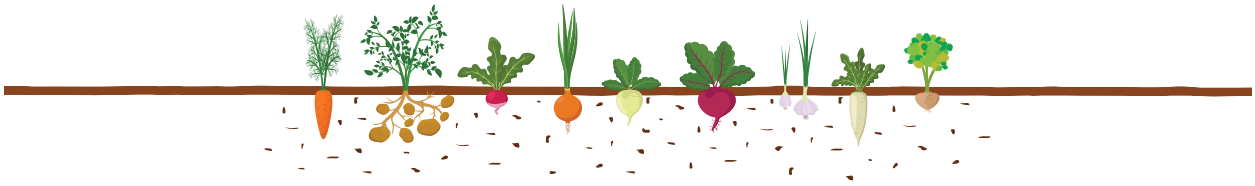
Chapter 4

Improving Soil Health



Soil health is one of the most important factors in the success of a garden. An understanding of your soil's texture, pH, nutrients, and biology will help you make decisions that will support the health of your soil and ultimately your plants. A healthy soil has a high level of organic matter that supports a diversity of beneficial microbes.

Soil Components

Soil is made up of both mineral and organic components, and both are needed for a healthy soil.

The mineral part of the soil is comprised of some ratio of sand, silt, and clay. The ratio of these mineral components determines the soil texture, such as sandy loam or silty clay loam. The more sand a particular soil has, the faster water drains and the less it can hold nutrients. The more clay a particular soil has, the slower water will drain, but it will hold much higher levels of water and nutrients.

If you are not sure what type of soil texture you have, there are some simple at-home tests that you can try. You can also consult the Web Soil Survey. (*https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm*)

The organic part of the soil is made up of decomposing plant or animal detritus, stable humus, living plant roots and microorganisms. While it is tempting to assume that all soil organisms are harmful to plants, the vast

Characteristics of Soil Types

Soil Characteristic	Sandy Soil	Loam Soil	Clayey Soil
Water-holding capacity	Low	Medium to high	High
Ability to store plant nutrients	Low	Medium to high	High
Capacity to supply plant nutrients	Low	Medium to high	High
Aeration	Good	Medium	Low
Drainage	Good	Slow to medium	Very slow
Organic matter levels	Low	Medium to high	High to medium
Compactability	Low	Medium	High
Susceptibility to wind erosion	Moderate	High	Low
Susceptibility to water erosion	Low	High	Low if aggregated, high if not

majority are beneficial organisms that help plants access nutrients and water they need to grow. Maintaining a soil organic matter level of at least 5% is critical to keeping soil microorganisms alive and healthy to benefit your plants. In many cases, it is also recommended to keep growing plants in your soil as much of the year as possible through the use of cover crops.

