Plant nutrition

Plants need seventeen basic chemical elements in order to grow.

The first three - carbon, hydrogen, and oxygen - are collected from the atmosphere and are readily available to plants as carbon dioxide and water. The remaining elements must be collected from the soil.

Soil nutrients

Soil nutrients are arranged into three categories based on the amount plants need to grow. The major elements, needed in the greatest quantity, are nitrogen, phosphorus, and potassium. The secondary elements are needed in smaller quantities; they are calcium, magnesium, and sulfur. Together, the elements in these first two categories are called macronutrients. The remaining elements are needed in varying amounts by different crops, and in extremely small quantities, and are therefore called micronutrients. They are iron, manganese, boron, molybdenum, copper, zinc, chlorine, and nickel.

All these nutrients are present in soil but they may not be available to plants in appropriate quantities. To be available, each nutrient must be dissolved in the soil solution. In nature, both the weathering of parent material (rock) and the breakdown of soil organic matter release nutrients into the soil solution. (In a cultivated garden, we often add organic materials or mineral fertilizers to boost nutrient levels.) Remember that the availability of nutrients is affected by the soil pH, with the majority of nutrients being most available at a pH of 6.0 to 6.8. By first adjusting your soil to an appropriate pH you can make the most efficient use of subsequent nutrient amendments, and soil testing is the best way to determine the pH and nutrient status of your soil.

Plant requirements

In general, crops can be categorized as heavy-feeders, medium-feeders, and light-feeders. Table 1 rates nitrogen (N), phosphorus (P), and potassium (K) demands for several crops. It also indicates other nutrients critical for good growth and development.

TABLE 1: NUTRIENT REQUIREMENTS OF VARIOUS CROPS

Crop	N	P	K	Other critical nutrients
Corn	HIGH	LOW-MOD	HIGH	zinc, magnesium
Potatoes	HIGH	HIGH	HIGH	manganese
Root crops	LOW	LOW-MOD	LOW-MOD	Boron
Beans and peas	LOW	MOD	LOW-MOD	calcium, zinc, molybdenum, sulfur
Cabbage family	HIGH	MOD-HIGH	MOD-HIGH	iron, boron, calcium
Cucurbits	MOD-HIGH	MOD	MOD	magnesium
Leafy crops	HIGH	MOD	MOD	iron, copper
Onions	MOD-HIGH	MOD	LOW-MOD	copper, sulfur
Tomatoes (peppers, eggplant)	MOD	LOW-MOD	MOD-HIGH	iron, magnesium

Adapted from Gershuny & Smiley, 1986

Symptoms of nutrient deficiency

When plants aren't getting the nutrients they need, they may show visible symptoms of deficiency (see Table 2 for leaf symptoms). Some symptoms, like stunted growth and weak stems, are the same for many types of deficiencies. Others are more specific and give clues as to which nutrient is deficient. When problems are first noticeable on the older, lower leaves, deficiencies are more likely to be nitrogen, phosphorus, potassium, or magnesium. When younger leaves are affected, deficiencies are more likely to be calcium or boron, or others. However, it often takes an experienced gardener to accurately diagnose deficiencies by visual symptoms alone. Several books and websites give detailed descriptions and photographs of deficiency symptoms.

TABLE 2. SYMPTOMS OF NUTRIENT DEFICIENCY

Deficiency	Symptom
Lower leaves Leaf yellowing; starts at tip and spreads up middle	Nitrogen
Purpling of leaf edges	Phosphorus
Browning of leaf edges	Potassium
Yellowing between veins	Magnesium
Leaf edges brown; fruits rot at blossom end	Calcium
Yellowing between veins	Iron, Manganese, Zinc, Copper
Death of growing points	Boron, Calcium
Leaf yellowing	Sulfur

Natural source fertilizers

Nutrients can be applied in the form of organic materials such as compost, manure, green manure, plant residues, and wood ash. Additional supplements can be purchased at garden centers and by mail-order. Some, such as rock phosphate and Sul-Po-Mag are mined from the earth. Others, like seaweed, fishmeal, and greensand, are from the ocean. And still others, such as bone meal, blood meal and feather meal, are animal byproducts.

