Soil Nutrients

Slide 1

Plants need at least 16 elements to live and grow. Three of those - carbon, hydrogen, and oxygen - make up most of the plant tissue, and come entirely from air and water. The other 13 essential elements come mostly or entirely from the soil, and are called plant nutrients.

These nutrients are classified as major nutrients or micronutrients, depending on how much of the nutrient the plant needs. Plants need relatively large amounts of the major nutrients compared with the micronutrients.

In western Washington, deficiencies of any of the major nutrients are common. Among the micronutrients, only boron deficiencies are common west of the Cascades. Because excess boron can lead to toxicity, boron should be applied only when a soil test or fertilizer recommendation indicates a need.

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Nitrogen, phosphorus and sulfur are major nutrients that are most likely to be deficient in eastern Washington. In soils with high pH, deficiencies of micronutrients such as zinc can also occur.

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Let’s look at nitrogen as an example. Nitrogen is an essential part of many key substances in the plant, such as chlorophyll, proteins, and DNA. Each green cell in the plant contains many molecules of chlorophyll, and each chlorophyll molecule contains four nitrogen atoms. Chlorophyll plays an essential role in photosynthesis. Proteins perform a vast array of functions on plants. Proteins are long chains of amino acids, and each amino acid in the chain contains nitrogen. DNA molecules are made of thousands of nucleic acids that carry the genetic code, and each of the nucleic acids also contains nitrogen. We can see why plants need large amounts of nitrogen to thrive.

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Plant growth and health, and the yield and quality of harvested fruits and vegetables will suffer if one or more of the nutrients is deficient. Some nutrient deficiencies show diagnostic symptoms of discoloration or death of plant tissue. Visual symptoms of severe P deficiency and Mg deficiency on corn are shown on this slide.

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It is possible to apply too many nutrients. Excess nitrogen results in enlargement of leaf
tissue without a proportional increase in the strength of stems, making plants more susceptible to storm or disease damage. Excessive levels of nitrogen can delay fruiting or flowering in some plants, potentially decreasing yield and quality of harvest. Nitrogen can also leach into groundwater or sensitive bodies of surface water, where it becomes a contaminant. Excess levels of some other nutrients, such as boron, are also harmful to plants.

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How do nutrients become available?

**Slide 8**

The source of the nutrients in soil is the soil mineral matter and organic matter.

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Soil mineral matter is derived from rocks and contains all of the elements found in rocks – including every plant nutrient except nitrogen. Soil organic matter contains all of the plant nutrients, and is particularly important as a source of nitrogen, phosphorus, and sulfur.

Most of the nutrients in soil are part of the matrix of mineral matter and organic matter, and are tied up in forms that are not available to plants.

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Nutrients are released from the mineral matter into soluble, available forms by a very slow dissolution process called weathering. Although there is a huge supply of nutrients within the mineral matter, only a tiny amount is released by weathering each year.

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Soil organisms release the nutrients from organic matter into soluble available forms. A complex web of organisms, including bacteria, fungi, actinomycetes, nematodes, insects, and others play a role in the degradation of organic matter and release of nutrients. These organisms are most active when the soil is warm and moist, and become dormant in cold or dry soil. Plants respond similarly to their environment, resulting in a synchrony between nutrient release from organic matter and the potential for nutrient uptake by plants.

Soil organic matter is resistant to degradation, and it decomposes at a rate of only 1 to 2% per year. Fresher organic materials, such as cover crops, grass clippings, or manures decompose at a much faster rate, and release a greater proportion of their nutrients in to available form. More information on the availability of nutrients from organic materials will be covered when we discuss fertilizers.

Once nutrients are released into soluble form, can rainfall and irrigation water leach them below the root zone and into ground water?
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It depends on the nutrient. Many nutrients have positive charges when in soluble form (they are positive ions or cations). The surfaces of clay particles and humus have negative charges, which attract the nutrient cations and hold them on or near their surfaces, reducing the potential for leaching.

