FERTILIZATION FOR NURSERY AND LANDSCAPE MANAGEMENT

Carl Rosen and Bert T. Swanson

Essential Elements

At least 16 elements are required for normal plant growth and development. Each of these elements has a specific function in plant metabolism and a deficiency of any one can limit plant growth. Carbon (C), hydrogen (H), and oxygen (O) are derived from the air or water and are generally not growth limiting. The 13 remaining elements are derived from the soil and are supplied to plants by natural soil processes. These 13 elements can be categorized further into macronutrients and micronutrients. Three elements - nitrogen (N), phosphorus (P) and potassium (K) are considered primary macronutrients because they are often required in larger quantities than are made available through natural soil processes. The secondary macronutrients: calcium (Ca), magnesium (Mg), and sulfur (S), are needed in lower quantities than the primary macronutrients and, except for acid sandy soils, are usually not deficient in Minnesota soils. The micronutrients: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), chlorine (Cl), and molybdenum (Mo), are required in very low quantities and are not generally deficient in Minnesota soils except for iron or manganese in sandy or alkaline soils.

From a nursery production standpoint, N, P, and K are the nutrients that often need to be applied as fertilizer for optimum plant growth in the field. For plants grown in container media, the secondary macronutrients and some micronutrients can also be limiting to plant growth if not supplied in adequate amounts.

Both organic and inorganic forms of fertilizer are used for plant nutrition. Inorganic fertilizers are usually more soluble, higher in analysis, and more rapidly available to plants than organic forms. A nutrient element must usually be in the inorganic form to be absorbed by the plant. Some fertilizers are manufactured to control the solubility and release of nutrients. These fertilizers function similarly to a time-release capsule or slow-release fertilizer and extend the length of time when nutrients are available to the plant.

Symptoms of Nutrient Deficiency or Excess

Some nutrient deficiency or toxicity symptoms in plants can be readily recognized while others are less defined. These symptoms may vary from species to species and may resemble non-nutritional disorders such as disease, insect, or pesticide damage. Use of soil and/or tissue analysis can help confirm whether symptoms are nutritional. General deficiency and toxicity symptoms associated with nutrient disorders in plants are described below.

<u>Nitrogen (N)</u>

Deficiency – Leaves turn pale green to yellow. <u>Oldest</u> leaves are affected first, but in severe cases the whole plant may turn yellow. Growth is usually stunted. Occurs most frequently on sandy soils.

Excess – N excess results are usually excessive and weak vegetative growth and poor flower and fruit production. Extremely high N rates can result in leaf margin burn or scorching of new leaves.

<u>Phosphorus (P)</u>

Deficiency – Leaves appear reddish-purple. <u>Oldest</u> leaves are affected first. Plant growth is stunted. Common in acid and alkaline soils or soils low in P. Occurs on cool wet soils in the spring. Plants may grow out of a P deficiency as the soil warms.

Excess – High rates of P fertilizer may induce Zn or Fe deficiency.

<u>Potassium (K)</u>

Deficiency – Leaves develop gray or tan areas near the margins. <u>Oldest</u> leaves are affected first with characteristic symptoms of scorching around the leaf margins. Occurs on sandy soils and soils low in K.

Excess – High rates of K fertilizer can cause salt burn. Soils with high K levels can induce a Mg deficiency.

<u>Calcium (Ca)</u>

Deficiency – Growing points of plant may die. <u>Younger</u> leaves are affected first. Root tips die and root growth is slow. Most common on acid and/or dry soils.

Excess – Not known to occur in the field, but can be associated with excessively high soil pH.

<u>Magnesium (Mg)</u>

Deficiency – <u>Oldest</u> leaves turn yellow between the veins. In severe cases, younger leaves may also be affected and older leaves may drop off. May occur on acid soils, sandy soils, or soils with high K levels.

Excess - Not known to occur in the field.

Sulfur (S)
Deficiency – Symptoms of S deficiency are similar to N deficiency except that youngest leaves are usually affected first. Can occur on sandy soils low in organic matter.
Excess – Rarely occurs, usually associated with saline conditions.

Boron (B)
Deficiency – Usually occurs on younger plant tissue. Growing points die. Leaves appear distorted (rosetted). Can occur on sandy soils in crops with a high B requirement.
Excess – B can be highly toxic to some plants at low levels. Avoid excess B applications. Toxicity usually occurs on oldest leaves as a scorching of the margins.

Chlorine (Cl)
Deficiency – Rarely occurs. Not known to occur in the field.
Excess – Marginal scorch of older leaves. Can occur on salt affected soils, near streets where salt is used, or when excessive rates of fertilizer containing Cl are used.

Copper (Cu)
Deficiency – Yellowing or dieback of youngest leaves. Sometimes yellowing between the veins. Most Cu deficiencies occur in organic soils such as peat or muck.
E**xcess** – Can occur due to continuous use of copper containing fungicides. May induce Fe chlorosis and cause stunted root systems.

Iron (Fe)
Deficiency – Yellowing occurs between the veins on youngest leaves; veins remain green resulting in intervainal chlorosis. Occurs frequently on high pH soils (pH greater than 7.2). Some plant species are more susceptible than others. With acid-loving plants (blueberry, azalea), chlorosis may occur at a pH as low as 5.5-6.0.
Excess – Rarely occurs. High levels of Fe may induce a Mn deficiency.

Manganese (Mn)
Deficiency – Similar to Fe deficiency. Yellowing occurs between the veins of youngest leaves. Usually only the main veins remain green causing a fishbone-like appearance. In some plants, older leaves may develop gray streaks or dots giving a mottled appearance. Occurs on high pH soils (pH greater than 7.2). Can also occur on organic soils with a pH greater than 6.0.
Excess – Mn toxicity can occur on acid soils (pH less than 4.5), or after heat sterilization of container media. Chlorosis and brown spots appear on leaves.

Molybdenum (Mo)
Deficiency – Pale, distorted, narrow leaves. Terminal leaf does not fully expand. Leaf color is often bluish-green. Can occur on acid soils (pH less than 5.0).
Excess – Rarely occurs.

Zinc (Zn)
Deficiency – Short internodes, may cause rosetting appearance in trees. Younger leaves usually affected first and may show signs of yellowing between the veins. High levels of P fertilizer may induce Zn deficiency. Can occur on high pH soils or acid sandy soils.
Excess – May induce Fe deficiency.

Although micronutrients are usually in minute quantities, a deficiency in any one of them can disrupt a metabolic process that severely affects growth of the entire plant.

