CHAPTER 2

Soils and Fertilizers

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Soil is formed when rock (parent material) is broken down by climate and vegetation over a period of time. Soil is weathered rock fragments and decaying remains of plants and animals (organic matter). It contains varying amounts of air, water, and micro-organisms. It furnishes mechanical support and nutrients for growing plants.

Fertilizers are materials containing plant nutrients that are added to the environment around the plant. Generally, they are added to the water or soil, but some can also be added to the air or sprayed on the leaves. Fertilizer is not plant food; plants produce their own food using water, carbon dioxide, and energy from the sun. This food (sugars and carbohydrates) is combined with the plant nutrients to produce protein, enzymes, vitamins, and other elements essential to plant growth.

Soils

A desirable surface soil in good condition for plant growth contains approximately 50% solid material and 50% open or pore space. The mineral component is usually made up of many different kinds and sizes of particles, ranging from those visible to the unaided eye to particles so small that they can only be seen with the aid of a very powerful (electron) microscope. This mineral material comprises about 45% to 48% of the total volume. Organic material makes up about 2% to 5% of the volume and may contain both plant and animal material in varying stages of decomposition. Under ideal or near-ideal moisture conditions for growing plants, soil or pore spaces contain about 25% air and 25% water based on the total volume of soil.

Although most New England soils developed under forest vegetation, climatic conditions from the southern to northern New England and from sea level to the highest mountains vary considerably and have resulted in rather marked effects on the soils that have formed. The glaciers, in recent geologic time, left loose, stony debris which is presently being changed into soil and accounts for New England's soils being thin and very young.

The percentage of mineral matter and organic matter in a cubic foot of surface soil varies from one soil to another, and within the same soil, depending on the kinds of crops grown, frequency of tillage, and wetness or drainage of the soil. Content of organic matter will usually be high in soils that have not been cultivated over long periods of time. Soils that are tilled frequently and have relatively small amounts of plant residues worked into the soil are usually low in organic matter. Plowing and tilling the soil increases the amount of air in the soil, which increases the rate of organic matter decomposition. Further tillage leaves the soil open without cover. Erosion caused by wind and rain can easily move the finer clay particles and organic matter content off the land. Soils with poor drainage or high water tables usually have higher organic matter content than those which are well drained. As a result, decomposition of plant material is slowed and organic matter builds up in the soil.

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

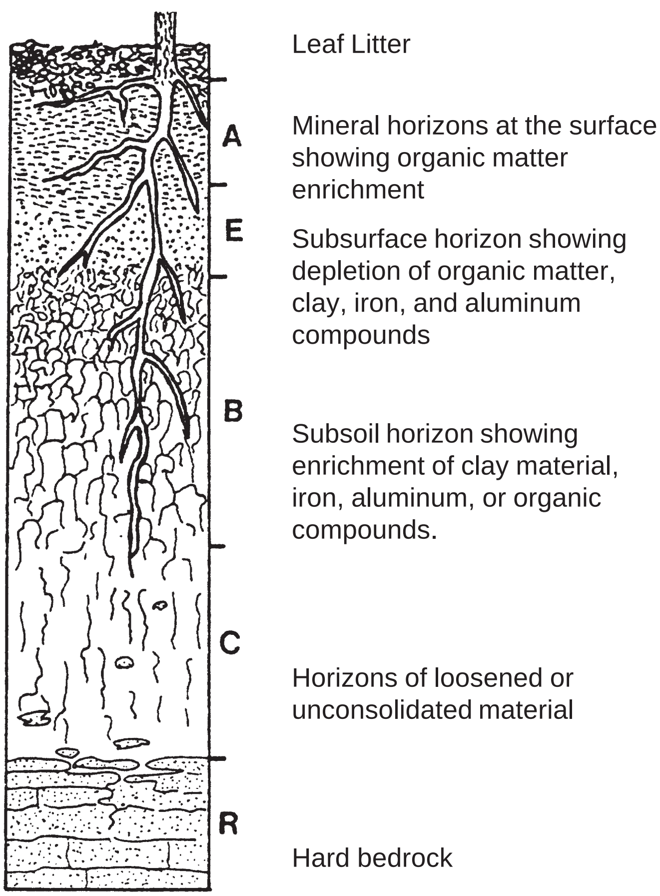
Increasing organic matter content usually increases water-holding capacity, but addition of large amounts of decomposed organic material can reduce water capacity until the material has partially decomposed. Dark brown or black soils usually have high organic matter content.

As defined above, a soil contains four principal components: **mineral matter, organic matter, water, and air**.

Soil Horizons or Layers

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

Soil Profile



The **surface** and **subsurface** are usually the coarsest layers. The surface soil contains more organic matter than the other soil layers. Organic matter gives a gray, dark-brown, or black color to the surface horizon, the color imparted depending largely upon the amount of organic matter present. Soils that are highest in organic matter usually have the darkest surface colors. The surface layer is usually most fertile and has the greatest concentration of plant roots of any horizon of the soil. Plants obtain much of their nutrients and water from the surface soil.

The **subsoil** layer is usually finer and firmer than the surface soil. Organic matter content of the subsoil is usually much lower than that of the surface layer. Subsoil colors are strong and bright; shades of red, brown, and yellow are frequently observed. The subsoil supports the surface soil and may be considered the soil reservoir, providing storage space for water and nutrients for plants, aiding in temperature regulation of the soil, and supplying air for the roots of plants.

The bottom horizon, or **parent material**, is decomposed rock that has acquired some characteristics of the subsoil and retained some characteristics of the rock from which it weathered. It is not hard, like rock, but may show the form or structure of the original rocks or layering if it is in a water-laid deposit. The parent material influences soil texture, natural fertility, rate of decomposition (and thus rate of soil formation), acidity, depth, and in some cases, topography (or lay of the land) on which the soil is formed.

Physical Properties of Soil

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

The physical properties and chemical composition largely determine the suitability of a soil for its planned use and the management requirements to keep it most productive. To a limited extent, the fertility of a soil determines its possible uses, and to a larger extent, its yields. However, fertility level alone is not indicative of its productive capacity, since soil physical properties usually control the suitability of the soil as growth medium. Fertility is more easily changed than soil physical properties.

Soil Color

Color is an obvious and easily determined soil property. It is one of the most useful properties for soil appraisal and identification because other characteristics can be inferred from soil color. Generally, soil color is a reflection of: 1) parent material from which the soil is derived, 2) amount of organic matter, and 3) degree of oxidation and or saturation.

Surface soil colors may vary from light brown to dark brown or black. Lighter colors indicate low amounts of organic matter whereas darker colors indicate higher amounts. Lighter colors in the surface horizons are frequently associated with soils having relatively rapid oxidation of organic matter as a result of properties that favor the decomposition of organic matter. These include sandy or gravelly textures, or highly leached well drained soils that often have relatively high annual temperatures. In soils without amendments darker colors frequently occur in soils where the oxidation of organic matter is slowed by properties that favor the accumulation of organic matter, such as high water table conditions (poor drainage) or low annual soil temperature. Adding organic material (manure) to gardens results in dark, rich surface soils.

Subsoil colors generally are indications of the air and water relationships that occur in the soil. Light brown to yellow subsoil colors indicate a good state of oxidation with a relatively free movement of air and water. Subsoils that are mottled with a mix of rusty brown and gray colors indicate a fluctuating water table and a variable state of oxidation. These are subsoils that may be periodically saturated, often times for two to eight weeks in the spring, that dry out during the summer as water tables drop.

Gray subsoil colors indicate a poor state of oxidation (reduced soil conditions) due to saturation for extended periods of time.

Gray colored subsoils usually indicate extended periods of saturation or a layer that may have restricted drainage (i.e. hardpan). Most mottled subsoils that have a mix of gray and rusty brown colors suggest an environment that is alternately wet and then dry often due to seasonal fluctuations in the water table. Yellow-to-brown colors in the subsoil indicate that iron coatings on soil particles are oxidized, implying good aeration. In contrast, wet soils have gray colors indicating that iron coatings on soil particles have been chemically and biologically reduced, implying saturation and poor aeration.