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As plants use nutrients in the soil solution, they are replaced by nutrients on the clay and organic matter surfaces. This process is called cation exchange, and the exchangeable cations are a ready reserve of nutrients for plants. When we add nutrients back to the soil through fertilizers or soil amendments, some will exchange back onto the clay and organic matter surfaces, building the reserve in the soil.

We can use money as an analogy for nutrients. Available nutrients are like cash in our pocket, ready to spend immediately. Exchangeable nutrients are like money in our bank account that we can easily access with an ATM card to make it available to spend. Nutrients bound within the matrix of organic and mineral matter are like money in a trust fund that is made available slowly over a long period of time.

What about nutrients that are negatively charged? These include the nitrate, sulfate, and phosphate, among others, and are called anions. The picture is more complicated than for cations, and we will not go into it in detail. There is a process called anion exchange, similar to cation exchange, but our soils generally have only a small anion exchange capacity. As a result, anions such as nitrate leach readily in areas with moderate to high rainfall. On the other hand, phosphate is bound to soil by other, stronger processes, and is not highly available to plants or prone to leaching.

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Let’s look in more detail at nitrogen, a key nutrient. Nitrogen is the nutrient needed in the greatest amounts by plants, and it is the only nutrient that is not contained in the mineral fraction of the soil. Its natural sources are organic matter and fixation of atmospheric nitrogen.

Most of the nitrogen in the soil is tied up within the organic matter and is not immediately available to plants. Other sources of organic nitrogen include plant residues and manures. As the soil warms in the spring, the soil organisms become more active, decomposing soil organic matter and plant residues, and releasing nitrogen from the decomposing residues as ammonium (NH$_4^+$). Ammonium is a simple soluble ion, and is available to plants. As the soil continues to warm, specialized bacteria called nitrifiers convert ammonium into nitrate (NO$_3^-$), another simple, soluble ion that is available to plants. Nitrate is negatively charged and not held tightly to the soil particles. It will leach below the root zone during the winter wet season or during excessive irrigation. As a result, any nitrate that is not used by plants during the growing season will be lost to leaching during the winter. The only exception is in the most arid parts of the state, where there is seldom enough rainfall to leach nitrate completely out of the root zone.
What if you have a wet area where water appears to pond rather than leach? Nitrate will still be lost. In saturated soils, microbes convert nitrate to nitrogen gases, which are not available to most plants, and diffuse to the atmosphere. This process is called denitrification.

The key to managing nitrogen supply is to provide enough to meet the needs of your garden plants, without having an excess subject to winter leaching or denitrification.

*N* fixation. Nitrogen fixation is the process that incorporates atmospheric nitrogen into plants and ultimately soils. Nitrogen gas comprises nearly 80% of the earth’s atmosphere. Nitrogen gas (N₂) is very stable chemically and biologically, and only a few organisms are able to convert N₂ gas into biologically useful forms. These are nitrogen-fixing bacteria such as *Rhizobia* and *Frankia*. *Rhizobia* form nodules in the roots of legumes (such as peas, beans, alfalfa, clover, and vetch), and convert N₂ gas from the soil atmosphere into biologically available N within those nodules. The available nitrogen is used by legumes to meet their nitrogen needs. The plants supply energy (from photosynthesis) and nutrients to the bacteria and the bacteria supply fixed N to the plants. This is a fairly costly arrangement for the legumes, because the *Rhizobia* need a lot of energy to fix nitrogen. Alder trees have a similar symbiotic relationship with *Frankia*.

The fixed nitrogen is returned to the soil as organic nitrogen in the residues of the nitrogen-fixing plants after they shed leaves or die. This organic nitrogen is eventually released to other plants by the soil organisms. Humans can also fix atmospheric nitrogen by using natural gas as the energy source. Because nitrogen fixation requires large amounts of energy, the price of nitrogen fertilizers is directly related to fossil fuel prices.

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When you use an organic fertilizer, most of the nitrogen is usually in organic forms, and is not immediately available to plants. The nitrogen is released into available form as the soil organisms decompose the fertilizer, as shown in the nitrogen cycle. Thus, organic fertilizers are slow-release fertilizers. Processed fertilizers contain ammonium or nitrate, which are immediately available to plants, making them fast-release fertilizers. Some processed fertilizers contain urea, which breaks down rapidly to ammonium, and is also considered a fast-release fertilizer.