Plant Utilization of Macronutrients
Fertilizers are used to supplement certain soil nutrients when native nutrient levels and soil processes are not sufficient to supply those nutrients for optimum plant growth. N, P, and K are the three major elements used in plant growth. Their utilization is described below.
Nitrogen (N) – Of all the essential elements, nitrogen is often the one most limiting for optimum plant growth. Adequate nitrogen produces vigorous growth and green color. Most of the nitrogen in soils is present as part of the organic matter and becomes available for use by plants as organic matter is decomposed by soil microorganisms. The amount of nitrogen provided by these natural soil processes is generally not enough to maintain vigorous growth of most plants, therefore, supplemental nitrogen from fertilizer is usually required.

Nitrogen is available to plant roots in either the ammonium or nitrate form. In most soils, ammonium is quickly converted to nitrate, so most of the nitrogen absorbed by plant roots is actually in the nitrate form. Nitrate is not tightly held by soil particles and is soluble in soil water. Consequently, in sandy soils with excessive precipitation or irrigation, nitrate can move with the water to depths below the root zone. Slow release nitrogen fertilizers are used to prevent rapid leaching of nitrogen. Because of the mobility of nitrogen, soil tests for nitrogen are valid for shorter periods of time than most other elements.

Phosphorus (P) – Phosphorus is important in stimulating root growth and promoting plant vigor. Unlike nitrogen, phosphorus is bound tightly by soil particles and moves very little in the soil. Therefore, it is very advantageous to add phosphorous to the backfill at the time of planting. When soils are moderately high in phosphorous, supplemental fertilization with phosphorous may be unnecessary. Soil testing should be used to determine the correct level of soil phosphorous. Phosphorus is essential for root growth, flowering, and fruiting. Minnesota law prohibits the use of phosphorus on lawns except for new seedings and if a soil tests indicates that P is deficient.

Potassium (K) – Potassium is important in plant water relations and the regulation of many physiological processes. It enhances pest and cold resistance. Potassium is held on the surfaces of soil particles and moves little in most soils; therefore, incorporation into the root zone before planting is important. However, in very sandy soils, it can move out of the root zone. When soils are moderately high in potassium, supplemental fertilization with potassium may be unnecessary. Soil testing should be used to determine the current level of soil potassium.

Soil Testing

The rate and timing of fertilizer application depends on soil tests, soil type, fertilizer type and analysis, environmental conditions and the plant being grown. It is essential that fertilizer is applied at proper rates. Excessive fertilizer use can not only injure or kill plants, it can also pollute the environment. Use a soil test to determine the analysis and rate of fertilizer to apply in all nurseries, garden centers, large landscapes, or any other production enterprise.

Soil testing is a procedure that is used to take the guesswork out of applying fertilizer. Soil type, nutrient levels, and acidity or alkalinity (pH) can all be determined by a soil test. County extension offices can provide information and containers for soil testing. Most homeowner soil tests are difficult to interpret due to the severe disturbance of the soil around the house during construction. Therefore, soil tests for trees and shrubs in the home landscape are primarily recommended only when a particular problem such as pH or high salts is suspected. Normally, trees and shrubs in such disturbed sites will benefit from an application of fertilizer, particularly nitrogen.

The validity of soil test results is dependent on obtaining a representative sample and the results of a soil test are of no value unless the sample is representative of the soil in question. Scrape off any mulch and surface vegetation where the sample is to be collected. Use a clean sampling tool, such as a trowel or a thin-walled piece of tubing fitted with a wooden plunger for emptying, to obtain a core of soil. Each core of soil should extend to the container or bench bottom, to a depth of six to twelve inches in ground beds, or to 12-24 inches in nursery fields and landscapes. Randomly take cores from at least ten containers or randomly take 15-20 cores from each field area and mix thoroughly to form one composite sample. For the University of Minnesota soil testing lab, request the Florist Test for container media. For nursery fields or landscape samples, request the Regular Series, plus Nitrates and Soluble Salts Test. Submit field and landscape samples with the Laboratory Form shown in Figure 1A and 1B and request the appropriate soil or media collection bags as shown in Figure 2, in which to submit the sample. If plants in one particular portion of an area indicate a problem, and plants in the remainder of the area are growing normally, do not combine soils from these two areas into one sample. Two separate samples, one from the problem area and one from the normal area, should be sent in for analysis. Request the Florist Test for all Container Media. If the University of Minnesota bag is used, an additional form is not required.

Understanding the Fertilizer Label

Although there is a great diversity of fertilizers available for use, they all have something in common. The label on the bag must, by law, indicate the minimum percentage by weight of nutrients contained in the fertilizer. The manufacturer must guarantee that the analysis printed on the bag is correct. This label lists the percentages of the three primary nutrients as a series of three numbers. This is referred to as "Fertilizer Grade." The first number refers to percentage of nitrogen, the second to the percentage of phosphate or phosphorus expressed as P_2O_5, and the third to the percentage of potash or potassium expressed as K_2O. For example, 20-10-20 means that the fertilizer contains 20% nitrogen, 10% phosphate and 20% potash. If a fertilizer is labeled 10-10-10-20S-5Fe, then it also contains 20 percent sulfur and 5 percent iron. A complete fertilizer contains the three primary macronutrients: N, P, K, such as 10-10-10, 15-30-15, 9-45-15, etc. Fertilizers that have the same three numbers such as 10-10-10 are called balanced fertilizers. Some fertilizers are single nutrient carriers and contain only one primary macronutrient.

UNIVERSITY OF MINNESOTA
Soil Testing Laboratory

FARM/FIELD CROPS and COMMERCIAL HORTICULTURAL CROPS

Report No.