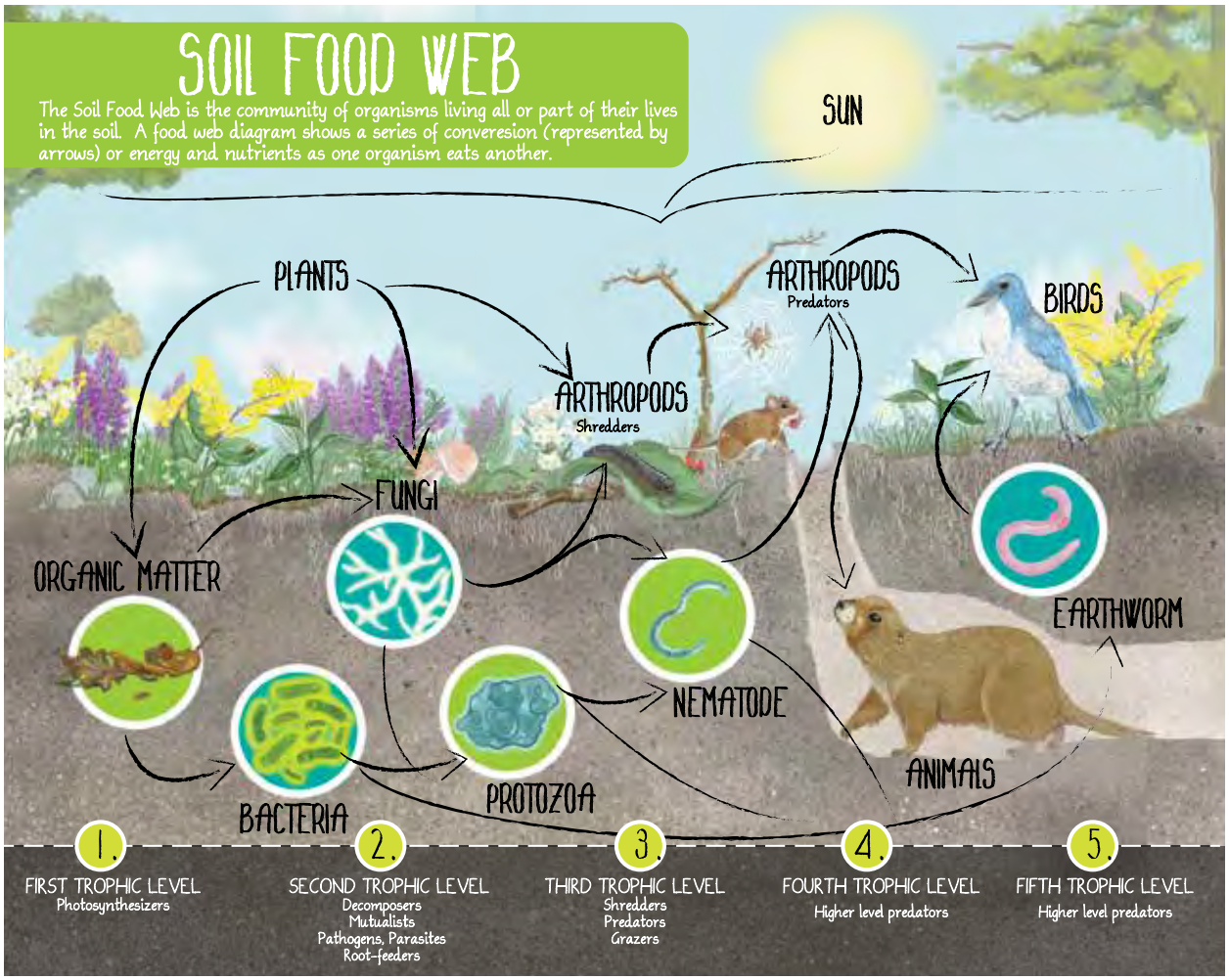
Adding Organic Matter

Adding organic matter is an effective way of improving all kinds of soil. In almost every case, adding organic matter to the planned garden area is recommended. It is beneficial to add organic matter regularly, every 1-3 years. Organic matter serves the following purposes:

- It loosens tight clay soils to provide better drainage.
- It provides for better soil aeration, which is necessary for good root growth.
- It increases water-holding capacity especially of sandy soils.
- It makes soil easier to till and easier for plant roots to penetrate
- It provides nutrients for plant growth.

Most home gardeners prefer to add organic matter by using one of the following materials:

- **Stable manure.** Use 50–100 pounds per 100 square feet.
- **Poultry and sheep manure.** Use 10–20 pounds per 100 square feet.
- **Compost.** Compost is decayed plant material. Apply 50–100 pounds per 100 square feet of garden space. (See *Using Compost* on page 43.)



- **Cattle manure.** Use 10–20 pounds per 100 square feet.

If you use uncomposted manure, bear in mind that this is a potential source of microbial contamination that could lead to foodborne illness. Applying raw manure in the fall allows adequate time for decomposition before crop harvest the following summer.

Regular application of manures and composts can increase soil nutrient levels significantly over time. It is important to regularly test your garden soil to monitor nutrient and organic matter levels. It is common for excessive levels of organic matter and nutrients to reduce garden yields of some crops, especially tomatoes and related species. If you suspect these issues, be sure to request your soil organic matter and nitrogen levels when completing a soil test.

