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Chapter 12

Inorganic Fertilizer Materials

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The various sources of plant nutrients can be grouped into two general categories, inorganic and organic. The inorganic materials generally are relatively "high-analysis" fertilizers with few impurities. The organic materials, on the other hand, are relatively "low-analysis" fertilizers that often contain a wide range of nutrients as well as organic compounds (see Chapter 15, Table 15-8). Both sources of nutrients have a place in farming, and to use them to their best advantage, it is important that their properties be understood. Their costs also vary. A judicious selection of the right fertilizer for a given situation requires consideration of several factors: properties affecting their use by plants, economic costs, and environmental effects (both short-term soil reactions and long-term environmental fate).

Many of the more commonly used inorganic fertilizers are described below, and their analyses are summarized in Table 12-1. Much of the information presented here was obtained from Tisdale et al. (1993).

Nitrogen fertilizers

Inorganic N sources include ammonium and nitrate forms and urea.

Ammonium sulfate [$(NH_4)_2SO_4$] has been used in Hawaii for many years in both the sugarcane and pineapple industries as well as on small farms. It contains 21% N and 11% S. It will lower soil pH if used continuously over long periods of time.

Ammonium phosphates: Monoammonium phosphate (MAP) [$NH_4H_2PO_4$] supplies both N and P, at 11–13% N and 48–62% P_2O_5. Diammonium phosphate (DAP) [$(NH_4)_2HPO_4$] is also widely used to supply both N and P, at 18–21% N and 46–53% P_2O_5. Both fertilizers are completely water soluble. Row or seed placement of DAP must be done with caution, especially in soils with high pH, because free NH_3 can be produced, causing seedling injury. When these materials come in contact with soil in banded applications, MAP initially causes soil pH to be 3.5, while with DAP the pH is 8.0.

Potassium nitrate [KNO_3] contains two essential nutrients, N (13%) and K_2O (44%). It is not hygroscopic (that is, it does not pick up moisture from the air) so it is easy to apply, the NO_3^- is readily available, and it causes soil pH to increase slightly.

Calcium nitrate [$Ca(NO_3)_2$] contains 15% N and 34% CaO. The NO_3^- is readily available, but the material is extremely hygroscopic. It is prone to liquefication if it is not stored in moisture-proof bags.

Urea [$CO(NH_2)_2$] contains 45–46% N. It has very good physical properties in that it has less tendency to cake than ammonium nitrate and it is less corrosive than other N fertilzers. Its high concentration of N brings about savings in storage, transportation, handling, and application. Urea is soluble and can leach as readily as nitrate. However, once it has been converted to NH_4^+ and HCO_3^- in the soil by the enzyme urease, the NH_4^+ can be held on exchange sites and is thus less subject to leaching. Initially, urea can raise soil pH in the zone of application due to the release of NH_3, but over time, soil pH can decrease from the original pH due to the nitrification of NH_4^+ to NO_3^-. Urea can contain varying amounts of biuret, an impurity that can be phytotoxic. Most crops can tolerate biuret levels of 2% or less. However, sensitive crops such as citrus and pineapple should be sprayed with urea containing less that 0.25% biuret. If urea is applied to the surface of soils with high pH, NH_4^+ may form ammonia (NH_3), which can be lost by volatilization.

Sulfur-coated urea (SCU) is a controlled-release fertilizer that has a sulfur shell around each urea particle. The release of urea depends on the oxidation of the sulfur shell by soil microorganisms. The thickness of the sulfur shell can be varied to give different rates of release of urea. SCU contains 36–38% N and is useful in areas of porous soils with high rainfall or irrigation where NO_3^- can be leached readily. SCU also supplies S as it is oxidized by microorganisms.

Phosphorus fertilizers

Rock phosphate [$Ca_{10}OHF(PO_4)_6$]. Rock phosphates contain apatite, which varies greatly in composition and solubility and becomes available to plants only in acid soils (pH <6.0). Rock phosphates contain 27–41% P_2O_5,which is slowly available to plants but persists in the soil for many years. Applications of rock phosphate made by the sugar industry in the 1930s can still be detected by chemical extractants in some soils along the Hilo coast. Rock phosphates should be broadcast and thoroughly mixed with acid soils to allow maximum contact of the fertilizer with the soil so that dissolution can occur more rapidly, making P more available to plants. Rock phosphate can be quite effective on certain long-term crops, such as pastures and perennials. The dissolved Ca can be beneficial in acid, low-Ca soils.