Instructions for filling out this form are given on the back side

SOIL SAMPLE INFORMATION SHEET

LOCATION REFERENCE

Name ____________________

Address ____________________

City, State, Zip ____________________

Phone ____________________

Soil location: County ____________________

Township ____________________

Check for $____________ enclosed

Customer Number ____________________
(pre-arranged accounts only)

MAIL REPORT TO:

Name ____________________

____

Address ____________________

City, State, Zip ____________________

Phone ____________________

Sample Identification			1 Crop History				2 Proposed Crops						3 CHECK TESTS REQUESTED (plow layer sample)								
			Crop Grown Before Last		Last Crop Grown		Option 1		Option 2		Option 3		* Regular Series P, K, pH, %OM	Sulfur **	Zinc	Zinc, Copper, Iron, Manganese	Boron	Calcium and Magnesium	Nutrient Management P	Soluble Salts	Nitrate Before selecting this test please read section on nitrate on the BACK SIDE. Sampling to 24" is required for this test.
Laboratory Number (Lab Use Only)	Field or Sample No. or Letter	Check If Irrigated	Crop Code No.	If Alfalfa check plants per sq ft	Crop Code No.	If Alfalfa check plants per sq ft	Crop Code No.	Expected Yield	Crop Code No.	Expected Yield	Crop Code No.	Expected Yield	$9	$4	$4	$10	$6	$6	$5	$5	
				❑ 4+ ❑ 2-3 ❑ 0-1		❑ 4+ ❑ 2-3 ❑ 0-1															Nitrate ❑ 0-6"/6-24" sample $5.00 ❑ 0-24" sample $5.00
				❑ 4+ ❑ 2-3 ❑ 0-1		❑ 4+ ❑ 2-3 ❑ 0-1															Nitrate ❑ 0-6"/6-24" sample $5.00 ❑ 0-24" sample $5.00
				❑ 4+ ❑ 2-3 ❑ 0-1		❑ 4+ ❑ 2-3 ❑ 0-1															Nitrate ❑ 0-6"/6-24" sample $5.00 ❑ 0-24" sample $5.00
				❑ 4+ ❑ 2-3 ❑ 0-1		❑ 4+ ❑ 2-3 ❑ 0-1															Nitrate ❑ 0-6"/6-24" sample $5.00 ❑ 0-24" sample $5.00
				❑ 4+ ❑ 2-3 ❑ 0-1		❑ 4+ ❑ 2-3 ❑ 0-1															Nitrate ❑ 0-6"/6-24" sample $5.00 ❑ 0-24" sample $5.00
				❑ 4+ ❑ 2-3 ❑ 0-1		❑ 4+ ❑ 2-3 ❑ 0-1															Nitrate ❑ 0-6"/6-24" sample $5.00 ❑ 0-24" sample $5.00

Recommendations available for these crops

** See comment on back side

* THE REGULAR SERIES NOW INCLUDES PERCENT ORGANIC MATTER

Crop Code	Name	Yield Unit
	LEGUMES	
01.	Alfalfa, New Seed	tons/acre
02.	Alfalfa, Established	tons/acre
03.	Birdsfoot Trefoil	tons/acre
04.	Legume/Grass Hay	tons/acre
05.	Legume/Grass Pasture	–
06.	Red Clover	tons/acre
	CORN	
07.	Corn, Grain	bu./acre
08.	Corn, Silage	tons/acre
09.	Sweet Corn	tons/acre
	SMALL GRAINS	
10.	Barley	bu./acre
11.	Oats	bu./acre
12.	Rye/Triticale	bu./acre
13.	Wheat	bu./acre
	MISCELLANEOUS	
14.	Buckwheat	lb./acre
15.	Edible Beans	lb./acre
16.	Fallow	–
17.	Flax	bu./acre
18.	Grass Hay	tons/acre
19.	Grass Seed Prod.	lb./acre
20.	Grass Pasture	–
21.	Millet	lb./acre
22.	Native Grasses	tons/acre
23.	Potatoes	cwt/acre
	MISCELLANEOUS (continued)	
24.	Rape/Mustard/Canola	cwt/acre
25.	Sorghum Sudan	–
26.	Soybeans	bu./acre
27.	Sugarbeets	tons/acre
28.	Sunflowers	lb./acre
29.	Wild Rice	–
	VEGETABLES	
30.	Asparagus, New Planting	
31.	Asparagus, Establ. Planting	
32.	Beans, Snap	
33.	Beets, Table	
34.	Broccoli	
35.	Brussels Sprouts	
36.	Cabbage	
37.	Cauliflower	
38.	Carrots	
	VEGETABLES (continued)	
39.	Celery	
40.	Cucumbers	
41.	Lettuce	
42.	Melons	
43.	Onions, Dry	
44.	Onions, Green	
45.	Parsnips	
46.	Peas	
47.	Peppers	
48.	Pumpkins/Squash	
49.	Radishes	
50.	Turnips	
51.	Rhubarb	
52.	Rutabagas	
53.	Spinach	
54.	Tomatoes	
	FRUITS	
55.	Apples	
56.	Blueberries	
57.	Grapes	
58.	Raspberries/Brambles	
59.	Strawberries	
	TURF	
60.	Cultured Sod	
61.	**NURSERY – FIELD STOCK TREES/SHRUBS** Suggested tests: Regular, Soluble Salts, Nitrate. For sampling instructions, please see Nursery Form MI-3658-GO.	
62.	**Other** ____________	

REV 3/03

Figure 1A. University of Minnesota Soil Testing Laboratory Form to be used for the soil test submission of Nursery Field and Landscape soil samples.

INSTRUCTIONS FOR COMPLETING SOIL SAMPLE INFORMATION SHEET

Field History (1): This information is essential for us to provide the most accurate nitrogen recommendations. Indicate crops grown the past **two** most recent growing seasons. BE SURE TO USE THE CROP CODE NUMBER FROM THE LISTING ON THE FRONT SIDE. If alfalfa was the crop grown during either or both of the two previous growing seasons, it's important to indicate the number of plants (crowns) per sq. ft.

Proposed Crops and Yield Goals (2): You can select recommendations for up to three crops by entering the corresponding crop code number, **or three yield goals** for one crop. At least one option must be completed to receive a fertilizer recommendation, but there is no requirement to complete all options. If alfalfa is planned for the second crop year, list the crop code 01 under Option 2 or Option 3 with the desired yield in order to get a lime recommendation to pH 6.5. For CRP acres, list the crop most similar to that being seeded (e.g., 04 for legume/grass hay, or 22 for native grasses.)

Tests Requested (3): Indicate the test choices for each sample. Cost for each test is shown. **Before selecting nitrate, read the information below for Nitrate Test** to see if it applies to your area or crop.

- Regular Series: Sample the plow layer for cultivated land, or to 3 inches for pastures or sod fields. Includes phosphorus, potassium, pH and lime requirement, percent organic matter, estimated texture.

- Special Tests: These tests are to be determined only on the plow layer sample. Includes zinc, copper, iron, manganese, boron, calcium, magnesium, soluble salts (electrical conductivity).
  Copper recommendations apply only for peat or muck soils. Research has shown that for Minnesota soils, tests for iron and manganese are not practical; they are included because of requests for the test.

- Sulfur Test: The sulfur test is not a reliable predictor of sulfur needs. Sulfur recommendations are based on crop and soil texture. See your county extension educator for details.