Using Cover Crops in a Garden

Cover crops are plants grown to improve soil quality or to provide a benefit to the garden ecosystem. They are generally not grown with the intent to be harvested. Cover crops can benefit your garden soil in a variety of ways. They can help add organic matter and nutrients to your soil. They can help improve soil structure and drainage, reduce erosion, recycle nutrients, improve soil fertility, and reduce weed problems. Some cover crops can be food sources for pollinators and other beneficial insects.

For all their benefits, cover crops can also add an additional level of management and maintenance to a garden. Select cover crops that fit the needs of the garden, the correct planting time, and the availability of proper equipment and tools to terminate the cover crop when it is time to plant vegetable crops. A cover

crop that is left to grow too long or that is not properly managed can become a weed in the garden.

Types of Cover Crops

Cover crops are divided into three main categories: legumes, non-legume broadleaves, and grasses. Legumes can collect nitrogen from the air and store it in the soil where it can be used by plants. Many non-legumes are grasses, although not all of them. It can be beneficial to plant a blend of cover crop species that includes at least one legume and one grass or a three way mixture that includes a legume, a grass, and non-legume broadleaf.

Cover crops can be planted at different times depending on the garden planting plan. Cover crops adapted for summer planting can be seeded after spring crops are harvested. Cover crops adapted for fall/winter growth can be planted after summer vegetable crops are finished. Some will grow through the winter while others will die during the winter cold.

When cover crops are chosen for a garden, consider how you will cut down and incorporate the plant material, as well as the time needed for good decomposition of the cover crop before you plant your vegetable crops. You may find that you need a tiller to readily incorporate a cover crop before planting. Some cover crops, such as sorghum sudangrass, are very common in commercial cropping systems, but may not be a good choice for a home garden due to the volume of plant material produced and the difficulty in removing or killing the plants to replant the garden.

Termination of Cover Crops

Cover crops should be terminated 2-4 weeks before planting to allow adequate time for decomposition. Options for termination include: mowing, rolling/crimping, herbicides, rototilling, or a combination of these methods. In addition, some cover crops will naturally winter kill, either at frost or over the winter. Be sure to terminate a cover crop before it goes to seed to prevent unintended reseeding that can create weed concerns. A good guideline is to terminate the cover crop when about 50% of the crop is in bloom.

Cover Crop Planting Seasons

Cover Crop	Planting Season
Legumes	
Crimson clover	Spring, fall
Field peas	Spring, summer
Hairy vetch	Fall
Southern pea	Spring, summer
Sunnhemp	Summer
Non-Legume/Broadleaves	
Buckwheat	Spring, summer
Tillage radish	Fall
Mustard	Spring, fall
Field turnip	Spring, fall
Grasses	
Annual ryegrass	Early spring, fall
Winter wheat	Fall
Millets	Summer
Oats	Spring
Winter rye	Fall

Nutrients Needed for Plant Health

Nutrients most frequently lacking for growth are nitrogen (N), phosphorus (P), and potassium (K).

- **N (Nitrogen).** This nutrient element provides dark green color in plants. It promotes rapid vegetative growth. Plants deficient in nitrogen have thin, spindly stems, pale or yellow foliage, and smaller than normal leaves.
- **P (Phosphorus).** This nutrient promotes early root formation, gives plants a rapid, vigorous start, and hastens blooming and maturity. Plants deficient in this element have thin, shortened stems, and the leaves often develop a purplish color.
- **K (Potassium).** Potassium or potash hastens ripening of fruit. Plant disease resistance as well as general plant health depend on this element. It is also important in developing plump, full seeds. Plants deficient in this element have graying or browning on the outer edges of older leaves.

Nitrogen (N) – Phosphate (P_2O_5) – Potash (K_2O)

The content of N, P, and K is specified on fertilizer bags. The analysis or grade refers to the percent by weight of nitrogen, phosphate, and potassium in that order. Thus, a 10-10-10 fertilizer contains 10 percent nitrogen (N), 10 percent phosphate (P_2O_5) and 10 percent potassium (K_2O).