In wooded or previously wooded sites soils may have a gray or ashy colored layer directly below a dark surface. This gray color is the result of a soil forming process, not wetness. Also, in some areas of New Hampshire gray colors are a result of the gray color of the “parent rock” from which the soil was developed.

Texture

Texture refers to the relative amounts of differently sized soil particles, or the fineness/coarseness of the mineral particles in the soil. Soil texture depends on the relative amounts of sand, silt, and clay. In each texture class, there is a range in the amount of sand, silt, and clay that class contains.

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

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

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

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

Although there are approximately 20 classes of soil texture, most surface soils in New England fall into five general textural classes. Each class name indicates the size of the mineral particles that are dominant in the soil. Texture is determined in the field by rubbing moist-to-wet soil between the thumb and fingers. These observations can be checked in the laboratory by mechanical analysis or by separation into clay, silt, and various-sized sand groups. Regardless of textural class, all soils in New Hampshire contain sand, silt, and clay, although the amount of a particular particle class may be small.

Principal Surface Soil Classes Found in New England:

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

Other textural designations of surface soils are sands, loamy sands, sandy clay loams, and clays. In each textural class there is a range in the amount of sand, silt, or clay that class may contain. The composition of each textural class does not allow for overlap from one class to another.

Texture influences many different characteristics of soil. A brief comparison between sandy and clay soils will highlight these points. Coarse-textured or sandy soils allow water to enter at a faster rate and to move more freely in the soil. In addition, the relatively low water-holding capacity and the large amount of air present in sandy soils allows them to warm up faster than fine-textured soils. Sandy soils are also more easily tilled and more readily worked in the spring. They are well-suited for the production of special crops such as vegetable and certain fruits.

Structure

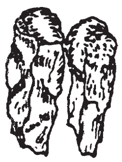
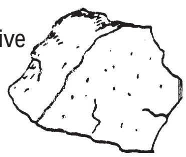
Soil particles are grouped together to form structural pieces called peds or aggregates. In surface soil, the structure will usually be granular unless it is disrupted. The soil aggregates will be rounded and vary in size from that of a very small shot to that of a large pea. If organic matter content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

Structure of the soil is closely related to air and water movement within it. Good structure allows rapid movement of air and water, while poor structure slows down this movement. Water can enter a surface soil that has granular structure more rapidly than one that has little structure. Since plant roots move through the same channels in the soil as air and water, good structure allows extensive root development while poor structure discourages it. Water, air, and plant roots move more freely through subsoils that have blocky structure than those with a flaky horizontal structure. Good structure of the surface soil is promoted by an adequate supply of organic matter, and by working the soil only when moisture conditions are fitting.

Soil consistency. This terminology describes the tendency of the soil to crumble or to stick together when moist. “Friable” indicates a soil that will form a ball when squeezed but will crumble when handled. “Plastic” would relate to a soil high in silt or clay particles that would tend to remain stuck together. By working a heavy clay soil when it is too wet, one can destroy its natural structure or compact it.

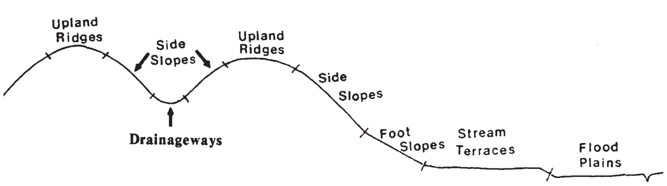
Tilth. Tilth is the result of tillage practices. It is the physical or mechanical conditioning of the soil to render it more suitable for gas exchange and moisture movement needed for good plant growth.

Growing plants also change the soil structure as they send their roots into the soil for mechanical support and to gather water and nutrients. The roots of plants, as they grow, tend to enlarge the openings in the soil. When they die and decay, they leave channels for movement of air and water. In addition to the plants that we see, there are vertebrates (moles, gophers), invertebrates (slugs, earthworms), bacteria, fungi, and very small plants (algae) growing in the soil which can be seen only with the aid of a microscope. All of these organisms enrich the soil by adding organic matter when they die.

NAME	SHAPE	DESCRIPTION	WHERE COMMONLY FOUND IN SOILS
Single grain		Usually individual sand grains not held together	Sandy or loamy textures
Granular		Porous granules held together by organic matter and some clay	A horizons with some organic matter
Platy		Aggregates that have a thin vertical dimension with respect to lateral dimensions	Compacted layers and sometimes E horizons
Blocky		Roughly equidimensional peds usually higher in clay than other structural aggregates	B horizons with clay
Prismatic		Structural aggregates that have a much greater vertical than lateral dimension.	In some B horizons
Massive		No definite structure or compact shape; usually hard.	C horizons or transported material.

Drainage

Soil drainage is defined as the rate and extent of water movement in the soil; that is, movement across the surface as well as downward through the soil. Slope is a very important factor in soil drainage. Other factors include texture, structure, and physical condition of surface and subsoil layers. Soil drainage is indicated by soil color. Clear, bright colors indicate well-drained soils. Mixed, drab, and dominantly gray colors indicate imperfection in drainage. Low-lying areas within the landscape receive run-off water. Frequently, the water from these areas must escape by lateral movement through the soil or by evaporation from the surface, as poor structure and other physical influences do not allow drainage through the soil. Often soils in the stream terraces and flood banks are poorly drained due to groundwater moving upward in these areas.

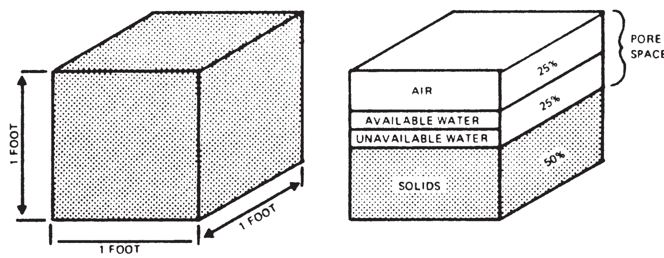


Too much or too little water in the soil is equally undesirable. With too much water, most plants will suffocate. Where there is too little water, plants will wilt and eventually die. The most desirable soil moisture situation is one in which approximately one-half of the pore space of the surface soil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

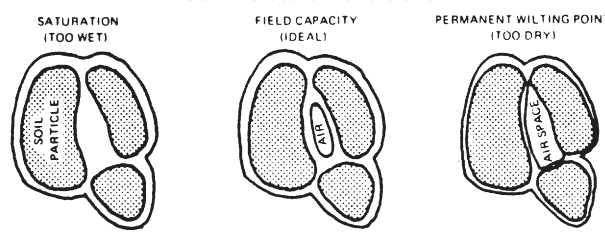
Soil **porosity** is defined as the number, size, and formation of the open spaces in the soil. Soil porosity is related to the number and size of open (air) spaces in the soil and depends on the size and arrangement of the individual soil particles present. The smaller pores permit liquids to rise against gravity by capillary action. The larger pores are those which allow excess water to drain from the soil profile.

Effects of Texture on Capacity to Hold Water

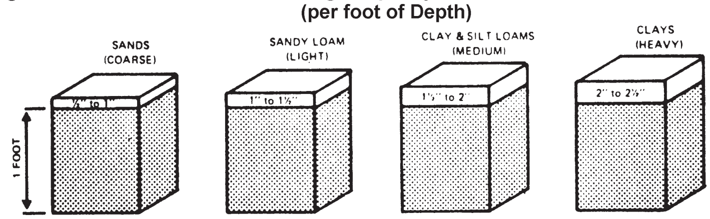
A **Irrigated Soil**



B **Soil Moisture Conditions**



C **Available Moisture Storage Capacity for Various Textured Soils (per foot of Depth)**



Depth

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

Very shallow:	Soil surface is less than 10 inches from a layer that retards root development.
Shallow:	Soil surface is 10 to 20 inches from a layer that retards root development.
Moderately deep:	Soil surface is 20 to 36 inches from a layer that retards root development.
Deep:	Soil surface is 36 to 60 inches from a layer that retards root development.
Very deep:	Soil surface is 60 inches or more from a layer that retards root development.

