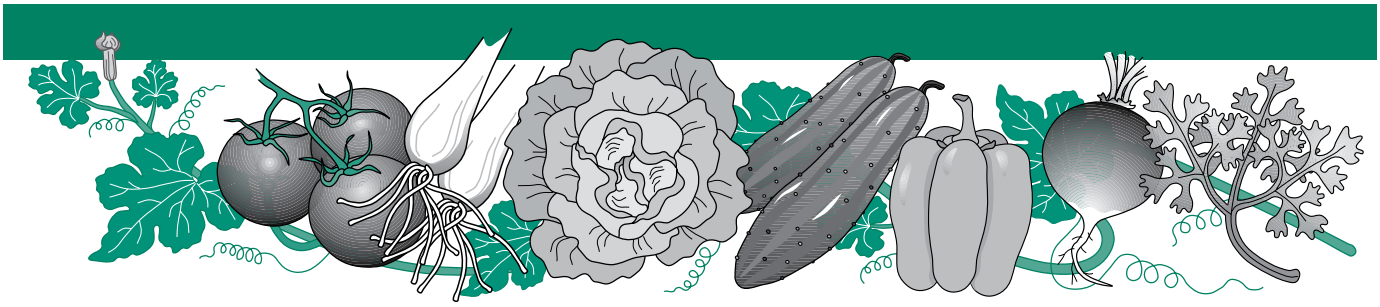
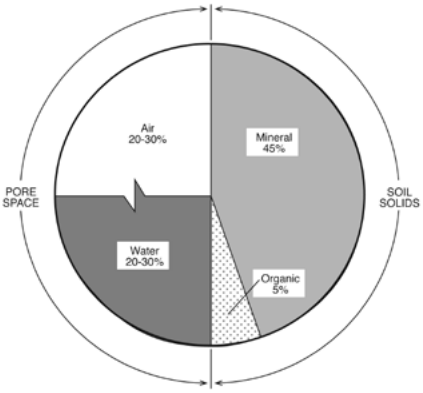


Garden soil management

Soil is a complex living system made up of minerals, organic materials, water, and air. The mineral portion represents the major component of the soil. It has specific physical and chemical properties that were determined when the soil was formed from glacial deposits thousands of years ago. Physical properties such as soil texture (soil particle size) and soil structure (how particles are held together) determine air and water movement which in turn affects plant growth. Soil color is determined by the amount of organic matter, drainage conditions, and oxidation or weathering.

Most soils in Iowa are well suited for vegetables, flowers, and turf; a few may have special problems needing correction before planting. Some are too wet due to poor drainage, others are difficult to till due to high clay content, and a few dry out too quickly due to the large amount of sand in the soil. There are thousands of kinds of soil, each different from others in color, depth, size, and arrangement of the individual sand, silt, and clay particles, mineral composition, and content of organic matter.



"Ideal" soil has about half the total volume made up by equal parts of air and water.

Tillage affects soil structure and plant growth

The soil should never be worked when too wet. If worked under wet conditions, the soil will become hard and restrict root growth, causing unproductive plants. If a handful of soil formed into a ball retains its shape, delay soil tillage until the water content diminishes. If a handful of soil formed into a ball crumbles when pressed with the thumb, it is ready for plowing or spading.

Fall is the best time to plow or spade the garden soil unless the site poses a danger of water or wind erosion. Fall tillage helps control certain insects and diseases that overwinter on the plant refuse. Fall prepared soils are subjected to the early spring freezing and thawing action that helps improve the tilth and general soil aggregation. Also, the soils will dry out and warm up quicker in the spring.

Soil too wet for soil tillage.

Soil is ready for plowing or spading.

Organic matter improves soil quality

Also known as humus, the dark brown to black organic compounds that result from decomposition of vegetative and animal matter make up the smallest percentage of soil by volume but are essential in a good garden soil.

IOWA STATE UNIVERSITY
Extension and Outreach

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Organic matter

- improves the physical condition or structure of soil, thereby increasing the tilth or ease of working (especially true of soils that tend to pack badly or crust over);
- increases water absorption;
- increases aeration, allowing more oxygen to roots;
- increases nitrogen and other nutrient retention; and
- aids soil microorganism population.

As crops grow, the amount of organic matter in the soil becomes progressively lower unless organic materials are added. Commercial fertilizers are not a substitute for organic matter—both are needed for fertile, productive garden soil.

Sources of organic matter include compost, well-rotted animal manure, green manure crops, and finely ground yard waste.