Other Plant Nutrients

Ten other elements that plants require come from the soil. They include calcium, magnesium, sulfur, boron, chlorine, copper, iron, manganese, molybdenum, and zinc. The majority of Kansas soils naturally provide

Fertilizer Sources with Concentrations of Specific Elements

	Analysis
Nitrogen sources	
Ammonium sulfate	20-0-0
Nitrate of soda	15-0-0
Nitrate of potash	13-0-44
Monoammonium phosphate	11-48-0
Diammonium phosphate	18-46-0
Urea	45-0-0
Sulfur sources	
Elemental sulfur	98% sulfur
Copper sulfate	20% sulfur
Ammonium sulfate	24% sulfur
Iron sources*	
Iron chelate	6%, 10%, or 12% iron for foliar or soil application
Iron sulfate	
Zinc sources*	
Zinc sulfate	36% zinc
Zinc chelates	Variable
Magnesium sources**	
Epsom salts ($Mg SO_4$)	10.4% Mg
Boron sources*	
Borax	11.3% boron

*Other commercial sources may be available. Consult the label for content.
** Some types of limestone (dolomitic) will also be sources of magnesium.

adequate amounts of these nutrients, unless the soil pH reduces their availability. A common micronutrient element found lacking in high pH soils is iron. The symptom of iron deficiency is a pale yellow color that develops in plants. This can be corrected by a foliar application of iron or by reducing the soil pH.

If you suspect a deficiency of one of these nutrients, you can request an additional test with your soil test. Work with your local Extension agent to identify the needed tests. Standard soil tests analyze for N,P, K and pH, while additional soil tests can be made for other fertilizer elements that may be required in unusual cases. Iron, zinc, magnesium, sulfur, or other elements are seldom required to correct a particular soil fertility deficiency. Some of these deficiencies might best be corrected with a foliar application as described.

Soil Testing

The winter before you begin to garden, you will want to get a sample of your garden soil tested to determine pH and nutrient content. The soil test provides a starting place for a soil improvement program. Unless you know the deficiencies in your garden soil, you are only guessing when you apply fertilizer. The soil test will tell you how much fertilizer you must add to your garden initially. It is then much easier to maintain a high level of fertility as you garden year after year.

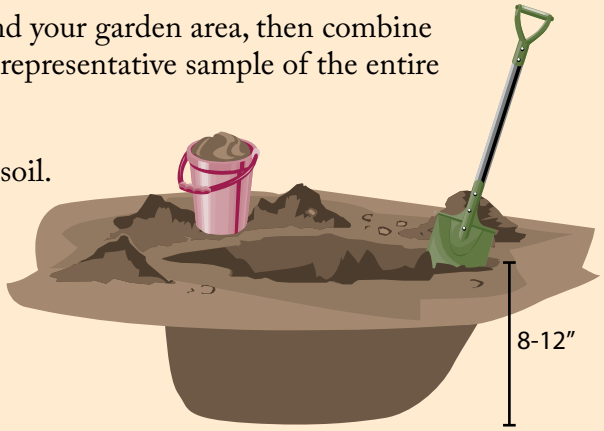
Check with your local K-State Research and Extension agent for soil testing information. Find your local extension office here: *www.ksre.k-state.edu/about/statewide-locations.html*

Taking a Soil Sample

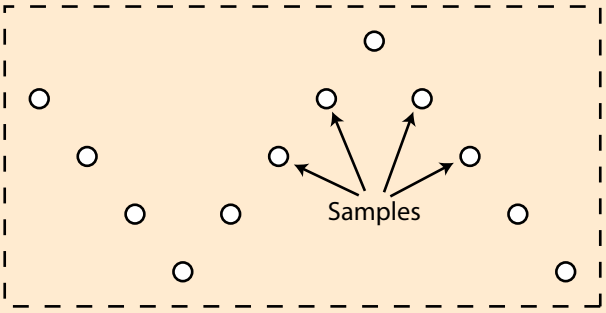
Use a soil probe, spade, or shovel to sample the soil profile to a depth of 8-12 inches. It is important to obtain a representative sample of the soil in the root zone rather than from the surface soil.

