COOPERATIVE EXTENSION SERVICE
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UNIVERSITY OF ALASKA FAIRBANKS

Soil and Fertilizer Management for Healthy Gardens

Soil Management

Soil Physical Properties. Healthy root growth requires both air and water. Soil texture, soil structure, soil depth and soil organic matter influence the balance between air and water availability in the root zone by affecting drainage, aeration and water holding capacity.

Soil texture refers to the relative proportions of sand-, silt- and clay-sized particles in a soil. A soil's "textural class" (loamy sand, loam, silt loam, etc.) is a fixed soil property. Coarse-textured soils (dominated by sand) are usually well drained and aerated, but have low water-holding capacities. Fine-textured soils (dominated by clay) have high water-holding capacities, but often have poor drainage and aeration. A simple method of determining the texture of your soil is described at the end of this publication.

The sand, silt and clay particles are combined into larger, aggregated particles with large pore spaces between them and smaller pore spaces within them. This arrangement of soil particles into blocks is called **soil structure** and is a property that can be manipulated by management practices. A soil with "favorable" structure is about 50 percent solids and 50 percent pore space, with the pore space evenly distributed between large, air-filled pores and smaller, water-holding pores.

Soil depth impacts the rooting depth, which in turn affects plant growth. Shallow soils over bedrock or gravel, or soils with dense, compacted layers such as plow pans, restrict root growth. Shallow soils are more prone to moisture extremes. During dry conditions shallow soils have lower moisture reserves compared to deeper soils. Likewise, during periods of high rainfall shallow soils may not drain as effectively, resulting in waterlogged root zones.

Soil organic matter is an important soil property that affects many biological, chemical and physical characteristics of the soil. One of its most valuable roles is to increase the aggregation of soil particles, which improves soil structure. Organic matter also has a very high water-holding capacity. The combination of these two factors results in the unique ability of organic matter to improve the physical properties of both coarse- and fine-textured soils. Increasing organic matter content can improve water retention in sandy soils and improve drainage and aeration in the surface layers of clayey or silty soils. Soil organic matter also has a very high capacity to hold nutrients in the soil. As the organic matter breaks down over time it releases these nutrients for crop use.

Soil Amendments

Applying organic soil amendments can provide the benefits described above. Organic amendments may also increase soil microbial activity, provide disease suppression and release essential plant nutrients. Although a wide variety of organic materials can be used to improve the soil, there are differences between amendments. Even though all organic amendments will eventually break down and release nutrients to the soil, some amendments break down rapidly and release nutrients during the same season. Other organic amendments

Compost applied as an organic soil amendment.

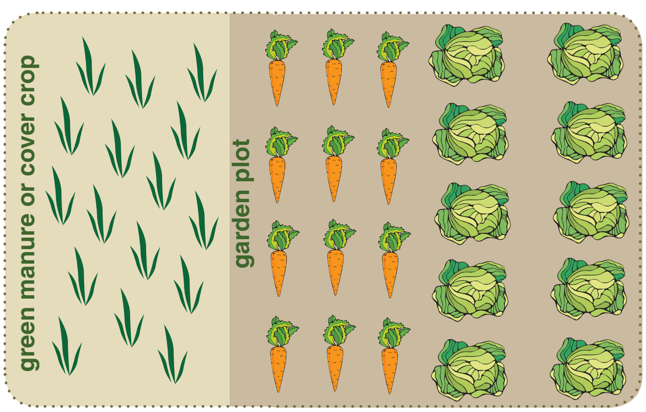
Straw used as a mulch in a strawberry bed.

will actually require additional nutrients from the soil to help the microbes break down the material. Compost and well-rotted manure are among the most valuable organic amendments and have higher nutrient values than many other choices. Materials that are very high in carbon, like straw, wood chips, shredded bark and sawdust, will require additional nitrogen from the soil to assist decomposition. This temporary loss of soil nitrogen to the decomposing organic amendment decreases the nitrogen availability to plants and usually requires supplemental nitrogen fertilizer to maintain adequate nitrogen levels for good crop growth. These high carbon amendments are often best utilized as mulches, where they will eventually break down and become soil organic matter.

Peat, hay, grass clippings, tree leaves and other plant residues are also organic amendments. Backyard composting of yard and food wastes is an excellent way of recycling nutrients and returning organic matter to the soil. Composting can also be used to break down woody yard wastes and convert them from a disposal challenge into a desirable soil amendment.