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Break Time

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“Organic” has multiple meanings, which can cause confusion when discussing organic fertilizers. For Master Gardeners, we define organic fertilizers and soil amendments as materials that are close to their natural state – they may have been dried, composted,
ground, or blended with other natural materials, but they have not been subject to industrial processing to refine, concentrate, or synthesize them into different chemical forms. Organic fertilizers include biologically based materials such as animal manures, composts, or alfalfa meal, and unaltered mineral materials such as rock phosphate.

Processed or synthetic fertilizers have been altered from their natural source to concentrate nutrients and increase their availability to plants.

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Because organic fertilizers have not been concentrated, they tend to have a low nutrient analysis compared with processed fertilizers. Analysis refers to the concentration of nutrients in the fertilizer. There is nothing wrong with a low analysis; it just means that you will need to apply a larger amount of fertilizer. Neither is there anything wrong with the high analysis of a processed fertilizer. You need less material, and there is less to ship and package.

Organic fertilizers are usually slow-release, because most of the nutrients must be released by the soil organisms or by weathering, as described earlier. Most processed fertilizers are fast-release, because the nutrients have been processed into soluble, available forms. Some processed fertilizers have been synthesized to release nutrients more slowly, mimicking organic fertilizers. Slow-release fertilizers can be applied a single time to gardens to meet nutrient needs for the year, while it is often better to make split applications of fast-release fertilizers to avoid loss of the available nutrients before the plants need them.

Processed fertilizers have a known analysis – the label specifies the percentages of the major nutrients and the specific materials used. Packaged organic fertilizers have similar labels, but nutrient availability is not guaranteed, because not all of the nutrients are released the first year, and nutrient release varies with soil temperature and moisture. Homegrown organic fertilizers such as cover crop residues or manure from a neighbor’s livestock have no analysis, and we need to rely on published data to estimate the nutrient concentration and availability of those materials.

Organic fertilizers of biological origin contain organic matter, while processed fertilizers do not. The amount of organic matter in most fertilizers is small compared with soil amendments such as compost, but it still provides benefits to the soil.

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One of the most interesting differences between organic and processed fertilizers is the source of the materials. Many organic fertilizers (manures, wood ashes, feather meal, etc.) would be waste products if they were not used as fertilizers. Using these materials responsibly helps reduce waste and close the recycling loop.

The nitrogen source of processed fertilizers is atmospheric nitrogen, which is abundant and free. But, it requires a large amount of fossil fuel energy to fix atmospheric nitrogen into plant available forms. Phosphorus fertilizers are made by treating mined rock
phosphate with acid, and potassium fertilizers are mined from deep salt deposits, and then separated from the sodium and other salts.

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Plants primarily take up nutrients as simple, soluble ions, whether the source of nutrients is a processed fertilizer, an organic fertilizer, or soil organic matter. The differences between organic and processed fertilizers are in their source and processing, nutrient levels, nutrient availability, and how they fit into overall garden management.

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The labels on processed fertilizer packages tell you the amount of each of the three primary nutrients in the fertilizer, expressed as a percent of total fertilizer weight. Nitrogen is always listed first, phosphorus second, and potassium third. Thus, a bag of fertilizer labeled 5-10-10 contains 5 percent nitrogen, 10 percent phosphorus (expressed as units of phosphate), and 10 percent potassium (expressed as units of potash).

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Extension bulletins provide recommendations for fertilizer needs for gardens and different crops. Extension bulletin recommendations are a "one size fits all" approach, providing recommendations for average garden conditions. If you have soil test done, as described below, the recommendation will be adjusted to fit the nutrient levels in your garden. In some cases the recommendations will be given on a per plant basis, such as for a blueberry bed, and you simply measure and apply fertilizers to each plant as directed in the recommendation. In many other cases, the recommendation is given on an area basis, and you need to choose a specific fertilizer to meet the nutrient recommendations, and then calculate how much you need to cover the area of your garden, lawn, etc.