It is advisable to take at least 10 samples around your garden area, then combine these in a clean bucket or pail. This provides a representative sample of the entire garden area.

From the bucket or pail, select about a pint of soil. Special soil sample containers are available from your local K-State Research and Extension office or a fertilizer supplier. You may use a clean milk carton, ice cream container, or similar package. Label it with your name, address, and information on the garden to be grown. If you send more than one sample, be sure to label each plainly.



Slice for sample: 8-12 inches long by 1-1½ inches thick.



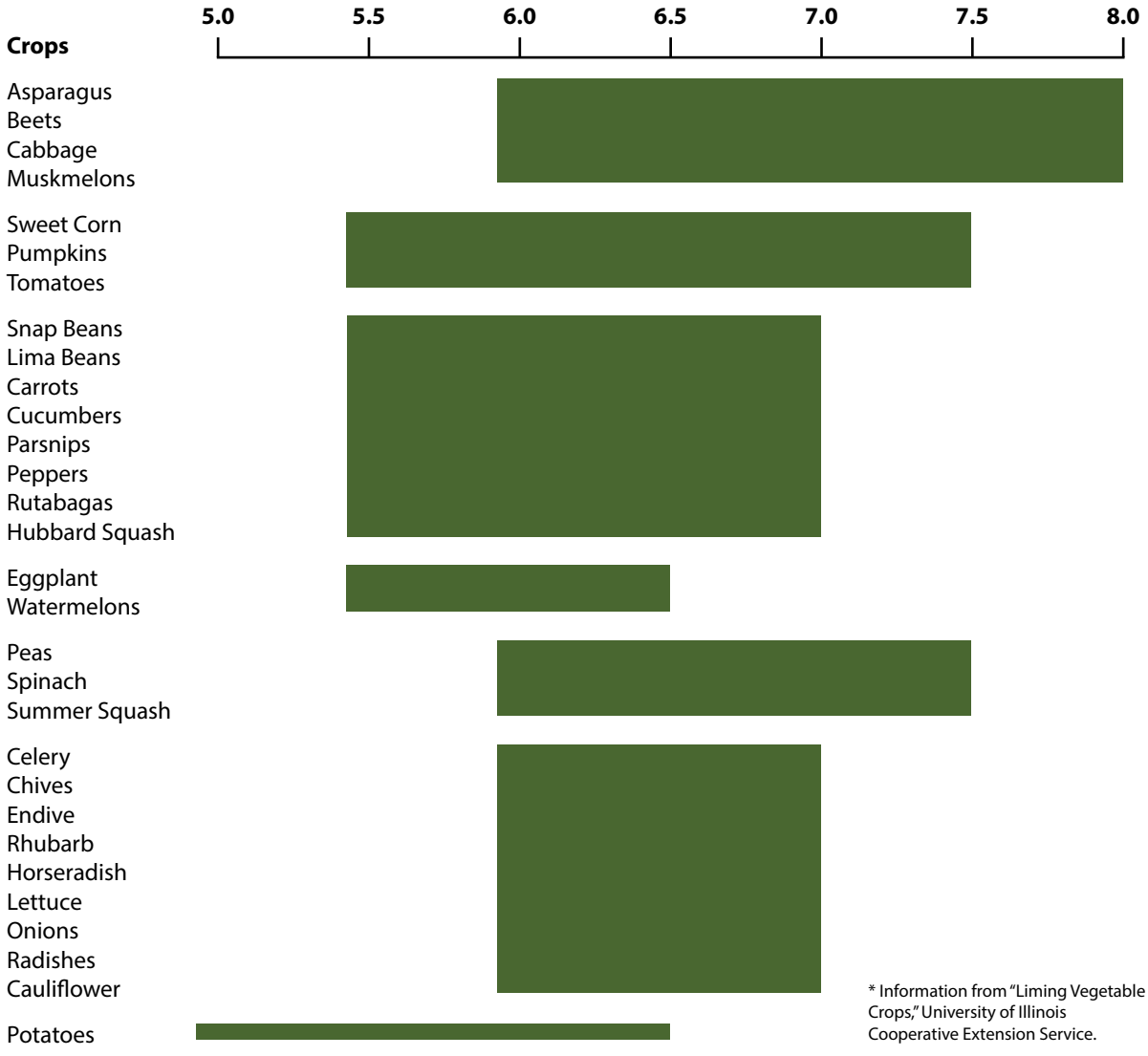
Your local agriculture or horticulture agent will either test the sample in the county soil lab or send it to the Kansas State University soil testing laboratory. The agent will make recommendations on the amounts of fertilizer to use on your garden. Rely on your local agent for information and advice concerning your garden.

