Soil is a mixture of weathered rock fragments, organic matter and living organisms at the earth’s surface. The nonliving components are the minerals and “dead” organic matter. The living portion is biologically active — a home to countless microorganisms, invertebrates and plant roots. There can be over a billion living organisms in a teaspoon of healthy soil.

Soil varies in depth from a few inches to 25 feet or more. Pore spaces occupy approximately 50 percent of the total soil volume and form a complex network consisting of varying sizes, much like those in a sponge.

Soil provides nutrients, water and physical support for plants and air for plant roots. Soil organisms are nature’s primary recyclers, turning dead cells and tissue into available nutrients, energy, carbon dioxide and water to fuel new life.

### Soil temperature

Cold soil temperatures are a distinguishing feature of Alaska soils and a challenge to gardeners. Soil temperature cycles naturally vary throughout the different regions of Alaska, but at different times of the year and at different soil depths it can have a dominant effect on plant growth in most Alaska soils. Soil temperature affects seed germination, root growth, microbial activity and nutrient availability and uptake. Cold soils slow the establishment of young plants, reduce plant rooting depth — especially for trees and shrubs, restrict the decomposition of organic matter and the release of available nutrients, and limit the uptake of plant nutrients (especially phosphorus).
Soils and fertilizers terminology

**Aggregation**—The process by which individual particles of sand, silt and clay cluster and bind together to form peds.

**Anion**—A negatively charged ion. Plant nutrient examples include nitrate (NO$_3^-$), phosphate (H$_2$PO$_4^-$), and sulfate (SO$_4^{2-}$).

**Aspect**—Direction of exposure to sunlight.

**Biosolids**—A by-product of wastewater treatment (sewage sludge) sometimes used as a fertilizer.

**Capillary force**—The action by which water molecules bind to the surfaces of soil particles and to each other, thus holding water in fine pores against the force of gravity.

**Cation**—A positively charged ion. Plant nutrient examples include calcium (Ca$^{2+}$) and potassium (K$^+$).

**Cation exchange capacity (CEC)**—A soil’s capacity to hold cations as a storehouse of reserve nutrients. Sometimes referred to as the fertilizer bank.

**Clay**—The smallest type of soil particle (less than 0.002 mm in diameter).

**C:N ratio**—The ratio of carbon to nitrogen in organic materials. Materials with a high C:N ratio are good bulking agents in compost piles, while those with a low C:N ratio are good energy sources.

**Cold composting**—A slow composting process that involves simply building a pile and leaving it until it decomposes. This process may take months or longer. Cold composting does not kill weed seeds or pathogens.

**Compaction**—Pressure that squeezes soil into layers that resist root penetration and water movement. Often the result of foot or machine traffic.

**Compost**—The product created by the breakdown of organic waste under conditions manipulated by humans.

**Cover crop**—A crop that is dug into the soil to return organic matter and nitrogen to the soil. Also called green manure.

**Decomposition**—The breakdown of organic materials by microorganisms.

**Dolomitic lime**—Lime that is a mixture of calcium and magnesium carbonates.

**Fertilizer**—A natural or synthetic product added to the soil to supply plant nutrients.

**Fertilizer analysis**—The amount of nitrogen, phosphorus (as P$_2$O$_5$), and potassium (as K$_2$O) in a fertilizer expressed as a percent of total fertilizer weight. Nitrogen (N) always is listed first, phosphorus (P) second and potassium (K) third.

**Green manure**—Same as cover crop.

**Hot composting**—A fast composting process that produces finished compost in 6 to 8 weeks. High temperatures are maintained by mixing balanced volumes of energy materials and bulking agents, keeping the pile moist and turning it frequently to keep it aerated.

**Humus**—The end product of decomposed animal or vegetable matter.

**Immobilization**—The process by which soil microorganisms use available nitrogen as they break down materials with a high C:N ratio, thus reducing the amount of nitrogen available to plants.

**Infiltration**—The movement of water into soil.

**Ion**—An atom or molecule with either positive or negative charges.

**Leaching**—Movement of water and soluble nutrients down through the soil profile.

**Loam**—A soil with roughly equal influence from sand, silt and clay particles.

**Macropore**—A large soil pore. Macropores include earthworm and root channels and control a soil’s permeability and aeration.

**Micronutrient**—A nutrient used by plants in small amounts (iron, zinc, molybdenum, manganese, boron, copper and chlorine). Also called a trace element.

**Micropore**—A fine soil pore, typically a fraction of a millimeter in diameter. Micropores are responsible for a soil’s ability to hold water.
**Soils and fertilizers terminology (cont.)**

**Mycorrhizae**—Beneficial fungi that grow in association with plant roots and increase their ability to take up nutrients and water from the soil.

**Nitrifier**—A microbe that converts ammonium to nitrate.

**Nitrogen cycle**—The sequence of biochemical changes undergone by nitrogen as it moves from living organisms, to decomposing organic matter, to inorganic forms and back to living organisms.

**Nitrogen fixation**—The conversion of atmospheric nitrogen into plant-available forms by *Rhizobia* bacteria.

**Organic fertilizer**—A natural fertilizer material that has undergone little or no processing. Can include plant, animal and/or mineral materials.

**Organic matter**—Any material originating from a living organism (peat moss, compost, ground bark, manure, etc.).

**Pathogen**—A disease-causing organism. Pathogenic soil organisms include bacteria, viruses, fungi and nematodes.

**Ped**—A cluster of individual soil particles.

**Permafrost**—Permanently frozen soil.

**Permeability**—The rate at which water moves through a soil.

**pH**—A measure of acidity or alkalinity. Values from 0 to 7 indicate acidity, a value of 7 is neutral and values from 7 to 14 indicate alkalinity. Most soils in Alaska have a pH between 3.5 and 8. Most gardeners are working with a pH of 4 to 6.

**Phosphate**—The form of phosphorus listed in most fertilizer analyses (P₂O₅).

**Potash**—The form of potassium listed in most fertilizer analyses (K₂O).

**Primary nutrient**—A nutrient required by plants in a relatively large amount (nitrogen, phosphorus and potassium).

**Processed fertilizer**—A fertilizer that is manufactured or is refined from natural ingredients to be more concentrated and more available to plants.

**Quick-release fertilizer**—A fertilizer that contains nutrients in plant-available forms such as ammonium and nitrate.

**Rhizobia bacteria**—Bacteria that live in association with roots of legumes and convert atmospheric nitrogen to plant-available forms, a process known as nitrogen fixation.

**Rhizosphere**—The thin layer of soil immediately surrounding plant roots.

**Sand**—The coarsest type of mineral soil particle (0.05 to 2 mm in diameter).

**Secondary nutrient**—A nutrient needed by plants in a moderate amount (sulfur, calcium and magnesium).

**Silt**—A type of soil particle that is intermediate in size between sand and clay (0.002 to 0.05 mm in diameter).

**Slow-release fertilizer**—A fertilizer material that must be converted into a plant-available form by soil microorganisms.

**Soil**—A natural, biologically active mixture of weathered rock fragments and organic matter at the earth’s surface.

**Soil porosity**—A measure of the total air spaces in the soil.

**Soil salinity**—A measure of the total soluble salts in a soil.

**Soil solution**—The solution of water and dissolved minerals found in soil pores from which plants take up nutrients.

**Soil structure**—The arrangement of aggregates (peds) in a soil.

**Soil texture**—How coarse or fine a soil is. Determined by the percentages of sand, silt and clay in the soil.

**Soluble salt**—A compound often remaining in soil from irrigation water, fertilizer, compost or manure applications.

**Water-holding capacity**—The ability of a soil’s micropores to hold water for plant use.
Gardeners in Alaska often warm the soil in order to improve plant growth by using plastic mulches, raised beds, subsurface insulation, row covers and warm irrigation water. Some of these practices are discussed in more detail in other chapters of this manual. In the rest of this chapter, the effects of cold soil temperatures on different soil properties are frequently mentioned, along with their resulting effects on plant growth.