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pH is a measure of how acid or alkaline a soil or solution is. Soils with pH 7 are neutral, pH less than 7 are acid, and pH greater than 7 are alkaline. The pH scale is a logarithmic scale, meaning that every one unit change in pH is a ten-fold change in acidity or alkalinity. A soil at pH 5 is 10 times more acid than at pH 6; a soil at pH 4 is 100 times more acid than at pH 6.

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pH affects the solubility, and thus the availability of many nutrients. Phosphorus, for example, is most soluble near the middle of the pH range, while iron is more soluble in acid soils. Some plants develop iron deficiencies in alkaline soils, because there is not enough iron available to meet their needs. Soil pH also affects the availability of toxic metals, such as aluminum. Aluminum is abundant in soil, but does not cause toxicity problems in most soils because its solubility is low over most of the soil pH range. Aluminum becomes more soluble as pH decreases, and toxicity becomes a problem in highly acid soils. Soil microorganisms are also sensitive to pH, with the greatest microbial
activity and greatest potential for nutrient cycling in the middle of the pH range.

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Acidification of soils is a natural process in humid regions, a result of the formation of acids during decomposition of organic matter and the leaching of soil minerals. Some fertilizers (such as ammonium sulfate and urea) also increase soil acidity, as their transformation in soils produces more acids. In arid regions soluble minerals tend to accumulate in soils faster than they leach, raising pH.

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Most garden vegetables are best adapted to the middle of the pH range – between pH 6 and 7.5. “Acid-loving plants” such as blueberries and rhododendrons have a high iron requirement and grow best in soils at pH 4.5 to 5.5.

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In the humid areas of western Washington, we often need to raise soil pH to provide the best conditions for growing garden vegetables. We use agricultural lime (CaCO₃) to neutralize soil acidity and raise pH. Lime is ground limestone and is considered an organic amendment. Adding lime to soil is analogous to adding baking soda to vinegar. The bicarbonate in the baking soda neutralizes the acidity in the vinegar, producing carbon dioxide (the fizz) and water. The carbonate in the lime reacts similarly with soil acidity – we don’t see the soil fizz because the neutralization of soil acidity occurs slowly. The calcium in the lime provides a nutrient that is often deficient in acid soils. Using dolomite lime provides magnesium as well as calcium. A soil test is the best way to determine if you need lime, and to estimate how much to add.

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Sometimes we want to acidify soil to grow acid-loving crops. We may need to acidify soil to grow blueberries in some western Washington gardens, and we will usually need to acidify to grow blueberries in most locations east of the Cascades. Elemental sulfur is oxidized by soil bacteria, creating acids and reducing the pH of the soil. Adding too much sulfur can reduce the pH excessively. Ammonium sulfate fertilizer acidifies soil more slowly. For more information on acidifying garden soils, link to the Oregon State University bulletin EC 1569-E, Acidifying Soil for Blueberries and Ornamental Plants in Yards and Gardens West of the Cascades.

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A soil test is a valuable tool to estimate your lawn or garden fertilizer needs. Soil testing is most useful if you are starting a new lawn or garden or if you are observing problems that you suspect are related to nutrients. Soil testing is also very useful if you have an old garden where you have added manures or fertilizers for many years – you may learn that you don’t need to add as much fertilizer as you have in the past.
A soil test reports the levels of nutrients in the soil relative to crop needs, and gives you a fertilizer recommendation. The test results are based on years of field research that studied the relationship between soil test levels and fertilizer needs over a wide range of crops and soils. A basic garden soil test for western Washington includes phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), boron (B), soil pH, and the lime requirement. A basic eastern Washington soil test includes P, K, zinc (Zn), pH, and soluble salts.

Nitrogen levels in the soil can change rapidly in response to biological release of available N and plant uptake, making soil tests for N less useful to gardeners than tests for other nutrients.

