining high organic matter levels in the soil usually reduces or eliminates the problem. Also, periodic surface application of yellow sulfur will make the soil acidic and reduce the chance of iron chlorosis if the soil is high in pH.

Chapter 4
Gas and Oil for the Garden and Lawn

Plant Nutrient Uptake Patterns

Mobile and Immobile Nutrients

There are many ways to group the essential elements in relation to their chemistry and plant need, such as cations or anions, whether or not they can be chelated, whether they form soluble or insoluble compounds, etc. From the standpoint of managing the nutrients, however, their mobility in the soil has been the most useful characteristic. One of the most mobile nutrients in the soil is nitrogen and one of the most immobile is phosphorus. Potassium is intermediate in mobility. Relative mobility, on a scale of 1 to 10, for these three nutrients is illustrated in Figure 4.1.

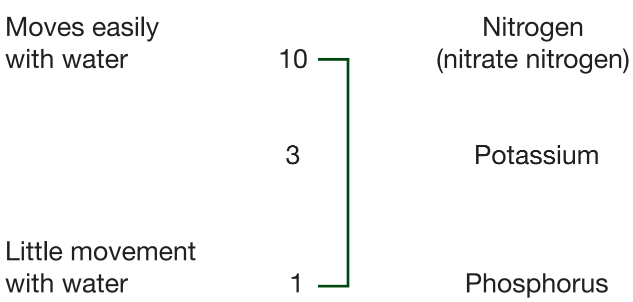

Figure 4.1. Relative mobility of the major plant nutrients supplied through the soil.

Mobile Nutrient Uptake by Plants

The way plants extract nutrients from the soil depends on how easily the nutrients move in soil water. Uptake of mobile nutrients, like nitrogen, is shown in Figure 4.2.

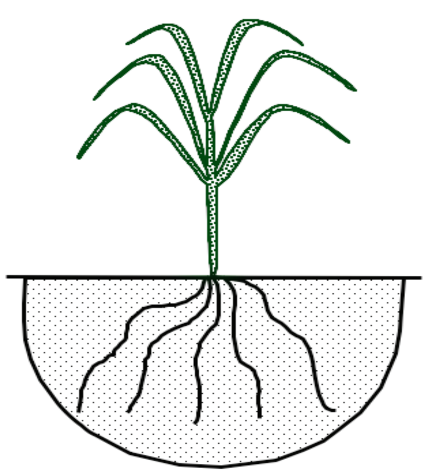

Figure 4.2. Volume of soil (shaded area) mobile nutrients, such as nitrogen, can be absorbed from by plants.

Figure 4.2 shows that nitrogen, which commonly occurs as nitrate, can be utilized from the soil that is beyond the reach of the longest roots. This is because as the plant extracts water from the soil next to its root surfaces and that soil begins to dry out, water from surrounding moist soil moves into this region of dry soil next to the root. Some of this movement is the result of a wick-like action within the soil. As water moves to the root surface, it carries nitrogen with it.

When several plants are growing in an area, such as a row in the garden or at random in the lawn, the volumes of soil, from which they each can draw nitrogen, overlap (Figure 4.3). In this volume of soil, plants are competing for the same nitrogen (or water, since it is also a mobile nutrient source). As more and more plants are crowded into an area, competition continues to increase. If the nitrogen supply from the soil was adequate to support normal growth for one plant, without competition from other plants, then with a second plant nearby competing for nitrogen, more nitrogen is needed. If additional nitrogen is not added, growth will be limited to less than normal. From this illustration we learn that as the yield of plant material (lettuce, corn, spinach, grass clippings, etc.) from an area is increased, the demand for mobile nutrients like water and nitrogen also increases. In other words, the competition among plants can be reduced or eliminated by adding more of the nutrient.

The above concept for mobile nutrients is very important because it clearly shows that good nitrogen management begins with a yield goal or estimate of how much is to be grown in an area in a given period of time. For bermudagrass lawns that receive adequate water in the summer, adding nitrogen at the rate of 1 pound per

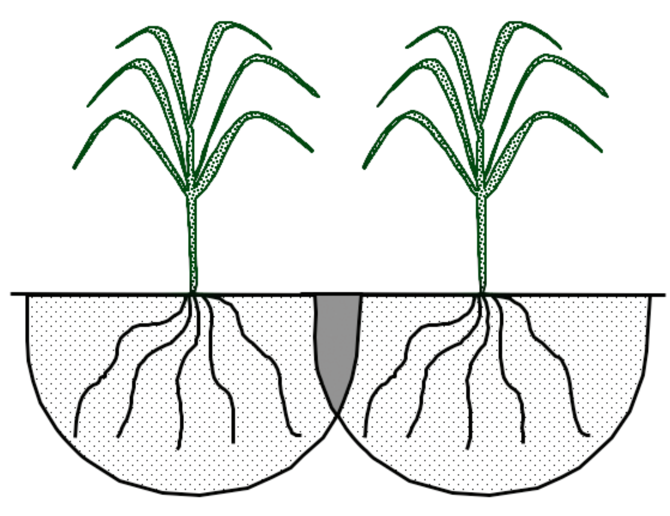

Figure 4.3. Competition for mobile nutrients (nitrogen and water) among plants growing close together.

1,000 square feet per month will normally support growth with a good green color that will require mowing once or twice a week. If two to three times that rate of nitrogen is available to the turf, it will require twice as much mowing because competition among plants will be much less and growth will be doubled. So, if water is not limited, mowing frequency can be regulated by nitrogen supply. Similarly, nitrogen deficiency is often a result of rapid plant growth (promoted by the growth environment) and/or a high yield of plant material when the supply of nitrogen is marginal.

Immobile Nutrient Uptake by Plants

Nutrients that do not readily move in the soil as water moves, are taken up differently than mobile nutrients by plants. Uptake of immobile plant nutrients occurs from only a thin cylinder of soil immediately surrounding the roots (Figure 4.4).

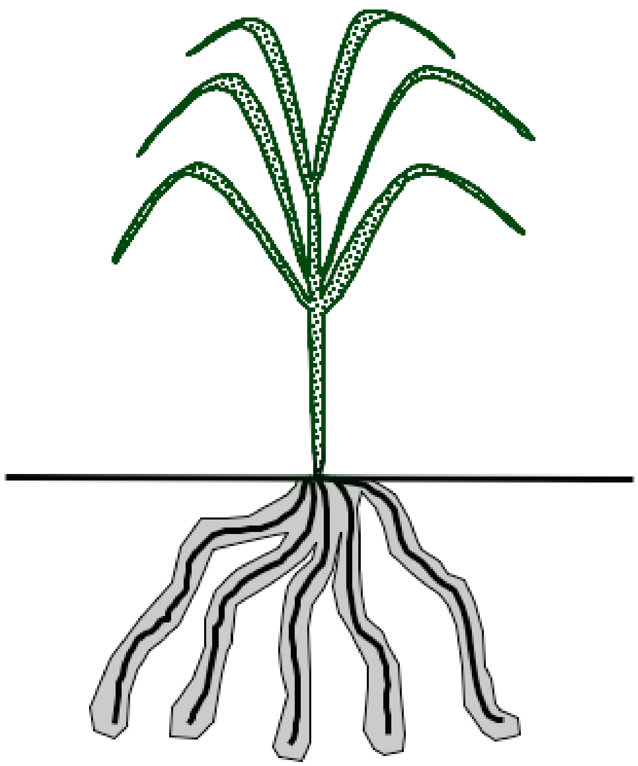

Figure 4.4. Volume of soil (shaded area) that immobile nutrients, such as phosphorus, can be absorbed from by plants.

Compared to uptake of nitrogen, only soil from a small volume of the plant root zone is used to provide phosphorus to the plant. The volume of soil is so small, that even when plants are crowded close together, as shown in Figure 4.5, there is little competition among plants for the immobile nutrient in the soil.