Permanently frozen soil, permafrost, is common in many areas of Alaska. Permafrost and the cold soil layers above it limit root growth, rooting depth and water availability. That is why the forest in permafrost areas has smaller trees. The permafrost layer begins to thaw when land is cleared of natural vegetation, and over time the active soil depth will increase. As soil depth increases, so will plant productivity. If cultivation of the soil ceases and natural vegetation returns, soils will become colder and permafrost can reform.

### Soil and water

**Soil pores, water and productivity**

A productive soil is both permeable to water and able to supply water to plants. A soil’s permeability and water-holding capacity depend on its network of pores:

- **Large pores** (*macropores*) control a soil’s permeability and aeration. Macropores include insect, earthworm and root channels. Because they are large, water moves through them rapidly by gravity. Rainfall and irrigation infiltrate into the soil and excess water drains through it.

- **Micropores** are fine soil pores, typically a fraction of a millimeter in diameter. They are responsible for a soil’s water-holding capacity. Like the fine pores in a sponge or towel, micropores hold water against the force of gravity. Much of the water held in micropores is available to plants, while some is held so tightly that plant roots cannot use it.

Soil that has a balance of macropores and micropores provides adequate permeability and water-holding capacity for good plant growth. Soils that contain mostly macropores drain readily but are droughty and need more frequent irrigation. Soils that contain mostly micropores have good water-holding capacity but take longer to dry out and warm up in the spring. Runoff of rainfall and irrigation water also is more likely on these soils. The total amount of pore spaces in the soil is its **porosity**.

**What affects soil porosity?**

Several soil properties affect porosity, including texture, structure, compaction, organic matter and living organisms. You can evaluate your garden soil with respect to these properties to understand how they affect its porosity. The only tools you need are your eyes, fingers and a shovel.

**Soil texture**

Texture describes how coarse or fine a soil is. The coarsest (largest) soil particles are sand. They are visible to the eye and give soil a gritty feel. Silt particles are smaller than sand — about the size of in-
individual particles of white flour. They give soil a smooth, floury feel. On close inspection, sand and silt particles look like miniature rocks (Figure 1).

Clay particles are the smallest — about the size of bacteria and viruses — and can be seen only with a microscope. They commonly have a flat, plate-like structure similar to a sheet of mica. Soils rich in clay feel very hard when dry, but are easily shaped and molded when moist.

Although all of these particles seem small, the relative difference in their sizes is quite large. If a typical clay particle were the size of a penny, a sand particle would be as large as a house.

*Soil porosity.* Pores between sand particles tend to be large, while those between silt and clay particles tend to be small. Sandy soils contain mostly macropores and have rapid permeability but limited water-holding capacity. Micropores predominate in soils containing mostly silt and clay, creating high water-holding capacity but reducing permeability.

Particle size also affects the surface area in a volume of soil. Surface area is important because surfaces are the most chemically and biologically active part of the soil. They hold plant nutrients, provide a home for microorganisms and bind contaminants. Clay particles have a very large surface area relative to their volume, so a small amount of clay makes a large contribution to a soil’s total surface area.

Nearly all soils contain a mixture of particle sizes, giving them a pore network containing a mixture of pore sizes (Figure 2). A soil with roughly equal influence from sand, silt and clay particles is called a *loam.*
Loams usually make good agricultural and garden soils because they have a balance of macropores and micropores. They usually have good water- and nutrient-holding capacity, along with moderate permeability.

A sandy loam is similar to a loam, except that it contains more sand. It feels gritty, yet has enough silt and clay to hold together in your hand. Sandy loams usually have low to moderate water- and nutrient-holding capacity and good permeability. Water will move easily into the soil when applied to the surface.

Silt loams are richer in silt and feel smooth rather than gritty. They are pliable when moist but not very sticky. Silt loams usually have high water-holding capacity, medium to high nutrient-holding capacity and low to moderate permeability. Heavy rain or excess irrigation water applied to the surface will have a tendency to run off before moving into the soil.

Clays and clay loams are very hard when dry and sticky when wet, and they can be molded into ribbons when moist. They have high water- and nutrient-holding capacity and low permeability. Very high clay soils are uncommon in Alaska.

Almost any texture of soil can be suitable for gardening, as long as you are aware of the soil’s limitations and adjust your management to compensate. Clay soils hold a lot of water, but they are hard to dig and dry slowly in the spring. Sandy soils need more frequent watering and lighter, more frequent fertilization, but you can plant them earlier in the growing season because they warm more rapidly in the spring. Many soils can benefit from additions of high-quality organic matter, as described below under the section “Adding organic matter.” The term organic matter covers an array of materials, and many of them help improve the balance between permeability and water-holding capacity in different types of soil.

Many soils contain coarse fragments, i.e., gravel and rocks. Coarse fragments do not contribute to a soil’s productivity and can be a nuisance when you are digging. Don’t feel compelled to remove them all from your garden, however. Coarse fragments aren’t harmful, and your time is often better spent doing other gardening tasks. Rocks are a problem when you have nothing but rocks and gravel on your land. Then water- and nutrient-holding capacities are so low that it is difficult to grow healthy plants.

**Soil structure**

*Peds* are soil aggregates that provide structure to the soil. They are made up of sand, silt and clay particles that cluster and bind together. Organic matter, microorganisms and roots provide the glues that help hold the peds together. Dig up a piece of grass sod and examine the soil around the roots. The granules of soil clinging to the roots are examples of peds. They contain sand, silt, clay and organic matter.

Aggregation is a natural process, caused largely by biological activity such as root growth, microbial action and earthworm burrowing. Soil organic matter is also an important binding agent that stabilizes and strengthens peds.

The macropores, or spaces between peds, improve permeability, drainage and recharge of air into the soil profile. The micropores, or pores within peds, contribute to the soil’s water-holding capacity. A well-structured soil is like a sponge, allowing water to enter and soak into the micropores and excess water to drain downward through the macropores. Good structure is especially important in medium- to fine-textured soils because it increases the soil’s large pore spaces, improving permeability and drainage. Excessive rototilling and discing can damage soil structure by break-
ing up the peds and reducing the number of both macro- and micropores. The soil is also more prone to erosion.

**Compaction and loss of structure**

Soil structure is fragile and can be damaged or destroyed by compaction, excessive tillage or tillage when the soil is too wet. Loss of organic matter also weakens structure.

Compaction squeezes macropores into micropores and creates horizontal aggregates that resist root penetration and water movement (Figure 3). Compaction often results during site preparation or house construction and from winter activities such as snow machining and dog mushing, creating a difficult environment for establishing plants. Protect your soil from compaction by avoiding unnecessary foot or machine traffic.

Tilling when soil is too wet also damages soil structure. If you leave footprints or can mold a piece of clay soil into a ribbon in your hand, it is too wet to till. If the soil crumbles when you try to mold it, it is dry enough to till.

Structural damage caused by human activity usually is most severe within the top foot of soil and can be overcome by proper soil management. In some soils there is deeper compaction, or hardpans, resulting from animals, machine traffic and factors like the pressure of previous glaciers. If your soil has a hardpan that cannot be broken up with tillage, consider using raised beds to increase soil depth.

**Organic matter**

Adding organic matter is the best way to improve the environment for plants in many soils. This is because organic matter plays a key role in almost all soil properties, whether they are physical, chemical or biological.

Soil organic matter can be divided into three pools: 1) The diverse array of living organisms, including plant roots — living organic matter, 2) “active” organic matter that is readily turned over or decomposed under favorable conditions (a half-life measured in months, or perhaps several years in Alaska) — dead organic matter and 3) **humus**, which is relatively stable and resistant to further decomposition (a half-life measured in hundreds of years) — very dead organic matter.

Living organisms feed on and decompose crop residues, manure, compost, organic mulches and other materials added to a garden. Dead but active organic matter is the main pool involved in the nutrient cycling carried out by living organisms. Very dead organic matter (humus) is a long-term nutrient source that also promotes good soil structure by acting as a glue to bind and strengthen soil aggregates.