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

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

The physical characteristics of soil strongly influence **erosion**. Soils that have lost part or all of their surface are usually harder to till and have lower productivity than those that have desirable thickness of surface soil. To compensate for surface soil loss, better fertilization, liming, and other management practices should be used. Increasing the organic matter content of an eroded soil often improves its tillage characteristics, as well as its water and nutrient capacity.

The principal reasons for soil erosion in New Hampshire are:

- insufficient vegetative cover
- overexposure through the use of cultivated crops on soils not suited to cultivation
- improper equipment and methods used in preparation and tillage of the soil

Soil erosion can be held to a minimum by:

- producing crops to which the soil is suited
- adequate fertilization and liming to promote vigorous growth of plants
- thorough and proper soil preparation
- proper tillage methods
- mulching

Components of Soil

Organic Matter

Organic matter in soil consists of the remains of plants and animals. When temperature and moisture conditions are favorable in the soil, earthworms, insects, bacteria, fungi, and other types of plants and animals use the organic matter as food, by breaking it down into simpler compounds and soil nutrients. Through this process, materials are made available for use by growing plants.

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

Organic matter content depends primarily on the kinds of plants that have been growing in a soil, the long-term management practices, temperature, and drainage. Soils that have native grass cover for long periods usually have a relatively high organic matter content in the surface area. Those that have native forest cover usually have relatively low organic matter content. In either case, if the plants are grown on a soil that is poorly drained, the organic matter content is usually higher than where the same plants are grown on a well-drained soil. This is due to differences in available oxygen and other substances needed by the organisms that attack and decompose the organic material. Soils in a cool climate have more organic matter than those in a warm climate.

In New Hampshire, it is common to use cover crops to protect sloping land from soil erosion during the fall, winter, and early spring period. Because of the modest amount of organic matter contributed and its rapid decomposition, cover crops used in the garden setting contribute very little organic matter to soil but their value to soil protection cannot be ignored. Both winter rye and oats are commonly used as cover crops. Oats will winterkill and are easily incorporated into soil with a rototiller in the spring. Winter rye grows aggressively in the spring and its springtime incorporation into soil may pose a problem if excessive rye canopy develops during a protracted period of wet weather.

Muck. One of the terms associated with organic matter is muck. Muck in its pure form is nothing more than an accumulation of decaying or decayed vegetable matter. It may be entirely devoid of any mineral soil. Soils containing more than 10% of this material are unsatisfactory for growing most plants. It is usually too soggy when wet and it dries out too much when exposed to the air. However, it is an excellent source of humus to add to other mineral soils.

Humus. This is a term which is often misused even by experienced gardeners. True humus is vegetable and animal matter that has been modified from the original tissue through decomposition. It is the ultimate end product formed by the decay and oxidation of organic matter by the soil organisms. It is not the black material one buys in bags or bales. It is not even the rough compost obtained from piles of leaves, grass clippings, or manure, etc. While humus will eventually be derived from this material, only the final end product of complete decomposition can be called humus. With true humus there is no offensive smell and the organic source of the humus can not be determined. It is this humus which makes up the organic faction in the soil that is so important to the chemical reactions in the soil.

Water and Air

All water in the soil ultimately comes from precipitation (rain, snow, hail, or sleet), entering the soil through cracks, holes, and openings between the soil particles. As the water enters, it pushes the air out. Oxygen is taken up by roots for respiration. If anaerobic (lack of oxygen) conditions persist for too long, the roots will die.

Plants use some water, some is lost by evaporation, and some moves so deep into the soil that plant roots cannot reach it. If it rains very hard or for a long time, some of it is lost through run-off.
When organic matter decomposes in the soil, it gives off carbon dioxide. This carbon dioxide replaces some of the oxygen in the soil pores. As a result, soil air contains less oxygen and more carbon dioxide than the air above the soil surface. Carbon dioxide is dissolved by water in the soil to form a weak acid. This solution reacts with the minerals in the soil to form compounds that can be taken up and used as foods by the plants.

Plant Nutrients

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

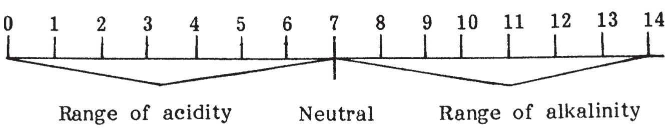
The other 13 essential elements are iron, calcium, phosphorus, potassium, copper, sulphur, magnesium, manganese, zinc, boron, chlorine, cobalt and molybdenum. These elements come from the soil. With the exception of calcium, magnesium, phosphorus, and potassium, there is usually a large enough quantity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

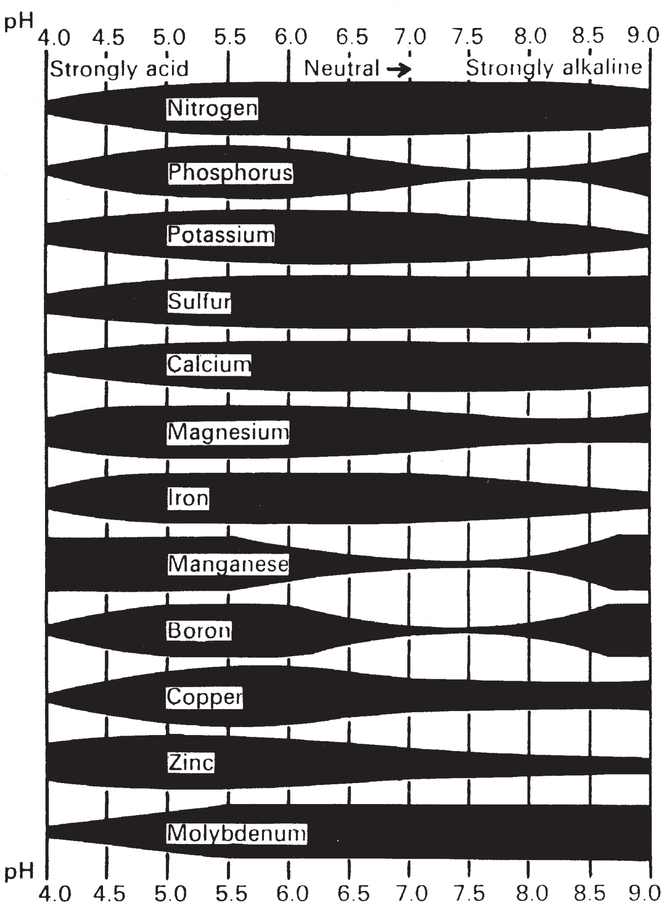
Cation Exchange Capacity

Soils consist of solids, liquids and gases. The solid portion (or phase) consists of the minerals (sand, silt and clay) and the organic matter. Since soils naturally have a strong negative charge, they attract cations (positively charged ions) such as calcium (Ca^{++}), magnesium (Mg^{+}) and potassium (K^{+}). Cation exchange is the ability of a soil to trade one cation for another, either between soil particles or between soil particles and the soil solution. <u>Cation Exchange Capacity</u> (CEC) is a measure of the soil=s ability to <u>adsorb</u> (attach to the surface) cations and then release them to the soil solution or to plant roots. The CEC of a soil is related to the amount of clay mineral and the amount of organic matter in the soil. Since most New Hampshire soils do not have a high percentage of clay, the organic matter fraction plays an important role in determining this value. A soil with a higher CEC with hold more cations and will help protect against leaching losses of these cations. Another soil property related to CEC is **base saturation**. This is a measure of the percentage of the CEC sites which are occupied by basic cations such as calcium, magnesium, potassium and sodium. Soils with high pH and or a history of being limed would likely have high base saturation percentages. Soils with a low pH and or no history of liming would have a low base saturation. In soils like these, the CEC sites would be occupied by acidic cations such as aluminum (Al^{3+}) and hydrogen (H^{+}).

Soil pH

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





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

The pH condition of soil is one of a number of environmental conditions which affect the quality of plant growth. A near-neutral or slightly acidic soil is generally considered ideal for most plants in the northeast. Some types of plant growth can occur anywhere in a 3.5 to 10.0 range. With some notable exceptions, a soil pH of 6.0 to 7.0 requires no special cultural practices to improve plant growth.