Grass bagging vs. mulching mowers

In some parts of Alaska a mulching mower is very appropriate. These mowers grind up the grass clippings and leave them in the lawn to decompose and recycle nutrients back to the lawn. In the cooler areas that receive more rainfall, the clippings can create a thatch problem. This situation seems worse with some of the popular Kentucky Bluegrasses used for lawns. See your local CES agent to determine what is right for you.



A green manure crop builds soil organic matter.

Another way to build organic matter in your soil is to "grow your own." Buckwheat and small grains like oats and barley are among the plants that can be used as green manure or cover crops; in gardens with pH levels above 6.0, various clovers can be used. These crops are grown when the soil is not producing a main crop. The cover crop will be incorporated into the soil before it reaches maturity. The leaves, stems and roots of the cover crop will decompose, returning nutrients and organic matter to the soil, hence the nickname "green manure." Some cover crops can be grown before or after short-season vegetable crops. The use of a "fallow" year to build the soil in preparation for a new planting is an opportune time to use cover crops to add organic matter.

Fertilizer Management

Essential plant nutrients. There are 17 elements that are essential for growth of all plant species.

Primarily from the Atmosphere	Primarily from the Soil	
Carbon(C)	**Macronutrients**	**Micronutrients**
Hydrogen (H)	Nitrogen (N)	Iron (Fe)
Oxygen (O)	Phosphorus (P)	Manganese (Mn)
	Potassium (K)	Zinc (Zn)
		Copper (Cu)
	Secondary Macronutrients	Boron (B)
		Molybdenum (Mo)
	Calcium (Ca)	Chlorine (Cl)
	Magnesium (Mg)	Nickel (Ni)
	Sulfur (S)	

All essential nutrients are equally important for healthy plant growth, but there are large differences in the amount of each nutrient that the plant needs. Nitrogen, phosphorus and potassium are considered the primary nutrients because plants need these in larger amounts than other nutrients and our soils are naturally more likely to be deficient in these macronutrients. Calcium, magnesium and sulfur are called secondary macronutrients because they are required in lesser amounts than nitrogen, phosphorus and potassium. The micronutrients (Fe, Mn, Zn, Cu, B, Mo, Cl and Ni) are elements that are required in minute amounts, although a shortage of them can still limit crop production.

Soil acidity and liming. Statewide, Alaska soils vary from acid to alkaline. In addition to natural variation, soil management practices also impact soil acidity. The level of soil acidity, or inversely, soil alkalinity, is measured by soil pH. Acid soils have low pHs and alkaline soils have high pHs. One of the slang terms for an acidic soil is a "sour soil." Since pH affects both the chemical forms and solubility of nutrient elements, soil pH greatly influences nutrient availability. Some of the micronutrients such as iron, zinc and manganese are more available in acidic soils than in neutral or alkaline soils. On the other hand, other nutrients such as molybdenum are more available under higher pH conditions. The ideal soil pH range for mineral soils (soils primarily composed of sand, silt and clay particles) is 5.5 to 7, because overall nutrient availability is greatest in this range. This pH range is also a healthy range for microbes, earthworms and other soil organisms. In organic soils (peats and mucks), the optimum pH for nutrient availability for most plants is slightly lower at a pH range of 5.2 to 6.2.

Optimum soil pH for some plants is lower than the general range of 5.5 to 7 given above. Acid-loving plants like the wild iris (*Iris setosa*) and the bog blueberry (*Vaccinium uliginosum*) prefer a pH range of 4.5 to 5.2 and will develop symptoms of iron deficiency or "iron chlorosis" above this pH range. In some cases, the ideal soil pH for crop production is determined by factors other than nutrient availability. Potatoes, as an example, are often grown at a soil pH of 5.4 or less (in mineral soils) to reduce the incidence of potato scab, despite the plant's preference to grow in higher pH levels.

Soils become acidic through a variety of natural and human processes. Acid rain, nutrient leaching and decomposition of organic matter are all natural processes that contribute to soil acidification. Management practices such as poor water management or the application of acidifying nitrogen fertilizers can also lower the soil's pH. Ammonium forms of nitrogen fertilizer, including urea, which breaks down into ammonium, generate acidity when converted to the nitrate form of nitrogen or taken up directly by plant roots.

Raising soil pH. To counteract the tendency of the soil to become more acidic, applications of lime are regularly required on many soils to maintain soil pH in the desired range. Limestone (calcium carbonate), an alkaline rock product, is the most common material used to raise a soil's pH. Limestone also supplies calcium, another required nutrient. Where available, dolomitic limestone will supply magnesium in addition to calcium. The amount of limestone that is needed to raise the pH to the optimum range (the liming rate) depends on both the initial soil pH level and the soil's buffering capacity. The buffering capacity of a soil is its ability to resist changes in pH and is related to the amount of clay and organic matter in the soil. Soils that are high in clay content with high organic matter content will need more lime to raise the pH than a comparable sandy, low pH soil. How often one has to lime a soil (liming frequency) also depends on the soil's buffering capacity. Soil pH changes slowly on well-buffered soils, so the higher lime rates that are needed can be applied less frequently than on poorly buffered soils. Soils with low buffering capacity need frequent applications of lower lime rates to maintain the pH in the desired range.