Organic matter helps build and stabilize soil structure in fine-textured and compact-
ed soils, thus improving permeability and aeration and reducing the risk of runoff and erosion. Organic matter also helps sandy soils hold water and nutrients. See “Adding organic matter” later in this chapter for information on amending soil with organic matter.

**Slope, aspect, depth and water**

Slope, *aspect* (direction of exposure) and soil depth affect water availability and use in a soil. Choose plants that are best suited to conditions on your property.

Ridgetops and side slopes tend to shed water, while soils at the bottoms of slopes and in low areas collect water (Figure 4). Often, soils that collect water have high spring water tables, which can affect the health of some plants. Soils on ridgetops are more likely to be droughty.

Site aspect also is important. South- and southwest-facing exposures collect the most heat and use the most water.

Soil depth affects water availability by determining the rooting zone. Soil depth is limited by compacted, cemented or gravelly layers, or by bedrock. A shallow soil has less available water simply because the soil volume available to roots is smaller.

Dig below the topsoil in your garden. The deeper you can dig before hitting a restrictive layer, the greater the soil volume for holding water.

**Water management in your garden**

**Soils and irrigation**

Gardens in many regions of Alaska require summer irrigation. The need for irrigation varies, depending on soil water-holding capacity, weather, site aspect and the plants grown and their growth stage.

In most cases, the goal of irrigation is to recharge the available water in the top foot or so of soil. For sandy soil, one inch of irrigation water is all you need for a single watering. If you apply more, nutrients can leach down through the root zone with the excess water. A silt loam or clay soil can hold more than two inches of water, but you may need to irrigate more slowly to prevent runoff.

**Wet soils**

If your soil stays wet in the spring, you will have to delay tilling and planting. Working wet soil can damage its structure. Seeds are less likely to germinate and often rot in cold, wet soil.

Many plants don’t grow well in wet soil. Raspberries, for example, often become infected by root diseases in wet soil and lose vigor and productivity.

A soil’s color gives clues to its tendency to stay wet. If a subsoil is brown or reddish, the soil probably is well drained and has few wetness problems. Gray subsoils, especially those with brightly colored mottles, often are wet. If your soil is gray and mottled directly beneath the topsoil, it probably is saturated during the wet season.

A few simple actions can reduce the problems associated with soil wetness.

- Divert runoff from roof drains away from your garden.
- Avoid plants that perform poorly in wet conditions — these includes most common garden and landscape plants. Use native wetland species in wet areas.

![Figure 4.—Ridgetops and slopes tend to shed water; while soils at the bottoms of slopes and in low areas collect water.](image)
• Use raised beds for perennials that require well-drained soil and for early-season vegetables.
• Investigate whether a drain will remove excess water in your situation. Installing drainage can be expensive. When considering drainage, make sure there is a place to divert the excess water. Check with local regulatory agencies to see whether there are restrictions on the project.

Soil organisms

Soil abounds with life. Besides the plant roots, insects and earthworms you can see, soil is home to an abundant and diverse population of microorganisms. A single gram of topsoil (about ¼ teaspoon) can contain as many as a billion microorganisms (Table 1). Microorganisms are most abundant in the rhizosphere — the thin layer of soil surrounding plant roots.

The main function of soil organisms is to break down the remains of plants and other organisms. This process releases energy, nutrients and carbon dioxide and creates stabler forms of soil organic matter (humus).

Organisms ranging from tiny bacteria to insects and earthworms take part in a complex soil food web (Figure 5). Mammals such as voles (meadow mice) also are part of the food web.

Table 1.—Approximate abundance of microorganisms in agricultural topsoil.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Number per gram (dry weight basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>100 million to 1 billion</td>
</tr>
<tr>
<td>Actinomycetes</td>
<td>10 million to 100 million</td>
</tr>
<tr>
<td>Fungi</td>
<td>100,000 to 1 million</td>
</tr>
<tr>
<td>Algae</td>
<td>10,000 to 100,000</td>
</tr>
<tr>
<td>Protozoa</td>
<td>10,000 to 100,000</td>
</tr>
<tr>
<td>Nematodes</td>
<td>10 to 100</td>
</tr>
</tbody>
</table>

Figure 5.—The soil food web.
Some soil organisms play other beneficial roles. *Mycorrhiza* are fungi that form symbiotic associations with plant roots and increase their ability to take up nutrients and water from the soil. *Rhizobia* bacteria are responsible for converting atmospheric nitrogen to plant-available forms, a process known as *nitrogen fixation*. This symbiotic process is slowed considerably in cold soils and is less efficient in Alaska than in more temperate regions, where high populations of earthworms are present. Earthworms mix large volumes of soil and create macropore channels that improve permeability and aeration (Figure 6).

Not all soil organisms are beneficial. Some are *pathogens*, which cause diseases such as root rot of raspberries and scab on potatoes. Voles can damage crops and lawns, and slugs are a serious pest in many Alaska gardens, especially in higher rainfall areas like the Southeast. Slugs are becoming much more of a problem annually, even in moderate rainfall areas like the Kenai Peninsula.

The activity of soil organisms depends on soil moisture and temperature, as well as on the soil’s organic matter content. Most organisms prefer moist soil. Many soil organisms do not become active until soil temperature reaches 50°F and are most active when soil temperature is 70°F or higher. Cool soil temperatures often limit biological activity, including root growth, in Alaska soils. Because organic matter is at the base of the soil food web and is the ultimate source of energy in the soil ecosystem, soils with more organic matter tend to have more organisms.

The relationships between gardening practices, microbial populations and soil quality are complex and often poorly understood. Almost all gardening activities — including tillage, the use of fertilizers, manures and pesticides, and the choice of crop rotations — affect the population and diversity of soil organisms. For example, amending soils with organic matter, returning crop residues to the soil and rotating plantings tend to increase the number and diversity of beneficial organisms.

### Soil nutrients

Soil supplies 13 essential plant nutrients. Each mineral nutrient plays one or more specific roles in plants. Nitrogen, for example, is a component of chlorophyll, amino acids, proteins, DNA and many plant hormones. It plays a vital role in nearly all aspects of plant growth and development, and plants need a large amount of nitrogen to grow well. In contrast, plants only need a tiny amount of molybdenum, which is involved in the functioning of only a few plant enzymes. Molybdenum nonetheless is essential, and plant growth is disrupted if it is deficient. Plants also require carbon, hydrogen and oxygen, which they derive from water and air.

A soil nutrient is classified as a *primary nutrient*, *secondary nutrient*, or *micronutrient*, based on the amount needed by plants (Table 2). If a soil’s nutrient supply is deficient, fertilizers can provide the additional nutrients needed for healthy plant growth.
Nutrient deficiencies

The most common nutrient deficiencies are for the primary nutrients — N, P and K—which are in largest demand by plants. Nearly all soils in Alaska lack enough available N and P for ideal plant growth.

Secondary and other micronutrients also are deficient in some soils and for some crops in Alaska. Sulfur fertilizer is recommended for optimum growth of grain and forage crops in many areas. Calcium and magnesium may be deficient in acid soils, and boron and molybdenum are low in some Alaska soils. Boron deficiencies are most likely for sensitive crops like broccoli, cauliflower, beets, strawberries and rhubarb.

Each nutrient deficiency causes characteristic symptoms. In addition, affected plants grow more slowly, yield less and are less healthy than plants with adequate levels of nutrients.

Excess nutrients

Excess nutrients can be a problem for plants and the environment. Excesses usually result because too much of a nutrient is applied or because a nutrient is applied at the wrong time.

Too much boron is toxic to plants. Too much nitrogen can lead to excessive foliage production, increased risk of disease, wind damage and delayed flowering, fruiting and dormancy. Available nitrogen left in the soil at the end of the growing season has the potential under certain conditions to leach into groundwater and threaten drinking water quality.