The major impact that pH extremes have on plant growth is the availability of plant nutrients and concentration of the plant-toxic minerals (such as aluminum) in the soil. In highly acidic soils, calcium, phosphorous, and magnesium become tied up and unavailable, and manganese can be concentrated in toxic levels. At pH values of 7 and above, phosphorus, iron, copper, zinc, boron, and manganese become less available.

By the application of certain materials to the soil, adjustments can be made in pH values. To reduce acidity, apply a material that contains some form of lime. Ground agricultural limestone is the most frequently used. The finer the grind the more rapidly it becomes effective. Different soils will require a different amount of lime to adjust the reaction to the proper range. The texture of the soil, organic matter content, crop, and soil type are all factors to consider in adjusting pH. For example, soils low in organic matter require much less lime than soils high in organic matter to make the same pH change.

Wood ash is often used as a soil amendment. It contains potash (potassium), phosphate, boron, and other elements. Wood ash can be used to raise soil pH with twice the weight of ash applied as limestone for the same effect. Ash should not come into contact with germinating seedlings or plant roots as it may cause root damage. Incorporate the ash into the soil in the spring. Check pH yearly if you use wood ashes. Never use coal ash or large amounts of wood ash (no more than 20 lbs. per 1000 square feet), as toxicity problems may occur.

If pH is too high, elemental sulfur or aluminum sulfate can be added to the soil to reduce alkalinity. Most ornamental plants require slightly to strongly acidic soil. These species develop iron chlorosis when grown in soils in the alkaline range. Iron chlorosis is often confused with nitrogen deficiency since the symptoms (a definite yellowing of the leaves) are similar. This problem can be corrected by applying chelated iron sulfate to the soil to reduce the alkalinity and add iron.

The term chelate comes from the Greek word for claw. Chelates are chemical claws that help hold metal ions, such as iron, in solution, so that the plant can absorb them. Different chemicals can act as chelates, from relatively simple natural chelates like citrate to more complex, manufactured chemicals. When a chelate metal is added to the soil, the nutrient held by the chelate will remain available to the plant.

Most nutrients do not require the addition of a chelate to help absorption. Only a few of the metals, such as iron, benefit from the addition of chelates. The types of chelate used will depend on the nutrient needed and the soil pH.

A Guide for Estimating Moisture Content of Soil

% OF FIELD CAPACITY	ADEQUACY OF SOIL MOISTURE FOR PLANT GROWTH	RESPONSE TO PHYSICAL MANIPULATION		
		LOAMY SAND, SANDY LOAM	SILT LOAM, LOAM	SILTY CLAY LOAM
100 plus	Saturated soil - too much moisture and too little air in the soil; can damage plants if this condition persists	Free water appears on soil when squeezed	Same as sandy loam	Same as sandy loam
100	Excess moisture has drained into subsoil after rainfall or irrigation and optimum amounts are available in root zone for plant growth	When squeezed, no free water appears on surface, but it leaves a wet outline on your hand	Same as sandy loam	Same as sandy loam
		Forms weak ball; usually breaks when bounced in hand	Forms a very pliable ball; sticks readily	Ribbons out (can be formed into a thin strand when rolled between thumb & forefinger), has a slick feeling
75	Adequate moisture for plant growth	Tends to ball under pressure, but breaks easily when bounced in hand	Forms a ball, somewhat plastic, sticks slightly with pressure	Forms a ball, ribbons out between thumb and forefinger, has slick feeling
	Marginal moisture for plant growth; time toirrigate			
50	Inadequate moisture for plant growth	Appears too dry; will not form a ball with pressure	Somewhat crumbly, but holds together with pressure	Somewhat pliable, balls under pressure
25	Moisture in soil is unavailable for plant growth	Dry, loose, falls through fingers	Powdery, sometimes crusty, but easily broken down into a powdery condition	Hard, cracked, difficult to break down into a powdery condition
0				

Note: Soil sample was at 4 to 6 inches depth. Adapted from: Craig, C.L. 1976. Strawberry Culture in Eastern Canada. Agric. Canada Publications 1585:19

Fertilizers

There are 17 elements essential to plant growth. Nitrogen, phosphorous and potassium are considered fertilizer macronutrients because plants require them in quantity for maximum growth. Calcium, magnesium, and sulfur are secondary macronutrients but usually are either present in sufficient quantities or are added coincidentally with other materials (e.g., lime). The other 11 nutrients, called micronutrient, are just as important but necessary in smaller amounts. If plants lack any of these elements, they exhibit signs of nutrient deficiency.

Fertilizers Analysis

The fertilizer analysis given on the package refers to the amount of an element present in a formulation based on percentage of weight. All fertilizers are labeled with three numbers, giving the percentage by weight of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) respectively. However, to simplify matters, these are usually just referred to as nitrogen, phosphorus and potassium or N, P, and K.

Some soil test labs report phosphorus results in terms of P and others in terms of P_2O_5. In order to compare results you may need to convert phosphorus to phosphate, or vice versa. To convert P to P_2O_5 you would multiply by 2.29. (This factor is related to the molecular weight of the two products). To convert P_2O_5 to P multiply by 0.43. To convert potassium (K) to potash (K_2O) multiply K values by 1.2. To convert potash (K_2O) to potassium multiply the K_2O value by 0.83. For example, if we have a 100 pound bag of 10-10-10, there are 10 pounds of N, 10 pounds of P_2O_5, 10 pounds of K_20 and 70 pounds of filler. The amount of actual phosphorus (P) in the bag is 4.3 pounds (10 pounds of phosphate x 0.43).

Filler can be important so that we can evenly spread the fertilizer and avoid burning plants with too much fertilizer. A 100-pound bag of fertilizer labeled 0-20-10 would have 0 pounds of N, 20 pounds of P_2O_5, 10 pounds of K_2O, and 70 pounds of filler.

For many years, there has been a model label law which many states have adopted for the classification of fertilizers. The law also establishes minimum levels of nutrients allowable and provides specific labeling requirements. To date, model label legislation has not met with total acceptance, so there are still differences from state to state as to what constitutes a fertilizer and the type of information on labels. Even so, the information contained on fertilizer labels has been well standardized, and the consumer is protected by state laws requiring manufacturers to guarantee the claimed nutrients.

The law requires that the manufacturer guarantees accuracy of what is claimed on the label. In some cases, a fertilizer will contain secondary nutrients or micronutrients not listed on the label because the manufacturer does not want to guarantee their exact amounts. The gardener/consumer is assured that nutrients listed on the label are actually contained in the fertilizer.

On fertilizer labels, the initials W.I.N. and W.S.N. stand for Water Insoluble Nitrogen and Water Soluble Nitrogen, respectively. The water soluble nitrogen (W.S.N.) dissolves readily and is usually in very simple form, such as ammoniacal nitrogen (ammonia) or nitrate nitrogen. Nitrogen which will not dissolve readily may exist in other forms in the fertilizer. These are usually organic forms of nitrogen (with the exception of urea) that must be broken down into simpler forms before it can be used. Water insoluble nitrogen (W.I.N.) is referred to as a slow-release nitrogen source and delivers nitrogen at different rates according to the amount and kind of material in its composition.

The best fertilizer to use depends on many factors, such as the nutrients needed, soil structure, soil chemistry, and method of applying the fertilizer.

Complete Versus Incomplete

A fertilizer is said to be complete when it contains nitrogen, phosphorus, and potassium. The manufacturers of commercial fertilizers are required to state the amounts of nutrients on the container as a guaranteed analysis. Examples of commonly used fertilizers are 10-10-10, 16-16-16, and 20-10-5. An incomplete fertilizer will be missing one of the major components.

The fertilizer ratio indicates the proportion of nitrogen, phosphate, and potash contained in the fertilizer. The specific fertilizer ratio you will need depends on the soil nutrient level. For example, a 1-1-1 ratio (10-10-10, 15-15-15, 20-20-20) is widely used at the time of lawn establishment, but established lawns generally respond better to fertilizer ratios high in nitrogen. Two of the more common complete fertilizers used by homeowners for flowers and vegetables are 10-10-10 and 5-10-10.