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A soil test is only as good as the sample you collect. Follow these steps to collect and prepare a sample that is representative of your garden or lawn:

**Taking Soil Samples for a Soil Test**

1. Sample a defined area. This is an area with similar type of soil, crops, and management, such as a vegetable garden, a blueberry bed, a lawn, or a pasture.
2. Collect at least 10 samples from the area and combine them in a bucket. Each sample should extend from the surface to a depth of 7 to 12 inches in a garden, or from the surface to a depth of six inches in a lawn. Samples should be representative of the area, avoiding unusual spots.
3. The best tool for sampling is a soil probe, because it takes uniform samples throughout the entire depth of the core. Short-handled soil probes for gardeners cost about $20. An alternative is to use a spade to open a hole, and then take a slice along the side of the hole for your sample. Some gardeners use bulb planters, but these may not sample deep enough.
4. After you have mixed the soil well in the bucket, spread it onto paper or trays to air dry. Do not send moist or wet soil to the lab.
5. Once the soil has dried, mix it again, and take a 1 cup sample to send to the lab. Avoid rocks, sticks, and thatch. A plastic sandwich bag with a sealing top is a handy container for the sample. Mark the bag clearly with your name and the location of the soil sample (vegetable garden, lawn, etc.).
6. Fill out the paperwork provided by the lab, and send the sample to the lab along with the paperwork.

Several commercial laboratories do soil tests for gardeners. Check with your county Master Gardener program to find out about laboratories and lab choices. If you have questions about a laboratory, don’t hesitate to call them to find out if they test samples for gardens, what the test costs, and how they present the results.

Home soil test kits are not as reliable as professional laboratory tests, and often they are not calibrated to our local soils. A home pH test kit using colored dyes can get you in the ballpark on pH, but otherwise we do not recommend home soil tests.
We will now move to a discussion of organic amendments for gardens and landscapes.

Soil organisms are responsible for the decomposition of organic residues in the soil and the cycling of nutrients between organically bound and soluble, available forms. Soil organisms form a complex ecosystem that functions as nature's land-based recycling system, decomposing organic remains and releasing energy, carbon dioxide, water, and available nutrients. This recycling process also creates humus, strengthens soil structure, kills pathogens, and breaks down many contaminants. Specialized organisms play other key roles in soil, such as symbiotic nitrogen fixation by Rhizobia, and enhanced root function through Mycorrhizae. Organic soil amendments and plant residues fuel the microbial recycling process in soil.

A large variety of organic amendments are available for gardeners. The key to understanding how to choose and use these amendments is based on the carbon to nitrogen ratio (C:N) and stability of the amendments. These two properties influence nutrient availability of the amendment, and its suitability for garden and landscape uses.

We’ll describe C:N ratio in the next slide. Stability refers to the degree of decomposition of the amendment. A composted material is more biologically stable than a fresh material. Composts are becoming more like humus – they break down slowly in the soil. As a result, they do not stimulate as much biological activity as a fresh material, but their effects last longer.

All organic materials contain carbon and nitrogen, but the amount of nitrogen relative to carbon varies widely. The C:N ratio ranges from less than 5:1 (or 5 parts C to 1 part N) to greater than 500:1 in organic materials. Materials derived from animals (such as fish meal, feather meal, or many fresh manures) have the lowest C:N ratios (they are rich in nitrogen), while woody materials have the highest C:N ratios (they contain little nitrogen).

Materials with low C:N ratios supply nitrogen to plants when they are added to soil. As the soil organisms decompose these materials, the organisms use some of the carbon as an energy source, respiring it as CO₂. They use additional C to grow and reproduce (producing new biomass), incorporating some of the nitrogen into their bodies as well. They do not need all of the nitrogen, and the remainder is released as ammonium, which is available to plants (as described earlier under The Nitrogen Cycle).

When materials with high C:N ratios are added to soil, the organisms begin decomposing those materials, using some carbon as an energy source, and incorporating some carbon into their bodies as new biomass. In this case, the organic material does not contain
enough nitrogen to meet the growth needs of the soil organisms, and the organisms scavenge available nitrogen from the soil, *reducing* the supply of nitrogen available to plants in the short term. This is called nitrogen immobilization.

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We can divide organic amendments into three classes based on their C:N ratios. These classes are hot stuff, cool stuff, and woody stuff (not scientific terms, but easy to remember).