The key to applying fertilizers is to meet plant needs without creating excesses that can harm plants or the environment.

Nutrient availability to plants

Plants can take up only nutrients that are in solution (dissolved in soil water). Most soil nutrients are not in solution; they are tied up in soil mineral and organic matter in insoluble forms. These nutrients become available to plants only after they are converted to soluble forms and dissolve into the soil solution.

This process occurs through weathering of mineral matter and biological decomposition of organic matter. Weathering of mineral matter is a very slow process that releases small amounts of nutrients each year. The rate of nutrient release from soil organic matter is somewhat faster and depends on the amount of biological activity in the soil.

Nutrient release from soil organic matter is fastest in warm, moist soil. Thus, the seasonal pattern of nutrient release is similar to the pattern of nutrient uptake by plants. About 1 to 4 percent of the nutrients in soil organic matter are released in soluble form each year. Alaska soils are at the lower end of this range, due to cool soil temperatures.

Soluble, available nutrients are in ionic chemical form. An ion has either positive

<table>
<thead>
<tr>
<th>Table 2.—Essential plant nutrients.</th>
</tr>
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<tbody>
<tr>
<td><strong>Name</strong></td>
</tr>
<tr>
<td>Primary nutrients</td>
</tr>
<tr>
<td>Nitrogen</td>
</tr>
<tr>
<td>Phosphorus</td>
</tr>
<tr>
<td>Potassium</td>
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<tr>
<td>Secondary nutrients</td>
</tr>
<tr>
<td>Sulfur</td>
</tr>
<tr>
<td>Calcium</td>
</tr>
<tr>
<td>Magnesium</td>
</tr>
<tr>
<td>Micronutrients</td>
</tr>
<tr>
<td>Zinc</td>
</tr>
<tr>
<td>Iron</td>
</tr>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Manganese</td>
</tr>
<tr>
<td>Boron</td>
</tr>
<tr>
<td>Molybdenum</td>
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<tr>
<td>Chlorine</td>
</tr>
</tbody>
</table>

See Chapter 1, Botany Basics.

See Chapter 7, Your Yard and Water Quality.
or negative charge. Positively charged ions are cations and negatively charged ions are anions. Potassium (K\(^+\)), calcium (Ca\(^{++}\)) and magnesium (Mg\(^{++}\)) are examples of nutrient cations. The nitrate (NO\(_3^-\)) form of nitrogen is an example of a nutrient anion.

Clay particles and soil organic matter have negative charges on their surfaces and can attract cations. They hold nutrient cations in a ready reserve form that can be released rapidly into soil solution to replace nutrients taken up by plant roots. This reserve supply of nutrients contributes to a soil’s fertility. A soil’s capacity to hold cations is called its cation exchange capacity or CEC. In addition to nutrient retention, CEC affects pH buffering capacity and the amount of lime required to change the pH of an acid soil.

**The nitrogen cycle**

Managing nitrogen is a key part of growing a productive and environmentally friendly garden. Nitrogen is the nutrient needed in the largest amount by plants, but excess nitrogen can harm plants and degrade water quality. Some forms of nitrogen can easily be lost to the air through volatilization when soil temperatures are warm. Other forms can be lost in water runoff, leaching and snow melt. Understanding how the nitrogen cycle affects nitrogen availability can help you become a better nutrient manager (Figure 7).

Nitrogen is found in four different forms in the soil (Table 3). Only two of them — ammonium and nitrate — can be used directly by plants.

Most nitrogen in soil is tied up in organic matter in forms such as humus and proteins. This organic nitrogen is not available to plants. As soil warms in the spring, soil microbes begin breaking down organic matter, releasing some of the nitrogen as ammonium (NH\(_4^+\)). Ammonium is a soluble cation that is available to plants and soil microbes. When the soil is warm, a group of microbes called nitrifiers convert the ammonium to nitrate (NO\(_3^-\)). Nitrate also is soluble and available to plants. The ammonium and nitrate ions released from soil organic matter, manure or compost are the same as the ammonium and nitrate contained in processed fertilizers.

Because nitrate has a negative charge, it is repelled rather than held by the surface of negatively charged clay or organic matter particles and can be lost by leaching. Nitrate remaining in the soil at the end of the growing season may leach during the fall or spring and has the potential under certain soil conditions to reach groundwater and become a contaminant. In soils that are saturated during the wet season, soil microbes convert nitrate to nitrogen gases, which diffuse back into the atmosphere.

Ammonium and nitrate taken up by plants are converted back to organic forms in plant tissue. When plant residues are returned to the soil they decompose, slowly releasing nitrogen back into available forms. In Alaska, this natural process of biological decomposition and nutrient cycling can be very slow since cold soils limit microbial activity.

The nitrogen cycle can be a leaky one, with losses to leaching and to the atmosphere. Harvesting crops also removes nitrogen. To maintain an adequate nitrogen supply, nitrogen must be added back into the system through fixation or fertilization.

Nitrogen fixation is a natural symbiotic process involving certain plants and Rhizobia bacteria. The Rhizobia form nodules on
the plant roots, and through these nodules they are able to take atmospheric nitrogen (N₂ gas) from the soil air and convert it to available nitrogen within the plant. This process is limited by cold soil temperatures, which is one reason why many legumes do not establish well in Alaska.

Legumes such as peas, beans and clovers are nitrogen-fixing plants. Growing legumes as cover crops is a good way to supply nitrogen to future crops, but its effectiveness depends on cover crop selection (must break down easily), how fine the cover crop is chopped prior to incorporation, the amount
You can check whether nitrogen fixation is occurring by looking for nodules on the roots of nitrogen fixing plants. Cut the nodules in half with a knife and look at the plant tissue. The inside of the nodule will be red if nitrogen fixation is occurring.

Soils in Alaska often do not have the Rhizobia bacteria needed to form the symbiotic nitrogen fixing nodules. Seed can be inoculated before planting with the species of bacteria it needs. Different types of Rhizobia bacteria are needed for different species of legumes. Garden inoculum for beans and peas can be purchased at some garden centers and nurseries. The inoculum is made up of living organisms; it has a short storage life and should be stored in a cool place until used.

Understanding fertilizers

Fertilizers supplement a soil’s native nutrient supply. They are essential to good plant growth when the soil nutrient supply is inadequate. Rapidly growing plants such as annual vegetable crops generally need more nutrients than slowly growing plants such as established perennials.

You can use processed fertilizers, organic fertilizers or a combination of the two to supply soil nutrients.

Comparing processed and organic fertilizers

Processed fertilizers are manufactured or are refined from natural ingredients to make them more concentrated and more available to plants (Table 4). Typically, the nutrients are processed into soluble, ionic forms that are immediately available to plants.

Organic fertilizers are natural materials that have undergone little or no processing. They include both biological (plant and animal) and mineral materials (Table 4). Once in the soil, organic fertilizers release nutrients through natural processes, including biological breakdown of organic matter and chemical weathering of mineral materials. The released nutrients are available to plants in water-soluble forms. These soluble forms of nutrients are the same as those supplied by processed fertilizers.

When compared with processed fertilizers, organic fertilizers usually have a lower concentration of nutrients and release nutrients more slowly. Thus, larger amounts of organic fertilizers are needed, but their effects last longer. In addition, using organic fertilizers is a way to recycle materials that otherwise would be discarded as wastes.

Choosing organic fertilizers involves trade-offs in cost or convenience. Farmyard manure usually is inexpensive or free, where it is available, but can be inconvenient and costly to apply, and it may introduce unwanted weed seeds. Packaged organic blends, on the other hand, are convenient but often expensive. The price per unit of nutrient can be very high.