Special Purpose Fertilizers

When fertilizer shopping, you will find fertilizers packaged for certain uses or types of plants such as Camellia Food, Rhododendron and Azalea Food, or Rose Food. The camellia and rhododendron/azalea fertilizers belong to an old established group, the acid plant fertilizers. Some of the compounds used in these fertilizers are chosen because they have an acid reaction, so they are especially beneficial to acid-loving plants where soil is naturally neutral or alkaline. The other fertilizers packaged for certain plants do not have as valid a background of research. For example, the next time you are shopping, compare the fertilizer ratios of different brands of rose fertilizers.

A soil test should be performed before the purchase of any expensive, special-purpose fertilizers. It is not possible to make a blanket statement that one fertilizer is best for every area of a particular state. It is true that different plants use different nutrients at different rates. What is unknown is the reserve of nutrients already in the soil. This changes with every soil type and location.

Slow-Release Fertilizers

Plants can absorb nutrients continuously, so it is beneficial to provide them with a balance of nutrients throughout their growth. Perhaps the most efficient way to achieve this is to apply a slow-release fertilizer, which releases nutrients at a rate that makes them available to the plants over a long period. Slow-release fertilizers contain one or more essential elements. These elements are released or made available to plants over an extended period.

Slow-release fertilizers can be categorized according to their release mechanism. The three major types of nutrient release mechanisms are: (1) materials that dissolve slowly, (2) materials containing microorganisms which release nitrogen, and (3) granular materials with membranes made of resin or sulfur to control the rate of nutrient release into the soil.

Sulfur-coated urea is a slow-release fertilizer with a covering of sulfur around each urea particle. Different thicknesses of sulfur control the rate of nitrogen release, which increases with temperature. Watering does not affect its release rate. Sulfur-coated urea applied to the soil's surface releases nitrogen more slowly than if incorporated into the soil. This material generally costs less than other slow-release fertilizers, and it supplies the essential element, sulfur.

When fertilizer products coated with multiple layers of resin come into contact with water, the layers swell and increase the pore size in the resin so that the dissolved fertilizer can move into the soil. Release rate depends on the coating thickness, temperature, and water content of the soil. There is often a large release of fertilizer during the first two or three days after application. Release timing can be from 0 to 6 months, depending on the coating.

Slow-release fertilizers need not be applied as frequently as other fertilizers, and higher amounts can be applied without danger of burning. Plants may use the nitrogen in slow-release fertilizers more efficiently than nitrogen in other forms, since it is released over a longer period of time and in smaller quantity. Slow-release fertilizers are generally more expensive than other types. The real benefit, however, is the frequency of application, which is much lower than conventional fertilizers.

Urea formaldehyde and sulfur-coated urea have been used as turf fertilizer, while resin-coated fertilizers are predominantly used in container growing.

Caution should be used in applying slow-release fertilizers around trees or shrubs, as they may keep the plant in growth late in the summer. The late-season growth may not harden off completely, and excessive winter damage may occur.

The table below compares slow-release fertilizers and conventional fertilizers.

Comparison of Fertilizers

Slow Release Fertilizers

Advantages	Disadvantages
1. Fewer applications	1. Unit cost is high
2. Low burn potential	2. Availability is limited
3. Release rate varies depending on fertilizer characteristics	3. Release rate is governed by factors other than plant need

Conventional Fertilizers

Advantages	Disadvantages
1. Fast acting	1. Greater burn potential
2. Some are acid-forming	2. Solidifies in bag when wet
3. Low cost	3. Some nitrogen forms leach readily

Manures or Sewage Sludge

Advantages	Disadvantages
1. Low burn potential	1. Salts may build up
2. Relatively slow-release	2. Bulky
3. Contains micronutrient	3. Odor
4. Conditions the soil	4. Expensive per pound for actual nutrient
	5. Contains weed seed
	6. Heavy metals may be present in sewage sludge from large cities or industrial areas

Organic Fertilizers

The word organic, applied to fertilizers, simply means that the nutrients contained in the product are derived solely from the remains or by-products of a once-living organism. Urea is a synthetic organic fertilizer, an organic substance manufactured from inorganic materials. Cottonseed meal, blood meal, bone meal, hoof and horn meal, and all manures are examples of organic fertilizers. When packaged as fertilizers, these products will have the fertilizer ratios stated on the labels. Some organic materials, particularly composted manures and sludges, are sold as soil conditioners and do not have a nutrient guarantee, although small amounts of nutrients are present. Most are high in one of the three major nutrients and low in the other two, although you may find some fortified with nitrogen, phosphorus, or potash for a higher analysis. Many are low in all three. In general, organic fertilizers release nutrients over a fairly long period; the potential drawback is that they may not release enough of their principal nutrient at a time to give the plant what it needs for best growth. Because organic fertilizers depend on soil organisms to break them down to release nutrients, most of them are effective only when soil is moist and soil temperature is warm enough for the soil organisms to be active.

Plants cannot differentiate between chemical or organic sources of basic nutrient elements. Research has also indicated that sources of basic mineral plant nutrients have no impact upon plant growth, vigor, flavor, or human nutritional value.

Cottonseed meal is a by-product of cotton manufacturing; as a fertilizer, it is somewhat acidic in reaction. Formulas vary slightly, but generally contain 7 percent nitrogen, 3 percent phosphorus, and 2 percent potash. Cottonseed meal is readily available to plants in warm soils, and there is little danger of burn. For general garden use, apply 2 to 5 pounds per 1000 square feet. Cottonseed meal is frequently used for fertilizing acid-loving plants such as azaleas, camellias, and rhododendrons.

Blood meal is dried, powdered blood collected from beef processors. It is a rich source of nitrogen — so rich, in fact, that it may do harm if used in excess. The gardener must be careful not to use more than the amount recommended on the label. In addition to supplying nitrogen, blood meal supplies certain of the essential trace elements, including iron.

Fish emulsion, a complete fertilizer, is a partially decomposed blend of finely pulverized fish. No matter how little is used, the odor is intense — but it dissipates within a day or two. Fish emulsion is high in nitrogen and is a source of several trace elements. In the late spring, when garden plants have sprouted, an application of fish emulsion followed by a deep watering will boost the plant's early growth spurt. Contrary to popular belief, too strong a solution of fish emulsion can burn plants, particularly those in containers.

Manure is also a complete fertilizer, but low in the amounts of nutrients it can supply. Manures vary in nutrient content according to the animal source, bedding material used, and what the animal has been eating, but a fertilizer ratio of 1-1-1 is typical. Manures are best used as soil conditioners instead of nutrient sources. The straw or litter in some manures can help add organic matter to the soil, however barnyard manure usually contains large numbers of weed seeds. Commonly available manures include horse, cow, pig, chicken, and sheep. The actual nutrient content varies widely: the highest concentration of nutrients is found when manures are fresh. As it is aged, leached, or composted, nutrient content is reduced. However, the subsequent reduction in salts will reduce the chances of burning plants. Ammonia toxicity may be another concern. Fresh manure should not be used where it will contact tender plant roots. Commercially dried manures are very expensive for the benefits received. Typical rates of manure applications vary from a moderate 70 pounds per 1000 square feet to as much as one ton per 1000 square feet.

Sewer sludge is a recycled product of municipal sewage treatment plants. Two forms are commonly available: activated and composted. Activated sludge has higher concentrations of nutrients (approximately 6-3-0) than composted sludge, and is usually sold in a dry, granular form for use as a general purpose, long-lasting, non-burning fertilizer. Composted sludge is used primarily as a soil amendment and has a lower nutrient content (approximately 1-2-0). There is some question about the long-term effects of using sewage sludge products in the garden, particularly around edible crops. Heavy metals, such as cadmium, are sometimes present in the sludge, and may build up in the soil. Possible negative effects vary, not only with the origin of the sludge, but also with the characteristics of the soil where it is used. It may be appropriate to have the sludge analyzed for heavy metals.

The following table shows the approximate nutrient content of manures and common organic fertilizers plus the suggested yearly rates of application per 1000 square feet of garden area. Rates given are for materials used singly; if combinations of two or more materials are used or some chemical fertilizer is used, the rate should be reduced accordingly.