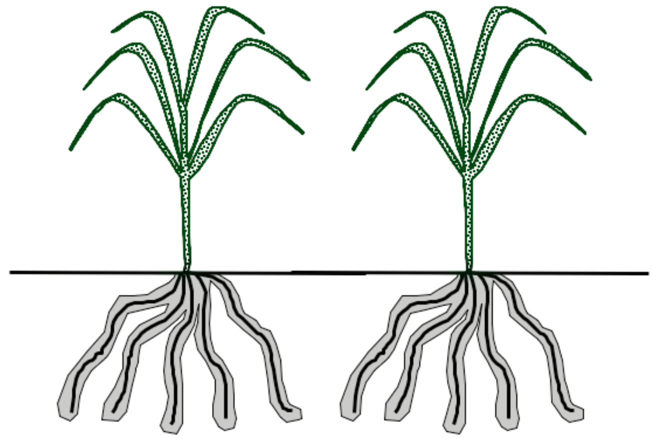

Figure 4.5. Lack of competition among plants for immobile nutrients.

Since there is nearly no competition among plants that are crowded close together to provide high yields, management of immobile nutrients is not dependent on or related to yield level. If the soil capacity to supply phosphate is adequate to meet the needs of one corn plant every two feet of row, then it will also be adequate if there is four times that number of plants in the row.

When a phosphorus deficient soil is fertilized, and the phosphate fertilizer is tilled in, only a small portion of the fertilizer (10 to 15 percent) will be in a position where roots may come in contact with it. Since it does not move with water in the soil, most of the fertilizer will slowly react with the soil and add to phosphorus already in the soil (Figure 4.6). If fertilizer is added each year, there will be a gradual build up of soil phosphorus until finally the phosphorus availability throughout the soil (soil test P) will be adequate to supply the needs of whatever plants are being grown. Because phosphate is so immobile in soil, it is not effective when applied to the soil surface during the growing season, unless, as in the case of bermudagrass lawns, the plant roots (such as bermudagrass rhizomes) are close to the surface.

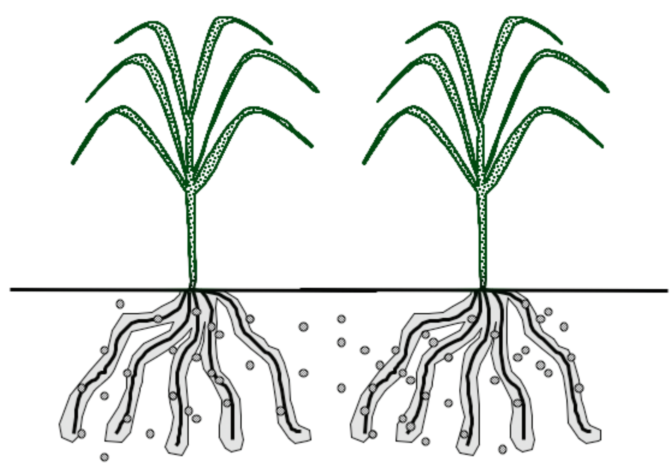

Figure 4.6. Distribution and plant availability of incorporated phosphate fertilizer (granules shown around the roots).

Knowing When and How Much to Fertilize

Taking care of the nitrogen, phosphorus and potassium needs of plants in the landscape is, in many respects, like taking care of the gas and oil requirements for a car (or other internal combustion engine).

Nitrogen for Plants is like Gas for an Engine

If a lawn mower is to be used for several hours of mowing, the engine's gasoline tank will very likely need additions sometime during the operation. If, on the other hand, the mower will only be used to trim the grass along a sidewalk leading from the street to the house, additional gas will likely not be needed. Whether or not the lawn mower engine needs gas added to its tank depends on how much mowing will be done.

In a similar way, nitrogen requirements for plants in the landscape depend upon how much they will grow over a period, and on an area basis, how much growth will occur in a specified area (like 1,000 square feet). So, a bermudagrass lawn that is not expected to grow much at all (and for which the light green color will be acceptable) will need little or no nitrogen fertilizer. However, if the lawn is expected to grow vigorously and frequent mowing is required, in order to maintain a medium to dark green color it will need at least 1 pound of actual nitrogen per 1,000 square feet each month of growth.

When preparing to mow a large lawn, or mow for an hour or more, the fuel tank may be filled initially. Similarly, it is a good practice when preparing to provide N for vigorously growing plants, to make sure the plants have at least 1 pound of actual N available per 1,000 square feet (1 lb N/1000 ft^2) of area. Additional N can be added during the growing season if there is enough growth (yield) to use up the initial supply of N and continued growth is desired. Thus for lawns that will grow four or five months, N may need to be applied two or three times during the season.

Sometimes there is the temptation to apply all the N required for one season, at the beginning of the season. This is somewhat like trying to put all the gas the lawn mower will need, for three hours of mowing, into a tank that can only hold enough for one hour. The tank will overflow and much gas will be wasted (to say nothing of the risk of starting a fire when the engine is started). Applying excess nitrogen does not result in all of the excess being wasted, but some will be lost and the remaining excess will cause unwanted rapid lush growth, requiring two to three mowing a week if growing conditions are good.

Because N is a nutrient that is mobile in the soil, surplus N can cause a problem of undesirable excessive growth, promote or encourage disease, or contribute to the pollution of surface and groundwater. Continued vegetative growth is promoted and fruiting delayed in some plants when excess nitrogen is available. Examples of this are tomatoes and okra. Excess nitrogen will result in continued vine and leaf growth, but few tomato sets; okra will be tall and leafy, but with few fruit sets. For these plants, it is important that they have enough nitrogen available early in the season to develop reasonably-sized plants with capacity to capture the sun's energy and manufacture food to develop the fruit. Allowing the plants to run short of N mid season causes the plant to begin fruit set (the plant thinks it is going to starve and decides to hurry up and provide for its off-spring before it dies).

Nitrogen Deficiency Symptoms

Managing fuel for a lawn mower becomes relatively easy with a little experience. It may be a matter as simple as just filling the tank on the mower each time before beginning to mow if the job is small enough that it can be completed without running out of fuel. If the mowing job is large enough to require refueling, the need for re-fueling can be gauged by how long the engine has been used, a fuel gauge, or the experience of running out of gas. Running out of gas is sensed by the spitting and sputtering of the engine. If we know what to look for, we can also tell when plants are running out of nitrogen. The symptoms of nitrogen deficiency are:

1. Poor or slow growth
2. Light green color
3. Yellowing (chlorosis) of the oldest leaves, beginning at the tip and proceeding along the midrib toward the base, or stalk

The first two symptoms are difficult to recognize if healthy plants are not nearby for comparison (e.g., a uniform lawn that is moderately deficient will not grow much and will not be dark green, but may be desirable). The pattern of chlorosis is easy to recognize on large plants like corn, but difficult to see on small leafed plants like fescue. Nevertheless, these symptoms can be useful in managing nitrogen, because unlike the fuel tank for the lawn mower, it is not easy or convenient to identify how much available nitrogen is in the soil when plants start growing or after they have been growing for some time.

Some plants in the landscape, especially trees and shrubs, have a slow growth rate and produce only a small amount of new, nitrogen-containing, growth each season. For this reason these plants need very little nitrogen, and usually will receive enough from natural soil supplies and the run-off or spillage of fertilizer applied to adjacent areas, such as lawns.

Other Mobile Nutrient Excesses

Water, sulfate, boron and chloride are also mobile in the soil. Because boron and chloride are micronutrients, only very small supplies of these nutrients are required for normal plant growth. Above average supplies of these nutrients do not stimulate additional growth like nitrogen, instead, they are usually detrimental.

A homeowner called wondering what to do to get flowers to grow again in the flower bed after having killed chickweed with borax. A pound of borax had been applied to an area 3 feet by 20 feet. This rate is equivalent to 80 pounds of boron per acre. Normal rates of boron for correcting deficiencies in alfalfa and peanuts range from only 0.5 to 2.0 lbs per acre! Rates above 5 pounds per acre are considered toxic and expected to decrease yield. Obviously, the 80-pound-per-acre rate killed the chickweed and sterilized the soil, so nothing else would grow either. The options for correcting this mistake were to wash the boron out of the soil (difficult at best for the clayey soil) by excessive irrigations over an extended period or to remove the contaminated soil to a landfill and replace it with good topsoil (best option). ***Moral of the story: beware of advice from sources that are not science based (e.g., testimonials from friends and mass media).***

The reason some nutrients are mobile in the soil is because they do not react much with the soil, compared to the immobile elements. As a result, if these elements are present in great excess they can cause a salt problem, even if the element is not toxic itself (as boron in the above story). Chloride, nitrate and sulfate are soluble salts because they do not form solids easily when they react with other ions. Sodium chloride, common table salt, is a good example of a soluble salt. When added to water, table salt easily dissolves (the solid disappears) because the sodium and the chloride would rather be surrounded by water than each other. In fact, the sodium and chloride hold the water tight enough that plants can not get it as easily and may die of drought when the soil is salty, even though the soil is kept moist. A common example of this phenomenon, is demonstrated when salt is added to water to raise the boiling point so food can be cooked or processed faster. The salt holds on to the water, so it takes more heat to convert the liquid to vapor (boil).