---

**Table 3.—Common forms of nitrogen in soil.**

<table>
<thead>
<tr>
<th>Form of nitrogen</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic N</td>
<td>Primary form of N in soil. Found in proteins, lignin, amino acids, humus, etc. Not available to plants. Mineralized to ammonium by soil microorganisms.</td>
</tr>
<tr>
<td>Atmosphere N (N₂)</td>
<td>Makes up about 80 percent of the soil atmosphere. Source of N for N-fixing plants. Not available to other plants.</td>
</tr>
</tbody>
</table>
Nutrient release

Nutrients in most processed fertilizers are available immediately. Processed fertilizers can furnish nutrients to plants in the spring before the soil is warm enough for breakdown and release of nutrients from organic nutrient sources. This can be especially important for phosphorus in Alaska’s cold soils. Do not apply fertilizer to a garden too early, however, because nitrogen may move below the root zone where plants no longer can use it, or it may leach into groundwater under some conditions. It is important to note that leaching and unwanted N movement is possible from both organic and commercially synthesized fertilizers. That is why calibration of fertilizer equipment and accurate fertilizer application is so important, no matter what type of fertilizer is used.

Organic fertilizers are slow-release fertilizers because their nutrients become available to plants over the course of the growing season. The rate of nutrient release from organic materials depends on the activity of soil microorganisms, just as it does for nutrient release from soil organic matter. Temperature and moisture conditions that favor plant growth also favor the release of nutrients from organic matter.

Some organic fertilizers contain immediately available nutrients as well as slow-release nutrients. These fertilizers can supply nutrients to plants both early in the season and later. Fresh manure and fish meal are examples of organic fertilizers containing available nutrients. As manure ages, the most readily available nutrients are often lost into the air or leached into the soil, leaving only slow-release material in the aged manure.

Some material in organic fertilizers breaks down so slowly that it is not available the first season after application. Repeated application of organic fertilizers builds up a pool of material that releases nutrients very slowly. In the long run, this nutrient supply decreases the need for supplemental fertilizer.

Fertilizer labels

The labels on fertilizer packages tell the amount of each of the three primary nutrients in the fertilizer, expressed as a percent of total fertilizer weight. Nitrogen (N) is always listed first, phosphorus (P) second and potassium (K) third.

Historically, the amount of phosphorus in fertilizer has been expressed not as P, but as units of P₂O₅ (phosphate). Similarly, fertilizer potassium is expressed as K₂O (potash).
This practice still is used for fertilizer labels and recommendations, even though there is no practical reason for the system except that people are accustomed to it. If you need to convert from P to P$_2$O$_5$, the conversion is 1 pound P = 2.3 pounds P$_2$O$_5$. For potassium, the conversion is 1 pound K = 1.2 pounds K$_2$O.

Thus, a bag of fertilizer labeled 5-10-10 contains 5 percent nitrogen, 10 percent phosphorus expressed as P$_2$O$_5$ and 10 percent potassium expressed as K$_2$O. This information is called the fertilizer analysis, or fertilizer grade. The total percentage of nutrients in this labeled fertilizer is 25. The other 75 percent of the product is the carrier.

The analysis for processed fertilizers guarantees the amount of available nutrients in the fertilizer. The analysis for organic fertilizers represents the total amount of nutrients rather than available nutrients. Because nutrients in most organic fertilizers are released slowly, the amount of immediately available nutrients is less than the total. How quickly nutrients are released is determined by the composition of the organic fertilizer and by the temperature, moisture and the biological activity in the soil.

### Table 5.—Examples of processed nitrogen fertilizer materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Analysis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>46-0-0</td>
<td>Rapidly converted to ammonium in soil.</td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>21-0-0</td>
<td>Also contains 24 percent available sulfur. Used with acid-loving plants.</td>
</tr>
<tr>
<td>Diammonium phosphate</td>
<td>18-46-0</td>
<td>Used in mixed fertilizers as a source of nitrogen and phosphorus.</td>
</tr>
<tr>
<td>Sulfur-coated urea (SCU)</td>
<td>35-0-0</td>
<td>Sulfur coating slows release of available N, making this a slow-release fertilizer.</td>
</tr>
</tbody>
</table>

### Common processed fertilizers

#### Nitrogen

The raw material for processed nitrogen fertilizer is nitrogen gas from the atmosphere. The manufacturing process is the chemical equivalent of biological nitrogen fixation and requires a substantial amount of fuel energy. Examples of processed nitrogen fertilizers available for home garden use or lawn and garden fertilizer blends include those listed in Table 5.

#### Phosphorus and potassium

Processed phosphorus fertilizers come from phosphate rock. The rock is treated with acid to release phosphorus into plant-available forms.

The most common raw material for potassium fertilizers is sylvinite, a mixture of sodium chloride and potassium chloride salts. The potassium in sylvinite already is in soluble form, but the sylvinite is treated to remove the sodium salts to make it suitable for use as a fertilizer. Some other potassium fertilizers are potassium sulfate salts, which supply sulfur as well as potassium.

Table 6 lists examples of processed phosphorus and potassium fertilizers.

### Complete fertilizers

Complete fertilizers contain all three primary nutrients. The ratios can vary. Fertilizers for annual gardens typically have
N:P₂O₅:K₂O ratios in the range of 1:1:1 or 1:2:2. Examples include 16-16-16 and 10-20-20. Fertilizer blends for starting or transplanting plants usually have a higher proportion of phosphorus, such as 15-30-15 or 8-32-16. Lawn fertilizers, 22-4-4 for example, are higher in nitrogen.

### Common organic fertilizers

#### Animal manure and compost

Farmyard and horse manure can be an inexpensive source of nutrients where available. If you or your neighbors have livestock, it makes environmental and economic sense to recycle the manure as fertilizer. Packaged manure products cost more than manure off the farm, but they usually are more uniform and convenient to handle.

Animal manures vary widely in nutrient content and nutrient availability, depending on the type of animal that produced the manure and the age and handling of the manure. For example:

- Fresh manure has higher levels of nutrients than aged manure.
- Manure diluted with large amounts of bedding has fewer nutrients than undiluted manure.
- Exposure to rain leaches nutrients.
- Composting under cover retains more nutrients but reduces nutrient availability.

Table 7 compares average nutrient contents of typical manure products.

Fresh manure can carry disease-causing pathogens and weed seeds. Be sure to read the sidebar on manure safety before using fresh manure. Composting can kill pathogens and seeds. In a home composting situation, it is hard to ensure that all areas of the compost pile reach the required temperature to kill all weed seeds and pathogens.

It takes larger amounts of aged, diluted or leached manure to provide the same amount of nutrients as fresh manure. Increase the amount of manure applied based on how much it is aged, diluted and/or leached.

Composted manures have low nutrient availability, so you can apply them at higher rates than fresh manure. Use these manures as much for the organic matter they supply as for nutrients. To use manure or compost, spread it over the surface of the soil and turn it in 4 to 6 inches. Compost can also be used as a 1- to 2-inch mulch.
**Timing manure applications**

Manure or compost can be applied in the spring before planting or the preceding fall. Fall-applied manure should be incorporated early in the season to prevent nutrient losses.

**Biosolids**

Biosolids (sewage sludge) are a by-product of wastewater treatment. Some of the biosolids in Alaska are composted into a soil amendment and available to gardeners and landscapers. The composting process is done according to the standards of the Environmental Protection Agency and is monitored for safety by the Alaska Department of Environmental Conservation. Like other composts, biosolids release nutrients very slowly. They are a good source of organic matter and provide small amounts of nutrients to plants.

Biosolids contain small amounts of trace elements. Some trace elements are micro-nutrients, which can be beneficial to crops. However, large amounts can be toxic to crops, animals and humans. When you apply approved biosolids at proper rates to provide nutrients, the risk of applying harmful amounts of trace elements is negligible.

Because biosolids come from the wastewater treatment process, they contain synthetic materials that were present in the wastewater or added during treatment. Biosolids are not certified as organic fertilizers.

**Using manure safely**

Fresh manure sometimes contains disease-causing pathogens that can contaminate garden produce. *Salmonella* bacteria are among the most serious pathogens found in animal manure. Pathogenic strains of *E. coli* bacteria also can be present in cattle manure. Manure from swine, dogs, cats and other carnivores can contain *helminths*, which are parasitic worms.