Type of Dry Manure or Fertilizer	Nitrogen %	Phosphorus %	Potassium %	Suggested Approx. Rate (lbs. per 1000 Sq Ft of garden area)
Chicken manure	2.0-4.5	3.0-4.6	1.2-2.4	125
Horse manure	.5-1.0	.2-.5	.3-.7	700
Dairy manure	1.2-2.75	.6-1.4	2.0-3.6	600
Sheep manure	1-1.5	.3-.5	.7-1.3	700
Green sand	0	0	4-7	50
Granite dust	0	0	3-5	50
Rock phosphate	0	33.0	0	100

Compared to synthetic fertilizer formulations, organic fertilizers contain relatively low concentrations of actual nutrients, but they perform other important functions which the synthetic formulations do not. Some of these functions are: increasing organic content of the soil; improving physical structure of the soil; and increasing bacterial and fungal activity, particularly the mycorrhiza fungus, which alone makes other nutrients more available to plants.

Fertilizers Combined with Pesticides

The major reason for buying a fertilizer combined with a pesticide is convenience. It is very convenient to combine everything you need in one application, but it is also very expensive. The problem is that the timing for a fertilizer application often does not coincide with the appearance of a disease or an insect problem. In the case of a number of turfgrass diseases, a primary cause of disease infestation is merely a lack of proper fertilizer.

A fertilizer-insecticide combination, when applied at the proper stage of a pest’s life-cycle, can do an adequate job of controlling the turf pest while also giving the grass “a shot in the arm” to help its recovery. However, fertilizers with pesticides intended for use with turf or ornamentals should not be used in the vegetable garden where it may contaminate food crops. Always read the label carefully.

Fertilizers Formulation

Fertilizers come in many shapes and sizes. Different formulations are made to facilitate types of situations in which fertilizer is needed. Packaging for all formulations must show the amount of nutrients contained, and sometimes it tells how quickly a nutrient is available. Some of the formulations available to the homeowner are: water-soluble powders, slow-release pellets, slow-release collars or spikes, liquids, tablets, and granular solids.

Liquid fertilizers come in a variety of different formulations, including complete formulas and special types that offer just one or two nutrients. All are made to be diluted with water; some are concentrated liquids themselves, others are powder or pellets. Growers of container plants often use liquid fertilizers at half the recommended dilution twice as frequently as recommended so that the plants receive a more continuous supply of nutrients.

Fertilizer Application

Computing the amount of fertilizer needed for a given area is rather tricky at first, but after a few times, this becomes second nature. Following is an example of a fertilizer determination for a lawn.

Since the element that is often the one usually lacking in most soils and also required more by most plants is nitrogen, many fertilizer recommendations are based on this element. For vegetable gardens, flower beds, small fruit plantings, etc. the rule of thumb is 1 lb. of actual nitrogen per 1,000 sq. ft. for maintenance and 2 lbs. of nitrogen at the time of establishment (worked into the soil).

Example. Determine the amount of ammonium sulfate needed by a 5000 square-foot lawn if 1 pound of nitrogen per 1000 square feet is required.

Lawn: 5000 square feet
Fertilizer: ammonium sulfate (21-0-0)
Rate: 1 pound of nitrogen per 1000 square feet

1. Since we need 1 pound of nitrogen for every 1000 square feet and we have 5000 square feet, we need 5 pounds of nitrogen.
2. Ammonium sulfate is 21 percent nitrogen (round to 20 percent).
3. 20 percent is the same as 0.20 or 1/5. This means that we need 5 pounds of fertilizer to get 1 pound of nitrogen.
4. Since we need 5 pounds of nitrogen, 5 x 5 = 25 pounds of fertilizer.

Total fertilizer needed =

$$\frac{\text{N application rate (lbs./1000 sq. ft.)}}{\text{N content of fertilizer expressed as a decimal}} \times \frac{\text{lawn size (sq. ft.)}}{1000} = \frac{1}{0.20} \times \frac{5000}{1000} = 25 \text{ lb. fertilizer}$$

Nitrogen fertilizers do not burn or damage plants if they are applied correctly. Fertilizers are salts, much like our familiar table salt, except that they contain various plant nutrients. When a fertilizer is applied to a soil, nearby water begins to move very gradually towards the area where the fertilizer has been applied. Salts in the fertilizer begin to diffuse or move away from the place where they had been applied. This dilutes the fertilizer and distributes it through a much larger area. If tender plant roots are close to the area where the fertilizer is placed, water will be drawn from these roots and from the surrounding soil. The more salt or fertilizer applied, the more water will be drawn from nearby roots. As water is drawn from the roots, plant cells begin to dehydrate and collapse, and the plant roots burn or dehydrate to a point from which they cannot recover. If soil moisture is limited, most of the water drawn towards the salt will come from plant roots and the damage will be severe.

Two rules should be kept in mind when applying a fertilizer during hot weather when soil moisture is limited: 1) do not over-apply nitrogen fertilizers; and 2) make sure adequate moisture is present after applying fertilizers high in salts. The following table is a chart of commonly used garden fertilizers high in salt content or burn potential. The last column is the practical measure of relative saltiness. A higher number indicates greater saltiness.

Relative Saltiness

Material	Nutrient level	per weight of nutrient
Ammonium nitrate	33 percent Nitrogen	1.49
Ammonium sulfate	21 percent Nitrogen	1.63
Potassium nitrate	14 percent Nitrogen	2.67
Natural organic fertilizer	5 percent Nitrogen	0.41
Urea formaldehyde	38 percent Nitrogen	0.13
Urea	45 percent Nitrogen	0.81
Superphosphate	20 percent Phosphorus	0.21
Potassium chloride	60 percent Potash	0.87
Potassium sulfate	50 percent Potash	0.43
Dolomite	30 percent Calcium	—
	20 percent Magnesium	—
Gypsum	33 percent Calcium	0.12
Epsom salts	16 percent Magnesium	1.38

Soluble salts will accumulate on top of the soil in a container and form a yellow-to-white crust. A ring of salt deposits may form around the pot at the soil line or around the drainage hole. Salts will also build up on the outside of clay pots. Soluble salts accumulate when fertilizer is applied repeatedly without sufficient water to leach or wash the old fertilizer's salts through the soil. It also occurs when water evaporates from the soil and minerals, but salts stay behind. As the salts in the soil become more concentrated, plants find it harder to take up water. If salts build up to an extremely high level, water can be taken out of the root tips, causing them to die.

Soluble-salt problems commonly occur on plants in containers but are rarely a problem in the garden. The best way to prevent soluble salt injury is to stop the salts from building up. Water correctly. When water is applied, allow water to drain through the bottom holes and then empty the drip plate. Water equal to one-tenth the volume of the pot should drain through each time you water. Do not allow the pot to sit in water. If you let the drained water be absorbed by the soil, the salts that were washed out are taken back into the soil. Salts can be reabsorbed through the drainage hole or directly through a clay pot.

Potted plants should be leached every 4 to 6 months. Leach a potted plant before fertilizing to avoid washing away all newly added fertilizer. Leaching is done by pouring water on the soil and letting it drain completely. The amount of water used for leaching should equal twice the volume of the pot. For example, a 6-inch pot will hold 10 cups of water, so 20 cups of water are used in leaching. Keep the water running through the soil to wash the salts out. If a layer of salts has formed a crust on top of the soil, you should remove the salt crust before you begin to leach. Do not remove more than ¼-inch of soil. It is best not to add more soil to the top of the pot. If the soluble salt level is extremely high or the pot has no drainage, repot the plant.

The level of salts that will cause injury varies with the type of plant and how it is being grown. A plant grown in the home may be injured by salts at a concentration of 200 ppm. The same plant growing in a greenhouse where the light and drainage are good will grow well until salts reach concentrations 10 times that level, or 2000 ppm. Some nurseries and plant shops leach plants to remove excess salts before the plant is sold. If you are not sure that has been done, leach a newly purchased plant the first time you water it.

Soil type dictates the frequency of fertilizer application. Sandy soils require more frequent applications of nitrogen and other nutrients than do clay-type soils. Other factors affecting frequency of application include the type of crop, the level of crop productivity required, frequency and amount of water applied, and type of fertilizer applied and its release rate.