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Hot stuff includes animal products such as fish and feather meal, poultry and rabbit manures, seed meals from canola and other seeds, and dried biosolids.

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These materials have low C:N ratio and break down rapidly in the soil, supplying nitrogen to plants. They are the most nitrogen-rich of organic materials, and are used as fertilizers. Over-application can lead to excess nutrients in the soil, potentially harming the crop and water quality, and causing acute salt problems in arid areas.

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Most composts fall in this category, as do some fresh organic materials, including yard debris, cover crop residues, and solids separated from dairy manure.

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These materials typically have C:N ratios between 15 and 25:1, resulting in slow nitrogen availability. Because they do not supply large amounts of nutrients in the short term, they can be applied at higher rates without risk of over-fertilization. These materials are used as soil amendments, to build organic matter in the soil. In eastern Washington, salts may limit application rates, so it is important to learn about the salt concentration of different materials, and how to handle them in arid environments.

It is also important to be aware of nitrogen release dynamics from these materials. When fresh cool stuff is added to the soil, biological degradation is fairly rapid, resulting in a period of N immobilization (tie-up) that may last for several weeks. This may slow the growth of your garden if you don’t add a little extra nitrogen fertilizer. By the end of the season the amendment will supply small amounts of nitrogen. Short term immobilization of nitrogen is less common with composts, because they don't decompose as quickly.

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Woody materials include straw, sawdust, paper waste, and horse (or other) manures that are rich in bedding.
These materials have C:N ratios greater than 30:1 and immobilize nitrogen when incorporated into the soil. If you use these as a soil amendment, you will need to add extra nitrogen fertilizer to meet the needs of both the plants and soil organisms. It is better to use woody materials as mulch or a bulking agent for compost. Immobilization is not a problem when woody stuff is used as mulch, because the soil microbes and the woody materials only contact each other at the point where the mulch meets the soil surface. The rest of the root zone is not affected. If you later mix the woody mulch into the soil, immobilization will occur.

This slide gives some simple guidelines for estimating application rates for organic amendments. For a hot material such as poultry manure you only need 3 to 5 gallons per 100 square feet of garden to meet the nutrient needs of a long-season heavy feeding crop such as sweet corn. You would need less for plants that require less nitrogen. Rabbit manure supplies less nitrogen than poultry manure, and you can apply up to 20 to 40 gallons per 100 square feet to meet nutrient needs.

For cool materials such as horse manure, dairy solids, and composts you can add up to an inch each year to an annual garden in western Washington to build organic matter. In eastern Washington, where salt accumulation can be an issue, application rates may be limited by the salt concentration of the material you are using.

If you are building new beds or establishing a new garden or landscape in poor soil, you can add up to 1/3 compost by volume to your soil, unless limited by salts.

Nitrogen-rich organic materials such as feather meal, fish meal, and canola meal release most of their nitrogen during the first growing season. You can use these like inorganic fertilizers (Slide 18). To do more detailed calculations for organic fertilizers, check out the Organic Fertilizer Calculator on the web.

We have already discussed the role of compost as a soil amendment. You can purchase municipal compost made from yard debris, manure, biosolids, food waste, or other organic materials, or you an make your own from residues from your yard and garden. The main benefit of compost is that it is a long-lasting source of organic matter. Most composts release nutrients only at very slow rates, although nutrient availability does vary somewhat among different composts.

Planting cover crops is a way to grow your own organic matter in your annual vegetable or flower garden. Cover crops are usually grown during the winter in otherwise fallow areas of the garden. They provide a number of benefits, and your choice of cover crops depends on which benefits are most important to you. Cover crops help protect the soil from erosion during the winter, they compete with weeds, and they provide fresh biomass
when tilled into the soil, or act as a mulch when cut and left on the soil surface. Legume cover crops fix nitrogen and can supply some of the nitrogen needed for the next crop.

Winter cover crops need to be planted early to get the greatest benefits. Early means September in most of Washington. How can you plant early cover crops when you are still harvesting from your garden late into the fall? You can plant selectively in areas of your garden where you have finished harvesting – such as a sweet corn plot. You can also plant cover crops between the rows of fall garden crops – such as planting hairy vetch between rows of carrots, lettuce, or spinach. This is called relay planting or interseeding. Plant the cover crop 3-4 weeks after planting the vegetable crop, so the cover crop doesn’t compete too much until after you have harvested the vegetables.