These pathogens are not taken up into plant tissue, but they can adhere to soil on plant roots, leaves, fruit of low-growing crops or roots. The risk is greatest for root crops (e.g., carrots and radishes) or leaf crops (e.g., lettuce) where the edible part touches the soil. The risk is negligible for crops that do not contact the soil or for any crop that is thoroughly cooked. Avoid using fresh manure where you grow high-risk crops.

Cooking destroys pathogens, but raw food carries a risk. Washing and peeling raw produce removes most pathogens, but some may remain.

Composting manure at high temperatures kills pathogens, but it is very hard to maintain rigorous composting conditions in a backyard pile. Commercial manure composts are composted under controlled conditions to destroy pathogens.

Bacterial pathogens die naturally over a period of weeks or months, so well-aged manure should not contain them. Helminths in dog, cat or pig manure can persist for years, however, so do not add these manures to your garden or compost pile.
Commercial organic fertilizers

Many organic by-products and some unprocessed minerals are sold as organic fertilizers. Table 8 shows approximate nutrient contents of some of these materials. The numbers represent total nutrient content; because most are slow-release fertilizers, not all of the nutrients are available the year they are applied.

Table 8 shows that most organic fertilizer materials contain one main nutrient, with other nutrients present in smaller amounts. Thus, although organic fertilizers contain a variety of nutrients, they may not be present in the proportions needed by plants. Several companies produce balanced organic fertilizers by blending these materials into a single product that provides all of the primary nutrients in balanced proportions.

Commercial organic fertilizers tend to be more expensive per pound of nutrients than either processed fertilizers or farm manures. Sometimes the difference in price is substantial. Nevertheless, many gardeners use these products because of convenience or quick availability of some of the nutrients. They are most economical for small gardens where little fertilizer is needed.

The cost per pound of nutrients in organic fertilizers varies widely, depending on the type of material, the concentration of nutrients and the package size. Compare costs and nutrient availability when shopping for organic fertilizers. Add the percentages on the label to determine the cost per nutrient.

### How much fertilizer to use

The goal of applying fertilizer is to supply enough nutrients to meet plant needs without accumulating excess nutrients in the soil that could leach into groundwater or run off into surface water. Soil tests are a standard method for estimating fertilizer needs.

#### Table 8.—Total nitrogen, phosphate and potash content of some organic fertilizers.

<table>
<thead>
<tr>
<th>Material</th>
<th>Nitrogen (%)</th>
<th>P₂O₅ (%)</th>
<th>K₂O (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cottonseed meal¹</td>
<td>6–7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Blood meal²</td>
<td>12–15</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>Bat guano³</td>
<td>10</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Fish meal¹</td>
<td>10</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Fish emulsion¹</td>
<td>3–5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bone meal</td>
<td>1–4</td>
<td>12–15</td>
<td>0</td>
</tr>
<tr>
<td>Rock phosphate²</td>
<td>0</td>
<td>25–30</td>
<td>0</td>
</tr>
<tr>
<td>Greensand</td>
<td>0</td>
<td>3–7</td>
<td></td>
</tr>
<tr>
<td>Kelp meal</td>
<td>1</td>
<td>0.1</td>
<td>2–5</td>
</tr>
<tr>
<td>Spent brewery grain³</td>
<td>0.9–4.1</td>
<td>0.1–0.6</td>
<td>0.02–0.7</td>
</tr>
<tr>
<td>White cod bone meal⁴</td>
<td>5–6</td>
<td>6–8</td>
<td>0.5</td>
</tr>
</tbody>
</table>

¹Contains a substantial amount of quickly available nitrogen that plants can use early in the season.
²Very low P availability (only 2–3 percent). Useful only in acid soils.
³Low values from Alaska microbrewers. High values from a large Alaska brewery.
⁴Produced in Alaska.

### Soil tests

A soil test gives information on the levels of nutrients in your soil and recommends how much fertilizer to add each year based on the test results and the crops you grow. You don’t need to test your soil every year; every 3 to 5 years is often enough.

A garden soil test for Alaska should include the plant nutrients ammonium nitrogen, nitrate nitrogen, phosphorus and potassium, as well as soil pH and a buffer pH that is used to determine how much lime is required to raise pH, if that is necessary. For greenhouse and potting soils, a test for soluble salts or the electrical conductivity (EC) is also helpful.

To take a soil sample, first collect subsamples from at least 5 to 10 different spots in your garden or lawn, depending on the size of the area. Avoid any unusual areas, such as the site of an old trash dump, burn pile or rabbit hutch. Sampling depth
depends upon what is being grown. For gardens and lawns before seeding, collect a sample from 0 to 6 inches deep. Sample established lawns to a depth of 3 to 4 inches and trees and shrubs to a depth of 10 to 12 inches. Air-dry the samples and mix them together well. Send about a pint of the mixed sample to the lab.

Because management and fertilizer recommendations vary for different crops, such as vegetables, lawns and flowers, send separate samples for each area.

The University of Alaska Fairbanks (UAF) Agricultural and Forestry Experiment Station, Soil and Plant Analysis Laboratory in Palmer does soil tests for garden soils. You can obtain sample forms from your district Extension office. Results are sent to your district Extension agent, who will provide you with fertilizer recommendations. There are no private soil testing laboratories in Alaska. Out-of-state laboratories can be used if their soil testing methods are suitable for Alaska soils. See the UAF Cooperative Extension Service publication FGV-00045, *Factors to Consider in Selecting a Soil Testing Laboratory*, for more information on this topic. Testing prices vary, so it pays to shop around.

**General guidelines**

If you do not have a soil test, a general fertilizer recommendation for an established Alaska garden is to apply 0.5 pound of nitrogen per 100 square feet of garden area, 1 pound of phosphate/100 square feet, and 1 pound of potash/100 square feet. Fertilizer rates twice as high may be needed for a first-year garden. This can be applied as a mixed fertilizer with a 1:2:2 ratio, such as 10-20-20.

Newly cleared land may need extra phosphorus, and a general recommendation is to apply 4.5 pounds of 8-32-16 plus 0.75 pound of 34-0-0 (ammonium nitrate) or 0.5 pound of 46-0-0 (urea) per 100 square feet.

**Calculating fertilizer amounts**

Fertilizer recommendations usually are given in pounds of nutrient (such as nitrogen) per unit area (typically 100 square feet for gardens or 1,000 square feet for lawns). You will need to convert the recommendation from pounds of nutrient to pounds of fertilizer.

Example: You are following a fertilizer recommendation that calls for adding 0.5 pound of N per 100 square feet of garden, 1 pound of phosphate/100 square feet and 1 pound of potash/100 square feet. Follow these steps to find out how much fertilizer to use:

1. **Choose a fertilizer with an appropriate analysis.** Commonly available garden fertilizers include 16-16-16, 10-20-20 and 8-32-16. In this case, the 10-20-20 fertilizer matches the desired NPK ratio of 1:2:2.

2. **Calculate how much 10-20-20 is needed for 100 square feet.** Divide the amount of nitrogen recommended for 100 square feet (0.5 pound) by the fraction of nitrogen in the fertilizer (10% or 0.10):

   \[
   0.5 \text{ lb} \div 0.10 = 5 \text{ lb of 10-20-20 per 100 sq ft}
   \]

3. **Calculate the area of your garden.** If it is a rectangle, the area is length times width. For example, a garden 25 feet long by 20 feet wide has an area of:

   \[
   25 \text{ ft} \times 20 \text{ ft} = 500 \text{ sq ft}
   \]

If your garden is an odd shape, divide it into rectangles, calculate the area...
of each rectangle and then add them together.

4. **Calculate the amount of fertilizer needed for your garden.** Divide the area of your garden (500 square feet) by the area in the fertilizer recommendation (100 square feet). Then multiply by the fertilizer amount calculated in Step 2 above:

\[(500 ÷ 100) \times 5 = 25\text{ lb of 10-20-20 fertilizer}\]

This is the amount of fertilizer needed for your garden.