- Nutrient Management P Test: This test is an Olsen extractable P method, but is designed for situations where the soil test level for phosphorus is expected to be in the high range (>50 ppm Olsen) and is required for nutrient management decisions. Range is 20 – 250 ppm extractable Olsen P.

- Nitrate Test: For the N recommendation to be based on the nitrate value, the soil MUST be collected to a depth of 24 inches. There are two options: 1) submit two samples, 0-6" depth (if a regular series or other tests are included) and a 6"-24" depth sample; 2) collect the soil from 0-24" for the nitrate test only. The test applies to non-sandy soils in western Minnesota with an exception noted below. This test is preferred for making N recommendations for the counties west of and including Lake of the Woods, Beltrami, Becker, Otter Tail, Douglas, Pope, Kandiyohi, Renville, Redwood, Cottonwood and Jackson. In these counties, the test is used in making N recommendations for corn, small grains, potatoes and sugar beets.
  For the counties EAST of those cited, the nitrate test is used to recommend N only if the sample is collected in the spring before or near planting (April 1 – June 15).
  N fertilizer recommendations will not be based on the analysis of only plow layer samples for nitrate-nitrogen. If only a plow layer sample is submitted, N recommendations will be based on cropping history, intended crop, yield goal, and soil organic matter level.
  Samples collected for the nitrate test must be air-dried immediately to slow down microbial activity. Drying can be accomplished by spreading the soil in the sun, or placing near a heat source. If only nitrate is to be determined, the samples can be dried in a microwave oven using several 2-minute power cycles, stirring between each cycle. Alternatively, samples can be frozen and sent to the lab in a well-insulated package, which is additional shipping expense by the sender.

SAMPLING INSTRUCTIONS

Divide the field into uniform areas. Each area should have the same soil color and texture, cropping history, fertilizer, lime and manure treatments. One sample should not represent more than 20 acres on level, uniform landcapes, or 5 acres on hilly or rolling land. Within each area collect 15-30 sub-samples (cores, borings or spade slices) in a zig-zag pattern throughout the designated field area. The more variable the soil, the more sub-samples should be combined per area sampled. Mix the sub-samples thoroughly in a clean plastic pail, and fill the sample box or bag to the fill line (1 pint). If samples must be taken wet, they should be dried before being mixed and submitted to the laboratory. Do not exceed a drying temperature of 97°F, and do not use a microwave oven unless only the nitrate test is requested.

Sample each area as follows: Scrape off all surface residue. Sample to a depth of 6-8 inches (plow layer) for cultivated crops or 3 inches for pasture or sod fields. Sample row crop fields between rows, except for ridge-till plantings. Where RIDGE-TILL is used, take the sample to a depth of 6-8 inches on the shoulder of the ridge, avoiding the starter fertilizer band. Also avoid sampling dead or back furrows, terraces, old fence rows, lime or fertilizer spill areas, headlands, eroded knolls, low spots, or small saline areas. Sample at least 300 feet away from gravel or crushed limestone roads because their dust changes soil pH.

SHIPPING INSTRUCTIONS

Fill out the information sheet as completely as possible so that accurate recommendations can be given. Keep a copy for your records. Place samples in a shipping carton, enclose the information sheet with check made payable to The University of Minnesota. Please do not send cash. The lab is not responsible for cash sent through the mail. If the shipping carton is a re-used box, wrap in heavy brown paper.

Ship samples to:

Soil Testing Laboratory
University of Minnesota
135 Crops Research Building
1902 Dudley Avenue
St. Paul, MN 55108

For additional information or requests for additional soil sample information sheets and collection bags, call or visit your local county extension office, or call the laboratory at (612) 625-3101 or fax (612) 624-3420.

Website: http://soiltest.coafes.umn.edu

Location of the Laboratory

↑ N

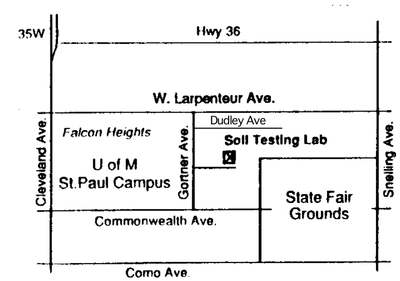

Figure 1B. University of Minnesota Soil Testing Laboratory Form to be used for the soil test submission of Nursery Field and Landscape soil samples.

For Container Media and Greenhouse Soil Samples

UNIVERSITY OF MINNESOTA

FLORIST TESTING SERVICE
UNIVERSITY OF MINNESOTA

MEDIA Sample Bag

- ☐ Spurway OR S.M.E. $20.00
- ☐ pH and Soluble Salts **ONLY** $8.00

WATER

- ☐ Water Test $25.00
- ☐ pH and Alkalinity **ONLY** $10.00
- ☐ Special Test (without Alkalinity) $20.00

SAMPLE ID: *Deciduous Container Media #3*

GROWER: *Pete Peat*

ADDRESS: *Container Plants, Inc.*
456 Nursery Lane
Tree City, MN 12345

For Nursery Fields and Landscape Soil Samples

UNIVERSITY OF MINNESOTA

SOIL SAMPLE BAG

Fill to this line

Name: *Joe Grow*

Address: *ABC Nursery*
123 Nursery Row
Arbortown, MN 12345

Sample #: *F L D 6*

4 letter/number code

Enter Sampling Depth: *0-24 Inches*

Figure 2. Examples of University of Minnesota soil sample bags for the submission of Container Media for the Florist Test, and for the submission of Nursery Field or Landscape soils for the Regular Series plus Nitrates and Soluble Salts Test.

Examples are: ammonium nitrate, 34-0-0 which supplies nitrogen; super phosphate, 0-20-0 which supplies phosphorus; or potassium chloride, 0-0-60 which supplies potassium. Whether a complete, balanced, or single nutrient fertilizer is best for plant growth will depend on factors such as soil type, soil test results, plant species being grown, the purpose for which it is grown, and current plant performance. It is important to know that two fertilizers with the same analysis may react significantly different in the same soil or container medium depending on the type of elements used to develop the fertilizer and how much of the analysis is slow release and in what form. Always request a complete label and full explanation of the composition as to what is soluble or slow release or both.

Fertilizer Selection

There are many different sources and formulations of fertilizers. Some are very soluble in water or soil solution and, therefore, are immediately available to the plant. Others must be decomposed or broken down in manner by temperature and/or moisture before becoming available to the plant. These are called "Slow Release" (SR) fertilizers.

