Inorganic and Organic Fertilizers

Any substance that contains one or more essential plant nutrient elements has the potential to be used as a fertilizer. Fertilizers are broadly classified as either organic or inorganic, although the distinction between the two types is not always clear-cut. Urea, for example, is a naturally occurring organic compound, but chemically synthesized urea is generally grouped with inorganic fertilizers. According to the Minnesota Department of Agriculture, a natural organic fertilizer has to be derived from either plant or animal materials containing one or more elements (other than carbon, hydrogen, and oxygen) that are essential for plant growth. Organic food production, however, allows for a broader definition that includes naturally occurring inorganic substances such as rock phosphate, elemental sulfur, and gypsum that are not chemically modified.

Plant roots absorb the majority of their nutrients from the soil solution as simple, inorganic ions (charged atoms or molecules). Larger molecules can also be absorbed, but their rate of absorption is slow. Most inorganic fertilizers dissolve readily in water and are immediately available to plants for uptake. When used according to recommendations, these types of fertilizers efficiently supply the required nutrients for plant growth and are safe for the environment. However, excessive rates can injure plant roots and potentially lead to environmental degradation.

Organic fertilizers are more complex chemical substances that take time to be broken down into forms usable by plants. They are slow-release type fertilizers, compared to the quick-release characteristics of most inorganic fertilizers. It is important to apply these organic fertilizers well before periods of rapid plant growth. Organic fertilizers usually have a low salt index, so larger amounts can be applied at one time without causing injury to plant roots. With organic nitrogen sources (except urea), one application can be made without having to be concerned about losing most of the nitrogen to leaching. However, even organic fertilizers applied at excessive rates can cause environmental degradation due to nitrate leaching or runoff of soluble organic compounds. The cost of organic fertilizers at garden centers on a per pound of nutrient basis is usually higher than quick-release inorganic fertilizers.

Manure, compost, and many other materials used as organic fertilizers add considerable quantities of organic matter to the soil. Organic matter can increase soil drainage, aeration, water holding capacity, and the ability of the soil to hold nutrients. The beneficial effects of organic matter on soil structure can have a greater effect on plant growth than the fertilizer value of some of these organic materials.

Slow-Release Fertilizers

Slow-release fertilizers are inorganic fertilizers made up of either larger molecules that require microbial action for degradation or regular fertilizer such as urea that is coated in some way to reduce solubility. Like organic fertilizers they have a low burn potential. They also release fertilizer over a longer period of time. Many formulations are now available that have release rates of 50 days to over one year. They are particularly useful on sandy soils where leaching of nitrogen is a concern. Higher rates of fertilizer can be applied without the fear of losing nitrate with excessive rainfall. The main disadvantages of slow release fertilizer are the high cost relative to quick-release fertilizer and the release rate is too slow for fast growing crops.

Fertilizer Grades

The grade or analysis of a fertilizer represents its percent composition of the three primary plant nutrients. By convention, nitrogen is expressed on an elemental basis as percent N, whereas phosphorus and potassium are expressed on an oxide basis as percent P_2O_5 (phosphate) and percent K_2O (potash), respectively. Minnesota state law requires that any material sold as fertilizer be clearly labeled with its fertilizer grade (e.g., 10-10-10) and this analysis is guaranteed by the manufacturer. The first number in the series is the percent N, the second number is the percent P_2O_5, and the third number is the percent K_2O. It should be noted that N, P_2O_5, and K_2O do not exist in fertilizer in these forms. Rather, these forms are calculated based on the elemental analysis and then simply used to allow a convenient way of comparing the nutrient value of one fertilizer with another. For example, a 10-20-10 fertilizer has the same amount of nitrogen and potash, but twice as much phosphate as a 10-10-10 fertilizer. Also note that the percentages do not add up to 100. This is because the fertilizer is made up of other elements not included in the analysis and in some cases may also contain a filler or carrier.