Using Wood Ash to Raise Soil pH

Ash from the wood stove is commonly used by Alaska gardeners to raise pH. Likewise, land managers often use the ash from the berm rows to raise the pH in the surrounding field. The ash is applied at rates that are about double the recommended rates of limestone (calcium carbonate). Wood ash also contributes potassium (potash) to the soil in addition to raising pH.

Lowering soil pH. Sometimes the soil's pH is higher than the optimal range for crop needs and must be lowered. Elemental sulfur is the most commonly used material to lower soil pH. As with liming, rates depend upon the buffering capacity of a soil in addition to the initial measured pH. Iron sulfate is more expensive than elemental sulfur, but it lowers the pH more rapidly (2 to 3 weeks for iron sulfate vs. 3 to 4 months for elemental sulfur). Amending the soil with an acidic peat also lowers the pH. Ammonium sulfate fertilizer will help to maintain a low soil pH, but do not use it to reduce the initial pH since the amount required will usually result in a large over-application of nitrogen.

Local Challenges

Ground elemental sulfur has not proven to lower soil pH successfully in Kenai Peninsula soil acidifying trials.

Soil sampling and soil testing. The first step in managing soil fertility is to determine the existing nutrient and pH levels by testing the soil. Soil testing is an important soil management tool and forms the basis for nutrient and lime recommendations. The goal of soil testing is to evaluate the soil's nutrient status by determining if any nutrients are deficient or are present in excess. Soil fertility is an environmental, as well as a plant growth, concern.

It is important to do a soil test and apply the necessary amounts of lime and fertilizer before planting to allow the tillage operations to mix the materials throughout the topsoil layer. With perennial plants, the time before planting may be the only chance to properly mix in lime, phosphorus and potassium. The issue is not quite as important with nitrogen fertilizer since it dissolves in water and readily moves with water through the soil.

Soil test frequency. How often you should test the soil depends upon factors like previous soil testing history, plans to make major changes in what you are growing in a certain area, suspected fertility problems and recent lime, fertilizer, manure and compost applications. We usually recommend testing the soil every 1-3 years, depending on how intensively you plan on managing the system. In areas with a good soil testing history, nutrient levels brought to the desired range and good plant growth, testing every 3-5 years may be adequate. Choose a reliable laboratory that makes recommendations suitable for the soil types and growing conditions in your area. This is an important factor since laboratories in other states may use testing procedures that are optimized for their local soils but not appropriate for Alaska soils.

For further information see *Factors to Consider in Selecting a Soil Testing Laboratory*, UAF Cooperative Extension Publication FGV-00045

Collecting a representative soil sample is often the weakest link in a soil-testing program, so follow the specific guidelines for recommended sampling depth, sampling pattern, number of soil cores, etc. If you are tempted to save time and collect fewer cores to represent larger areas, remember that fertilizer recommendations from a soil test are only as accurate as the sample taken to represent the garden.

Divide lawn or garden spaces into uniform areas based on differences in soil type, slope and vegetation and previous lime, fertilizer, manure or compost applications. If you can think of any reason why one part of a lawn or garden area could be different than another part, then sample it separately. Collect 5-10 soil cores or subsamples from the selected area in a random, zigzag pattern. Sampling to the proper soil depth is very important and the required depths for different situations are as follows:

Situation	Depth
Established lawns	top 3-4 inches
Lawns before seeding or sodding	top 6 inches
Vegetable and flower gardens	top 6 inches
Trees, shrubs, perennial fruits	top 6 inches

Mix the subsamples together well in a clean, plastic container and take about a pint of this composite soil sample to submit to a laboratory for analysis. If a soil sample is very wet it should be air-dried by spreading a thin layer of soil on a clean surface and allowing the moisture to evaporate before mixing the sample for analysis. Slightly moist samples are acceptable and can be sent to the lab for further drying. Follow this procedure for each of the separate areas that you identified.

Soil tests and fertilizer recommendations. The soil analysis that you get when ordering a "standard soil test" varies with the laboratory that you send your sample to. Please refer to UAF Cooperative Extension Service publication FGV-00045, *Factors to Consider in Selecting a Soil Testing Laboratory*, for further information on choosing a soils laboratory.

