

Chapter 8. Commercial Fertilizers

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Introduction

Plants require optimal amounts of available nutrients for normal growth. These nutrients can come from several sources, including soil organic matter, native soil minerals, organic materials that are added to the soil (e.g., animal manures), air (e.g., legumes), and commercial fertilizers. When a soil is not capable of supplying enough nutrients to meet crop/plant requirements, commercial fertilizers can be added to supply the needed nutrients. There are numerous types of fertilizers that can be used to supply primary, secondary, or micronutrients. This chapter will provide an overview of the key issues related to commercial fertilizers.

Before using any fertilizers, it is important to understand how to read a fertilizer label. All fertilizers are labeled as %N - %P₂O₅ - %K₂O. For example, a fertilizer labeled as a 15-5-10 means that the product contains 15 percent N, 5 percent P₂O₅, and 10 percent K₂O by weight.

Nitrogen fertilizers

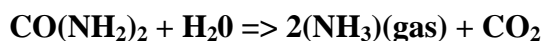
Introduction

Inorganic N fertilizers are produced by fixing N from the atmosphere. Natural gas is used as the energy source and is a major component of the cost of N fertilizers. The following section lists the primary N materials used by the fertilizer industry and describes some of the key characteristics of each product.

Urea

Urea [CO(NH₂)₂]:

- Fertilizer grade: 46-0-0.
- Soluble, readily available source of N.
- Dry fertilizer product.
- Produced by reacting ammonia (NH₃) with carbon dioxide under pressure at an elevated temperature.
- Contains the highest percentage of N of all dry fertilizers.
- Applying too much near germinating seeds can kill seedlings due to NH₃ release.
- Rapid hydrolysis to ammonium carbonate can cause significant N losses as NH₃ gas through volatilization when urea is applied to the surface of soil and is not incorporated:



- Incorporation or injection into the soil is important to avoid volatilization losses as NH_3 gas.
 - Rainfall or irrigation (0.5 inches or more) will prevent NH_3 volatilization.
-

Ammonium nitrate

Ammonium nitrate (NH_4NO_3):

- Fertilizer grade: 34-0-0.
 - Soluble, readily available source of N.
 - Dry fertilizer product.
 - 50% of the N is present as ammonium (NH_4^+).
 - 50% of the N is present as nitrate (NO_3^-), which is the form susceptible to leaching and denitrification losses.
 - NH_3 volatilization is **not** an issue unless applied to high pH soils (i.e., >7.5).
 - Strong oxidizer that can react violently with other incompatible materials.
 - Should be stored properly to prevent risk of explosion.
 - Natural affinity to absorb moisture limits bulk storage during summer.
-

Ammonium sulfate

Ammonium sulfate [$(\text{NH}_4)_2\text{SO}_4$]:

- Fertilizer grade: 21-0-0-24S.
 - Contains 24% sulfur.
 - Soluble, readily available source of N and S.
 - 21-0-0 is dry fertilizer product.
 - NH_3 volatilization is **not** an issue unless applied to high pH soils (i.e., >7.5).
 - Also marketed in a liquid form as 8-0-0-9S.
 - Density of 8-0-0-9 is 10.14 lbs/gal @60°F; salting out temperature is 15°F.
-

Non-pressure nitrogen solutions

Non-pressure nitrogen solutions:

- Fertilizer grade: ranges from 28-0-0 to 32-0-0.
 - Soluble, readily available source of N.
 - Liquid fertilizer product that does not require pressure for storage.
 - Usually referred to as UAN (urea and ammonium nitrate).
 - Works well as herbicide carrier.
 - Prepared by dissolving urea and ammonium nitrate in water.
 - NH_3 volatilization is an issue for the urea portion of this fertilizer.
 - Density and salting out:
 - density of 28-0-0 is 10.65 lbs/gal @60°F; salting out temperature is 1°F.
 - density of 30-0-0 is 10.84 lbs/gal @60°F; salting out temperature is 14°F.
 - density of 32-0-0 is 11.06 lbs/gal @60°F; salting out temperature is 28°F.
-