Timing

The type of crop influences timing and frequency of application since some crops are heavier feeders of particular nutrients than others. Root crops require less nitrogen fertilization than do leafy crops. Corn is a heavy feeder of nitrogen, while most trees and shrubs are generally light nitrogen-feeders. Corn may require nitrogen fertilization every four weeks, while most trees and shrubs perform nicely with one, good, well-placed application every year or two. A general rule of thumb is that nitrogen is for leafy top growth; phosphorus is for root and fruit production; and potassium is for cold hardiness, disease resistance, and general durability.

Proper use of nutrients can control plant growth rate and character. Nitrogen is the most critical nutrient in this regard. If tomatoes are fertilized heavily with a nitrogen fertilizer into the summer, the plants may be all vine and no fruit. This is also the case with potatoes, which will show excess vining and poor tuber formation. If slow-release fertilizers or heavy amounts of manure are used on crops that form fruit or vegetables, leaf and vine growth will continue into late summer, and fruit and vegetable development will occur very late in the season.

Remember that a nitrogen application will have its greatest effect for three to four weeks after application. If tomatoes are fertilized heavily on June 1, there may be no flower production until July 1, which will, in turn, delay fruit ripening until late August. For this reason, it is important to plant crops with similar fertilizer needs close together to avoid improper rates of application.

Late fertilization (after July 1) of trees and shrubs can cause new flushes of growth to occur on woody plants that are normally adjusting themselves for the coming winter. This may delay dormancy of woody plants and cause severe winter die back in new growth.

The following suggestions about groups of garden plants are given as general guides. Gardeners should be aware that individual species within these groups vary considerably. After each group of plants, the need for the primary nutrients (nitrogen, phosphorus, and potassium) is indicated as high, medium, or low.

Vegetables	High
Herbs	Medium to Low
Lawns	Medium to High
Fruits	Medium
Annual flowers	Medium
Perennial flowers	Medium to Low
Deciduous shrubs	Medium to Low
Evergreen shrubs	Low
Deciduous shade trees	Medium to Low
Evergreen shade trees	Low

Application Methods

There are different methods of applying fertilizer depending on its formulation and the crop needs.

Broadcasting — A recommended rate of fertilizer is spread over the growing area and left to filter into the soil or incorporated into the soil with a rototiller or spade. Broadcasting is used over large garden areas or when time or labor is limited.

Banding — Narrow bands of fertilizer are applied in furrows 2 to 3 inches from the garden seeds and 1 to 2 inches deeper than the seeds or plants. Careless placement of the fertilizer band too close to the seeds will burn the roots of the seedlings. The best technique is to stretch a string where the seed row is to be planted. With a corner of a hoe, dig a furrow 3 inches deep, 3 inches to one side, and parallel with the string. Spread one-half the suggested rate of the fertilizer in the furrow and cover it with soil. Repeat the banding operation on the other side of the string, then sow seeds underneath the string.

For widely spaced plants, such as tomatoes, fertilizers can be placed in bands 6 inches long for each plant or in a circle around the plant. Place the bands 4 inches from the plant base. If used in the hole itself, place the fertilizer at the bottom of the hole, work it into the soil, and place a layer of soil about 2 inches deep over the fertilized soil before putting the plant in the hole.

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

Starter solutions — Another way to satisfy the need for phosphorus when setting out transplants of tomatoes, eggplant, peppers, or cabbage is through the use of a liquid fertilizer high in phosphorus, as a starter solution. Follow directions on the label.

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

Foliar Feeding — Foliar feeding is used when insufficient fertilizer was used before planting; a quick growth response is wanted; micronutrients (such as iron or zinc) are locked into the soil; or when the soil is too cold for the plants to use the fertilizer applied to the soil. Foliar-applied nutrients are absorbed and used by the plant quite rapidly. Absorption begins within minutes after application and, with most nutrients, it is completed within 1 to 2 days. Foliar nutrition can be a supplement to soil nutrition at a critical time for the plant, but not a substitute. At transplanting time, an application of phosphorus spray will help in the establishment of the young plant in cold soils. For perennial plants, early spring growth is usually limited by cold soil, even when the air is warm. Under such conditions, soil microorganisms are not active enough to convert nutrients into forms available for roots to absorb; yet, if the nutrients were available, the plants could grow. A nutrient spray to the foliage will provide the needed nutrients immediately, allowing the plants to begin growth.

Improving Soil Structure

In special cases, coarse sand, vermiculite, peat and perlite are added to heavy clays to help improve the soil texture or structure. However, these inert materials can be expensive and large quantities are needed to do any good. In some cases, they can make the situation worse by causing clays to “set up” similar to concrete. Compost, manures, and other organic amendments are more effective and economical for modifying the soil structure.

Organic matter is a great soil improver for both clay and sandy soils. Good sources of organic matter include manures, leaf mold, sawdust, and straw. These materials are decomposed by soil organisms. Various factors such as moisture, temperature, and nitrogen availability determine the rate of decomposition through their effects on these organisms. Adequate water must be present, and warm temperatures will increase the rate at which the microbes work. The proper balance of carbon and nitrogen is needed for rapid decomposition. The addition of nitrogen may be necessary if large amounts of undecomposed high-carbon substances such as dried leaves, straw, or sawdust are used. Fresh green wastes, such as grass clippings, are higher in nitrogen than dry material. In the process of breaking down the organic matter, nitrogen is used by the microbes and, therefore, may become deficient in the plants.

Peat Moss. One of the most popular sources of organic matter which has many uses is peat moss. It is fairly uniform, readily available, and easy to work with. Peat moss is partially decomposed organic matter which was formed under water (low oxygen) in bogs and swamps. There are several types of peat available on the market. They differ somewhat because of the site and depth where they were obtained, the parent plant material and the relative stage of decomposition. The actual pH of the various peats may also vary from about pH 3.0 to pH 4.5. Generally speaking, the European and Canadian peats are the result of sphagnum moss partially decomposing under bog conditions while the “domestic” peats often contain other mosses and additional woody or herbaceous plant material such as reed and sedge. “Native” or “Michigan” type peat mosses have usually progressed further along in their decomposition and are finer to the touch, with less visible plant parts remaining in them. They may also be darker in color. All peat moss will eventually break down in the soil and produce humus, but it is lacking in the nutrients required for adequate plant growth. A sound fertilizer program is therefore a requirement when using quantities of peat moss.

Compost. The use of compost is one way to avoid tying up nitrogen during decomposition. Compost is usually made by the gardener from plant wastes. Correct composting can result in a valuable nutrient and humus source for any garden. The basis of the process is the microbial decomposition of mixed raw organic materials to humus, a dark, fluffy product resembling rich soil, which is then spread and incorporated into the garden soil.

For more detailed information, refer to the composting chapter in this handbook.

Another source of inexpensive soil improvement that should not be underestimated is the cover crop. Green manures, or cover crops, such as ryegrass are planted in the garden in the fall for incorporation in the spring. For best results, seed should be sown a little before the first killing frost. In a fall garden, plant cover crops between the rows and in any cleared areas. Cover cropping provides additional organic matter, holds nutrients that might have been lost over the winter, and helps reduce erosion and loss of topsoil. Legume cover crops can increase the amount of nitrogen in the soil and reduce fertilizer needs. A deep-rooted cover crop allowed to grow for a season in problem soil can help break up a hardpan and greatly improve tilth. Incorporate green manures at least two weeks before planting vegetables. They should not be allowed to go to seed.

The “ideal” cover crop will:

- Establish satisfactory cover for soil erosion prevention over the winter.
- Add significant amounts of organic matter to the soil.
- Replace some of the fertilizer nitrogen requirement.

The following crops, which include both grasses and legumes, are possibilities for cover and/or green manure. The choice will be governed by (a) costs; (b) seeding date; (c) period of time allocated for growth; (d) vigor of establishment; (e) soil conditions and (f) eventual utilization.