**Estimating organic fertilizer rates**

Deciding how much organic fertilizer to use can be a challenge because you must estimate the availability of the nutrients in the fertilizer. Here are some general guidelines for estimating and modifying organic fertilizer rates:

- Organic fertilizers with large proportions of available nutrients (such as blood meal and fish emulsion) can be substituted for processed fertilizers on a one-to-one basis. Use the same quantity as called for in the processed fertilizer recommendation.
- Apply other packaged fertilizers according to their nutrient availability. Composts, rock phosphate and plant residues generally have lower nutrient availability than more concentrated animal products (e.g., blood meal, bone meal and chicken manure). The recommended application rates on packaged organic fertilizers are a good guideline. Check these recommendations against other products to make sure they seem reasonable.
- Nutrient concentration and availability in manures vary widely, depending on the type of manure and its age and handling.
- Nutrient concentration and availability in composts are lower than in manures and depend on the type of materials composted.
- Follow these general guidelines for applying manure or compost to gardens. Fresh manure: one to two 5-gallon buckets/100 square feet; aged manure: two to four 5-gallon buckets/100 square feet; and compost: four to six 5-gallon buckets/100 square feet. Experiment with the amount you apply and observe your crops’ performance.
- Organic fertilizer may not contain nutrients in the exact ratios your soil and crops need. Fish bone meal, for example, is very low in potassium. You may need to use several different organic nutrient sources to supply the correct balance of nutrients to your garden.
- Observe your crops carefully. Lush plant growth and delayed flowering and fruiting are signs of a high amount of available nitrogen and may indicate over-fertilization.
- Experiment with different fertilizer rates in different parts of a row and see whether you notice differences in crop performance. Plan your experiment carefully so you are confident that differences are the result of different fertilizer rates, rather than differences in soil, water, sunlight or management practices.
- Soil testing is valuable in understanding your soil’s nutrient status. Some established gardens have been built up to high levels of soil fertility and crops grow well with lower rates of fertilizer than recently cleared garden sites.
When to fertilize

In most cases, the best time to apply fertilizer is close to the time when plants need the nutrients. This timing reduces the potential for nutrients to be lost before they are taken up by plants.

Plants need the largest amount of nutrients when they are growing most rapidly. Rapid growth occurs in early summer for potatoes, earlier for spring plantings of lettuce and other greens. Plants also need available nutrients (especially phosphorus) shortly after seeding or transplanting.

For perennial plants, timing depends on the type of plant and its growth cycle. Perennial flowers, for example, benefit most from fertilizer applied early in the season at bud break, while June-bearing strawberries are commonly fertilized after harvest.

Adding organic matter

Organic matter builds and stabilizes soil structure, thus reducing erosion and improving soil porosity, infiltration and drainage. It holds water and nutrients for plants and soil organisms. It also is a long-term, slow-release storehouse of nitrogen, phosphorus and sulfur, which continuously become available as soil microorganisms break down organic matter.

The nutritive value of organic materials varies, depending on the nitrogen content or, more specifically, the carbon to nitrogen ratio (C:N). Organic materials with a low C:N ratio, such as undiluted manure or blood meal, are rich in nitrogen. They are a good source of nutrients but must be used sparingly to avoid over-fertilization and salt problems.

Materials with an intermediate C:N ratio (including many composts, leaf mulches and cover crop residues) have lower nutrient availability. They are the best materials to replenish soil organic matter. Because they are relatively low in available nutrients, you can add them to the soil in large amounts.

Materials with a high C:N ratio (such as straw, bark and sawdust) contain so little nitrogen that they reduce levels of available nitrogen when mixed into the soil. Soil microorganisms use available nitrogen to break down these materials, leaving little nitrogen for plants. This process is called immobilization and results in nitrogen deficiency. If you use materials with a high C:N ratio in your garden, add extra nitrogen fertilizer to compensate for immobilization. The best uses for these materials are mulching around perennial plants or in walkways, or as carbon sources in a compost pile. They do not cause a large amount of immobilization until you mix them into the soil.

Gardening references often suggest adding peat moss to increase the organic matter content of a soil. Many processed “topsoils” in the Anchorage area contain 40 to 60 percent organic matter. Frequently, this organic matter is peat moss. Where such topsoils are used, the application of additional peat moss is unnecessary.

Organic materials like sphagnum peat moss are very stable and resistant to decomposition. This prolongs their effect on physical properties of the soil, for example, by increasing water-holding capacity. It also means that peat moss does not enter into soil nutrient cycles and or stimulate microbial activity in the same way as organic amendments like compost and manure.
Sphagnum peat moss has a pH of 4.0–4.5, so large amounts will acidify the soil.

**Compost**

Compost is an excellent source of organic matter for garden soils. Composting also closes the recycling loop by turning waste materials into a soil amendment. You can make compost at home or buy commercially prepared compost.

**Making compost**

The key to composting is to supply a balance of air, water, easily degraded materials (those with a low C:N ratio, such as grass clippings, green garden trimmings or fresh manure) and bulking agents (materials with a high C:N ratio, such as straw and woody materials). You don’t need additives to stimulate your compost pile. You just need to provide conditions favorable for natural composting organisms. The microbes needed for composting are in the air or on the material to be composted. The best way to “inoculate” a compost pile is by adding soil or some compost from your last batch.

Home composting can be done in hot or cold piles, in worm bins or in soil trenches:

- **Hot (fast) composting** can produce useable compost in 5 to 8 weeks. Additional curing time may be required for mature, finished compost, but partially decomposed material suitable for use in the garden can be made in less time.
- **Cold (slow) composting** requires less work than hot composting. Build the pile and leave it until it decomposes. This process, also referred to as passive composting, will take months or longer. Cold composting does not kill weed seeds or pathogens. Bears, dogs and other pests can be attracted to edible wastes in cold compost piles.
- **You can compost noncitrus fruit and vegetable scraps in a worm bin.** This method works well for urban gardeners who have little space. See UAF Cooperative Extension publication HGA-01020, *Composting with Worms*.
- **You can bury fruit and vegetable scraps and allow them to decompose in the soil.**

**Commercial and municipal compost**

Commercial and municipal compost may contain yard debris, animal manure, biosolids, food waste, fish waste and wood waste. Commercial and municipal composting is usually on a large scale, with frequent aeration and/or turning to create conditions that kill weed seeds, plant pathogens and human pathogens.

**Using compost**

Adding 1 to 2 inches of compost each year helps build a productive garden soil.

You can till or dig compost directly into your garden or use it as a mulch before turning it into the soil. One cubic yard of compost covers about 300 square feet 1 inch deep.

In the first year after application, partially decomposed woody compost may immobilize some soil nitrogen, resulting in nitrogen deficiency for plants. If plants show signs of nitrogen deficiency (e.g., poor growth or yellow leaves), add extra nitrogen fertilizer (either organic or inorganic). In following years, most compost contributes small amounts of available nitrogen to the soil.
Cover crops and green manure

Green manures are cover crops grown specifically to be tilled or dug into the soil. Planting green manure crops is a way to grow your own organic matter. The value of cover crops goes beyond their contribution of organic matter, however. They also can do the following:

- Capture and recycle nutrients that otherwise would be lost by leaching.
- Protect the soil surface from rainfall impact.
- Reduce runoff and erosion.
- Suppress weeds.
- Supply nitrogen (legumes only).

No single cover crop may provide all of these benefits, but many serve more than one purpose. Deciding which cover crop or combination to grow depends on which benefits are most important to you and on what grows well in your part of Alaska. Climatic differences are an important variable and many popular cover crops in other areas, such as hairy vetch, are not suitable for Alaska.