Mixing undecayed, coarse plant materials—such as straw (with or without manure), cornstalks, waste hay, or cover crops—uniformly into the soil can be difficult without power tools. Rotary cultivators and disks can do the job. Putting coarse material through a power grinder-shredder makes it much easier to work into the soil with hand tools, but grinder-shredders do not work well with wet, limp materials. A lawn mower also can be used to cut up more tender materials such as cornstalks.

Animal manures—Dry, pulverized manures are a good source of humus and plant food if there is not too much litter (straw, sawdust, or shavings) mixed in, and if they have not been stored outside where heavy rains wash out the nutrients. Poultry or rabbit droppings taken from beneath roosts or hutches are high in nitrogen. They may burn plant roots if used too generously.

The value of manure as plant food depends on the extent to which it has been diluted or leached by water and the proportion of bedding, such as straw, sawdust, or shavings, that is mixed in it.

Compost—Compost can be a good source of humus and a good way of recycling plant refuse from the yard or garden. However, improper composting that fails to generate adequate heat will not kill weed seeds, disease organisms, or underground stems or roots of such plants as quackgrass and morning glory. Diseased plants and weeds that have gone to seed are best discarded another way. Additional information about composting is available from local ISU Extension offices and on the Web sites listed on page 6.

Many communities have municipal composting

Mulches and sawdust—Tree leaves, lawn clippings, peat, sawdust, straw, and spoiled hay and silage are good sources of organic matter. Another excellent source may be your local municipal yard waste compost site.

Yard waste, such as finely ground shrub and tree limbs, may be mixed with garden soil, whether fresh or weathered. Fresh yard waste will last longer when used as a mulch and will make soils lighter or more retentive of moisture when plowed under. Old or rotted yard waste will become humus more readily and is less likely to cause nitrogen deficiency. When mixing waste with soil, it is best not to work in more than 2 inches per year. It should be mixed thoroughly with 6 inches of soil.

Percent of available nutrient content in undiluted animal and poultry excrement

Undiluted excrement	%Nitrogen (N)	%Phosphorus (P_2O_5)	%Potassium (K_2O)
Cow*	0.60	0.15	0.45
Hog*	0.50	0.35	0.40
Horse*	0.70	0.25	0.55
Poultry**	1.30	1.17	0.48
Goat**	1.03	1.20	1.50
Sheep**	0.95	0.35	1.00
Rabbit**	1.10	1.50	0.47

*Cow, hog, and horse manure can be applied at the rate of 500 to 1,000 pounds for each 1,000 square feet of garden area. This is equivalent to 10 to 20 tons per acre.

**Poultry, goat, sheep, and rabbit manure are higher in nutrient content and should be added at the rate of 200 to 400 pounds per 1,000 square feet of area.

Buying or hauling manures, waste hay, etc., from barns, feedlots, or fields may add new weeds to your garden. Some commercially composted materials and manures available on the market are treated to kill weed seeds.

A cubic yard of sawdust or finely ground waste will cover 300 square feet 1 inch deep. A bushel will cover 15 square feet 1 inch deep.

Whenever a sizable quantity of sawdust or other coarse fibrous material is added to soil, extra nitrogen must be applied with it. Most coarse materials are high in carbohydrates (cellulose) and low in nitrogen. Soil microorganisms cannot get enough nitrogen from these materials to adequately break them down into humus, so they absorb additional nitrogen from soil reserves. In fact, so much soil nitrogen is "tied up" in bacterial action that plants experience a nitrogen deficiency, as shown by yellowing and stunted growth. This is the most common problem facing users of organic mulches.

To avoid a nitrogen shortage, use 1 pound of available nitrogen per 1,000 square feet by adding manure (100 pounds of poultry manure or 200 pounds of cow or hog manure) or a commercial fertilizer. Apply 2 pounds of urea (46-0-0) or similar high nitrogen analysis fertilizer (i.e., 4 pounds of 27-7-3) per 1,000 square feet.

Fall is the preferred time to add organic matter. This allows partial decomposition of the material, releasing essential plant nutrients before the following growing season. It is always wise to watch plant growth closely when large quantities of organic matter have been used. A side dressing in mid growing season may be necessary for slow growing, pale green plants.