Crop	Seeding Rate (lbs/A)	Comments
Winter Rye	100	First choice for gardeners for best cover. In spring may need to rototill early two-three times for complete kill.
Sweet Clover (white)	12	Excellent growth in second year after establishment. Needs relatively high pH (>6.0)
Oats		Seed in early spring or August for cover. Winterkills totally.
Hairy Vetch	40	Costly. Winterkills. Must seed in NH by Aug. 15 for good fall cover.
Wheat (spring & winter)	90	Spring wheat: Early planting important. Winter wheat: No vigor advantage over rye as a cover crop.
Buckwheat	75	Sow June 1 - July 15. Sensitive to drought. Reseed by discing after seed development. Rapid establishment.
Alfalfa	10	Long lived perennial. Slow cover establishment in fall with August seeding. Excellent N^2 fixation.
Red Clover	6	Good all-purpose legume for short term (2 yr.) Rotation. Sow by Aug. 20 for reasonable fall establishment.
Ladino Clover	2	Very slow to establishment. Low-growing perennial. Perhaps use for inter-row plantings. Sow by Aug. 15.
Japanese Millet	25	Used as summer annual. Rapid growth. Good organic matter source.
Sudan or Sorghum /Sudan hyb.	30-50	Excellent summer annual. May pose problems at plow-down due to biomass.
Perennial Ryegrass	30	Long-term cover crop. Some winterkill may occur.
Field Bromegrass	20	Permanent, vigorous grass cover. Reseed by discing after seed development.

The regular addition of manures, compost, cover crops, and other organic materials can raise the soil nutrient and physical level to a point at which the need for additional synthetic fertilizers is greatly reduced. This highly desirable soil quality does not come about with a single or even several additions of organic material, but rather requires a serious soil-building program.

Soil Testing

The purpose of a soil test is to supply the homeowner with enough information to make a wise fertilizer purchase. A soil test will provide information on buffer pH, soil pH, lime content, available phosphorus and potassium. The results of the soil test are mailed to the homeowner with recommendations as to what kind of fertilizer should be applied for economical growth of the desired crops. Soil tests should be performed if such tests have never been done before. A soil test need not be performed more often than every 3 to 4 years. The sample should be submitted in the fall, prior to planting or tilling, so that needed lime can be changing the pH over the winter. Fertilizers should be incorporated the next spring.

The accuracy of the soil test is a reflection of the sample taken. Be sure the sample is representative of the area to be treated. Sample the soil from 10 random areas of the garden to a depth of 6 to 12 inches. Avoid sampling unusual areas such as those near gravel roads, manure or compost spots, brush piles, or under eaves. Place the samples in a clean pail or container, and mix the soil thoroughly. Then transfer a pint of mixed soil to a container and take it to the local Extension office. Comparisons of results between home test kits, various state laboratories and commercial testing services cannot really be made because of varying extracting and analysis procedures.

Analysis and Use of Some Common Fertilizer Materials

Name of Material	Analysis $N-P_2O_5-K_2O$	Other Nutrients Supplied	Rate of Application: Dry (lbs/cu yd)*	Rate of Application: Liquid (lbs/100 gals)	Speed of Reaction	Effect on pH
Primary Fertilizers						
Ammonium sulfate $(NH_4)_2SO_4$	20-0-0	S	½-1 lb/100 sqft.	2-3	Rapid	Very Acid
Sodium Nitrate $NaNO_3$	15-0-0		¾-1¼ lb /100 sq ft	2 oz per 2 gal	Rapid	Basic
Calcium nitrate $Ca(NO_3)_2.2H_2O$	15-0-0	Ca	¾-1½ lb/100 sq ft	3 oz per 2 gal	Rapid	Basic
Potassium nitrate KNO_3	13-0-44		½-1 lb/100 sq ft	2 oz per 3 gal	Rapid	Neutral
Ammonium nitrate NH_4NO_3	33-0-0		¼-½ lb/100 sq ft	1¼ oz per 5 gal	Rapid	Acid
Urea $CO(NH_2)_2$	46-0-9		¼-½ lb/100 sq ft	1-1¼ oz /5-7 gal	Rapid	Sl. Acid
Mono-ammonium phosphate $NH_4H_2PO_4$	12-62-0		1 lb/100 sq ft	2 oz per 3 gal	Rapid	Acid
Di-ammonium phosphate $(NH_4)_2HPO_4$	21-53-0		½-¾ lb/100 sq ft	1¼-1½ oz/per 4-5 gal	Rapid	Acid
Treble superphosphate $Ca(H_2PO_4)_2$	0-40-0	Ca	1-2½ lb/100 sq ft	Insoluble	Medium	Neutral
Superphosphate $Ca(H_2PO_4)_2{}^+CaSO_4$	0-20-0	Ca+S	3-8 lbs.	Insoluble	Medium	Neutral
Potassium chloride KCl	0-0-60		½-¾ lb/100 sq ft	1¼-1½ oz/4-5 gal	Rapid	Neutral
Potassium sulfate K_2SO_4	0-0-50	S	½-1 lb/100 sq ft	Not advisable	Rapid	Neutral
Urea formaldehyde	38-0-0		3-5 lb/100 sq ft	Insoluble	Slow	Sl. Acid
Additives						
Limestone, Dolomitic	None	Ca+Mg	5-20 lb	Insoluble	Slow	Basic
Hydrated Lime $Ca(OH)_2$	None	Ca	2 lb/100 sq ft (Not advisable)	Relatively insoluble	Rapid	Basic
Gypsum (calcium sulfate) $CaSO_4$	None	Ca+S	2-5 lb/100 sq ft	Insoluble	Medium	Neutral
Sulfur	None	S	1-2 lb/100 sq ft	Insoluble	Slow	Acid
Epsom salts (magnesium sulfate) $MgSO_4.7H_2O$	None	Mg+S	8-12 oz/100 sq ft	1¼	Rapid	Neutral
Aluminum sulfate $Al_2(SO_4)_3$	None	S	1 tsp. per 6" pot (Not advisable)	20	Rapid	Very Acid

Name of Material	Analysis $N-P_2O_5-K_2O$	Other Nutrients Supplied	Rate of Application: Dry (lbs/cu yd)*	Rate of Application: Liquid (lbs/100 gals)	Speed of Reaction	Effect on pH
Complete						
Complete soluble (mixtures)	20-20-20 20-5-30 16-32-16	Var. Var.	Not advisable as dry	1½-2½ oz/3-5 gal	Rapid	Various
Complete dry (mixtures)	10-10-10 5-10-10	Var. Var.	2 lb/100 sq ft 2-3 lb/100 sq ft	Relatively insoluble Relatively insoluble	Various Various	Various Various
Organic	5-10-3	Var.	2-4 lb/100 sq ft	Relatively insoluble	Various	Various
Plastic coated pellets	Variable			Insoluble	Slow	Various
Magnesium ammonium phosphate	7-40-6	Mg		Insoluble	Slow	Neutral
Organics						
Activated sludge	Usually 5-4-0		3-5 lb/100 sq ft	Insoluble	Medium	Acid
Animal tankage	Usually 7-9-0		3-4 lb/100 sq ft	Insoluble	Medium	Acid
Castor pomace	5-1-1		3-5 lb/100 sq ft	Insoluble	Slow	-----
Cottonseed meal	7-2-2		3-4 lb/100 sq ft	Insoluble	Slow	Acid
Dried blood	12-0-0		2-3 lb/100 sq ft	Insoluble	Medium	Acid
Hardwood ashes	0-1-5		3-10 lb/100 sq ft	Insoluble	Medium	Basic
Hoof and horn metal	13-0-0		2-3 lb/100 sq ft	Insoluble	Slow	-----
Linseed meal	5-1-1		3-5 lb/100 sq ft	Insoluble	Slow	Acid
Seaweed (kelp)	Usually 2-1-15		2-3 lb/100 sq ft	Insoluble	Slow	-----
Soy bean meal	6-0-0		3-5 lb/100 sq ft	Insoluble	Slow	-----
Steamed bone meal	Usually 3-20-0		5 lb/100 sq ft	Insoluble	Slow	Basic
Trace						
$MnSO_4$		S	3-6 oz/100 sp. ft	-----		
$FeSO_4$		S	8-12 oz/100 sp. ft	-----		
Chelated iron (8-12%)		Fe	1-2 oz/100 sp. ft	¼		
Borax		B	½ oz/100 sp. ft			
$CuSO_4$		Cu+S	1-2 oz /100 sp. ft	-----		
FTE		many				

*These rates are also appropriate per 100 sq ft

Chapter 2
Soils and Fertilizer

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