The most successful cover crops in Alaska have been spring and summer planted cover crops. Spring grains like oats, barley and rye, or buckwheat for a summer green manure, are the most reliable. Other potential summer cover crops include ryegrass, field peas and red clover. Problems occur with spring grains when they are allowed to grow too long because of the long period of time it takes to break down crowns and the plugging up of equipment that results.

Most winter cover crops are not reliably hardy in Alaska. Winter rye has been successful in some locations, but other trials have suffered from severe winterkill. If you want to try winter rye in your area, use a very hardy variety such as ‘Bebral,’ which was developed at the Plant Materials Center in Palmer, Alaska.

Alaska is large and the suitability of specific cover crops for different parts of the state is naturally quite variable. Experiment on a small scale to see if a specific cover crop will work before planting a large area. Remember that a cover crop must be managed like any other crop to be successful. Some general guidelines for successful use of cover crops include the following:

- Till them into the soil before they flower. Cover crops can become a weedy pest if allowed to go to seed. Crowns are slow to degrade and difficult to work into the soil if they become too large.
- Legumes such as red clover need an early start to achieve enough growth to cover the soil before cold weather arrives. Many legumes are not winter hardy in Alaska, although winter persistence is unnecessary if they are used as summer cover crops.
- Quality of the cover crops is affected by age and timing of tillage. After flowering, plants become woody and decline in quality. Also, digging plants into the soil becomes quite difficult if they grow too large. If you cannot till a cover crop before it blooms, cut it off and compost it for later use. You still will get some short-term benefit of organic matter from the crowns and roots when you till your garden.

The organic matter benefits of cover crops are short-lived, so where they are suitable make cover crops a regular part of your garden rotation. If they do not fit into your garden plan, you can use mulches that are later incorporated as a substitute way of building soil organic matter.
Soil pH

Soil pH measures the acidity or alkalinity of a soil. At a pH of 7 (neutral), acidity and alkalinity are balanced. Acidity increases by a factor of 10 with each 1-unit drop in pH below 7. For example, a pH of 5.5 is 10 times as acidic as a pH of 6.5. Alkalinity increases by a factor of 10 with each 1-unit change in pH above 7.

Native soil pH depends on the parent minerals present in the soil and on rainfall. Soils in arid areas tend to be alkaline and those in rainy areas tend to be acid. Gardening and farming also affect soil pH. For example, some nitrogen fertilizers tend to reduce pH (this effect will be negligible on highly buffered soils), while liming increases pH.

Soil pH influences plant growth in three ways:

- It affects availability of plant nutrients (Figure 8).
- It affects availability of toxic metals.
- It affects the activity of soil microorganisms, which in turn affects nutrient cycling and disease risk.

The availability of phosphorus decreases in acid soils, while the availability of iron and zinc can be quite low in alkaline soils.

Aluminum availability increases in acid soils. Aluminum is not a plant nutrient, but it is one of the most common elements in soil and is toxic to plants in high concentrations. Very little aluminum is in solution in soils above pH 6 and it causes no problems for plants. As pH declines to 5 and aluminum availability increases, aluminum toxicity can become a problem.

Microbes also are affected by soil pH. The most numerous and diverse microbial populations exist in the middle of the pH range. Fewer organisms are adapted to strongly acid or strongly alkaline soils. Nutrient cycling is slower in acid and alkaline soils because of reduced microbial populations.

Many garden crops perform best in soil with pH of 5.5 to 7.0, but some (such as blueberries) are adapted to more strongly acid soils. Before amending soil to adjust pH, it is important to know the preferred pH ranges of your plants and the buffering capacity (ability to resist a change in pH) of your soil. The higher the buffering capacity, the more lime is required for an equivalent pH change.

Increasing soil pH

The most common way to increase soil pH is to add lime. Lime is ground limestone, a rock containing calcium carbonate. It is a natural amendment, suitable for use by organic gardeners.

Lime raises the pH of acid soils and supplies calcium, an essential nutrient. Dolomitic lime contains magnesium as well as calcium, so it is a good choice if soil mag-

<table>
<thead>
<tr>
<th>Acid pH</th>
<th>Neutral pH</th>
<th>Alkaline pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
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<td>8.0</td>
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</table>

Figure 8.—Effect of soil pH on the availability of plant nutrients.
The best way to determine whether your soil needs lime is to have it tested. You can get a laboratory soil test or a pH test kit can be purchased at many garden centers for a small fee. Do not lime areas where you grow acid-loving plants, because they are adapted to acid soils. Where potatoes are grown, a soil pH of 5.0–5.5 is recommended to reduce problems with potato scab.

Lime is a slow-release material. Apply it in the fall and incorporate it for best results.

Wood ashes are a readily available source of potassium, calcium and magnesium. Like lime, they also raise soil pH. High rates of wood ashes may cause short-term salt injury, so apply 15 to 25 pounds or less per 1,000 square feet. Do not apply wood ashes to neutral or alkaline soils.

Composts are often slightly alkaline and can increase soil pH to a limited extent.

Gypsum (calcium sulfate) is not a substitute for lime. It supplies calcium and sulfur and is a good fertilizer material for both of those nutrients when they are low, but it has little effect on soil pH. Gypsum has been promoted as a soil amendment to improve soil structure. In the majority of cases, it does not work for this purpose. Gypsum improves structure when the poor structure results from excess sodium in the soil, a rare condition in Alaska. Use organic amendments to improve soil structure, as described earlier under “Adding organic matter.” Use gypsum to supply the nutrients calcium and sulfur when they are needed and you do not want to change the pH of the soil. For example, gypsum is commonly used as a calcium source for blossom end rot control in tomatoes.

### Decreasing soil pH

You may need to decrease soil pH if you wish to grow acid-loving plants. Elemental sulfur lowers soil pH and is the most commonly used material. Iron sulfate also lowers pH and acts more rapidly than sulfur, but it takes more material and is more expensive. Ammonium sulfate and urea fertilizers can help maintain low pH, but they should not be applied at rates higher than required to meet the nitrogen requirement of the crops grown. Some organic materials like sphagnum peat moss also lower pH.

Soil testing is the best way to determine whether pH is too high for the plants you want to grow. In some areas, it is unrealistic to try and lower soil pH a significant amount. This is true for highly buffered soils on the Kenai Peninsula.

### Soil salinity

Salts from inorganic fertilizer, fish bone meal, compost and manure applications can accumulate to the point where they harm plant growth. Soil salinity is most commonly a problem in greenhouse soils. In outdoor
gardens, salts are usually leached from the soil with normal watering and rainfall, so salt does not accumulate in the root zone unless fertilization is excessive.

A salinity test measures the total soluble salts in a soil. It measures soluble salts indirectly by measuring the electrical conductivity (EC) of a soil/water solution. Table 9 shows how to interpret a salinity test.

You can leach salts from soil by applying irrigation water in excess of the water-holding capacity of the soil. The excess water must drain downward through the soil to carry away excess salts. When leaching, apply water slowly enough that it infiltrates the surface and drains freely through the subsoil. Three inches of excess water removes about half of the soluble salts in a soil. Five inches of water removes about 90 percent.

For more information

UAF Cooperative Extension publications

Composting in Coastal Alaska, HGA-01021.
Composting with Worms, HGA-01020.
Cucumber Production in Greenhouses, HGA-00434.
Fertilizer Nutrient Sources and Lime, FGV-00348.
Growing Everbearing Strawberries as Annuals in Alaska, HGA-00235.
Growing Tree and Bush Fruits in Alaska, HGA-00038.
Establishing a Lawn in Southeast Alaska, HGA-00238.
Factors to Consider in Selecting a Soil Testing Laboratory, FGV-00045.
Lawn Establishment, HGA-00036.
Lawn Maintenance, HGA-00334.

Make Your Own Complete Fertilizer, HGA-00131.
Soil Fertility Basics, FGV-00242A.
Soil Fundamentals, FGV-00242.
Soil Sampling, FGV-00044.
Worms in a Tote, HGA-01025.
Soil and Fertilizer Management for Healthy Gardens, HGA-00338

Other publications