Granular fertilizers purchased in a granular or powder form, require a low investment in material and application equipment. Use of granular fertilizers is, however, labor-intensive, unless injected into the irrigation system. Various drop or whirling applicators are used in field or landscape application of granular fertilizers. However, individual container application is time-consuming and the whirling method is inefficient because fertilizer is lost between containers and it is more likely to move to the surrounding environment. Also, the plant canopy prevents granules from reaching the container unless applied to deciduous plant material prior to bud break. Although granular fertilizers are relatively inexpensive, repeated applications are required. While most granular fertilizers are inorganic and soluble, some are organic such as Milorganite which is Milwaukee activated sewage sludge.

High-quality soluble fertilizers can be applied through an irrigation system. This is called fertigation. More applications are required to maintain a continuous and constant level of nutrition in the root zone because lower rates are applied per application and because the fertilizer is all soluble and therefore, very leachable. Labor requirement is low, but a precision injector is needed as well as skilled personnel to calculate rates and to operate the injector. Higher quality soluble fertilizer is more expensive than regular dry formulations. Nutritional deficiencies often develop when fertilization intervals are extended because of rainy or cloudy weather or removal of plants to a garden center or the landscape. A combination fertigation and slow-release fertilization program is more effective than fertigation alone.

The salt index and pH reaction, which would be acidic or basic, of a fertilizer are extremely important. Buildup of soluble salts from fertilizer with a high salt index causes injury to, and loss of, plant root systems. After an initial preplant pH adjustment, desired pH levels in container media can usually be maintained by using an acid- or base-reacting fertilizer. This is important to maintain the availability of all nutrients to the plant. Changes in pH and soluble salts in fields or in the landscape are not so easily corrected. Generally, ammonia-containing fertilizers tend to lower pH, while nitrate fertilizers tend to raise pH. Therefore, an acidic fertilizer should be selected for acid-loving plants.

Slow-release or controlled-release fertilizers are ideal for use in container and seedbed production systems. Initial fertilizer cost is high, but less labor is needed and application equipment costs are lower than with other systems. Also, the risks of over-fertilization and injury from the fertilizer are decreased. Mechanisms for controlled release include:

1. Resin-Coated Materials – Rate of release is determined by temperature and fluctuations in soil moisture; an example is Osmocote.

2. Low-Solubility Materials – Rate of release is determined by soil microbial population, temperature, and soil pH; an example is Urea Formaldehyde.

3. Sulfur-Coated Materials – Rate of release is determined by particle size, presence of water, and, to some extent, by soil temperature and pH; an example is Sulfur-Coated Urea.

4. Polyurethane-Coated Materials – Rate of release is determined by soil temperature and coating thickness; an example is Polyon.

Slow-release fertilizers are formulated to last from three to 16 growing months. Slow-release fertilizers are easily and rapidly incorporated into container media prior to containerizing. Enough can be added to provide at least one season-long supply to the plant. Lawn fertilizers also come in slow release formulations wherein the amount of "Water Insoluble Nitrogen" (WIN) is identified on the bag. References listed at the end of this chapter describe inorganic, organic, soluble, and slow-release fertilizers by chemical analysis, effect on pH, salt index, brand name, manufacturer, and various other categories.

Price is a major consideration in fertilizer selection. Consider the analysis of a fertilizer to determine its level of nutrients as well as its rate of application to the plant. Slow-release fertilizer will be more expensive, but fewer applications are required, injury potential is reduced, leaching and transport to the surrounding environment can be minimized, and often a greater number of nutrients are included.

Soil should be tested before planting, one to three times per year for field crops, three to six times per year for container crops and at regular intervals in the greenhouse to monitor nitrogen, phosphorus, and potassium levels. Tests of greenhouse and container media should also routinely include pH, soluble salts, nitrates, ammonium, calcium, magnesium, iron, and other micronutrients. Consideration must be given to the species grown, time of year, soil type, pH, method of irrigation, and type of fertilizer used.

Calibration of Fertilizer Application Equipment

Calibration of fertilizer application equipment is as important as the selection of fertilizer and the determination of the proper rate of application. Without accurate calibration, the proper rate cannot be applied. Calibration procedures depend on the type of fertilizer and the type of application equipment, as discussed below.

<u>Solid Fertilizers</u>

<u>Tractor-Mounted Broadcast Spreaders</u> – Stake the corners of an area 1,000 ft^2. Make the area width equal to the spreader width and adjust the length so that the total area will equal 1,000 ft^2. Choose and record a tractor speed that is not too fast, and a PTO setting, which is usually 540 RPM's. Record the spreader setting and place a known weight of a specific analysis fertilizer in the spreader. Spread fertilizer over the test area at the recorded speed and setting. Weigh remaining fertilizer in spreader and subtract it from the original weight to determine amount used. Adjust speed and spread again until proper amount is spread over the test area. If possible, collect the fertilizer as it comes from the spreader during calibration; this prevents wasting the fertilizer during calibration and provides a double check on the amount of fertilizer dispersed.

An example of a specific calculation is as follows: The spreader to be used has a spread of 20 ft. The desired rate is 25 lbs of calcium nitrate/1,000 ft^2. Stake an area 20 ft x 50 ft, which equals 1,000 ft^2. Add 35 lbs of fertilizer to the spreader. Set the spreader at a moderate setting or at an appropriate setting determined from prior experience. Select a tractor speed and set the PTO speed. Make a pass over the designated area, spreading the fertilizer. Weigh remaining fertilizer or collect the fertilizer spread or both. If 15 lbs remain, the spreader needs to be adjusted to spread more fertilizer. Reset the spreader and fill to 35 lbs. Again spread fertilizer and weigh remaining fertilizer. Continue this process until 25 lbs of fertilizer is spread on the test area and ten lbs. remain in the hopper. Record tractor speed, PTO and spreader setting for future use.

<u>Drop Spreader, Hand Pulled</u> – Use the same method as the tractor spreader, by spreading fertilizer on a known area and weigh the remaining fertilizer. Since the drop spreader may cover a smaller width, for example, six ft.; a 100 ft^2 area could be used as a test area. Lay a piece of plastic down the width and length of the desired test area. Spread the fertilizer on the plastic. Adjust the spreader until the correct amount of fertilizer is dropped on the plastic. Record settings for future use.

Drop spreaders usually drop fertilizer at a rate dependent upon the turning of the spreader wheels. Therefore, walking speed is not of great importance in calibration. However, if used on a bumpy or plowed field, more or less fertilizer may drop than under conditions used during calibration. For this reason, calibrate the spreader on existing field conditions.