Controlling Soil pH

The pH of the soil is a measure of acidity or alkalinity. Most plants grow best in a soil that is neither too acid nor too alkaline. Extremes of acidity or alkalinity are possible in Kansas soils. These extremes may make the soil nutrients unavailable to plants. Because of the parent rock materials, previous fertilizer use, cropping sequence, or other factors, the pH of the soil may differ from the desirable range.

One part of the soil test is measurement of the pH. Most Kansas soils tend to be somewhat alkaline, although soils in certain areas and under certain cropping and fertilizer regimens may become acidic. Your local K-State Research and Extension agent can recommend the amount of sulfur, lime, or other material needed to correct the soil pH. Correcting soil pH can be as important in improving plant growth as adding fertilizers.

Optimum pH Range for Vegetable Crops*



* Information from "Liming Vegetable Crops," University of Illinois Cooperative Extension Service.

Materials to Add to Correct Soil pH

Lime (to increase pH)			
pH level from soil test (increase to 6.5)	Lb Ground Limestone/100 sq ft		
	Sandy Soil	Loam Soil	Clay Soil
4.0	11	16	23
4.5	9	13	19
5	7	10	15
5.5	6	7	10
6	3	4	5

Sulfur (to lower pH)			
pH level from soil test (decrease to 7.0)	Lb Sulfur (95%)/100 sq ft		
	Sandy Soil	Loam Soil	Clay Soil
7.5	1.5	2	3
8	3	4	5
8.5	5	6	7
9	8	8	8

Add all materials to soil and incorporate to a depth of 6 inches with soil tillage when no crops are growing in the garden area. Note: Specific recommendations by your local county agent may vary from these amounts based on local conditions and knowledge of specific soil factors. Use your local recommendations in preference to this table if available.

Fertilizing the Garden

Fertilizing is an important practice, but it is not a cure-all. Fertilization cannot compensate for these problems:

- poor soil structure that does not allow for adequate drainage or aeration
- undesirable soil pH or salt content of the soil
- poor seeds, diseased or unhealthy plants
- shade trees or tree roots in or around the garden area.

The addition of organic matter will ensure that some fertilizer nutrients are in the soil. You may need to add additional fertilizer as well, especially if your soil has a significant deficiency. Most fertilizers are simply rock or mineral materials rich in nutrient elements.

Fertilizer Types

The nutrient elements that plants require can be supplied by either organic or synthetic fertilizers. All plants require 16 nutrient elements for growth. Thirteen of these come from the soil. Regardless of the form of fertilizer — organic or synthetic — the plant makes no distinction as long as the nutrients are there.There are a wide range of different fertilizer products available for purchase. Bagged or bottled fertilizer products can be either organic or synthetic.

Organic fertilizers are typically derived from biological organisms, both plants and animals. Some organic fertilizers will also include minerals from mined rock sources. Organic fertilizers often have a lower nutrient analysis than synthetic fertilizers, requiring a larger volume to provide sufficient nutrients. This can make organic fertilizer significantly more expensive to use, especially if your soil has a severe nutrient deficiency.