To the homeowner, water is the cheapest, most convenient nutrient to add, and probably for this reason is most commonly added in excess. Plants must absorb tremendous amounts of water and keep very little of it. Most of the water absorbed by plants is used to transport nutrients into and throughout the plant, and to cool the plant. Unless you are reading this book in a tropical rain-forest and plan to continue living where you are, most of the plants in your landscape prefer definite periods of drying conditions. For that reason, most of the plants will require good surface and internal soil drainage and will suffer during extended periods of rain or frequent irrigation.

Unlike the difficulty and inconvenience of checking soil to determine the need for nitrogen, soil moisture can be determined by physical inspection. Using a long sharp object like a nail or screwdriver, disturb the soil to the depth of most roots, often 8 inches or less, then look at and feel the soil. Darker soil below the surface indicates more moisture than the lighter colored surface soil. If it can be easily made into a ball by squeezing it in your hand, then it contains adequate moisture for the day and irrigation is unnecessary. If the surface of the ball appears wet and glistens then it is too wet and should not be watered for several days (wait longer for clayey soils than sandy soils). If it cannot be made into a ball because it falls apart (sandy soil) or remains in firm or hard chunks (clayey soil), then it should be irrigated.

For some plants during some times of the year, the soil is a better indicator of when to irrigate than is the plant. Plants that are intolerant of heat or drought may show signs of wilt during mid afternoon on extremely hot, windy days, when evapotranspiration is greatest. If checking the soil reveals there is adequate soil moisture, then do not irrigate. If the plants appear to be suffering, syringing, that is, spraying the plants with a fine mist of water just long enough to wet the leaf surfaces, will cool the plants several degrees and help them survive unusually hot weather (this only needs to be done once an afternoon). If the soil already contains adequate moisture, then adding more at this time will only lessen the amount of oxygen available for the root system and decrease the plants ability to survive. Obviously, experience in estimating when to irrigate and observing plant response to the decision of whether or not to irrigate, will help to achieve water management success.

Phosphorus and other Immobile Nutrients for Plants are like Oil for an Engine

Nutrients that are immobile in the soil, like phosphorus and potassium, need to be managed with the kind of approach used to manage oil for the lawn mower engine (Figure 4.7). It does not matter whether you are planning to use the lawn mower for one hour or five hours, if it is low on oil, some should be added to bring the level up to full before the project is started. If not, the engine may become damaged. If the oil level is already at the full mark, then oil is just as likely to be adequate for the five hour job as the one hour job. If the oil level is full, there will be a lubricating film on all the moving parts. Like oil for an engine, phosphorus and potassium needs for a growing season are not dependent on how much is to be grown, but rather on whether the initial concentration of phosphorus at the root-soil interface is adequate.

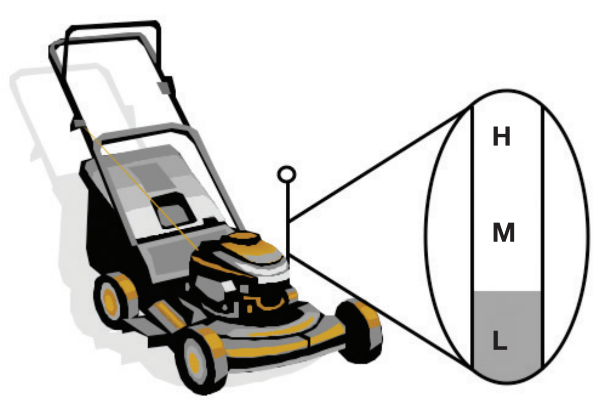

Figure 4.7. Dipstick used to check oil in engine (H-high, M-medium, L-low).

Adequacy of phosphorus and potassium in the soil for plant growth is determined by a calibrated soil test, a concept that is not easy to understand. However, the use of a soil test is similar to the use of the dip stick, commonly provided to check the oil level of internal combustion engines. When the engine was designed, an engineer added the right amount of oil to the crankcase (or oil reservoir) for the oil pump to be able to pump it to all the moving parts. Then, with the engine stopped, the engineer inserted a rod through a hole in the engine block, into the crankcase and the oil it held. The rod was removed, the oil level noted and a line with the word full stamped at that point on the rod. This identified the critical level for the engine oil supply. Next the engineer drained a quart of oil from the engine, inserted the rod again, noted the oil level on the rod and stamped 1 quart at that point. This resulted in calibrating the dip stick.

Now whenever the dip stick is removed it will indicate where the oil level is, compared to where it should be, and if it is not full you will have some idea of how much to add. If the level is just 1/4 inch from the full mark, you will probably not do anything about it. But if it is almost a quart low and you are getting gas at a service station anyway, you will probably add enough oil to bring it to the full mark. Good soil tests are calibrated, as is OSU's soil test, to identify the need for phosphorus and potassium fertilizer as shown in Table 4.1 (page 18).

Unlike engines, which may be harmed if a full quart of oil is added when only half a quart is needed, adding an extra 1/2 pound of P_2O_5 or K_2O will not hurt the soil or plants. However, large excesses may be harmful to plants and could contribute to local stream or pond pollution if heavy rains cause surface runoff and soil erosion carrying nutrients to bodies of water.

Phosphorus and Potassium Deficiency Symptoms

Like nitrogen, phosphorus and potassium are each translocated in plants although they are considered relatively immobile in soils. When the root system is not furnishing new vegetative growth an adequate supply of these nutrients, the nutrients are moved out of old tissue (usually on the lower part of the plant) up the plant to newly developing tissue. When the old tissue becomes deficient, characteristic symptoms usually appear.

Phosphorus deficiency usually is characterized by a purple coloring of the stem or stalk near the ground level together with a purple and/or yellow coloring of the lower leaves. Some plants have a normal purple coloring of the base of the stalk so this symptom is not always reliable.

Potassium deficiency shows up as a chlorosis or yellowing of the tips of the old leaves then progresses toward the base of the leaf along the margins. Within a few days the chlorosis develops into brown, dead tissue (necrosis) along the leaf margins (sometimes referred to as firing of the older leaves) (Figure 4.8). Dead tissue along the leaf margins can also result from excessive water stress or droughty conditions.

Figure 4.8. Notice the slightly discolored areas in the growth of these vegetable plants. This is due to a mild deficiency in nutrients.

Table 4.1. Amount of phosphorus and potassium fertilizers needed based on soil test calibrations for home landscapes.

Soil Test P Index	Fertilizer P_2O_5 Required
	-----lbs/1,000 sq ft-----
0 to 20	2.5
21 to 40	2
41 to 65	1
>65	0
Soil Test K Index	**Fertilizer K_2O Required**
	-----lbs/1,000 sq ft-----
0 to 100	6
100 to 200	3
200 to 300	1
>300	0

Chapter 5
Managing Nitrogen

Organic Gardening and Nitrogen

Nature's Conservation of Nutrients

When plants die and the residue is in contact with soil, a decay process carried out by soil microorganisms gradually converts the plant residue to soil humus, or what is commonly called soil organic matter. The residue is decayed because the microorganisms get the energy and carbon they need from the residue. Because the microorganisms are micro plants, they need all the essential chemical elements already identified for plants in the landscape. They get these nutrients from the plant residue as they decay it.

Eventually the residue is depleted as a food source, and many of the microorganisms themselves die and are decayed by those few remaining. When the environment for decay is aerobic much of the carbon in the residue is converted to carbon dioxide gas and lost to the atmosphere. As a result, the other mineral nutrients become more and more concentrated with time. Hence, humus is commonly a nutrient rich component of the soil. It is nature's storehouse for recycled nutrients that can be slowly released to support continued growth of higher plants.

