for the

Gardener

Center for Agroecology
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UC Santa Cruz

Building Fertile Soil

Healthy soil = healthy plants: when you build and maintain fertile soil rich in organic matter, you literally lay the groundwork for thriving plants that can develop quickly, resist pests and diseases, and yield a bountiful crop.

Can synthetic chemical fertilizers provide a shortcut to the healthy soil = healthy plants formula? After all, plants' needs are fairly basic: air, water, light, warmth, and a balance of nutrients and minerals. So why not put some seeds in the ground, apply the appropriate chemicals, and reap the harvest?

That's one possible approach to gardening—synthetic chemical fertilizers, such as the N-P-K (nitrogen-phosphorous-potassium) formulations sold in garden supply stores, do provide most of the nutrients plants need in an easy-to-use form. But these chemicals have a number of shortcomings. Because plants can only absorb a limited amount of nutrients at a time, much of these water-soluble products may be wasted and end up as runoff during rain or watering (nitrogen fertilizers are a major source of water pollution). Many chemical fertilizers provide a quick burst of nutrients, but may leave little for the plants to draw on over the course of the growing season. And because petroleum products are needed to produce the fertilizers, they use up valuable non-renewable resources. Finally, chemical fertilizers don't build or maintain healthy soil; much like taking a vitamin rather than eating your fruits and vegetables, they provide the chemicals but none of the added benefits that other soil inputs offer.

Fortunately, you can choose from a wide variety of inputs that will help you create healthy, fertile soil. Organic soil amendments such as compost, manure, cover crops, and fertilizers derived from non-synthetic sources can improve soil quality while providing a source of nutrients that lasts through the growing season. You can make or grow some of these amendments in your own garden to keep your costs low.

ORGANIC MATTER

Think of a natural system, such as a forest or meadow: it thrives year after year by recycling available nutrients. Leaves fall and break down; grasses and flowers grow, bloom, and fade; animals die and decompose—all life adds organic matter to the soil. This is the cycle you're trying to recreate in your garden.

Each time you harvest crops or pull weeds, you make a "withdrawal" from the soil's pool of nutrients and organic matter; if these aren't replaced, the soil is eventually robbed of the resources plants need to flourish. Organic matter, made up of decomposed plant and animal material, can help replenish nutrients and at the same time improve soil structure, making it easier to work and a more hospitable place for plants to thrive. Here are some readily available sources:

❑ *Compost* is rich in organic matter, and making compost is a great way to recycle weeds, kitchen scraps, leaves, manure, and other material that would otherwise have to be hauled to the dump. If you don't have a compost pile, consider starting one this fall, when there's a lot of garden and yard waste available (see page 3 of this information sheet for tips on making compost). If making your own compost isn't practical, there are commercial composts available at garden and landscape suppliers.

If you've been adding compost to your garden on a regular basis, you may be able to gradually decrease the amount you add to the soil, or try other soil-building techniques such as growing cover crops (see below). On the other hand, if you're just breaking ground or have heavy clay soils, you'll want to add lots of compost. Approximately two inches of fine-textured compost spread evenly over the beds and worked into the soil before planting is about right.

❑ *Manure* from cows, horses, poultry, and other livestock is another good source of organic matter and nutrients. It should be aged at least six months or put through the compost pile before being used in the garden. Some manures (especially poultry manure) generate too much heat when fresh and will damage plants if not aged.

Apply cattle or horse manure in a two-inch layer and work it into the soil before planting. Poultry, sheep, rabbit, and goat manures should be applied at a much lower rate, due to their higher nutrient content. If you're not growing cover crops, you can also cover your beds with manure following the harvest to rebuild organic matter and protect the soil from winter rains.

❑ *Cover crops* grown in your garden beds add organic matter to the soil, limit erosion during winter rains, and suppress weeds. In the Santa Cruz area, winter cover crops such as fava or bell beans, vetch, and rye grass can

be planted from October through early December. Between March and May, before they set seed, the plants should be harvested and composted or worked into the soil to break down. (Note: if you remove and compost your cover crops, be sure to add compost to the beds in which they were grown.)

Leguminous cover crops, such as fava beans and vetch, host a type of bacteria on their roots that fixes nitrogen from the air. These crops are known as "green manures" because they add this nitrogen to the soil when the crops break down. It takes from two to four weeks for cover crops to decompose once they're tilled in, depending on soil temperature (the organisms that decompose cover crops don't become active until the soil temperature rises to 55° F). Check with your garden supply store for seed mixes and seeding rates.