Selecting a product high in nitrogen content will help soil microorganisms in decomposition

Material	Nitrogen (N) Percent	Phosphorus (P_2O_5) Percent	Potassium (K_2O) Percent
Alfalfa hay	2.45	0.50	2.10
Alfalfa straw	1.50	0.30	1.50
Grass hay	1.20	0.35	1.75
Clover hay	2.10	0.50	2.00
Pea vines*	2.08	0.60	2.00
Oats*	1.50	0.65	2.20
Rye*	2.00	0.80	2.80
Wheat*	2.14	0.20	2.48
Wheat straw	0.50	0.15	0.60
Wood ashes	0.00	1.75	6.00

Based on dry weight except where noted for green forage.
*Green forage

Green manure crops—A variety of grasses can be planted and tilled into the soil to increase organic matter. Rye or wheat may be seeded at the rate of 3 to 4 pounds per 1,000 square feet (or annual ryegrass at 2 to 4 pounds). Seed sown in late August will grow sufficiently to be tilled under before cold weather. If soil erosion is a problem, rye could serve as a winter cover crop and be turned under the following spring.

Soil tests analyze specific soil nutrients

A general soil test provides information about soil pH plus levels of phosphorus and potassium. Special tests for organic matter, zinc, and nitrogen also are available. Yearly soil tests are not necessary; testing every three or four years is generally sufficient. The exception is a sandy soil; then testing every other year is desirable.

To improve the accuracy of soil test results, the soil samples should represent an area that is fairly uniform in color and texture. If different parts of the garden or yard are noticeably different in appearance, it may be advisable to do multiple tests.

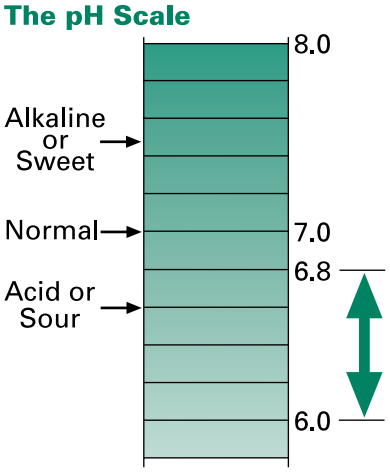
Soil testing is available from Iowa State University's Soil Testing Laboratory for a nominal fee. Sample bags and instruction sheets are available at local ISU Extension offices. Payment must accompany the samples. Additional information is available at their Web site, www.agron.iastate.edu/soiltesting/. Test results are accompanied by recommendations for fertilizer application.

Soil pH affects plant growth

Soil pH is a measure of soil acidity. Soil pH meters measure the hydrogen concentration in the soil solution. The concentration of hydrogen ions (H^+) is compared to the concentration of hydroxyl ions (OH^-). When the two are equal, the soil is neutral; it has a pH of 7.

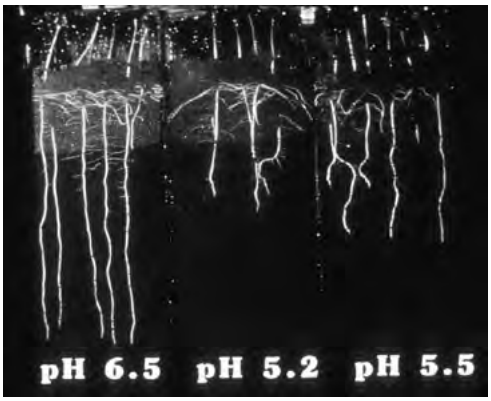
Most Iowa soils are neutral or slightly alkaline. A soil pH above 7.1 is alkaline or basic.

The hydroxyl ions outnumber the hydrogen ions.



A soil pH level of 6.0 to 6.8 (slightly acid) is the best range for most vegetables and flowers.

When the hydrogen ions outnumber the hydroxyl ions, the soil is acidic. It has a pH less than 7.



Most vegetables grow best in a slightly acid soil with a pH 6.0 to 6.8. Within this range root growth, plant vigor, nutrient availability, and microbial activity are optimal. Beyond this range, plant growth can be severely limited because nutrients become unavailable to the plant, and soil microbes work less effectively.

Adding lime raises soil pH

One way to neutralize an acid soil is by adding lime. However, only a small percentage of Iowa soils require liming. It is unwise to assume that lime is needed since excess lime can cause plant damage by reducing root growth and availability of some essential elements. The only way to determine the lime requirement is by soil analysis.

Various forms of lime are available, including calcitic limestone ($CaCO_3$), quicklime (CaO), hydrated lime ($Ca(OH)_2$), and dolomitic limestone ($CaCO_3 + MgCO_3$). These materials vary in fineness, rate of action, cost, magnesium content, handling, and caustic nature. All have a large amount of available calcium cations that neutralize the acidic hydrogen ions.

The only way to determine how much lime is needed is by a chemical soil test that measures soil pH buffering capacity. This unit is a common measure in soil test reports. The amount recommended varies by degree of soil acidity, amount of clay (CEC measure), and type of liming material used.