Soils that are naturally high in organic matter, and have not been farmed, are usually fertile, that is they have a good supply of the essential nutrient elements for supporting the growth of higher plants. However, soils that are nearly devoid of organic matter are not necessarily infertile. A good example of fertile soils, low in organic matter, are the desert soils of the southwest U.S. When irrigated and properly fertilized these soils are very productive (e.g., the San Joaquin Valley in Southern California).

The Nitrogen Cycle

The most important of the naturally recycled nutrients in the landscape, especially in the garden and lawn, is nitrogen. Nitrogen is most important because it is usually in greatest demand by growing plants and also present in high concentration in plant residue. This will be more obvious as we consider the dynamics of nitrogen recycling (Figure 5.1).

Humus to Fertilizer Nitrogen

When plant residues decay, some of the residue becomes humus-like and adds to the soil organic matter already present. Also, as shown in Figure 5.1, some of the N in the plant residue may be released in the decay process and be present as ammonium nitrogen (NH_4-N). When the soil is well aerated, the ammonium nitrogen is con-

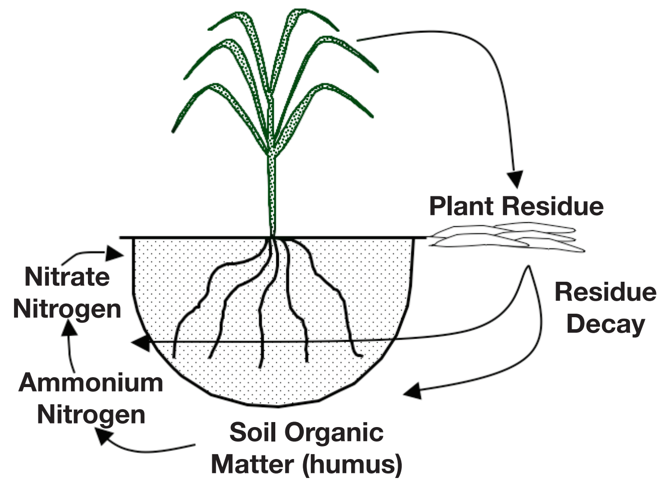

Figure 5.1. Natural biological cycling of nitrogen from organic to inorganic (mineral) forms and its use by growing plants.

verted to nitrate nitrogen (NO_3-N). The steps that convert nitrogen from the plant residue to nitrate nitrogen that is mobile in the soil are all carried out by microorganisms in the soil. In fact, nitrogen that is present in humus can also be converted to nitrate nitrogen by the same microorganisms. The nitrogen released from these organic materials is the same as the nitrogen sold as fertilizers, like ammonium nitrate. Plants cannot tell the difference between ammonium and nitrate that was released from decay of plant residue or humus, and the ammonium and nitrate that comes from use of ammonium nitrate fertilizer. The chemical forms of nitrogen are exactly the same.

Fertilizer Nitrogen to Humus

If the plant residue being decayed is poor in nitrogen, like wheat straw, then instead of nitrogen release, there will be nitrogen tie-up as decay proceeds. The microorganisms may get enough energy and carbon from the wheat straw, but not enough nitrogen. For them to remain active they must get ammonium or nitrate nitrogen from somewhere, so they will use whatever mineral nitrogen is available in the soil (Figure 5.2).

If you are trying to grow vegetables, at the same time the wheat straw is decaying, the vegetables may become nitrogen deficient. This happens because the microorganisms are so plentiful in the soil (more than a million per tablespoon of soil) that they will get to the available ammonium and nitrate nitrogen before the vegetables have their chance. Soil microbiologists like to say "it's like a banquet, and soil microorganisms sit at the head table and get served first." Figure 5.2 illustrates how soil microorganisms decaying residue low in nitrogen can cause available nitrogen tie-up.

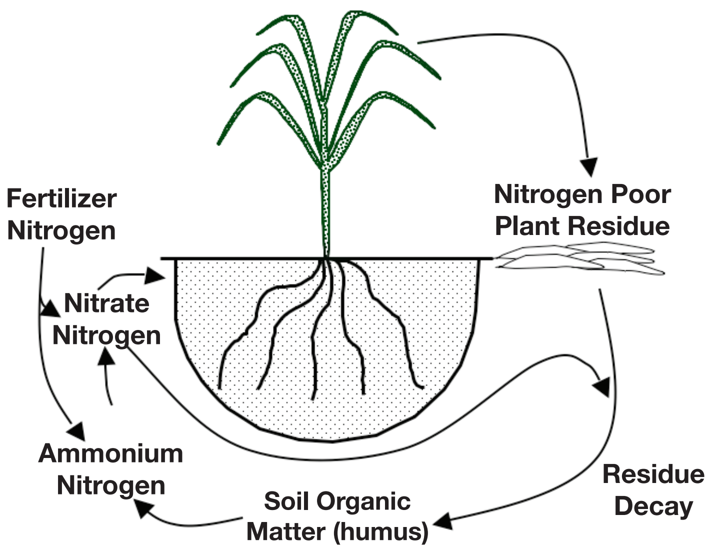

Figure 5.2. Natural biological cycling of nitrogen from inorganic (mineral) forms to organic nitrogen.

Organic Gardeners Take Note

The basic N cycles presented in Figures 5.1 and 5.2 are always present in the soil. With one exception, nitrogen cycling is stimulated by the same conditions that stimulate growth of higher plants, like vegetables or flowers. This exception is the supply of oxygen in the soil. Cultivation brings air and oxygen into the soil. Each cultivation stimulates the activity of the nitrogen cycle. Whenever the soil is cultivated by hoeing, tilling or any mixing action, it will be either an initial release or tie-up of available nitrogen. The result depends on whether the organic matter being decayed is protein rich (release of nitrogen) or protein poor (tie-up of nitrogen), and how much of it is present.

A few years ago, a Master Gardener questioned the soil test results for the sample submitted from their rose garden as a part of the Oklahoma County Master Gardener Training Program. The soil test results showed 320 pounds per acre of available nitrate nitrogen. The gardener could not understand why the nitrate level was so high because fertilizer had never been added to the flower bed. When questioned about how the flower bed was managed, the gardener explained "all we ever add is good alfalfa hay as a mulch."

As demonstrated by the above incident, decay of protein rich plant residue, such as from legumes, in a soil-plant situation where the plants do not require much nitrogen, can lead to build up of high levels of nitrate in the soil. A little bit of alfalfa will go a long way for providing the nitrogen needed by roses. The excess nitrogen likely fed bermudagrass and other responsive weeds in the flower bed.

Organic gardeners must pay particularly close attention to the kinds and amounts of organic material added to the garden and how often they cultivate. Organic matter is the main food for the soil microorganisms. If the soil is poor in organic matter and plant residue then very little happens to nitrogen no matter how much the soil is cultivated. This would be typical of virgin soils in the arid and semi-arid southwest U.S. On the other hand, if it is your goal to increase the soil organic matter level from 1 percent to 5 percent, then it will be important to add a variety of organic materials over a period of several years (at least five). Good sources of organic material for the garden include lawn clippings, tree leaves, animal manure, shredded paper, table scraps, hay, straw, cotton seed hulls, processed sewage sludge, pecan hulls and most anything that is organic (you can avoid a trashy looking garden by composting these and taking the compost to the garden). Many different types of composters are available (Figure 5.3), and you can choose one to fit your needs.

Figure 5.3. Mini-composters can be used in the yard to convert organic waste into fertilizer.

By adding small amounts of different composting materials, severe nitrogen tie-up or release is avoided. For example, when both straw and alfalfa hay are added the rapid release of nitrogen from decaying alfalfa is compensated for by the rapid tie-up of nitrogen by decaying straw.

A county agricultural educator called a few years ago, wanting assistance with a new homeowner who was having difficulty establishing a bermudagrass lawn in southern Oklahoma. The previous owners of the house had raised rabbits (they were not gardeners), and in preparing to move after selling the house, they cleaned all the rabbit hutches and left the remains on the area the new owners wished to convert to a lawn. The new owners simply tilled the area and sprigged bermudagrass. After the bermudagrass failed to grow and spread, the new owners took a soil sample from the area and submitted it for a routine test. The results showed a nitrate nitrogen level of more than 1,000 pounds per acre (about 20 times higher than desired). The bermudagrass was failing because of excess nitrogen causing a salty condition (tying up water). The question was "how do we get rid of the excess nitrate nitrogen?"