Synthetic fertilizers are derived from a combination of mined rock and lab synthesized or purified nutrients. They are often cheaper and more efficient in providing a large amount of nutrients to the soil at once.

Approximate Composition of Some Organic Fertilizers

Material	Nitrogen (N)	Phosphorus (P)	Potassium (K)
	---------- % ----------		
Bat guano	3	10	1
Blood meal	12	1	1
Alfalfa meal	5	1	2
Cottonseed meal	5	2	1
Feather meal	12	0	0
Coffee grounds	2	0.5	1
Cow manure, fresh	0.5	0.1	0.4
Cow manure, dried	2	1	1
Poultry manure, dried	3	3	1
Feedlot manure, dried	2	1	1
Bone meal	2	14	0
Worm castings	1	2	1
Wood ashes	0	1	5

Other commercial or processed fertilizers may be available. Consult label for variation in nutrient content by brands/sources. Organic materials should be incorporated into the soil and allowed to decompose if full fertilizer value is to be available.

Recommendations for Fertilizer Additions Based on K-State Soil Test Results

	Soil test interpretation		
	Low	Medium	High
Nitrogen* (Available nitrogen from lawn and garden soil test)	0-25 ppm	25-50 ppm	50-80 ppm
Phosphorus* (P from soil test results)	0-25 ppm	25-100 pmm	100+ ppm
Potassium* (K from soil test results)	0-125 ppm	125-250 ppm	250+ ppm

*If you do not have soil test results, follow recommendations for a medium application level.

Pounds of Actual Element to Add per 100 sq ft

	Nitrogen			Phosphorus			Potassium		
	Low	Med	High	Low	Med	High	Low	Med	High
Intensive or small gardens with successive plantings from spring, summer, and fall	.2	.1	0	.2	.1	0	.1	.05	0
Standard or large gardens with wider row spacings	.1	.05	0	.1	.05	0	.1	.05	0

Steps in Calculating Needed Fertilizer

1. Measure the length and width of your garden and calculate the area of your garden.
   - For example, suppose your garden is 10 feet wide by 20 feet long. Your garden area is 10 ft x 20 ft = 200 square feet.
2. Determine the nutrients you need to add per 100 square feet from the tables below. Use your soil test results to determine whether your nutrient levels are low, medium, or high. Then use the next table to determine the amount of nutrients to add.
   - For example, suppose your test results indicate that you have medium levels of nitrogen, phosphorus, and potassium. Based on the tables, you will need 0.1 pound N, 0.1 pound P, and 0.05 pound K.
3. Determine the total amount of fertilizer you will need for each nutrient.
   - Multiply the amount you need by the number of hundred square feet units in your garden. For example, if your garden is 200 square feet, you would need two times the amount above or 0.2 pound N, 0.2 pound P, and 0.1 pound K.
4. Look for a fertilizer that will provide nutrients in the correct ratio that you need.
   - Because you need equal portions of N and P but less of K, look for a fertilizer that may have the ratio of nutrients in this range. You might not be able to find a fertilizer that provides exactly the ratio you need, so try to get as close as you can.
   - For example, if you find a fertilizer that has 10-10-5, this would provide the exact ratio you need.
5. To calculate how much of this material to add, divide the amount you need by the nutrient concentration or analysis of the fertilizer and multiply by 100 because the analysis represents a percentage or fractional value of 100:
   - 0.2 lb needed ÷ 10 x 100 = 2 lb of fertilizer material needed to provide the N you need. This amount of fertilizer will also supply the P and K you need.
   - Apply 2 pounds of 10-10-5 fertilizer to your 200-square-foot garden.

Suggestions for Nutrients as Foliar Fertilizers

Element	Material	oz/3 gal water per 100 sq ft	Remarks
Iron	Iron chelate	Follow package directions	Iron deficiency found when pH is above 6.8
Magnesium	Magnesium sulfate (Epsom salts)	4-5	Use more than one application
Nitrogen	Urea	2-3	Most crops
Calcium	Calcium chloride	2	Direct at the growing point
Manganese	Manganese sulfate	1-2	May be needed in soils with high pH

Calculating the Amount of Fertilizer Needed

To calculate the amount of fertilizer needed for an area, consider the recommendation for the particular nutrient needed and the analysis.