Apply only enough lime to correct the acidic condition. No single application of pure lime should exceed 25 to 50 pounds per 1,000 square feet, depending on the material used.

Liming materials are most effective when they can be thoroughly mixed with the soil, thus they are best applied prior to planting. Late fall applications work well because the lime has time to react with tillage of plant residue. Ground limestone ($CaCO_3$) is preferred to hydrated lime because it will be available over a longer period and usually costs less.

Adding acidic organic matter or sulfur reduces soil pH

To make it possible for Iowa gardeners to grow azaleas, rhododendrons, blueberries, and other acid-loving plants, alkaline pH levels can be altered through the addition of acidic organic matter, sulfur, ammonium sulfate, or iron sulfate.

The ideal way to lower pH is to accomplish it naturally through the use of acidic organic matter. Canadian sphagnum peat, oak-leaf mold, or evergreen needles worked into the soil will gradually lower the pH and increase valuable organic matter content.

When using sulfur to reduce soil pH, the rate depends on the soil type, beginning pH level, and desired final pH level. Elemental sulfur should be worked into the soil before planting, preferably a year before.

Topdressed elemental sulfur becomes incorporated into the soil through insect activity and soil cracks. However it is not effective the year it is applied.

Elemental sulfur reacts slowly with soil and must be converted into sulfate before it can be active. Elemental sulfur applications are long lasting and may only be necessary every 3 to 4 years.

Amount of elemental sulfur needed to reduce soil pH to 4.5

Initial pH	Application rate (pounds/1000 square feet)	
	Sandy soil	Loam soil
7.0	19	58
6.5	15	46
6.0	12	35
5.5	8	24
5.0	4	12

Ammonium sulfate is a source of nitrogen fertilizer that contains 24 percent sulfur and also can be used to lower the pH of soils. Aluminum sulfate is a product often sold to lower the soil pH. It is not recommended because the aluminum can be toxic to roots. Sulfate forms of sulfur are fast acting and readily leach through the soil. Yearly applications of these products may be needed to keep the pH lowered. Sulfate forms work effectively applied as a topdressing.

Many Iowa soils, particularly in the northwest part of the state, contain calcium carbonate or lime in the topsoil. Soils of this type are termed calcareous soils and have a pH range of 7.3 to 8.5 (alkaline). The presence of free lime in the soil makes it almost impossible to permanently lower the soil pH.

New de-icing materials reduce need for gypsum

Gypsum is used as a soil amendment to help water infiltration in turf grass where high sodium (Na^+) soil conditions exist, such as in the arid west and southwest portions of the United States.

In Iowa, sodium problems may occur where de-icing materials containing salt (sodium chloride, NaCl) are used. This can occur along roads or driveways where ice and snow containing the de-icing compounds have accumulated. If sodium levels become too high, plant growth is affected directly by the high sodium content or indirectly through poor soil structure and drainage. Salt damaged soil is becoming less of a problem as new de-icing materials containing calcium chloride become available.

Gypsum will not improve soil drainage problems caused by compaction from traffic, heavy clay soils low in organic matter, or internal drainage problems. It is only effective when poor drainage is due to soil structure breakdown.

Gypsum requirements can be determined by tests that measure electrical conductivity of the soil solution or percent base saturation of cations in the soil solution. These types of soil tests are provided by commercial soil testing labs. Gypsum applications are most effective when worked into the soil. Maximum application rate of gypsum is 50 pounds per 1,000 square feet in spring and fall.

Gypsum ($CaSO_4 \bullet 2H_2O$) separates into calcium and sulfate. In the soil, sulfate forms sulfuric acid that neutralizes any affect the calcium may have on raising pH. Thus, adding gypsum does not change the soil pH. Calcium replaces the sodium on the cation exchange sites. The sodium and sulfate are leached from the soil through water application. Soil particles then come together to form aggregates or "soil crumbs" that improve soil structure (tilth) and drainage.

Use commercial fertilizers wisely

Commercial fertilizers are effective and economical for supplying some of the mineral elements used by plants. However, adding too much fertilizer can be as undesirable as using too little.

By law, all commercial fertilizers, including specialty fertilizers (such as organics) must state the guaranteed analysis on the bag in this order: percentage of nitrogen (N), percentage of phosphorus (as P_2O_5), and percentage of potassium (as K_2O). For example, a 6-10-4 fertilizer contains 6 percent available nitrogen, 10 percent available phosphoric acid, and 4 percent available potash. Other commonly available fertilizers have analyses such as 10-10-10, 12-12-12, or 5-10-10. As a rule, those with the higher numbers are more economical to use since the cost per unit of actual nutrient is lower.