The nutrient composition of common inorganic/chemical fertilizer sources is provided in **Table 8**. The approximate, primary macronutrient composition of selected organic fertilizers is provided in **Table 9**. Organic fertilizers also provide other plant nutrients including variable amounts of micronutrients.

Table 8. Approximate nutrient composition of various inorganic/chemical fertilizers; fertilizers marked with an asterisk (*) are acceptable for organic fruit and vegetable production

Nutrient	Fertilizer material	Composition		
		N	P_2O_5	K_2O
		---------- % ----------		
Nitrogen Sources	(quick release)			
	Ammonium nitrate	33	0	0
	Ammonium sulfate	21	0	0
	Ammonium thiosulfate	12	0	0
	Anhydrous ammonia	82	0	0
	Calcium nitrate	15.5	0	0
	Diammonium phosphate	18	46	0
	Mono-ammonium phosphate	11	48	0
	Potassium nitrate	13	0	44
	Sodium nitrate	16	0	0
	Urea	46	0	0
	Urea-ammonium nitrate (UAN)	28-32	0	0
	(slow release)			
	Isobutylidene diurea (IBDU)	31	0	0
	Polymer coated urea	40-44	0	0
	Sulfur coated urea (SCU)	36	0	0
	Urea formaldehyde (UF)	38	0	0
Phosphorus Sources				
	Diammonium phosphate	18	46	0
	Mono-ammonium phosphate	11	48	0
	*Rock phosphate	0	5	0
	Superphosphate	0	20	0
	Triple superphosphate	0	46	0
Potassium Sources				
	Potassium chloride	0	0	60
	*Potassium - magnesium sulfate	0	0	22
	Potassium nitrate	13	0	44
	*Potassium sulfate	0	0	50
Calcium Sources		% Ca		
	*Calcium sulfate (gypsum)	22		
	Calcium nitrate	20		
	Calcium chloride	36		
	*Calcitic lime	30-40		
	*Dolomite	22		
Magnesium Sources		% Mg		
	*Magnesium sulfate (Epsom Salts)	10		
	*Potassium - magnesium sulfate	11		
	*Dolomite	11		
Sulfur Sources		% S		
	Ammonium thiosulfate	26		
	Ammonium sulfate	24		
	*Calcium sulfate (gypsum)	19		
	*Elemental sulfur	90-100		
	*Potassium - magnesium sulfate	18		
	*Potassium sulfate	18		
	*Magnesium sulfate (Epsom salts)	13		
Boron Sources		% B		
	Borax	11		
	Boric acid	17		
	Solubor	28		
	Sodium pentaborate	14		
	Sodium tetraborate	20		
Copper Sources		% Cu		
	Cupric chloride	47		
	Copper sulfate	25		
	Copper chelates	8-13		
Iron Sources		% Fe		
	Iron sulfate	20		
	Iron chelates	5-12		
Manganese Sources		% Ma		
	Manganese sulfate	27		
	Manganese chelate	12		
Molybdenum Sources		% Mo		
	Ammonium molybdate	54		
	Sodium molybdate	39		
Zinc Sources		% Zn		
	Zinc oxide	80		
	Zinc sulfate	23		
	Zinc chelate	14		

Table 9. Approximate nutrient composition of various organic fertilizers[1]

Organic materials	Nutrient		
	N	P_2O_5	K_2O
	---	% dry weight basis	---
Manures			
Beef	1.2	2.0	2.1
Dairy	2.1	3.2	3.0
Horse	2.1	3.2	2.0
Poultry	3.0	5.0	2.0
Rabbit[2]	2.4	1.4	0.6
Sheep	1.6	1.2	1.0
Swine	2.5	2.1	2.0
Alfalfa hay	2.5	0.5	2.5
Blood meal	13.0	2.0	1.0
Bone meal, raw	3.0	22.0	0.0
Bone meal, steamed	1.0	15.0	0.0
Composted yard waste	1.3	0.4	0.4
Cottonseed meal	6.0	3.0	1.5
Fish meal	10.0	6.0	0.0
Grain straw	0.6	0.2	2.1
Kelp/seaweed	1.5	1.0	4.9
Lawn clippings	2.5	0.3	2.0
Leaves, broadleaves	0.9	0.2	0.8
Milorganite[3]	5.0	3.0	2.0
Sawdust	0.2	0.1	0.2
Soybean meal	7.0	1.2	2.0
Wood ashes	0.0	2.0	6.0