❏ Various *mulches* can also boost the soil's organic matter levels—these include sawdust, tree bark (such as redwood mulch), straw, and leaf mold. When used as a surface mulch, all of these amendments make effective weed barriers and help hold moisture in the soil, but they also temporarily tie up nitrogen as they decompose. If you plan to use these materials as a soil amendment, it may be best to compost them and return them to the soil in the form of finished compost so that they won't compete with plants for nutrients.

ORGANIC FERTILIZERS

Although organic matter (especially compost) provides many of the nutrients plants need, other purchased organic fertilizers can further enrich the soil and correct nutrient deficiencies. You can find out what nutrients your soil needs by having a soil test done; be sure to find a lab that can recommend organic amendments. Organic fertilizers are available from garden and farm supply stores and mail order companies.

❏ *Nitrogen (N) sources:* Plants need nitrogen to develop healthy leaves and stems; nitrogen-deficient plants will look yellow and grow slowly. Blood and bone meals, fish meal and emulsion, hoof and horn meal, soybean, cottonseed, and kelp meals all contain significant percentages of nitrogen. These can be dug into the soil prior to planting or used as a side dressing to nourish heavy-feeding plants such as corn and brassicas. Because it escapes so readily from the soil in the form of a gas or through leaching, nitrogen should be replenished each year with organic matter and/or fertilizers.

❏ *Phosphorous (P) sources:* Plants need phosphorous to grow, flower, and develop healthy root systems. Rock and soft phosphates, bone meal, and cottonseed meal all provide high percentages of P. Unlike nitrogen, phosphorous lasts a long time once added to the soil.

❏ *Potassium (K) sources:* Plants need potassium to strengthen plant tissue, make vegetation more disease-resistant, and develop chlorophyll. Sources include wood ashes, cottonseed meal, granite dust, and greensand. Wood ashes will also "sweeten" your soil by raising the pH, making it less acidic. Avoid contact between freshly spread ashes and germinating seeds or new plant roots, as the ash may burn plant tissue. Potassium, like nitrogen, turns over quickly in the soil system and must be replenished.

❏ *Other minerals:* In addition to the three major nutrients described above, plants need sulfur (S), magnesium (Mg), and calcium (Ca), and minor amounts of other minerals, or trace elements. These can be found in such inputs as greensand, soil sulfur, lime, and kelp meal.

Fertilizers from organic sources may be especially important for soil low in organic matter, or during the first seasons that you reduce or eliminate the use of synthetic chemical fertilizers. As the soil's texture and fertility improve with regular additions of organic matter and you build a pool of soil nutrients, you should need fewer inputs of purchased fertilizers.

The question of how much and what type of fertilizers to use will depend on your soil. One rule of thumb is to use 4 lbs of N, 10 lbs of P, and 6 lbs of K per 1,000 square feet on soil that has medium levels of phosphorous and potassium, or on untested soils.

Calculate the number of pounds of nutrient available by multiplying the number of pounds of material by the percentage of the nutrient in question: a 50-pound bag of fertilizer that is 5% nitrogen will contain 2.5 pounds (50 x .05 = 2.5) of nitrogen. Because they usually last through the cropping season, most organic fertilizers don't require repeated applications.

PREPARING GARDEN BEDS

Carefully prepared beds will make the most of rich, fertile soil. *Double digging,* a technique in which the soil is loosened to a depth of two shovel blades (about two feet), is one of the most effective ways to create *raised beds* (so called because the turned soil mounds higher than the surrounding paths). For detailed instructions on how to make raised beds, consult *How to Grow More Vegetables Than You Ever Thought Possible on Less Land Than You Can Imagine* or *Lazy-Bed Gardening: The Quick and Dirty Guide* (see ***Resources,*** page 4).

Soil that has been double dug and amended with compost and organic fertilizers provides ideal growing conditions: roots can penetrate deep into the loose, aerated soil, drawing on a large area for water and nutrients. Once formed, the beds should not be walked on—limiting foot and wheelbarrow traffic to the paths ensures that the soil in the beds retains its light, airy texture.

Beds don't need to be double dug every year. They can be renewed by forking in a layer of compost (an inch or more) over the bed's surface prior to planting crops in the spring.