<u>Hand Crank Spreaders</u> – Calibrate with the same techniques as for tractor-mounted or drop spreaders. However, in this case, the walking speed of the person spreading must be incorporated into the calculation. Here again the calibration should be made under actual field conditions of application, and preferably on the day of application so the walking speed during calibration will be a close as possible to the speed during application.

<u>Hand Held Perfect Feed or Easy Feeder</u> – Hold a measuring cup or spoon under the device and measure the amount of fertilizer expelled. Adjust the opening to allow more or less fertilizer out until the correct amount is achieved.

<u>Liquid Fertilizer</u>

<u>Tractor Boom Sprayer</u> – First determine the nozzle delivery rate and spray width of existing boom. Spray each nozzle for one minute and collect the spray. Calculate rate as follows:

$$\text{Gal per min} = \frac{\text{oz collected/min}}{\text{128 oz/gal}}$$

Multiply the single nozzle gal/min rate by the number of spray nozzles for total boom gal/min. Gallons per minute may also be obtained from a nozzle capacity chart. Next compute the area covered in ft^2/min (One mile/hour = 88 ft/min). Determine the width to be covered with the nozzles: ft^2/min = speed in ft/min x swath width in ft. Compute the gallons per acre as follows:

$$\text{Gal/acre} = \frac{\text{gal/min} \times 43{,}560\ \text{ft}^2\text{/acre}}{\text{ft}^2\text{/min}}$$

Next compute the chemical per gallon of water as follows:

$$\text{Chemical/gal water} = \frac{\text{chemical/acre}}{\text{gal/acre applied}}$$

Chemical/gal x sprayer capacity = chemical/sprayer

Proportioner or Injector – This process requires making a concentrated stock solution of known concentration. When mixing fertilizer concentrate, always put the fertilizer in the mixing container first and then add water to bring it up to the desired number of gallons. The formulation of the fertilizer to be used and the dilution ratio of the proportioner or injector must be known. For example: to apply 200 ppm nitrogen of 33-0-0, with a proportioner or injector ratio of 1:100:

$$\text{Weight of fertilizer/gal} = \frac{\text{ppm} \times \text{wt. of water} \times \text{proportioner ratio}}{\text{\% nutrient in fertilizer}}$$

$$= \frac{200/1{,}000{,}000 \times 8.34\ \text{lb/gal} \times 16\ \text{oz/lb} \times 100}{0.33}$$

$$= 8.09\ \text{oz/gal.}$$

An additional method to determine how many pounds of fertilizer to use to make one gallon of concentrate at a desired parts per million (ppm), is as follows:

Multiply the desired ppm of Nitrogen by the injector ratio and divide that by the percentage of Nitrogen in the fertilizer, expressed as a decimal, times 120,000. For example, to fertilize at 250 ppm using a 20-9-20 fertilizer with a 1:100 injector, calculate as follows:

$$\frac{\text{Desired ppm} \times \text{Injector Ratio}}{\text{\% Nitrogen (Decimal)} \times 120{,}000} = \frac{250 \times 100}{0.20 \times 120{,}000} = 1.04$$

Therefore, 1.04 pounds of fertilizer should be used per gallon of water with a 1:100 Injector.

Fertilization Application

Trees in urban and suburban landscapes are often under stress. Low moisture and fertility levels, soil compaction, competition from nearby trees, diseases, insects, damage from vandalism, and other factors can have a negative impact on plant growth. Under stress situations or poor soil conditions, fertility problems may increase. If growth is minimal, then it is necessary to determine the cause, and whether fertilizer will improve plant growth. Stress conditions often predispose trees to other problems; thus with good cultural methods, such as watering and fertilizing, trees are more likely to resist certain insect and disease problems. Fertilizer applications will ameliorate, but may not eliminate environmental stress. As a general guide, terminal twig growth should be six to 24 inches per year on young, healthy, deciduous trees and four to twelve inches per year on conifers. Growth is less on mature trees. A tree under nutrient stress may show a slow or stunted growth rate; reduced leaf, flower, or fruit size; a pale green or yellow green coloration of the foliage, or early fall defoliation. Nutrient stress can also be induced by poor drainage, incorrect pH, and other soil and plant factors. Thus, soil tests should be used to develop a fertilization program.

Soil type is important in determining the need for fertilizer. A fine-textured, clay-loam soil will hold more nutrients than a coarse-textured sandy loam. However, a tree growing in a heavy, compacted soil may still be stunted because of restricted root growth and lack of soil oxygen to facilitate nutrient uptake. Light, sandy soils will be low in nutrients, and may also restrict growth because of low moisture levels. Soils with a pH greater than 7.0 which is alkaline, may cause deficiencies of micronutrients such as iron and manganese in pin oak, river birch, red maple, silver maple, and other susceptible species. Deficiencies of these micronutrients, as well as nitrogen deficiencies, produce a condition known as "chlorosis," or a yellowing of the foliage. Nitrogen deficiency is characterized by uniform yellowing of the entire leaf, whereas the area surrounding leaf veins remain green when iron and manganese are deficient, thereby causing interveinal chlorosis. Low soil oxygen caused by excess water from poor drainage, flooding or compaction can also cause chlorosis. Soil tests and/or plant tissue tests should be used to determine the cause of chlorosis in commercial tree and shrub production and in large landscapes. A light fertilizer application can usually be applied to the home landscape without a soil test.

Fertilizer solubilization and subsequent plant absorption requires adequate levels of soil moisture and oxygen. If excess moisture or a lack of oxygen exists, nutrient uptake cannot take place even with adequate nutrients available. Continued fertilization under such conditions will result in excess fertilizer levels. Then, as the soil dries or becomes aerated, excess uptake may occur. Excess uptake will stimulate excessive succulent growth that is structurally weak, less likely to produce flowers, and more susceptible to diseases and insects, such as fire blight or aphids. The high soluble salt concentrations caused by excessive fertilization may also damage the tree causing root or leaf injury. Newly planted trees and shrubs should be fertilized at planting time. Fertilization at this time allows deep placement of phosphorus and potassium. Because these nutrients do not move readily in the soil, deep placement will make them immediately available to the new plant to enhance root and top growth. It is extremely important, however, that the fertilizer be mixed into the bottom of the hole and into the backfill and not placed in direct contact with the roots. A slow release fertilizer is most desirable for mixing with the backfill. Slow release fertilizers supply only small amounts of nutrients at any one time, so the possibility of root damage is eliminated and a longer-term response is obtained.