[1]These are total concentrations and only slowly available over weeks, months, or years. Many materials will vary in composition due to methods of handling and moisture content.
[2]The composition of rabbit manure is on a fresh weight basis.
[3]Not recommended for fertilizing fruit or vegetables.

Calculating Fertilizer Rates from Soil Test Recommendations

All fertilizer recommendations are based on the amount (lbs.) of nutrient (N, P_2O_5, K_2O) to apply per given area. Lawn and turf recommendations are given in pounds per 1000 sq. ft. and garden, tree, and shrub recommendations in pounds per 100 sq. ft. From this recommendation it is necessary to select an appropriate fertilizer grade and then determine how much of this fertilizer to apply to the garden area.

Fertilizers are sold in many grades. Complete fertilizers such as 10-10-10 or 5-10-10, contain all three primary nutrients. Single nutrient fertilizers contain only one, but they generally are a high analysis, economical source of that nutrient (e.g., 46-0-0, 0-46-0, 0-0-60). Single nutrient fertilizers are available through fertilizer dealers, but are either not available or very expensive at most garden centers.

Numbers on the fertilizer bag indicate the exact percentages of nutrients by weight. For example, a 100 lb. bag of 5-10-10 fertilizer contains 5 lbs. of nitrogen (N), 10 lbs. of phosphate (P_2O_5) and 10 lbs. of potash (K_2O). Most garden fertilizers are complete fertilizers. With the new phosphorus law, most turf fertilizers contain just nitrogen and potash. Complete fertilizers are convenient to use, but it may be difficult to find one that exactly matches the

ratio required in the fertilizer recommendation. *Since meeting the exact amount required for each nutrient will not be possible in all cases, it is most important to match the nitrogen required.* Calculating the amount of fertilizer to apply from its analysis requires basic arithmetic and an example is provided below. To reduce the number of calculations required, the amount of fertilizer to apply that will give the recommended amount of nitrogen can also be obtained from **Table 10**.

NOTE: 2 cups (1 pint) of dry fertilizer weighs approximately 1 pound.

To calculate fertilizer rates, the following example is provided:
A soil test recommendation for a garden calls for 0.1 lb. N/100 sq. ft., 0 lb. P_2O_5/100 sq. ft. and 0.1 lb. K_2O/100 sq. ft. The garden is 40 feet by 10 feet.

Four steps are required to determine how much of a given fertilizer is required for a given area:

Step 1 Measure the garden area to be fertilized in square feet.

Formula for calculating size of area to be fertilized:
feet long X feet wide = square feet

Example:
40 feet long X 10 feet wide = 400 square feet

Step 2 Select the fertilizer(s) to use based on the soil test by matching the ratio of nutrients recommended to the fertilizer grades available.

Example:
The N-P-K nutrient ratio based on the soil test should be 1-0-1. Ideally, a fertilizer such as a 10-0-10, 20-0-20 or 25-0-25 should be selected. At the local garden store, fertilizer bags marked 20-10-10, 27-3-3 and 25-0-12 were available. The one marked 25-0-12 best matched the ratio of 1-0-1 recommended by the soil test.