Aqua ammonia	<p>Aqua ammonia (NH₄OH):</p> <ul style="list-style-type: none"> • Fertilizer grade: 20-0-0 (most common). • Density of 20-0-0 is 7.60 lbs/gal at 60°F. • Produced by dissolving NH₃ gas in water. • Liquid product that must be kept under pressure to prevent free NH₃ losses. • Must be injected into the soil to prevent NH₃ losses.
Anhydrous ammonia	<p>Anhydrous ammonia (NH₃):</p> <ul style="list-style-type: none"> • Fertilizer grade: 82-0-0. • Fertilizer with the highest analysis of N. • Stored as a liquid under pressure. • Injected into soil as a gas. • Density of 82-0-0 is 5.15 lbs/gal at 60°F. • Losses during application can occur if not applied properly. Losses are more prevalent when soils are too dry or too wet during application. • Use extreme caution during handling. Accidents can cause severe burning of skin, lungs, and eyes.
Ammonium thiosulfate	<p>Ammonium thiosulfate [(NH₄)₂S₂O₃]:</p> <ul style="list-style-type: none"> • Fertilizer grade: 12-0-0-26S. • Density of 12-0-0-26S is 11.1 lbs/gal at 60°F; salting out temperature is 23°F. • Readily available source of N and S. • Liquid fertilizer that does not require pressure for storage. • Can inhibit germination if placed too close to germinating seeds.
Sulfur-coated urea	<p>Sulfur-coated urea:</p> <ul style="list-style-type: none"> • Nitrogen content usually ranges from 30 to 40%. • Slow release form of N. • Urea fertilizer granule is coated with elemental S. • N release is dependent on breakdown of S coating.
Urea-formaldehydes	<p>Urea-formaldehydes (ureaforms and methylene ureas):</p> <ul style="list-style-type: none"> • Nitrogen content usually about 35 to 40%. • Slow release form of N. • Products are a mixture of urea and formaldehyde. • N release is primarily driven by microbial decomposition. • Environmental conditions influence N release by impacting microbial activity. • Ureaforms usually contain more than 60% of N as insoluble, because they contain relatively long chained molecules, while methylene ureas usually

contain 25 to 60% of N as insoluble, and contain relatively medium-chained-length molecules.

IBDU

Isobutylidene diurea (IBDU):

- Nitrogen content usually at least 30%.
 - Slow release form of N.
 - Products are a mixture of urea and isobutyraldehyde.
 - Nitrogen release is primarily driven by hydrolysis, which is accelerated by low soil pH and high temperatures.
-

Polymer-coated urea

Polymer-coated urea:

- Nitrogen content varies with the product.
 - Slow release form of N.
 - Release rate of N depends on the product and is influenced mainly by temperature controlled breakdown of the polymer coating.
 - Release rate of N is more precise than most slow-release products.
 - Often more expensive than other forms of N.
-

Phosphorus fertilizers

Introduction

The basic ingredient for producing phosphorus (P) fertilizers is rock phosphate. Most rock phosphate comes from the mineral apatite, a calcium phosphate mineral that is mined out of the ground. The primary areas in the United States where rock phosphate is mined are in Florida, North Carolina, and several western states.

Most conventional P fertilizers are made by reacting rock phosphate with sulfuric acid to produce phosphoric acid. The phosphoric acid is then further processed to create many of the more common P fertilizers. The following section lists common P fertilizers and describes some of the key characteristics of each product.

Diammonium phosphate

Diammonium phosphate $[(\text{NH}_4)_2\text{HPO}_4]$:

- Fertilizer grade: 18-46-0.
- Soluble, readily available source of P and N.
- Dry fertilizer product.
- Initial soil reaction can produce free NH_3 , which can cause seedling injury if too much fertilizer is placed near the seed.
- Acid-forming fertilizer.

Mono-ammonium phosphate

Monoammonium phosphate ($\text{NH}_4\text{H}_2\text{PO}_4$):

- Fertilizer grade: 11-52-0.
 - Soluble, readily available source of P and N.
 - Dry fertilizer product.
 - Acid-forming fertilizer.
-

Ammonium polyphosphate

Ammonium polyphosphate [$(\text{NH}_4)_{n+2}\text{P}_n\text{O}_{3n+1}$]:

- Fertilizer grade: 10-34-0 or 11-37-0.
 - Soluble, readily available source of P and N.
 - Liquid fertilizer product.
 - Popular source for starter fertilizers.
 - Good fertilizer source for mixing and applying with micronutrients.
 - Density of 10-34-0 is 11.65 lbs/gal at 60°F.
 - Density of 11-37-0 is 11.9 lbs/gal at 60°F.
-

Concentrated superphosphate

Concentrated superphosphate [$\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$]:

- Fertilizer grade: 0-46-0.
 - Soluble, readily available source of P.
 - Dry fertilizer product.
 - Also called triple or treble superphosphate.
-

Potassium fertilizers

Potassium chloride

Potassium chloride (KCl):

- Most abundantly used form of potassium fertilizer.
 - Contains 60-63% K_2O .
 - Often referred to as *Muriate of Potash*.
 - Water soluble source of K.
-

Potassium sulfate

Potassium sulfate (K_2SO_4):

- Contains 50-53% K_2O , 18% S, and no more than 2.5% Cl.
 - Major use is for chloride sensitive crops.
-

Potassium-magnesium sulfate

Potassium-magnesium sulfate ($\text{K}_2\text{SO}_4 \cdot 2\text{MgSO}_4$):

- Contains about 22% K_2O , 11% Mg, 22% S, and no more than 2.5% Cl.
- Along with the K, this product is a good source of Mg and S.
- Often referred to as *Sul-Po-Mag* or *K-Mag*.
- Water soluble source of nutrients.