MAKING COMPOST: THE BASICS

Compost builds healthy soil which in turn produces healthy, strong plants. By using compost, you are feeding the soil creatures, from the tiniest bacteria to the longest worm, that in turn make nutrients available to plants.

All organic materials—whether leaves, bones, coffee grounds, or heaps of dead weeds—will eventually rot. However, a random stacking of organic materials won't necessarily result in great compost. For efficient decomposition, a compost pile needs a good balance of the Basic Four: Greens + Browns + Moisture + Air. "Greens + Browns" is a simplified reference to balancing the nitrogen-rich materials (grass clippings, vegetable trimmings, green weeds) with the carbon-rich materials (fallen leaves, straw, sawdust). "Moisture + Air" reminds us that fast decomposition requires both a good moisture content and ample oxygen for the decomposer organisms in the pile. Other variables that affect the composting process include the particle size of the compost materials, the volume of the pile, and the number of times the pile is turned.

Greens = Nitrogen Materials

For gardeners, green weeds, green crop residues, and vegetable trimmings are readily available sources of nitrogen materials. Young, green plants, such as new spring grass, are very high in nitrogen. But as a grass plant grows older and browner, it loses some of its nitrogen or uses it to produce seeds. To capture the most nitrogen for your compost pile, pull out finished crop plants and weeds while they are still green. If you let them languish in your garden, they not only lose some of their nutrient value, but also can serve as hosts to mildew, insect pests, snails, and slugs. Cover green materials with a tarp to retain moisture and nitrogen until you are ready to build your pile.

Browns = Carbon Materials

"Brown" materials, such as straw, leaves, dry grass, and sawdust, can be thought of as carbon sources for the compost pile. Brown materials can be stored easily in a bin for later use. For example, you can stockpile fallen leaves or dry weeds in autumn and layer them with fresh green materials the following spring.

Greens + Browns

Beginners can use this rule of thumb: layer 50% green to 50% brown by volume. Layers can be two to eight inches thick, depending on the particle size and moisture of the materials. For example, layer four inches of brown leaves on top of four inches of green weeds and repeat. Layering is a good way of estimating equal proportions.

Moisture

A compost pile should ideally be 40% - 60% moisture, or about as moist as a wrung-out sponge. The easiest way to ensure consistent moisture throughout the pile is to water each brown, dry layer as you go. Straw, leaves, and sawdust can be moistened in a wheelbarrow and then drained to remove excess water. If you water the pile itself, use a hose sprayer for good coverage and take special care to wet the corners and the edges of the pile.

Make sure to cover the pile with a hole-free, plastic tarp before winter rains start. Rain will waterlog the pile, and it can also leach away nutrients. Too much moisture can result in compaction and a loss of oxygen in the pile. If the pile seems too wet, turn it to aerate it and add some bulky materials.

Too little moisture can result in piles that decompose slowly and don't heat up. If a pile seems dry, turn it, examine it for moisture, and add water as needed. Sometimes a pile will have dry pockets where a layer was not watered enough. Always expect that the outside 8-12 inches of material will be drier and less decomposed than the inside.

Building Air into a Pile

The best decomposers for composting are aerobic (oxygen-requiring) bacteria. If a pile lacks oxygen—because it is either too wet, too dense, or too big—anaerobic bacteria will take over, producing their characteristic "rotten egg" smell. Without oxygen, a pile will still decay, but aerobic bacteria bring about faster decomposition that retains more nutrients and creates a pleasant odor.

Build air into a large pile in the following ways: 1. Loosen the soil that will lie under the pile; 2. Add bulky materials like cornstalks to the bottom of the pile; 3. If using wet, finely textured materials such as grass clippings, layer them with bulky materials to avoid compaction; 4. Turn the pile at least once.

Size of Materials

The size of your materials determines how fast they will compost. Materials with small particle sizes, such as grass clippings, have more overall surface area exposed for bacteria and other decomposers to munch on. For this reason, chopping large materials (especially woody stalks) will speed the composting process. Use a sharp spade to chop garden weeds and crop residues. A lawn mower will work for leaves, but you may need a shredder for woody prunings that are thicker than a pencil. If all your materials are very fine (for example, lawn clippings), however, the layers can compact and become matted.

Volume and Containers

A large, properly built pile is self-insulating and can sustain temperatures of 140º to 160º F for ten days to two weeks. These high temperatures will kill most weed seeds and diseases harmful to plants and humans.