Step 3 Determine the amount of fertilizer to apply by:
a. dividing the recommended amount of the nutrient by the percentage of the nutrient (on a decimal basis) in the fertilizer

$$\frac{\textbf{lb. nutrient recommended/sq. ft.}}{\textbf{\% nutrient in fertilizer}} = \textbf{lb. fertilizer/sq. ft.}$$

Example: *(use nitrogen percentage to determine the rate to apply)*

$$\frac{\textbf{0.1 lb. nutrient recommended/100 sq. ft.}}{\textbf{25\% nutrient in fertilizer (0.25)}} = \textbf{0.4 lb. fertilizer/100 sq. ft.}$$

b. **Table 10** simplifies the calculation by providing the total amount of fertilizer to apply based solely on its nitrogen content.

Example from Table 10:
The nitrogen recommendation calls for 0.1 lb. N/100 sq. ft. and the fertilizer grade selected has a ratio of **25**-0-12 (column one), apply 0.4 lb. (column two) of this fertilizer per 100 sq. ft.

Step 4 Adjust the amount of fertilizer to apply for the garden or lawn area.

$$\frac{\text{lb. fertilizer}}{\text{sq. ft.}} \times \frac{\text{sq. ft.}}{\text{garden or lawn}} = \frac{\text{lb. fertilizer}}{\text{garden or lawn}}$$

Example:

$$\frac{\text{0.4 lb. fertilizer}}{\text{100 sq. ft.}} \times \frac{\text{400 sq. ft.}}{\text{garden or lawn}} = \frac{\text{1.6 lb. 25-0-12 fertilizer}}{\text{garden or lawn}}$$

or about 3 cups of a 25-0-12 fertilizer per 400 sq. ft. garden/lawn

Because most fertilizers sold at garden centers have more nitrogen than potash, there is a potential for soils to become low in potassium. If soil test potassium is less than 100 ppm, it may be beneficial to apply a single nutrient fertilizer such as 0-0-60. To supply 0.3 lb. K_2O per 100 sq. ft., 0.5 lb. (0.3 divided by 0.6) of 0-0-60 fertilizer should be applied. To supply 3.0 lbs. K_2O per 1000 sq. ft., apply 5.0 lbs. of 0-0-60 fertilizer.

Calculating Organic Fertilizer Rates

Calculating fertilizer rates using organic fertilizer sources is often difficult. Their exact nutrient content is frequently unknown, so fertilizer rates can only be approximated using general values such as those in **Table 9**. Even though a total nitrogen content of the material is often reported, only a portion of that nitrogen may be available to plants the year of application. Nitrogen availability in organic materials depends on many factors including soil temperature, moisture, and carbon-to-nitrogen ratio of the material. The weight of the applied organic material must also be corrected for its moisture content. Bulky organic materials are usually low in nitrogen and must be supplemented with inorganic nitrogen fertilizers or an organic source that is high in nitrogen.
See page 21 for suggested application rates of yard waste compost.

Some types of organic fertilizer can be purchased in bags that are labeled with their fertilizer grade. *Fertilizer rates for these products can be calculated in the same manner as for inorganic fertilizers.*

Table 10. Total amount of fertilizer to apply based on recommended amounts of actual nitrogen.