Natural source fertilizers generally have lower concentrations of nutrients compared to synthetic fertilizers, so greater quantities are required to meet crop needs. The average nutrient content for a selection of materials are listed in Table 3. However, remember that the concentration can vary among products from different sources or from batch to batch. (For example, not all sheep manure will have the same nutrient content.) Where possible, check product labels for the type and quantity of nutrients and how they are best applied.

TABLE 3. NUTRIENT CONTENT OF NATURAL SOURCE FERTILIZERS

Material	Nitrogen (%N)	Phosphorus (% P_2O_5)	Potassium (% K_2O)
Fresh manure Cattle	0.55	0.15	0.45
Hog	0.50	0.35	0.45
Horse	0.65	0.25	0.50
Poultry	1.00	0.85	0.45
Rabbit	2.40	1.40	0.60
Sheep	1.05	0.40	1.00
Compost	1.5-3.5	0.5-1.0	1.0-2.0
Bonemeal	0.7-4.0	18-34	0
Sawdust	4	2	0
Kelp	0.9	0.5	4-13
Fishmeal	10	6.0	0
Soybean meal	7.0	1.2	1.5
Phosphate rock	0	30	1-2
Sul-Po-Mag	0	0	22
Wood ashes	0	2	6

Most natural source fertilizers take some time to break down in the soil so the timing of application is important. Organic materials such as raw or partially decomposed manure, leaves, grass clippings, and seaweed should be applied the previous fall and incorporated into the soil or composted and applied in the spring before planting. Liquid teas made from compost or manure can be applied throughout the growing season.

Bone meal is an example of a natural source fertilizer. ©Tracy Kittilsen, Dalhousie.

Green manures should be mixed into the soil the previous fall or, if planted as a cover crop, incorporated early in the spring together with some well-rotted manure or compost to encourage quick decomposition. Well-aged compost can be applied shortly before planting, or as a top dressing during the growing season.

Rock phosphate should be applied in the fall or incorporated into the compost pile for more rapid decomposition. Sul-Po-Mag (sulfur, potassium, magnesium) can be applied in early spring.

Liming materials

Lime, which is normally applied to soil for pH adjustment, is most effective if applied in the fall. Lime also supplies calcium and, if dolomitic lime is used, it also supplies magnesium. Gypsum is a source of calcium and sulfur, but it has little effect on soil pH. Gypsum should be applied in the spring to prevent the calcium from leaching down into the soil.

Wood ash contains potassium, phosphate, boron, and other elements. Wood ashes can also be used to raise soil pH, with twice as much ash as limestone needed for the same effect. Ashes should not come into contact with germinating seedlings or plant roots as they may cause root burn. Spread the ashes in a thin layer during late winter or early spring, and incorporate into the soil. Check pH yearly if you use wood ashes and never use large amounts of ash (no more than 5 to 10 kg per 100 square meters or 11 to 22 lbs per 120 yd2), as toxicity problems may occur.

Synthetic fertilizers

Synthetic granular fertilizers contain specified amounts of nutrients. The nutrients are present in a soluble form that dissolves into the soil solution and are readily available for plant uptake. Commonly used garden fertilizers are 12-24-24, 10-10-10, or 17-17-17. The numbers represent the percentage of nitrogen, phosphorus, and potassium contained in the fertilizer formulation. For example, 12-24-24 contains 12% nitrogen, 24% phosphorus (P2O5), and 24% potassium (K2O). Some fertilizer dealers will also custom blend fertilizers (for example, by combining materials in Table 4) and sell them in 25 kg bags.