Superphosphates [$Ca(H_2PO_4)_2$]. There are two types of superphosphates, single superphosphate (SSP) with 16–22% P_2O_5 and triple (or concentrated) superphosphate (TSP or CSP) with 44–52% P_2O_5. Single superphosphate is made by treating rock phosphate with sulfuric acid, so it contains 11–12% S. Triple superphosphate, on the other hand, is made by acidulating rock phosphate with phosphoric acid, so it has only 1–1.5% S. Phosphorus in both of these fertilizers is readily available to plants. These are neutral fertilizers, having little effect on soil pH.

Ammonium phosphates. Two forms of ammonium phosphate are monoammonium phosphate [$NH_4H_2PO_4$], with 11–13% N, 48–62% P_2O_5, and 0–2% S, and diammonium phosphate [$(NH_4)_2HPO_4$], with 18–21% N, 46–53% P_2O_5, and 0–2% S. Both are granular fertilizers that are completely water soluble.

Potassium fertilizers

Potassium chloride [KCl], known as *muriate of potash*, contains 60–63% K_2O and is completely water soluble. It is the most widely used potassium fertilizer.

Potassium sulfate [K_2SO_4] is known as *sulfate of potash* and contains 50–53% K_2O and 17% S. It is used on crops such as potato and avocado that are sensitive to large applications of chloride (Cl^-). It is completely water soluble.

Potassium nitrate [KNO_3] supples 44% K_2O and 13% N. It is not very hygroscopic, is readily soluble, and increases soil pH.

Potassium-magnesium sulfate [$K_2SO_4 \cdot 2MgSO_4$], sold as Sul-Po-Mag®, supplies 22% K, 11% Mg, and 22% S. It is widely used in dry fertilizer formulations.

Calcium fertilizers

Lime [$CaCO_3$] and **dolomite** [$CaMg(CO_3)_2$] are used as liming materials to adjust soil pH and supply calcium. Lime contains about 38% Ca, while dolomite contains about 22% Ca and 12% Mg. The amounts of Ca and Mg vary with the source of the material.

Calcium sulfate, gypsum [$CaSO_4 \cdot 2H_2O$] is an amendment supplying Ca in a form that changes soil pH very little, so it is useful in soils with adequate pH for plants. It contains 23% Ca and 19% S.

Calcium nitrate [$Ca(NO_3)_2$] is highly soluble and supplies 15% N and about 20% Ca. It is useful where rapid calcium availability with a minimal soil pH change is desired.

Superphosphates. Single superphosphate supplies 18–21% Ca, while triple superphosphate supplies 12–14% Ca. Thus, when superphosphate is applied to supply P to the soil, Ca is supplied also.

Magnesium fertilizers

Dolomite [$CaMg(CO_3)_2$], used as a liming material, supplies both Ca and Mg in amounts that may vary. One dolomite sold in Hawaii has about 22% Ca and 12% Mg. The agricultural lime sold in Hawaii is usually ground coral containing 38% Ca and 0.6% Mg.

Magnesium sulfate, Epsom salts [$MgSO_4 \cdot 7H_2O$] supplies both Mg (9.8%) and S (13%) without changing soil pH. It is readily soluble and can be applied to

Table 12-1. Composition (%) of some common fertilizer materials

Source	N	P_2O_5	K_2O	S	Other
Nitrogen					
Ammonium sulfate	21			24	
Calcium nitrate	15				24 (Ca)
Urea	45–46				
Sulfur-coated urea	36–38			Variable	
Phosphorus					
Rock phosphate		25–40			25 (Ca)
Single superphosphate		16–22		11–12	20 (Ca)
Triple superphosphate		44–53		1–2	13 (Ca)
Monoammonium phosphate	11	48–55		1–3	1 (Ca)
Diammonium phosphate	18–21	46–54		0–2	
Potassium					
Potassiun chloride			60–62		
Potassium sulfate			50–52	17	
Potassium-magnesium sulfate					
Calcium					
Lime					38 (Ca)
Dolomite					22 (Ca) 19 (Mg)
Calcium sulfate (gypsum)				19	23 (Ca)
Magnesium					
Magnesium sulfate (Epsom salt)				13	9.8 (Mg)
Magnesium oxice					55 (Mg)
Sulfur					
Elemental sulfur				100	
Micronutrients					
$FeSO_4{\cdot}7H_2O$				12	19 (Fe)
FeEDTA					5–14 (Fe)
$ZnSO_4{\cdot}H_2O$				18	35 (Zn)
ZnEDTA					14 (Zn)
$CuSO_4{\cdot}5H_2O$				13	25 (Cu)
CuEDTA					13 (Cu)
Borax					11 (B)
Granusol®					5.4 (Fe) 5.2 (Zn) 5.6 (Mn) 5.4 (Mg) 2.6 (Cu) 0.5 (B)