Fertilizer Nitrogen Percent (First number of fertilizer grade on bag)	Nitrogen Recommended			
	0.1 lb.	0.15 lb.	0.2 lb.	1.0 lb.
	per 100 sq. ft.			per 1000 sq. ft.
	Total amount of fertilizer to apply* lbs. per 100 sq. ft.			lbs. per 1000 sq. ft.
46 (urea)	0.22	0.33	0.44	2.2
40	0.27	0.41	0.54	2.7
36	0.28	0.42	0.56	2.8
34	0.29	0.44	0.58	2.9
33 (ammonium nitrate)	0.30	0.45	0.60	3.0
32	0.31	0.47	0.62	3.1
30	0.33	0.50	0.66	3.3
29	0.34	0.51	0.68	3.4
28	0.36	0.54	0.72	3.6
27	0.37	0.56	0.74	3.7
26	0.39	0.59	0.78	3.9
25**	**0.40**	0.60	0.80	4.0
24	0.42	0.63	0.84	4.2
23	0.43	0.65	0.86	4.3
22	0.45	0.68	0.90	4.5
21 (ammonium sulfate)	0.48	0.72	0.96	4.8
20	0.50	0.75	1.00	5.0
19	0.53	0.80	1.06	5.3
18	0.56	0.84	1.12	5.6
17	0.59	0.89	1.18	5.9
16	0.63	0.95	1.26	6.3
15	0.67	1.00	1.34	6.7
14	0.71	1.07	1.42	7.1
13	0.77	1.16	1.54	7.7
12	0.83	1.25	1.66	8.3
11	0.91	1.37	1.82	9.1
10	1.00	1.50	2.00	10.0
9	1.11	1.67	2.22	11.1
8	1.25	1.88	2.50	12.5
7	1.43	2.15	2.86	14.3
6	1.67	2.51	3.34	16.7
5	2.00	3.00	4.00	20.0
4	2.50	3.75	5.00	25.0
3	3.33	5.00	6.66	33.3
2	5.00	7.50	10.00	50.0
1	10.00	15.00	20.00	100.0

* 1 cup of fertilizer weighs about 0.5 lbs.

** See example on page 18.

Methods of Applying Fertilizers

Fertilizers can be applied in several ways. The most important point to remember is to apply them at the proper rate, as over-application can result in plant damage or death. Follow soil test recommendations or manufacturer's directions. Some of the common fertilizer application methods are as follows:

Broadcast Application

Broadcasting refers to uniformly applying the fertilizer over the entire area before planting. This is the safest and easiest method for the home gardener and best accomplished with a mechanical spreader. The fertilizer should be worked into the soil to a depth of 4 to 6 inches.

Band Placement

Banding fertilizer refers to placement of fertilizer 2 to 3 inches to each side and below the seed at planting. This technique is risky for gardeners to use as placement too close to the seed or at too high rate can cause fertilizer burn and inhibit germination.

Sidedress Application

Sidedressing refers to placing the fertilizer beside the row during the growing season. This technique is usually used to apply additional nitrogen during the growing season and is particularly useful for applying nitrogen on sandy soils.

Topdress Application

Topdressing is similar to sidedressing except that the fertilizer is applied around the plant. *Caution: fertilizer applied too close to the plant can cause fertilizer burn.*

Starter Solution Application

Starter solution fertilizers are soluble in water, usually high in phosphorus, and applied as a liquid around the plant roots at the time of planting. They are primarily used for vegetable transplants to hasten root development and establishment. Follow manufacturer's directions for application rates. A general recommendation for 8-16-16 or 15-30-15 is to dissolve 2 tablespoons in 1 gallon of water. Then apply 1 cup of the solution around the roots of each transplant.

Foliar Applications

Foliar fertilizers are dilute solutions applied directly to the leaves. They should not be relied upon to supply the total nitrogen, phosphorus, and potassium needs of plants. They can used to supplement soil applications of these nutrients. Foliar applications of micronutrients, especially iron, may be beneficial when high soil pH conditions make the soil iron unavailable to plant roots (refer to section on iron chlorosis on page 38).

Yard Waste Compost Application

Well-composted yard waste usually has a nitrogen availability between 10 to 15% the first year. Application of composted yard waste for general gardening is usually made to improve soil physical properties as well as to provide nutrients. An application of 100 lbs. of moist compost per 100 square feet (about 4 to 6, 5-gallon buckets) is sufficient for most gardens. Incorporate the compost to a depth of 6 to 8 inches. With this application of compost, the amount of fertilizer recommended can be cut in half.

Compost that is immature or not well decomposed should be used primarily as a mulch. Incorporation of immature compost into the soil may result in nitrogen deficiency and poor plant growth. Do not reduce fertilizer application if the compost is used as a mulch.