TABLE 4. NUTRIENT CONTENT OF SYNTHETIC FERTILIZERS

Material	Nitrogen (%N)	Phosphorus (% P_2O_5)	Potassium (% K_2O)	Other Nutrients
Urea	46	0	0	
Ammonium sulphate	20.5	0	0	24% S
Calcium nitrate	15.5	0	0	19% Ca
Calcium ammonium nitrate	27	0	0	4% Ca 4% Mg
Triple super phosphate	0	45	0	
Muriate of potash	0	0	62	
Common blend	17	17	17	
Common blend	12	24	24	

Granular fertilizers can be broadcast in the spring prior to planting and incorporated into the soil. They can also be banded 7-10 cm (3-4 inches) below and to the side of row crops after seedling emergence. This is called 'sidedressing'. Sidedressing is used to give the crop a boost of nutrients at an important growth stage.

The choice of fertilizer and rate of application should be determined from the results of a soil test. If a soil test is not available, use the following guidelines:

- Heavy feeders: 8 to 15 kg of 17-17-17 per 100 square meters (18-33 lb per 1000 ft2)
- Moderate feeders: 5 to 10 kg of 17-17-17 per 100 square meters (11-22 lb per 1000 ft2)
- Light feeders: 3 to 8 kg of 17-17-17 per 100 square meters (7-18 lb per 1000 ft2)

Take care when applying granular fertilizers, as direct contact with plant roots can cause burning. Also, because of the soluble nature of granular fertilizers, heavy rains can wash nutrients (especially nitrogen), out of the soil. Synthetic fertilizers can also harm soil structure by weakening soil granules, and they can be hard on soil organisms. If using synthetic fertilizers, make sure you also add organic matter to the soil to counter these effects.

A trip to your local garden centre or an internet search will show the range of natural source fertilizers available as well as the costs. ©Tracy Kittilsen, Dalhousie.

The label on this product reads '2-14-0'. This means that the product is 2% nitrogen, 14% phosphorous, and 0% potassium. ©Tracy Kittilsen, Dalhousie.

Activity

Calculate how much of an amendment you will need.

Soil test reports make recommendations for nitrogen (N), phosphorus (P2O5), and potassium (K20) in kilograms per hectare (kg/ha). You will have to figure out how much of an amendment to apply to meet the recommendation. Let's say the soil test report recommends adding nitrogen at 36 kg/ha. Here are the calculations you will have to make:

Vegetable gardens are usually much smaller than a hectare so the first step is to figure out how much nitrogen you will need for the area of your garden. Let's say your garden is 10 m x 10 m, or 100 square meters. (Note: 1 hectare = 10 000 square meters). So,

(36 kg N/ha)/(10 000 m^2/100 m^2) = 0.36 kg N per 100 square meters

Let's say you want to use a synthetic fertilizer; 12-24-24. This fertilizer contains 12% nitrogen, 24% phosphorus (P2O5), and 24% potassium (K2O) so 1 kg of fertilizer would contain 0.12 kg nitrogen, 0.24 kg phosphorus, and 0.24 kg potassium. How much fertilizer would you need to supply 0.36 kg N for your 100 square meter garden?

(0.36 kg N/100 m^2)/(0.12 kg N/kg of fertilizer) = 3 kg fertilizer/100 square meters

Use the following worksheet and information from Table 3 and Table 4 above to calculate how much of each amendment you will need to supply nitrogen at 36 kg/ha to a 100 square meter garden. Also calculate how much phosphorus and potassium you will be adding to the soil if you apply that rate of amendment.

Amendment	Amount needed to supply nitrogen at 36 kg/ha to a 100 square meter garden	Phosphorus (P_2O_5)	Potassium (K_2O)
12-24-24 fertilizer	3 kg	0.72 kg P_2O_5 per 100 m^2 OR 72 kg P_2O_5 /ha	0.72 kg K_2O per 100 m2 OR 72 kg K_2O /ha
Calcium ammonium nitrate fertilizer			
17-17-17 fertilizer			
Cattle manure			
Compost (assume 2% N;0.75% P_2O_5; 1.5% K_2O			
Fishmeal			