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This slide shows examples of relay planted and fall planted cover crops, and also an example of a short-term pasture used to rest a field for an entire year.

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As cover crops grow larger, the benefits of biomass increase, but so does the work of incorporation. Quality of the cover crop residues declines once they start flowering, and if you let them go to seed they may become a weed in the next garden crop. After you incorporate the cover crops, wait for two to three weeks before planting your garden crops, to allow time for initial decomposition of the residues. If the cover crop is tall and hard to turn under, mow it first to break up the stems. Some gardeners leave the cover crop residue on the surface to act as a mulch, and transplant tomatoes or other vegetables into the soil beneath the mulch.

Cover crops are best suited to beds that you will be harvesting early or are suitable for relay planting, and in areas that you won’t be planting first thing the next spring. Planning ahead will allow you to make best use of cover crops.

For information on the suitability and characteristics of specific cover crops, seeding rates, and more details on management, link to the bulletins on cover crops.
Cover Crops for Home Gardens
http://cru.cahe.wsu.edu/CEPublications/eb1824/eb1824.html
and the Oregon State University cover crops series
http://extension.oregonstate.edu/catalog/details.php?sortnum=0124&name=Cover+Crops

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Fresh manure can contain human pathogens such as salmonella and E. coli O157:H7. These pathogens can be present in soil on the surfaces of plants such as lettuce or spinach. The greatest risk of pathogen transmission occurs when fresh manure is applied to crops that may be eaten fresh and are in close contact with the soil, such as leafy greens, carrots, and strawberries. Pathogens will die off in the environment, but it may take weeks or months to reach safe levels, depending on the type of pathogen, numbers present, and environmental conditions (such as temperature and moisture).
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If you use animal manure in your vegetable garden, you can take several steps to ensure the safety of your food. If you incorporate the manure into the soil before planting, this reduces the amount of contact between manure and leafy crops. This alone does not solve pathogen problems, but it does reduce them.

The USDA recommends waiting at least 120 days between the time you apply fresh manure and the time you harvest high-risk crops such as lettuce and carrots. For low risk crops (such as sweet corn) the waiting period is 90 days. These waiting periods provide time for the pathogens to die off in the soil.

If you use thoroughly composted or well-aged manure you can harvest vegetables within a shorter time of manure application. The USDA has standards for composting times and temperatures required to kill pathogens, and most commercial composters follow these standards. It is very difficult for home composters to do so. There are no standards for what “well-aged” means, but gardeners should wait at least one year before using manure that does not meet composting standards if high risk crops will be harvested within 120 days of manure application.

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Biosolids come from the wastewater treatment process. They are a mixture of bacterial biomass produced during wastewater treatment and organic and inorganic materials from the wastewater. Biosolids must meet treatment and quality standards to be suitable for recycling onto land. Biosolids are a good source of recycled nutrients, and are usually rich in nitrogen, phosphorus, and micronutrients.

Use only Class A biosolids in yards and gardens. Class A materials have gone through additional treatment to remove pathogens to background levels. As with any nitrogen fertilizer, over-application of biosolids can harm plants and increase the risk of nitrate loss by leaching.

Heavy metals are low in modern biosolids and are not a problem. Biosolids are good at tying up metals, and they have been successfully used in reclaiming and establishing vegetation on contaminated mining sites, reducing erosion of contaminated sediments and improving water quality.

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Three main types of Class A biosolids products are available to the public. Which, if any, products are available in your local area will depend on what is produced by local wastewater treatment plants.

Biosolids compost is made from biosolids composted with wood products, yard debris, or other materials, and is used just as you would use any other compost. Heat-dried biosolids are used as slow-release lawn and garden fertilizers. The City of Tacoma produces a Class A cake that they mix with wood products to produce mulch, potting mix, and a lawn and garden amendment.
These references are available on the web as supplemental information.