Several minor or trace elements also are necessary for plant growth. Examples include iron, boron, manganese, molybdenum, nickel, and zinc. Most Iowa soils contain sufficient amounts of these trace elements; additional supplementation is rarely needed. Many of the commonly used commercial fertilizers contain the trace elements as impurities. Animal manures also contain a number of trace elements.

How much commercial fertilizer to use—The rate of fertilizer to apply will vary depending on past fertilizer use, crops grown, soil type, and other factors. Getting an initial soil test can be very helpful. Most Iowa garden soils are very high in nutrients and only nitrogen is needed on an annual basis. Look for a product that has a large first number (nitrogen) in the formula, such as 29-3-4. Apply 4 to 5 pounds per 1,000 square feet. Or, use urea (46-0-0) at 2 to 3 pounds per 1,000 square feet. (One pint weighs approximately one pound.) If a soil test report is not available use a low analysis fertilizer, such as 5-10-5 or 6-10-4 at the rate of 20 to 30 pounds per 1,000 square feet.

If manure has been used at the rate of 500 pounds or more per 1,000 square feet, reduce the rates of commercial fertilizer by one-half. If the manure used contains large quantities of straw, sawdust, or shavings, extra nitrogen may be needed in the general fertilizer program or as a side dressing during the growing season. If the plants need extra nitrogen, use about 2 to 3 pounds of actual nitrogen per 1,000 square feet of garden area.

Many garden centers also sell separate nitrogen sources in small convenient packages.

Recommended amounts of specific nitrogen products

Nitrogen Source	Pounds/100 feet of Linear Row
Ammonium nitrate (34-0-0)	1/3 to 3/4
Ammonium sulfate (21-0-0)	3/4 to 1 1/4
Urea (46-0-0)	1/4 to 1/2

How and when to apply fertilizer—The most efficient method of application is by side dressing. Apply less to closely spaced rows, such as carrots, beets, and lettuce. Use more for wider spaced rows, such as tomatoes, corn, and potatoes.

To apply the side dressing, spread the fertilizer evenly along the row in a 3- to 4-inch wide band. Rake it in below the soil surface or irrigate with an inch or more of water.

Many garden crops respond to additional fertilizer applications during the growing season. Cucumber, squash, broccoli, cabbage, and others can be fertilized by side dressed applications four to six weeks after planting. About 2 tablespoons of a complete fertilizer around each plant should be adequate. Tomato yields may be increased by side dressing, but the fertilizer should not be applied until the first cluster of fruit has set.

Overfertilization of any garden crop may cause the plant to make excessive vegetative growth at the expense of fruit set. Do not use a side dressing if rainfall has been below normal.

Using liquid starter fertilizers—Fertilizer in liquid form is often used at transplanting time. Completely soluble, high analysis materials are available for this purpose. Such fertilizers should not be applied in dry form but should be dissolved in water before application, following the directions on the container.

Complete fertilizers also may be adapted for use as a liquid starter application. Use low analysis materials at 2 tablespoons per gallon of water or high analysis forms at 1 tablespoon per gallon.

After planting, apply 1 to 2 cups around each plant.

Using foliar application fertilizers—Some specialty fertilizers are available that are promoted for foliar application. The claim is that the nutrients are readily available to the plant by absorption through leaf surfaces. This practice has more disadvantages than advantages for the homeowner. Usually less than five percent of the total nutrient enters the plant and this is not enough to make a difference in plant growth. Further, the risk of plant damage is high from salt burn, especially when applied when temperatures are above 80°F. or when humidity levels are low. Maintaining plant health through nutrient application is best done through a sound soil applied fertilizer program based on soil test results.

For more information

For more information on selection, planting, cultural practices, and environmental quality, contact your local Iowa State University Extension county office or visit one of these ISU Web sites:

ISU Extension Distribution Center
www.extension.iastate.edu/store

ISU Extension Publications
https://store.extension.iastate.edu/

ISU Horticulture
www.yardandgarden.extension.iastate.edu

ISU Soil and Plant Analysis Lab
https://crops.extension.iastate.edu/soil-and-plant-analysis-lab-iowa-state-university

Questions also may be directed to ISU Extension's Hortline by calling 515-294-3108 (Monday-Friday, 10 a.m. to noon, 1-4 p.m.)

Revised by Henry G. Taber, professor, department of horticulture; Diane Nelson, extension communication specialist, and Jane Lenahan, extension graphic designer.

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