When to Fertilize

Most trees in Minnesota have a single flush of growth in the spring, and spring is the time when trees have the greatest need for nutrients. Early spring, consequently, is the time when nutrients must be available. Fall fertilizer applications are easiest and can be the most effective, because the ground is easier to work and nutrients will be available to the tree very early in the spring when growth begins. Fertilizer may be applied from late September until about mid-November. To avoid runoff problems, do not apply fertilizer to frozen soil. Spring applications may be made as soon as the ground is workable until late April or early May. If soil conditions are extremely dry, irrigate prior to and after fertilization. On sandy soils, nitrogen should be applied only in the spring or much of it will be leached out of the soil in the late fall and early spring. If soil is extremely sandy, leaching can be minimized by applying a half rate in early spring and a half rate in late spring. However, this adds to the cost of application.

If a plant is showing symptoms of nutrient deficiency, fertilizer may be applied at any time during the growing season to correct the problem. Care must be taken, however, to provide sufficient water for absorption of the nutrients by the plant and prevent fertilizer injury to the roots. During periods of hot, dry weather, two to three inches of water should be applied every two to three weeks to wet the top 12 to 18 inches of an average soil. Heavy clay soils require more water at less frequent intervals, while light, sandy soils require less water at more frequent intervals. Do not apply fertilizer to non-stressed plants in late August as plants may force a new flush of growth in early September. However, do not allow plants to go into the winter under a nutrient stress, as this will also increase winter injury. A light application of fertilizer may be necessary in late August or early September to alleviate such stress.

What to Apply

Unless a tree is deficient in some other element, increased nitrogen provides the most pronounced effects on the growth of all plant nutrients. Just because an increase in nitrogen produces a more visible increase in growth, however, does not mean that other elements are not required. Phosphorus, for example, is essential for good root growth. A soil test provides the best indicator of elements that may need to be added to the soil to prevent nutritional problems. High rates of P fertilizer should not be used unless a need is indicated by a soil test. If the soil test is high in phosphorus, then it is best to use fertilizers such as 24-0-15, 32-3-10, 27-3-3, or 16-4-8 with a high rate of N and a low or zero rate of P. High rates of P can negatively affect the environment by causing excessive algae to grow in nearby lakes and streams, which will in time, kill fish and other aquatic life. If phosphorus is needed, an excellent fertilizer to use is 18-18-8 with iron and sulfur. It is 50 percent slow release. Plants in sandy soils will require more fertilizer; however, it is easy to over fertilize in sandy soil as it moves quickly into the root zone. Soils with more organic matter, not only hold more fertilizer, but they also tend to release some nutrients as the organic matter decomposes. Thus, the use of slow release or partially slow release fertilizer is much more critical in a low organic soil containing less than three percent organic matter, compared to a medium or high organic soil containing four percent or greater organic matter. Most soil tests will provide the percent organic matter content of the soil.

For nursery production, the recommended rates of fertilization are three to four pounds of actual nitrogen (N) per 1,000 ft^2 per year. When needed, 3.6 pounds of phosphate (P_2O_5) per 1,000 ft^2 and six pounds of potassium (K_2O) per 1,000 ft^2 should be applied. The above rates must be applied to a non-turf area or placed in holes drilled or punched into the soil under the tree to prevent injury to the turf or a cover crop. Established trees in the landscape require less fertilizer wherein one to three pounds of actual nitrogen will be sufficient. The recommended rate for application over turf is one lb N/1000 ft^2 at one time. Any rate greater than two pounds of nitrogen per 1,000 ft^2 in one application will result in injury to turf. Table 1 indicates some common fertilizer analyses and rates of each formulation that will give the recommended rates for application. Whenever possible, use a slow release or partially slow release fertilizer such as 18-18-8 or 25-3-7 to reduce the amount of fertilizer immediately available and to extend its feeding duration. Products that combine fertilizers and herbicides such as "Weed and Feed" should not be used on or around trees and shrubs. Such products will injure or kill trees, shrubs and perennials in the same way that they kill weeds.

How to Apply

Apply a complete fertilizer (N, P, and K) at the time of planting. Care must be taken to ensure that it is thoroughly mixed with the backfill and it is best to use a slow release or partially slow release product. Do not apply fertilizer of any type directly to the roots.

Fertilization should occur at planting time in the nursery and in the landscape. If the proper amount of fertilizer is thoroughly mixed with the backfill soil, no root injury will occur. The fertilization should be based on results of a soil test to avoid under or over fertilizing any tree or shrub. After planting, the easiest and most convenient method of applying nitrogen fertilizers in the landscape is to spread the fertilizer on the soil under the tree canopy with a standard lawn spreader. Although two pounds of nitrogen per 1,000 ft^2 is the maximum rate that can be applied to turf in this manner, it is better to apply one pound of nitrogen per application and make more applications. Higher rates must be incorporated (drilled) into the soil in a landscape setting. To promote good, healthy, vigorous, rapid growth in a nursery production situation, three to four pounds per 1,000 ft^2 of actual nitrogen can be applied in a band in the nursery row or to individual trees. Surface applications will not readily supply phosphate and potash because these two nutrients do not readily move down to the tree's root zone. In the landscape, determine the area under the tree to be fertilized by marking off a square that encompasses the spread of the tree several feet past the dripline as depicted in Figure 1. Multiply the length by the width to determine the area in square feet. The spreader should be calibrated to deliver the recommended amount of fertilizer per 1,000 square feet. For example, if the area under the tree is 40 feet by 40 feet or 1,600 square feet, 3.2 pounds of nitrogen is needed to provide two pounds of actual nitrogen per 1,000 square feet. As shown in Table 1, six pounds of ammonium nitrate will supply two pounds of nitrogen. Therefore, six pounds of ammonium nitrate (two pounds of nitrogen) should be spread over that 1,600 square foot area. This can be repeated again in three weeks to obtain the four lbs/1,000 ft^2 rate for faster growth rates on younger trees. This surface application should be done when the grass blades are dry and then followed with a deep watering. Note that much of the fertilizer applied to the surface will benefit the grass rather than the tree. If chips or gravel cover the entire area to be treated, the total four pounds can be applied in a single application. For mature landscape trees, the one to two pounds of actual nitrogen may be sufficient.

If higher rates of nitrogen, or if phosphate and potash are to be added, it is best to place the fertilizer in holes drilled or punched in the soil. Figure 3 illustrates this system wherein holes are drilled two feet apart with a soil auger in a series of parallel lines under the spread of the tree and extending two feet past the dripline, or four to six feet if the tree has an upright or columnar form. The holes should be two inches in diameter and 12 to 18 inches deep. No hole should be within three feet of the trunk to prevent damage to the root collar. Avoid damaging major roots when drilling. Too much nitrogen close to the surface of the soil will cause spotty turf growth.