The relationship of N, P, and K to each other, sometimes referred to as the ratio, indicates the proportion of each element. For example 1-1-1 means there are equal proportions of N, P_2O_5, and K_2O as does 10-10-10. However, a 2-1-1 ratio means there is twice as much N as P_2O_5 and K_2O, as is true for 10-5-5. The ratio does not indicate the weight of the elements in the fertilizer bag, but only their relationship to each other.

If you need to add 0.1 pound of N per 100 square feet and you have 10-10-10 fertilizer, which contains 10 percent N, you will have to add 1 pound of this material per 100 square feet to achieve the needed amount of N.

Most fertilizers you find are complete fertilizers with proportions of each major fertilizer element. Some sources supply specific concentrations of a single element only. Some of these are listed in the table on page 33.

Applying Fertilizers

Row applications. This provides the most efficient use of fertilizer for row garden crops. As a general rule, use about 1–2 pounds of the balanced analysis fertilizer per 100 feet of row. The best method of applying fertilizer is to dig a small trench 2–3 inches deep on either side of the row before planting. Sprinkle half the total amount of fertilizer in each trench. Cover the trenches and plant in the marked row. For tomatoes, cabbage, or other transplanted crops, as well as for melons or cucumbers planted in hills, use about 2 tablespoons of fertilizer placed 2–3 inches below the roots or seeds. Again, after placing the fertilizer, cover with soil and plant as usual.

Broadcast applications. An undesirable feature of row application is that it requires a lot of work. If you do not want to apply fertilizer to each row, you can broadcast or spread fertilizer throughout the garden area. Use 2–3 pounds of fertilizer per 100 square feet, spread uniformly over the surface, and incorporate into the soil before planting.

Starter solutions. For transplanted vegetables such as tomatoes, peppers, eggplant or cabbage, add a starter fertilizer to the water used in setting the plants to get them off to a faster start. Commercial starter fertilizers mix with water or are water soluble. Follow label directions, because mixing too much starter fertilizer can burn the plant roots.

Sidedressing. Nitrogen often leaches or washes out of the reach of plant roots, particularly in years when rainfall is abundant and in sandy garden soils. A sidedressing is simply an application of a nitrogen-containing fertilizer alongside the row of growing plants. Apply when corn is 12–18 inches high, after first fruits have set on tomatoes, or when plants lack a healthy, dark-green appearance.

It is possible to apply too much nitrogen; use fertilizer sparingly. Use ¼ pound of ammonium nitrate or ⅕ pound of urea per 100 feet of row. If these materials are not available, use an ordinary balanced fertilizer such as 5-10-10, 8-16-16, or others at the rate of 1–2 pounds per 100 feet of row. Don't put the material directly on the plant foliage and, when possible, water after applying the fertilizer.

Foliar feeding. In an emergency, it may be possible to add certain nutrients to a plant by applying to the foliage when nutrient deficiency symptoms develop. It is advisable to make every attempt to add the necessary nutrients to the soil before the symptoms develop because foliar application should be used only as an experimental or emergency treatment. Unless the soil conditions causing the symptoms are corrected, the symptoms will reappear soon.

Using a commercial wetting agent or a few drops of detergent in the solution provides better coverage of foliage. Apply sprays in early morning or late afternoon on a cloudy day, or soon after a rain. Mixing these elements with one another or with a pest control spray may be difficult. Do not attempt to mix foliar nutrients with pest control sprays.

Some Useful Measures

- 1 acre = 43,560 sq ft
- 100 lb/acre = approximately 2 lb/1,000 sq ft
- 3 tablespoons (level) = 1 oz
- 8 ounces = 1 cup
- 2 cups = 1 pint (equals 1 lb of most dried fertilizer materials)