There were several possible solutions to the problem, but the easiest, least expensive and most conserving was to take advantage of nature and the nitrogen cycle illustrated in Figure 5.2. The homeowner was advised to till as much wheat straw into the soil as possible. This allowed the soil microorganisms to use up the excess nitrate nitrogen as they decayed the nitrogen-poor straw. It converted all the readily available nitrogen (nitrate) into a slow-release form (microorganism biomass and humus). In a few weeks, the bermudagrass flourished.

Instant Organic Gardening

There is an exception to the rule of adding moderate amounts of a variety of organic sources to the garden over a five year period to raise organic levels to 4 or 5 percent. An exception would be the addition of organic material that is native or natural to soil, that is humus or peat. Peat or composted plant residue has already undergone the initial rapid decay responsible for release or tie-up of nitrogen.

Normal tillage depth, and depth of the greatest root mass for most plants, is about 6 inches. The weight of soil in a 10-foot x 10-foot area, 6 inches deep is about 4,000 pounds. It would take about 160 pounds of peat, added to this area, to increase the soil organic matter from 1 percent to 5 percent, on a weight basis. If added in a single incorporation, this would increase the soil-peat volume about 20 percent (soil surface would raise at least 1 inch). A more uniform mixture will be obtained by splitting the addition into two applications about a month apart**.** Limit using compost or animal manure to no more than half an inch thick per application. Otherwise, plants may be affected by too much salt or nutrients added.

Soil Organic Matter Maintenance

Once soil organic matter levels have been built up to 4 or 5 percent, they will only remain at that level if a balance is maintained between cultivation, which destroys soil organic matter, and addition of plant and animal residue, which builds soil organic matter. An important natural input is to grow high yields from plants that are spaced close together (Figure 5.4). Avoid having bare ground in the garden. The more you can use the soil to grow plants, the richer it will become in organic matter and humus.

Cultivate only when it is necessary. For small noncommercial gardens, it may be possible to eliminate cultivation altogether or at least reduce it to only one or two cultivations per year.

The three main reasons for cultivating are to control weeds, incorporate plant residue and prepare a seed bed. Weeds can be pulled by hand, plant residue can be shredded and left as a mulch on the surface and only a narrow band of soil needs to be disturbed to prepare soil for planting a row of vegetables. The garden area that is not cultivated will look trashy, but it can be very productive and will be easier to maintain soil organic matter in than the area that is cultivated. One timely cultivation a year can accomplish all three of the objectives of cultivating.

Figure 5.4. Note the spacing between the plants in this vegetable garden.

Planting a cover crop during the off season is another practice to increase soil organic matter (Figure 5.5). Cover crops provide other benefits to a garden, such as prevent erosion, supply nutrients, suppress weeds and break pest cycle.

Figure 5.5. Sugar pea as a winter cover crop. Pea shoots can be harvested as vegetables. Pea plants should be cut low as mulch for summer vegetables.

Chapter 6
Nutrient Supplements for the Soil

Nonsynthetic Fertilizers

Complete Fertilizers

The term complete, when used to describe fertilizers, usually refers to those materials that contain each of the three major nutrients supplied from the soil: nitrogen, phosphorus and potassium (commercial sources usually identify the nutrient concentrations in this same order, as percentage of N, P_2O_5 and K_2O). However, there are situations when the homeowner is interested in a nutrient supplement that is complete in the sense that it also contains the secondary and micronutrients. The most common situation is for house plants and other plantings that are grown in a soil-less medium, such as plants potted in vermiculite.

The term nonsynthetic is used instead of natural because some of the commercially available fertilizers are more natural than some of the so-called natural products. This is because without much processing they are used as they are found in nature. An example of this is the commercial fertilizer potassium chloride. It is mined from nearly pure geological deposits and except for crushing and screening is marketed as is. Bone meal, on the other hand, is extensively ground to a powder before it is marketed as a natural material. Similarly, blood meal must receive considerable processing before it can be marketed as a natural material.

Compost

Since plants must contain all the essential plant food elements if they are to complete their life cycle, it stands to reason that these nutrients should all be present in decayed plant material, such as humus and compost. For this reason, compost is a good source of all nutrients, and it provides them in about the same proportion as needed by the plants you are growing (some nutrients can be partially lost as a gas or washed out of the residue as it is decaying or being stored).

Adding a small amount of compost to the growth media for potted indoor plants assures they will not suffer deficiencies of the micronutrients. Maintaining a high level of soil organic matter in the garden will also assure an abundant supply of micronutrients (Figure 6.1). An additional characteristic of organic sources of the nutrients is that they are slow release, that is, they become available gradually over time as the organic matter continues to decay. This is usually a benefit, but can be a disadvantage when you wish to correct an existing nutrient deficiency quickly. Slow release nutrient sources may be inadequate to satisfy the nutrient demands of rapidly growing plants.

Figure 6.1. An example of a composting unit for use in the home garden.

Incomplete Fertilizers

Other fertilizers that have not been synthesized, or manufactured, and are marketed as primary source of only one or two nutrients are listed in Table 6.1.

Table 6.1. Approximate nutrient content of selected nonsynthetic fertilizer materials.

Material	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
		------------------------- % -------------------------	
Bone meal	3	22	0
Cottonseed meal	6	3	1.5
Soybean meal	7	1.2	1.5
Animal manure (dry)	2	2	2
Alfalfa hay	2.5	0.5	2.5
Wheat straw	0.5	0.15	0.1

Nonsynthetic fertilizers are characteristically slow-release and have low concentrations of the nutrients contained. Consequently, if the soil is inherently deficient in one or more of the nutrients, large quantities of the fertilizer will need to be added to the soil. For example, if you wish to add 1 pound of nitrogen in the form of animal manure, it will be necessary to add about 50 pounds of composted manure (50 x 0.02 = 1.0). However, since only about half of the nitrogen in the manure will become available in the first year, it will be necessary to double the addition and add 100 pounds.

Synthetic Fertilizers

Complete Fertilizers

One of the most common complete fertilizers used by homeowners has the analysis 10-20-10, and is commonly referred to simply as, ten-twenty-ten. This fertilizer contains 10 percent water soluble nitrogen, 20 percent available phosphate (expressed in units of P_2O_5) and 10 percent available potash (expressed in units of K_2O). Nurseries and garden centers usually market this fertilizer in 40-pound bags. This fertilizer is popular because it has relatively low nitrogen content and high phosphate content. Most homeowners think about fertilizing their gardens and lawn in the spring, when the soil is cool or even cold. Phosphate uptake by plants is slow in cold soil and so addition of a fertilizer with a relatively high content of phosphate often will stimulate early growth of garden and lawn plants, if available soil phosphorus is not adequate. The low nitrogen content will allow the homeowner to use the whole bag (as will surely happen) without applying excessive nitrogen and causing excessive growth. If the 40-pound bag is evenly spread over 4,000 square feet of lawn and garden, then the application rate of nitrogen will be 1 pound of nitrogen per 1,000 square feet. This rate is a good starting level for most plant-growth situations. Even if the homeowner has only 2,000 square feet of area to fertilize, the rate will only be 2 pounds of nitrogen per 1,000 square feet. This is usually not enough to cause excessive growth during cool spring weather. A final reason for 10-20-10 being such a popular fertilizer is that because of the low analysis, the user can spread it at a high enough rate (10 pounds of material per 1,000 square feet) that it is easy to see where you have been and feel a sense of accomplishment when the job is completed, without causing any harm (Figure 6.2).

There are many other complete fertilizers, such as 19-19-19; 10-10-10; 12-24-12; 6-24-24; 29-3-4; etc. These have been manufactured to provide a more concentrated fertilizer to meet the needs of different plants in different locations. However, there is little merit for these different fertilizer materials since soils vary greatly in their capacity to supply each of the nutrients and because once the fertilizer has been applied, its reaction with the soil changes the ratio in which the nutrients are supplied to plants.

Figure 6.2. The consistent color in this lawn indicates a properly applied fertilizer.

Single and Double Nutrient Fertilizers

Nitrogen

The most common synthetic fertilizers for supplying only nitrogen and the concentration of available nitrogen in each are listed below:

1. Ammonium sulfate (21 percent N)
2. Ammonium nitrate (34 percent N)
3. Urea (46 percent N)

These are all excellent sources of nitrogen.