If the soil's pH is less than 6.0, a buffer index test (SMP buffer pH) is run to determine the amount of lime that will be necessary to raise the pH to about 6.5 for that specific soil. Similarly, the test results indicating the levels of available P and available K form the basis for fertilizer recommendations of the garden or field represented by the sample.

Nitrogen is the most commonly applied fertilizer nutrient and usually gives the greatest plant growth response. University of Alaska Fairbanks nitrogen recommendations are based on the crop's nitrogen needs and the lev-

Nitrogen deficiency symptoms on cauliflower. Nitrogen is often the most limiting nutrient in the soil for optimum plant growth and is exhibited by lower yellow leaves.

el of available nitrogen in the soil. Adjustments to these basic recommendations are made for applications of manure, compost and other nitrogen-containing amendments. Since nitrogen in the form of nitrate (NO_3-N) is easily lost through leaching or by gaseous losses in wet soil conditions, sampling mineral nitrogen levels in the spring results in the most accurate nitrogen fertilizer recommendations for the upcoming growing season.

Organic nitrogen, the largest pool of nitrogen in the soil, is available to crops after the organic matter breaks down and the nitrogen is converted to mineral (nitrate and ammonium) forms. In general, the higher the soil's organic matter level is, the lower the soil's nitrogen fertilizer requirement will be. Soil testing for organic nitrogen is a poor measure of plant-available nitrogen because the rate of organic matter breakdown and subsequent nitrogen release varies by soil type, soil conditions, location, climatic conditions, etc. and is difficult to predict. Soil organic matter breakdown, also called mineralization, is a biological process that varies with temperature, moisture, aeration, the type of organic compounds being decomposed and the relative abundance of different types of soil organisms.

A variety of optional soil tests are available that may be useful in certain situations. Electrical conductivity (EC) is a measure of the soluble salts in a soil sample. High levels of soluble salts are usually caused by excessive applications of fertilizer, compost or manure. A soluble salt test may be useful if fertilizer misapplication is suspected. Testing for high levels of soluble salts is common in greenhouse soils where high fertilizer rates during the production season may be followed by bone-dry, off-season soil conditions, which stop most microbial degradation of the nutrients.

Fertilizer labels. Understanding the information on fertilizer labels allows you to select the right type of fertilizer and to apply it at the proper rate. The three numbers on a fertilizer bag refer to the amounts of the three primary macronutrients (N, P and K) in the fertilizer. This is the guaranteed analysis of the fertilizer. The numbers are percentages, so a bag of 8-32-16 fertilizer is 8 percent nitrogen, 32 percent phosphate and 16 percent potash. By convention, P in fertilizer is expressed on a phosphate (P_2O_5) basis and K on a potash (K_2O) basis. To avoid confusion, fertilizer recommendations and rates are generally expressed on the same basis.

Fertilizers like 8-32-16 are called complete fertilizers, because they contain all three major nutrients. A fertilizer like urea (46-0-0) is a single nutrient fertilizer, containing only N. The term fertilizer ratio refers to the proportion of each nutrient ($N:P_2O_5 : K_2O$) in the fertilizer. For example, 8-32-16 has a ratio of 1-4-2.

Calculating fertilizer rates. Calculating the amount of fertilizer to apply based on the recommendations in a soil test report is done in a series of three steps:

Soil Nitrogen Terminology Confusion

As you look in various references, the same nitrogen forms have different names. When the term "organic nitrogen" is used, some authors mean nitrogen that comes from an organic source such as manure. To soil scientists, the term organic nitrogen specifically means the nitrogen that is part of the organic matter, such as proteins in the manure. Plants take up nitrogen in the mineral forms of nitrate and ammonium. These mineral forms of nitrogen are considered inorganic nitrogen even though they may have originated from an organic source.

organic matter (manure) → mineral forms of N (nitrate & ammonium) → organic matter (garden flower)

Soil sampling under apple trees for soil fertility testing.

1. Calculate the area to be fertilized (in square feet).
2. Select a fertilizer grade with the closest ratio of plant nutrients to meet the recommendation.
3. Calculate the amount of fertilizer required based on the N recommendation.

Example recommendation for a vegetable garden in Alaska's Mat-Su Valley:**

Nitrogen	0.5 pound per 100 square feet
Phosphate	1.0 pound per 100 square feet
Potash	1.5 pounds per 100 square feet (1.0 pound per 100 square feet, Kenai Peninsula)

Step 1. Calculate the area to be fertilized.
Garden is 20 feet long and 10 feet wide, or 20 x 10 = 200 square feet.