To heat up properly, a pile must measure at least three feet square and three feet deep. Some experts say that piles should be closer to four feet on a side, but not much larger than five feet tall and five feet wide (and any length). A small pile will also make usable compost, but it won't sustain high temperature long enough to kill a significant number of weeds seeds and disease organisms.

Organic Matter Fuels Decomposition

Although it makes up only a small percentage of your soil, organic matter provides the fuel that drives the decomposition process. Invertebrate decomposers, such as earthworms and beetles, first reduce organic matter to smaller particles and incorporate it into the soil. Then bacteria, fungi, and other microorganisms break it down into its chemical constituents, which become available for plants to use as they develop.

Carbon dioxide released from the organic material combines with water to form carbonic acid, a weak acid that acts as a solvent to free calcium, potassium, magnesium, and other minerals from the soil for plant growth. Because decomposition is an ongoing process, the nutrients in organic matter are available over the course of the growing season, providing a long-lasting source for plants. But as you cultivate the soil and harvest plants, the soil's organic matter levels decrease, which is why it's critical to replace lost organic matter with compost, cover crops, or other sources in order to maintain productive soil.

Besides supplying nutrients, organic matter improves soil structure: the organisms that break down organic material secrete gluey substances that bind soil particles together in a crumb-like structure, creating air spaces where roots and water can penetrate. The spongy quality that organic matter imparts to soil also helps it retain moisture, thereby reducing water needs.

Some people like to contain their piles in wood, wire, plastic, or brick enclosures. Check the ***Resources*** section for compost publications—they describe ways to build a variety of compost bins.

Turning

Turning a compost pile speeds the composting process and produces a better end product. It reintroduces oxygen to the pile, remixes brown and green materials, and lets you troubleshoot any problems and remedy them immediately.

When Is It Done?

Signs that your compost pile is ready for use include a cool temperature inside the pile, the presence of worms, beetles, and sowbugs, and an earthy smell and rich brown color. Most pile take about four to six months to mature if they are not turned.

Using Finished Compost

Your finished compost may not look like the finely textured, stick-free stuff available in bags at the garden center. Fear not. Sticks and other materials that haven't thoroughly composted will continue to decompose in the soil. There is no need to sift compost that is going into a garden bed. For propagation mixes and seed beds, however, always use your most finished, stable compost that has been sifted through a 1/4-inch screen.

What Not to Compost and Why

- Meat, dairy products, and greasy foods are likely to attract pests.
- Cat, dog, and human feces can contain harmful pathogens.
- Pernicious weeds, especially those with rhizomonous root systems (e.g., bermuda grass), may not be killed in the composting process.
- Diseased or bug-infested plants should be kept out of slow, cool piles and should be added with discretion to the center of hot piles (when in doubt, keep it out).
- Weeds with mature seed heads should be kept out of slow, cool piles to avoid spreading.
- Needles from conifers are very slow to break down and can often be quite acidic (a few are okay).

RESOURCES

Golden Gate Gardening: The Complete Guide to Year-Round Food Gardening in the San Francisco Bay Area and Coastal California, by Pam Peirce, 3rd Edition. Seattle, WA: Sasquatch Books, 2010.

Home Composting. Santa Cruz: Ecology Action. (Information available free by contacting Ecology Action, 831.426-8935, or download publications from the web site, www.compostsantacruzcounty.org)

How to Grow More Vegetables Than You Ever Thought Possible on Less Land Than You Can Imagine, by John Jeavons, 7th Edition. Berkeley: Ten Speed Press, 2006.

Lazy Bed Gardening: The Quick and Dirty Guide, by John Jeavons and Carolyn Cox. Berkeley: Ten Speed Press, 1993.

Let It Rot! The Home Gardener's Guide to Composting, by Stu Campbell, 3rd edition. Storey Publishing Co., N. Adams, MA, 1998.

Start with the Soil, by Grace Gershuny. Emmaus, PA: Rodale Press, 1997.

The Soul of Soil: A Guide to Ecological Soil Management, by Grace Gershuny and Joseph Smillie. White River Junction, VT: Chelsea Green Publishing Co., 2008.

The Sustainable Vegetable Garden: A Backyard Guide to Healthy Soil and Higher Yields, by John Jeavons and Carol Cox. Berkeley, CA: Ten Speed Press, 1999.

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