Ammonium sulfate is the most acid forming and may be preferred for calcareous or high pH soils. Although it also provides sulfur, this is seldom a benefit because sulfur is usually adequate.

Ammonium nitrate may result in slightly faster plant response because some of the nitrogen is already in the mobile, nitrate form. This may be important when trying to improve the nitrogen supply to plants growing in cold, wet soils (early spring). Because of its use in the 1995 Oklahoma City bombing, availability has decreased. Although it has been used as an ingredient for explosives, ammonium nitrate fertilizer is a safe product (special effort must be taken to cause it to explode, as in the case of the Oklahoma bombing).

Urea is the highest analysis dry nitrogen fertilizer available and, consequently, it is the cheapest on a per pound nitrogen provided comparison. A disadvantage of urea is that it must react with the enzyme urease, present in all soil and plant material, to convert it to plant available ammonium. This requirement may delay plant response (one week compared to ammonium nitrate) and presents an opportunity for loss of nitrogen by volatilization as ammonia (a gas, like that in ammoniated cleaning solutions). The risk of this happening is increased if the urea is applied to wet turf and allowed to react for several hours while the leaf surfaces are wet and then warm, dry, windy conditions cause the turf to dry. This type of loss can be eliminated, or minimized, if the area is irrigated or cultivated soon after fertilizing.

Phosphorus

The only common fertilizer that supplies only phosphorus is called triple super phosphate. It has the analysis of 0-46-0 (46 percent available phosphate) and is made up of the compound monocalcium phosphate. Since the biggest fertilizer market is commercial agriculture, and it has a higher demand for nitrogen than phosphate, the fertilizer industry manufactures much more diammonium phosphate (18-46-0) and it is often more readily available, and at a lower cost per pound of phosphate, than 0-46-0. Either of these will be excellent sources of phosphate for the lawn or garden.

Potassium

The most common fertilizer that supplies only potassium, or potash as it is sometimes called, is the material called muriate of potash or potassium chloride. This fertilizer has the analysis of 0-0-60 and is a good source of external potassium. It is a natural material mined from geological deposits and may be either pink or white granules.

Handling Fertilizers

When they react with water, synthetic fertilizers will often become corrosive to metals and nonsynthetic materials will usually begin biological reactions, resulting in rot. It is a good practice to thoroughly wash containers and applicators after fertilizing, and to store unused material in a cool dry place. Whenever fertilizer materials are labeled, carefully follow instructions for use. Some fertilizers should not be mixed with others to prevent caking up or other potential problems.

Chapter 7
Using Soil Testing to Guide Nutrient Management

When and How Often to Soil Test

Soil Testing Rational

Soil testing should be viewed with the same approach as one would take toward servicing the lawn mower or car engine. If we do not know how much gas and oil are present, we check the fuel gauge and dip stick. In Chapter 4, nitrogen needs were related to gas for an engine and phosphorus and potassium needs were compared to engine oil.

Plant available nitrogen in the soil changes considerably from year to year and even within a season. Plant growth, addition of fertilizer nitrogen and decay of organic mater all will cause significant changes in available nitrogen in just a few days. It is not necessary to soil test each year or within the season to closely monitor nitrogen needs. Instead, add small amounts of fertilizer nitrogen (or aerate the soil by shallow cultivation to promote release of organic nitrogen) to improve plant growth or green color.

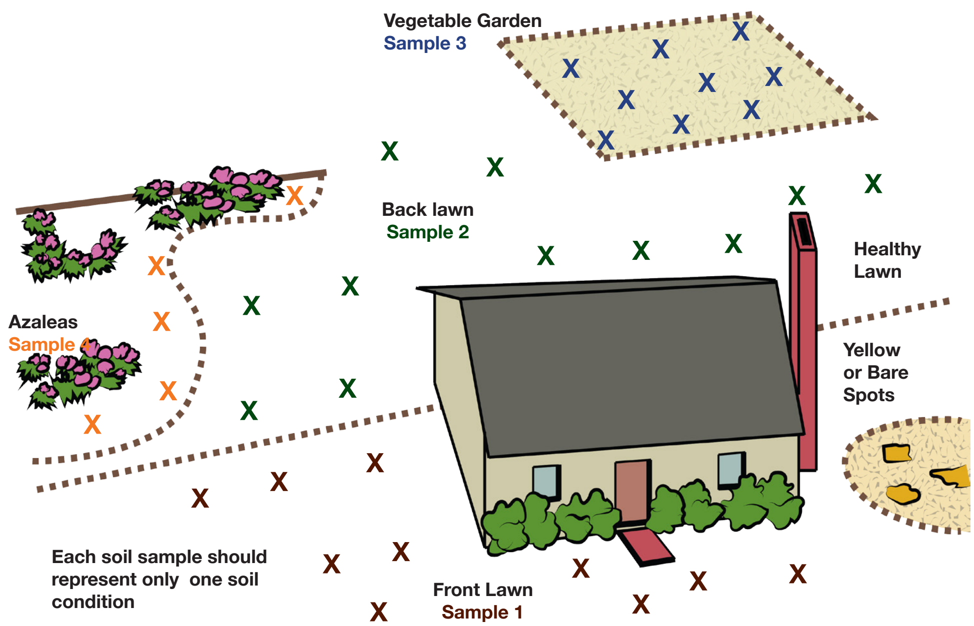

Figure 7.1. Taking soil samples separately to accurately represent pH and soil fertility levels of the vegetable garden, flower bed and lawn.

The value of soil testing is in identifying whether or not soil pH, available phosphorus, and available potassium exist at desirable levels, and then changing management of the tested area accordingly. Since these soil properties do not change much from one year to the next, it is not necessary to soil test the same area each year. However, a soil test once every three years will provide information needed to manage the lawn and garden properly.

How to Collect a Representative Soil Sample

Homeowners and lawn care professionals must realize the spatial variability existing around the yard when collecting a soil sample. Each sample collected should represent the area to be fertilized. The fertility level in the vegetable garden may be different from that of a flower bed. Soil test parameters in the front yard may be drastically different from those in the backyard. Therefore, separate samples may need to be collected from those areas so that they can be treated differently as shown in Figure 7.1. Avoid sampling odd-ball areas. A core or slice from the surface to a depth of 6 inches should be taken from 15 to 20 locations in each area and combined into one representative sample to be tested (Figure 7.2).

Figure 7.2. Key points of taking a good soil sample.

Soil samples may be submitted to your county OSU Extension office. They will send the samples to the Soil, Water and Forage Analytical Laboratory for testing, and then send the results back to you with fertilizer recommendations. Soil samples are analyzed routinely for pH, nitrate nitrogen, phosphorus and potassium, while secondary and micronutrients are tested on request. A number of other tests such as soil organic matter content are also available through the lab.

Soil Test Interpretations

Table 7.1 lists the soil test results received by members of a recent Master Gardeners program that involved samples from their lawns or gardens being tested by the OSU Soil Test Lab.

The highest and lowest values for each part of the soil test have been highlighted to call attention to the wide range in results of samples that came from a small urban community.

Soil pH and BI (buffer index)

The lowest pH was 4.7. This identifies a soil that is acidic enough to prevent normal growth of bermudagrass turf and most garden plants. This acidic soil would be ideal for blueberries and azaleas, also fescue turf would do well at this pH. For the normal growth of other plants a higher pH is desirable, and the soil should be limed for that purpose.

If the decision to lime the soil is made, then the amount of lime to apply can be estimated from the BI value in Table 2.1. Since the BI value is 6.8, according to Table 2.1, lime should be applied at a rate of about 55 pounds per 1,000 square feet. For gardens the lime should be applied and incorporated by cultivation. This may be done as a part of a regularly scheduled cultivation to incorporate plant residue. If the soil is from a lawn area, aerating the lawn after applying the lime will help get it incorporated. Bermudagrass lawns will benefit from lime even if it cannot be incorporated when the soil pH is less than 5.0. Irrigation and rainfall will help move the lime down into the thatch layer, and with time movement into cracks and worm channels will bring it into contact with the acid soil near the roots where neutralization will occur.