Place the recommended amount of fertilizer (Table 1) in each hole, water it in, and fill the holes with sand, compost, or peat; in heavy soils, leave the holes open to improve soil aeration. In addition to getting phosphorus and potassium down into the root zone, this method has an added advantage because the holes help decrease soil compaction and increase air and water penetration, both of which are essential for nutrient uptake by the tree. Holes may also be made with a punch bar, crowbar, or pipe. However, removing the core of soil with an auger is most beneficial.

Liquid injection root feeders are also acceptable provided that recommended application rates are maintained. This treatment effect may be less persistent than that of a dry fertilizer and, costs increase with the use of specialized equipment and fertilizers.

Large, slow-release pellets or spikes of fertilizer are available. They do provide nutrients to the tree, but the nutrient distribution may be somewhat limited compared to soil incorporation unless an abundance of spikes are used. Fertilizer release from spikes is very slow.

Fertilizers may be injected directly into the trunk of the tree either as a liquid or a slow release capsule. This method is commonly used to apply micronutrients. Repeating the injections over many years will cause some damage to the tree trunk.

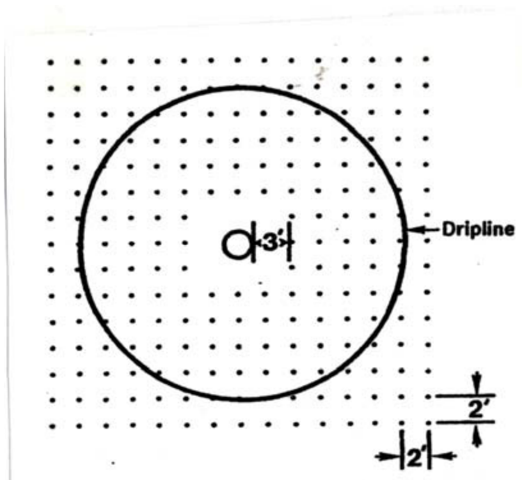

Figure 3. Determination of surface area to fertilize and distribution of holes for fertilizer incorporation. Fertilize to two feet beyond the dripline or four to six feet beyond the dripline for columnar trees. Do not fertilize closer than three feet from the trunk of the trees.

Micronutrients also may be applied to the soil or foliage using a dilute rate of 200-400 ppm soluble solution or by using a "chelate" formulation. A chelate is a chemical that combines with a nutrient element to make it available to the plant under a wider pH range. Various chelates are available at most landscape supply or fertilizer dealers. Follow label instructions for proper application. Foliar applications of iron chelates are effective, but repeated applications are necessary. Foliar applications of all nutrients are effective for a short term only, and usually have to be repeated several times during the season. Incorporation of iron sulfate, sulfur and/or acid peat into the soil to lower the pH before planting may alleviate most micronutrient problems on high pH soils. The best way to avoid micronutrient deficiency problems is to avoid planting sensitive tree species in high pH soils.

Nursery and landscape plants are easily stressed from fertility deficiencies or excesses. Apply appropriate amounts of the right nutrient at the right time to provide for optimum plant growth and vigor.

Table 1. Fertilizer nutrient analysis and application rates for trees and shrubs.

Product Analysis	Product	Amount to Apply for 2 lbs. N/1,000 ft^2		Amount to Apply for 4 lbs. N/1,000 ft^2		Amount to Mix with Backfill at Planting Time (Hole size = 3 ft^3)
		Pounds Product per 1,000 ft^2	Amount per Hole[2]	Pounds Product per 1,000 ft^2	Amount per Hole[2]	
45-0-0	Urea	4.5	0.8 Tbsp (8 g)	9.0	1.6 Tbsp (16 g)	0.13 lb
38-0-0[3]	Ureaform	5.0	1.0 Tbsp (11 g)	10.0	2.0 Tbsp (22 g)	0.25 lb
33-0-0	Ammonium Nitrate	6.0	1.0 Tbsp (11 g)	12.0	2.0 Tbsp (22 g)	0.13 lb
21-0-0	Ammonium Sulfate	9.0	1.5 Tbsp (16 g)	18.0	3.0 Tbsp (32 g)	0.33 lb
18-18-8[3]	United Ag Products	11.0	1.8 Tbsp (20 g)	22.0	3.6 Tbsp (40 g)	1.00 lb
25-3-7[3]	No. Star Minerals	8.0	1.4 Tbsp (15 g)	16.0	2.7 Tbsp (30 g)	0.75 lb
18-6-12[4]	Osmocote	11.0	1.8 Tbsp (20 g)	22.0	3.6 Tbsp (40 g)	1.50 lbs
14-14-14[5]	Osmocote	14.0	2.4 Tbsp (26 g)	28.0	4.8 Tbsp (52 g)	1.50 lbs
20-4-8[4]	Osmocote	10.0	1.7 Tbsp (18 g)	20.0	3.4 Tbsp (36 g)	1.75 lbs
19-5-8[6]	Harrell's	11.0	1.8 Tbsp (20 g)	22.0	3.6 Tbsp (40 g)	1.75 lbs
14-7-8[7]	Harrell's	14.0	2.4 Tbsp (26 g)	28.0	4.8 Tbsp (52 g)	1.50 lbs
19-3-9[4]	Harrell's	11.0	1.8 Tbsp (20 g)	22.0	3.6 Tbsp (40 g)	1.75 lbs
12-12-12		16.5	2.7 Tbsp (30 g)	33.0	5.5 Tbsp (60 g)	0.33 lb
10-10-10		20.0	3.3 Tbsp (36 g)	40.0	6.6 Tbsp (72 g)	0.50 lb
14-3-3[8]	Briquettes	Follow Label	Follow Label	Follow Label	Follow Label	Follow Label
23-2-0[8]	Briquettes	Follow Label	Follow Label	Follow Label	Follow Label	Follow Label

[1] The fertilizer rates cited are provided as examples only. Actual rates of application will depend on soil texture, percent organic matter, and moisture levels. One tablespoon of fertilizer weighs approximately 11 grams.
[2] Amount per hole when properly spaced 2 feet apart regardless of number of holes.
[3] 50 % slow release: 3-4 months.
[4] Slow release: 8-9 months.
[5] Slow release: 3-4 months.
[6] Slow release: 9-10 months.
[7] Slow release: 5-6 months.
[8] Very slow release: 1 year or more.