Step 2. Select a fertilizer.

- Determine the ratio of nutrients needed.
  From the recommendation above on the same 100-square-foot area we want
  0.5 pound nitrogen
  1.0 pound phosphate
  1.5 pounds potash
  For every unit of nitrogen we want the fertilizer to have 2 units of phosphate and 3 units of potash.
  We desire a fertilizer with an N:P:K ratio of 1:2:3.

- Select a fertilizer blend close to this ratio. Recognize that you will have to compromise between available options if the exact ratio is not available.

  Example: commonly available options (and their N:P:K fertilizer ratios).

8-32-16	(1:4:2)
16-16-16	(1:1:1)
10-20-20	(1:2:2)
22-11-11	(2:1:1)

  None are exact, but 10-20-20 is the closest (1:2:2 vs. desired ratio of 1:2:3). Product will supply slightly less K than desired.

- Guidelines for selecting a fertilizer blend.
  Make sure N is supplied to satisfy the recommended rate.
  Avoid applying excess N or P (because of potential water quality effects).
  Compromise on K rather than applying too little N or too much N or P.

Step 3. Calculate the required amount of fertilizer.

- Based on recommended N rate (in this example, 0.5 pound N/100 square feet):

  Apply enough 10-20-20 fertilizer to supply 0.5 pound N/100 square feet.
  10-20-20 = 10 percent N or 10 pounds of N in every 100 pounds of product, so set up the following ratio:

I Have **I Want**

$$\frac{\text{10 pounds N}}{\text{100 pounds product}} = \frac{\text{0.5 pounds N}}{\text{X pounds product}}$$

Solve for X, so…. 10 x X = 100 x 0.5, or X = 5

5 pounds of 10-20-20 fertilizer will supply 0.5 pound N.

Alternate method: If you don't want to think about solving an algebraic equation, another way of looking at it is that you simply divide the required amount of the nutrient (0.5 pound N) by the percentage of the nutrient in the fertilizer (10 percent) after converting the percentage to its decimal fraction (0.10).

- For 200 square feet to be fertilized (equivalent to two 100-square-foot areas):
  2 x 5 = 10 pounds of 10-20-20 for 200 square feet or about 20 cups of 10-20-20 since most fertilizers weigh about 0.5 pound per cup.

The "Feel" Method for Soil Texture

Textural class can be determined by feeling and manipulating moist soil with your fingers.

- Begin by placing a small sample of moist soil in the palm of your hand.
- Squeeze and flatten the soil between your fingers and thumb.

** *These recommendations vary by region and by soil test results. See your local Extension office for local information.*

- Extrude a ribbon of soil ¼ inch thick.
- Manipulate the soil until the longest possible ribbon is formed.

Characteristics of fine-, medium- and coarse-textured soils (many soils will have intermediate properties between these three basic textural classes):

Fine-textured Soils

- Form long, shiny, pliable ribbons
- Moist ribbons feel smooth and sticky
- Dry clods are very hard

Medium-textured Soils

- Do not form long ribbons
- Silts and silt loams feel fairly smooth and floury or soapy
- Loams and sandy loams are slightly gritty
- Silts are not gritty
- Dry lumps are readily broken

Coarse-textured Soils

- Do not form ribbons
- Casts fall apart easily
- Feel very gritty
- Not slick or smooth

Suggested References for Further Information

Magdoff, F. and H. Van Es. *Building Soils for Better Crops*, 2nd ed. Sustainable Agriculture Network Handbook Series. Bk-4. 240 pp.

Cavigelli, M., S. Demming, L. Pobyn and R. Harwood, eds. 1998. *Michigan Field Crop Ecology: Managing Biological Processes for Productivity and Environmental Quality*. Michigan State University Extension Bulletin E-2646. 92 pp.

Soil Fertility Handbook, Publication 611 of the Ontario Ministry of Agriculture, Food and Rural Affairs. 1998. Toronto Ontario: Queen's Printer for Ontario. 169 pp.

Brady, N. and R. Weils. 2008. *The Nature and Properties of Soils*, 14th Edition. Upper Saddle River, New Jersey: Pearson Prentice Hall. 965 pp.

Websites

Back to Basics: Soil Fertility Information, www.back-to-basics.net/

USDA supported programs for Sustainable Agriculture

- National Sustainable Agriculture Information Service (ATTRA)
  www.attra.ncat.org
- Alternative Farming Systems Information Center
  http//:afsic.nal.usda.gov/
- Sustainable Agriculture Research and Education (SARE
  www.sare.org

www.uaf.edu/ces or 1-877-520-5211

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