Once the liming has been done, it may take a few months before the pH changes, but it should not be necessary to lime again for several years. Some of the soil tests reported in Table 7.1 show BI values of 7.1 or above. Note from Table 2.1 that these only need about 23 pounds per 1,000 square feet, if the decision is made to raise the soil pH from the existing level to a pH near 7. It is interesting to note that the pH of sample 6 is higher than that for sample 7, but sample 6 has a lower BI value and requires more lime to raise the soil pH. This is a result of sample 6 containing more clay and organic matter, thus it has a higher buffering capacity than sample 7.

Table 7.1. Typical lawn and garden soil test results.

Sample No.	pH	BI	NO_3-N lb/acre	P	K
				-----lbs/ac or (2 x ppm)-----	
1	6.5		20	780	640
2	6.3	7.1	19	640	710
3	6.1	**7.3**	26	175	783
4	5.5	7.1	18	216	1052
5	6.5		6	149	347
6	4.8	**6.6**	8	247	266
7	**4.7**	6.8	5	152	466
8	6.7		9	392	569
9	6.4	7.3	7	235	584
10	5.6	6.9	10	560	504
11	6.2	7.3	14	139	429
12	5.7	7.1	**2**	264	320
13	6.0	7.2	7	206	435
14	6.5		5	117	367
15	6.4	7.3	3	148	**197**
16	6.5		16	364	778
17	6.6		12	365	863
18	6.1	7.2	15	294	379
19	6.2	7.2	11	176	579
20	5.5	6.7	15	241	554
21	6.1	7.2	9	122	616
22	5.7	6.9	12	248	479
23	5.7	7.2	18	115	457
24	5.4	6.9	13	197	703
25	6.9		4	203	537
26	**7.4**		22	244	**1,157**
27	6.0	7.1	37	153	787
28	6.6		2	**19**	401
29	6.7		30	570	810
30	6.5		**95**	**1,330**	653

Available Nitrate Nitrogen (NO_3-N)

Available nitrogen values ranged from a low of 2 pounds per acre to a high of 95 pounds per acre, with many of the soils containing less than 20 pounds nitrogen per acre. How these values are interpreted depends upon what time of year it is and also what is being grown (or planned) at the time.

The soil test reports available nitrogen in units of pounds per acre, the approximate equivalent in pounds per 1,000 square feet is easily obtained by dividing pounds per acre by 44 (because an acre is 43,560 square feet). Thus, the soil test reporting 95 pounds nitrogen per acre is about the same as 2 pounds of nitrogen per 1,000 square feet. A good starting point at the beginning of the growing season, for any crop, is 40 pounds nitrogen per acre or about 1 pound per 1,000 square feet. Values half this amount or twice this amount are not necessarily a problem, but they will need different degrees of attention during the growing season.

For example, if the sample was taken in the spring from either a bermudagrass lawn or a garden, then the test value of 95 indicates a good supply of nitrogen for all the spring garden crops through maturity, and enough nitrogen for the lawn into July. The soil test value of 2 for available nitrogen may be interpreted the same as zero, and in the spring of the year, this low level of nitrogen (as well as any value below 20 pounds per acre) is an indication plant growth will be limited without addition of supplemental nitrogen. If the soil is high in organic matter, or has recently received an addition of nitrogen rich organic matter, cultivation will aerate the soil and stimulate release of available nitrogen from the organic matter. Otherwise, nitrogen fertilizer should be added at a rate to provide about 1/2 pound of nitrogen per 1,000 square feet.

Having to add fertilizer to provide more nitrogen brings up the question of how much fertilizer must be added to get the predetermined nitrogen. The answer to this problem depends upon the fertilizer being used, since commercial materials containing just nitrogen will range from 46 percent (urea) to 21 percent (ammonium sulfate). Once we have decided on how much nitrogen to add, the amount of fertilizer material required to get that much nitrogen is calculated by dividing the nitrogen amount by the percent N in the fertilizer and multiplying the answer by 100. For example, if we need 1 pound of N from ammonium nitrate fertilizer (34 percent N), the amount of fertilizer needed is

(1 pound N/34) x 100 = 2.94 pounds ammonium nitrate fertilizer

Most of the soil test results listed in Table 7.1 show available nitrogen below 40 pounds per acre or 1 pound per 1,000 square feet. For samples that may have been taken in the fall, these levels represent good nitrogen management because there will be very little available nitrogen in the soil during the winter when no crops or plants will be growing. Just as we would like to have the fuel tank empty for the lawn mower when it is put away for the winter, there is no advantage in having a lot of available N in the soil during the time of year when we will not be growing anything.

The disadvantage of having high levels of available N in the soil late in the fall, for example the 95 pounds per acre for sample 30 in Table 7.1, is that it will stimulate growth of weeds that are winter annuals, like henbit. To avoid this, it is best not to fertilize after the first of September and allow the lawn and garden plants to deplete the soil of available nitrogen (the exception would be for fall and winter plantings, like fescue lawn). Too much late nitrogen may also promote diseases such as spring dead spots and reduce the winter hardiness perennial plants.

Soil Test Phosphorus (P)

The 30 lawn and garden sample test results for phosphorus reported in Table 7.1 ranged from 19 to 1,330. The calibration for phosphorus in Table 4.1 shows that the value of 19 indicates a phosphate need of about 2 to 2 ½ pounds per 1,000 square feet. This could be met by applying about 10 pounds of 10-20-10 per 1,000 square feet of area (2 pounds P_2O_5/20) x 100 = 10 pounds fertilizer. Because phosphate does not move easily in the soil, the best response to fertilizer phosphate will be obtained when it can be mixed with the soil by a light cultivation. This is true even if the fertilizer is a liquid formulation, because chemical reactions at the soil surface will prevent it from moving more than 1/2 to 1 inch deep in the soil. Also, since it requires about 15 pounds of fertilizer phosphate to raise the soil test value one unit (from 19 up to 20), it will take several annual applications of phosphate to get the soil test high enough to eliminate the need for phosphate fertilizer additions.

Just as it will take many years of small phosphate additions to raise the soil test level to adequate, it will take many years of crop removal to lower the soil test from high values to values below 65 that would signal the need to add phosphate. Except for the single value of 19, soil test phosphorus levels in Table 7.1 all exceed 100, with many in the 200 and 300 range. These high levels indicate the soil will be able to supply plants with adequate phosphate for many years without fertilizer or compost additions.

For lawns where the soil test phosphorus level is 100 or more and the clippings are not removed, the recycling of soil and plant phosphate will maintain high available soil phosphate levels for at least 10 to 20 years. Where soil test phosphorus levels are 500 and 600, there is enough phosphorus in the soil for two to three generations. And, for the area that has a soil test level of 1,330, the soil could be bagged and sold for fertilizer, or at least excellent potting soil.

Knowingly building soil phosphorus to such high values is foolish. Unknowingly doing it is a mark of ignorance or disregard for the environment or both. To have an area with a phosphorus soil test of 500; 600; or as high as 1,330, is like having a pick up truck with an engine that does not use oil, the crankcase is full, and the operator has

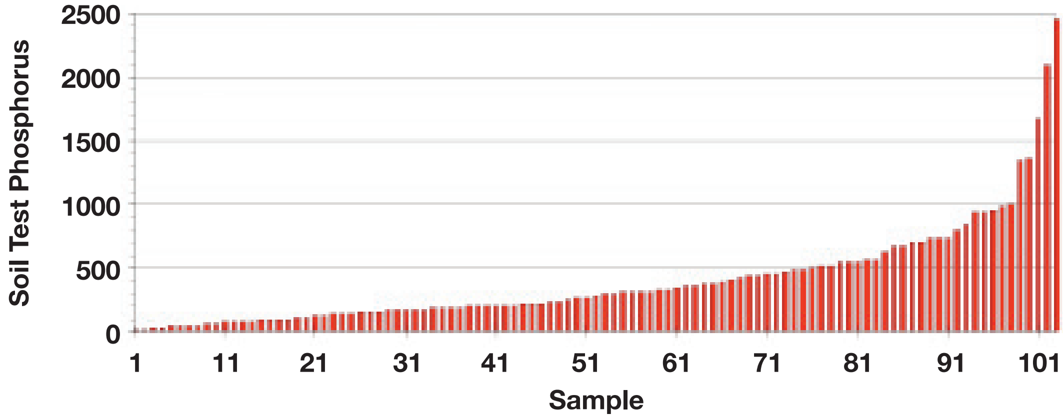

Figure 7.3. Soil test phosphorus for one Oklahoma County Master Gardeners program.

four 55-gallon barrels full of oil in the back, just in case. The soil tests listed in Table 7.1 were from one county, but are typical of gardeners as illustrated in Figure 7.3 for samples from other parts of Oklahoma. Of the more than 100 samples tested, about 90 percent were adequate (soil test P of 65 or higher) to very high in available phosphorus, with about 30 percent above a soil test level of 500.