From Tisdale et al. (1993) and Iwami (1995).

the soil or as a foliar spray.

Magnesium oxide [MgO] contains 55% Mg and will increase soil pH. It is not readily soluble, so it nearly always should be incorporated into the soil.

Sulfur fertilizers

Elemental sulfur [S] is inert and water-insoluble and must be converted to sulfate (SO_4^-) by soil microorganisms (*Thiobacillus* species) before it can be used by plants. Therefore, sufficient time must be allowed for the S to become available before any effect on the soil or plants can be expected. Elemental sulfur should be finely ground. The finer the particle size, the larger the surface area and the faster the sulfur will be oxidized by the bacteria to sulfate. Elemental sulfur should be broadcast and incorporated into the soil for the maximum rate of oxidation. Sulfur will lower soil pH.

Ammonium sulfate [$(NH_4)_2SO_4$] contains 24% S along with the nitrogen and is a means of supplying S to the soil and plants. This is one of the most acidifying fertilizer materials, because both ammonium and sulfate contribute to acidity.

Micronutrient fertilizers

Iron (ferrous) sulfate [$FeSO_4 \cdot 7H_2O$] contains about 19% Fe and may be used as a foliar spray (1–2% $FeSO_4$) or applied to the soil.

Iron chelate, iron EDTA [NaFeEDTA] contains 5–14% Fe and may be used as a foliar spray or applied to the soil.

Zinc sulfate [$ZnSO_4 \cdot H_2O$] contains about 35% Zn. Since Zn is relatively immobile in soil, zinc sulfate should be broadcast and incorporated into the soil or applied in a band. Zinc sulfate may also be applied to foliage.

Zinc chelate, zinc EDTA [$Na_2ZnEDTA$] contains about 14% Zn and is often applied as a foliar spray. It can also be applied to the soil.

Copper sulfate [$CuSO_4 \cdot 5H_2O$] contains about 25% Cu and may be applied to the soil or to foliage.

Copper chelate, copper EDTA [$Na_2CuEDTA$] is soluble and contains about 13% Cu. It is generally used as a foliar spray.

Sodium borate, borax [$Na_2B_4O_7 \cdot 10H_2O$] contains about 11% B and may be applied to the soil or as a foliar spray. Application rates of B depend on the crop and soil and are generally quite low, because B can become toxic at high rates.

Table 12-2. Formulations of some blended fertilizers available in Hawaii (Iwami 1995).

N	-	P_2O_5	-	K_2O	
6	-	20	-	20	
7	-	14	-	14	
7.5	-	0	-	12.2	“NK14” (liquid)
7	-	30	-	20	
10	-	5	-	10	
10	-	5	-	32	
10	-	20	-	20	
10	-	30	-	10	
11	-	37	-	0	
12	-	5	-	30	
14	-	14	-	14	+boron
15	-	2	-	11	
15	-	15	-	15	
16	-	16	-	16	
21	-	0	-	33	“A-1”
21	-	7	-	14	

Granusol® is a product available in Hawaii that contains several micronutrients (5.4% Fe, 5.2% Zn, 5.6% Mn, 5.4% Mg, 2.6% Cu, 0.5% B). It is quite insoluble, so it should be broadcast and incorporated into the soil.

Mixed fertilizers (blends)

Many different combinations or blends of the basic N, P, and K fertilizers are formulated by fertilizer manufacturers to meet the special needs of farmers and home gardeners. These formulations provide the opportunity to apply only the combinations of nutrients that are needed and thus make it possible to avoid overapplication of nutrients that are already adequate or in excess. It is necessary to identify the blend that best suits a particular purpose and costs the least per unit of nutrient. Some of the blends available in Hawaii are listed in Table 12-2.

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