Soil Test Potassium (K)

Soil test potassium values shown in Table 7.1 are generally adequate and typical of soils in central and western Oklahoma. One reason for this is because these soils developed under low rainfall and are inherently rich in K. The second reason is that the most commonly used fertilizers are low in their supply of K compared to P. Thus, with continued annual applications of 10-20-10 fertilizer, phosphorus builds up in the soil faster than potassium because twice as much is added. Like phosphorus, unless most of the vegetative material grown each year is removed from the area and not recycled, existing adequate soil supplies of K will persist for many years.

Table 4.1 identifies 300 as the soil test level above which potassium is adequate. Only two of the 30 samples in Table 7.1 were less than 300 for potassium. The lowest, a value of 197, is not likely a problem for most plantings. To assure potassium will not be deficient, a rate of 1 to 3 pounds K_2O per 1,000 square feet would be recommended. This could be achieved by spreading 2 to 6 pounds of 0-0-60 fertilizer per 1,000 square feet each year.

An alternative to using commercial fertilizer to supply potassium is to spread fireplace ash on potassium deficient soils. Care must be taken to not exceed rates of 10 gallons of ash per 1,000 square feet on sandy soils and 20 gallons on loamy or clayey soils. A 10-gallon bucket of ash will provide about 3 pounds of potash (available K_2O). Areas that receive ash should be recorded and not receive a second application for 10 years. Excessive use of fireplace ash can lead to the development of an alkali soil (high pH and poor water infiltration) as described in Chapter 2. Direct contact of fresh ash with actively growing plants may result in injury so it may be safer to apply ash during the off-season.

General Guidelines of Fertilization

A soil test estimates the ability of soil to provide nutrients to plants. This analysis takes some of the guesswork out of fertilizer. The key for a useful soil test is to provide the lab with a good soil sample. For most homeowners, you may only buy fertilizers formulated for lawn and gardens from nurseries or department stores. If your soil test is showing low P and K as well as N, use a com-

Figure 7.4. Over fertilization from compost resulted in a huge vine but small tubers for this yam plant that was grown in a raised garden.

plete fertilizer, such as 19-19-19 for a year or two and then retest your soil. If the test is already high in P and K, apply fertilizers containing N only or low in P and K, such as: 46-0-0 (urea); 27-3-3; and 31-3-4. This will avoid over applying certain nutrients (Figure 7.4).

Environmental Considerations

Excess fertilizer applied to the yard or landscape can be a pollution source. When it rains, the extra plant nutrients from lawns may be washed through storm drains to nearby lakes and streams (Figure 7.5). Nutrients that reach lakes and streams start a process called eutrophication. Rapid growth of aquatic weeds and algae use up the oxygen in the water. Extreme cases can lead to deteriorated water quality and fish kills. It is more environmentally friendly if a mulching lawn mower is used since it returns grass clippings to the lawn. This recycles nutrients, minimizes fertilizer inputs and cuts down on the volume of solid waste. Additionally, all the fertilizers and grass clippings on the sidewalk can be washed away; therefore, they should be collected and put back on the lawn or garden (Figure 7.6).

Figure 7.5. Abundant plant growth surrounding a small pond due to excessive nutrients in the water.

Figure 7.6. To protect the environment, the fertilizer and grass clippings should be collected and spread on lawns.

Chapter 8
Reference Tables

The previous seven chapters discussed the basics of soil and nutrient management in the yard, and recommended techniques to take care of lawns and gardens while minimizing the impact of our activity on the environment. Tables 8.1, 8.2, 8.3 and 8.4 contain helpful information on calculating the amount of fertilizers to apply to a given area.

Table 8.1. Homeowners Table of Measurements.

Container	Fertilizer	---------Weight--------	
		grams	pounds
34.5 oz			
Large Coffee Can	Ammonium Nitrate (34-0-0)	2,635	5.81
	Urea (46-0-0)	2,236	4.93
	Diammonium Phosphate (18-46-0)	2,503	5.52
	Potassium Chloride (0-0-60)	2,993	6.60
13 oz			
Coffee Can	Ammonium Nitrate (34-0-0)	889	1.96
	Urea (46-0-0)	712	1.57
	Diammonium Phosphate (18-46-0)	861	1.90
	Potassium Chloride (0-0-60)	1,011	2.23
1-gallon recyclable plastic milk container			
	Ammonium Nitrate (34-0-0)	3,075	6.78
	Urea (46-0-0)	2,590	5.71
	Diammonium Phosphate (18-46-0)	2,980	6.57
	Potassium Chloride (0-0-60)	3,565	7.86
½-gallon recyclable plastic milk container			
	Ammonium Nitrate (34-0-0)	1,483	3.27
	Urea (46-0-0)	1,215	2.68
	Diammonium Phosphate (18-46-0)	1,424	3.14
	Potassium Chloride (0-0-60)	1,700	3.75

Table 8.2. Amount of nitrogen fertilizers needed at two different rates.

N Turf Recommendations	Yard Size, ft^2	Fertilizer	Quantity to Apply, lbs
1 pound N per 1,000 ft^2	10,000	34-0-0	29.4
1/2 pound N per 1,000 ft^2	10,000	34-0-0	14.7
1 lb pound N per 1,000 ft^2	10,000	46-0-0	22
½ pound N per 1,000 ft^2	10,000	46-0-0	11

A garden reminds us the value of intention — plan, prepare, nurture... A garden lets us work the soil, teaching us everything is interrelated and independent. Why not enjoy the company.

– Jean Larson

Table 8.3. Fertilizer recommendations for various soil test results.

Soil Test Condition	Action
pH above 6.0 pH below 5.5	no change needed add lime
Soil test nitrogen less than 40 lb/acre Soil test nitrogen above 80 lb/acre	add 1 lb N/1,000 sq ft no fertilizer needed
Soil test phosphorus below 65 lb/acre Soil test phosphorus above 120 lb/acre	add P fertilizer no P fertilizer needed
Soil test potassium below 300 lb/acre Soil test potassium above 400 lb/acre	add K fertilizer no K fertilizer needed

Table 8.4. Fertilization Tips

Bermudagrass Lawn	Nitrogen rate = 1 pound N per 1,000 square feet per month								
Yard Area, Square feet	1,000			3,000			6,000		
Fertilizer Source	46-0-0	34-0-0	18-46-0	46-0-0	34-0-0	18-46-0	46-0-0	34-0-0	18-46-0
Number of 13-ounce Coffee Cans of Fertilizer To Apply	1.4	1.5	2.9	4.2	4.5	8.8	8.3	9.0	17.5
Number of 1/2-Gallon Milk Containers of Fertilizer To Apply	0.8	0.9	1.8	2.4	2.7	5.3	4.9	5.4	10.6
Vegetable Garden	Nitrogen rate = 1 pound N per 1,000 square feet per month								
Garden Area, Square feet	200			600			1,000		
Fertilizer Source	46-0-0	34-0-0	18-46-0	46-0-0	34-0-0	18-46-0	46-0-0	34-0-0	18-46-0
Number of 13-ounce Coffee Cans of Fertilizer to Apply	0.3	0.3	0.6	0.8	0.9	1.8	1.4	1.5	2.9
Number of 1/2-Gallon Milk Containers of Fertilizer to Apply	0.2	0.2	0.4	0.5	0.5	1.1	0.8	0.9	1.8

[1] 46-0-0 (Urea)
[2] 34-0-0 (Ammonium Nitrate)
[3] 18-46-0 (Diammonium Phosphate)

Additional Information

- 18-46-0 is not recommended unless your soil test indicates that you have a P deficiency
- If 10-20-10 is the fertilizer material, apply twice the amount indicated for 18-46-0
- pounds per acre divided by 40 = 1 pound per 1,000 square feet

Notes

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