Potassium nitrate	<p>Potassium nitrate (KNO_3):</p> <ul style="list-style-type: none"> • Contains about 44% K_2O and 13% N. • All N is in the nitrate (NO_3^-) form.
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Sulfur, calcium, and magnesium fertilizers

Sulfur fertilizers	<p>Sulfur is sometimes applied when other fertilizer sources are applied. For example, when ammonium sulfate is applied to supply N, plant-available S is also applied. Sulfur is taken up by plants as the sulfate ion (SO_4^{2-}), so most fertilizers that are applied in the sulfate form will be immediately available for root uptake by plants. Gypsum (CaSO_4) is less water soluble than the other sulfate fertilizers, but it can be an effective and efficient source of S, as well as Ca.</p>
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Sulfur that is applied in a form other than sulfate, such as elemental S, must be oxidized by S-oxidizing bacteria in the soil before the S can be taken up by plants. The oxidation of elemental S to sulfate creates acidity, so elemental S can be used as an amendment to reduce soil pH. Elemental S is quite insoluble, so it will take several weeks to reduce soil pH. Factors that will influence the rate of oxidation of elemental S include: temperature, moisture, aeration, and particle size of the fertilizer granules.

Common types of S, Ca, and Mg fertilizers are shown in Table 8.1.

Calcium fertilizers	<p>Calcium is a nutrient that is present in soils in relatively large amounts. Most soils that are deficient in Ca are acidic, so a good liming program will usually provide adequate Ca to meet most plant needs. Gypsum (CaSO_4) can be a good source of Ca in the unusual situation that Ca is needed but lime is not needed to increase soil pH.</p>
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Magnesium fertilizers	<p>The most common fertilizer source of Mg is dolomitic limestone. When a soil test shows that lime is needed to raise the soil pH and soil Mg concentrations are low to marginal, apply dolomitic limestone to raise soil pH and add Mg to the soil. Limestone has a low solubility and breaks down slowly in soils; therefore, if a quick response to Mg is needed, a more soluble source of Mg fertilizer should be considered (e.g., Epsom salts).</p>
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Table 8.1. Sulfur, Ca, and Mg fertilizer materials.

Element	Name of Material	Chemical Composition	% of Element	CCE*
S	Elemental sulfur	S	100.0	none
S	Ammonium bisulfate	NH ₄ HSO ₄	17.0	none
S	Ammonium polysulfide	(NH ₄) ₂ S _x	40-50	none
S	Aluminum sulfate	Al ₂ (SO ₄) ₃	14.0	none
S	Ammonium sulfate	(NH ₄) ₂ SO ₄	24.2	none
S	Ammonium thiosulfate	(NH ₄) ₂ S ₂ O ₃ •5H ₂ O	26.0	none
S	Gypsum	CaSO ₄	18.6	none
S	K-Mag	K ₂ SO ₄ •2MgSO ₄	22.0	none
S	Potassium sulfate	K ₂ SO ₄	18.0	none
S	Magnesium sulfate	MgSO ₄	13.0	none
Ca	Calcitic limestone	CaCO ₃	32.0	85-100
Ca	Dolomitic limestone	CaMg(CO ₃) ₂	22.0	95-108
Ca	Hydrated lime	Ca(OH) ₂	45.0	120-135
Ca	Calcium oxide	CaO	55.0	150-175
Ca	Gypsum	CaSO ₄	22.3	none
Ca	Calcium nitrate	Ca(NO ₃) ₂	19.4	none
Ca	Basic slag	-----	29.0	50-70
Mg	Dolomitic limestone	CaMg(CO ₃) ₂	3-12	95-108
Mg	Epsom salts	MgSO ₄ •7H ₂ O	9.6	none
Mg	Kiserite	MgSO ₄ •H ₂ O	18.3	none
Mg	K-Mag	K ₂ SO ₄ •2MgSO ₄	11.0	none
Mg	Magnesium nitrate	Mg(NO ₃) ₂	19.0	none
Mg	Magnesia	MgO	55-60	none
Mg	Basic slag	-----	3	none

*CCE (*calcium carbonate equivalent*) = Relative neutralizing value, assuming pure calcium carbonate at 100%.

Micronutrient fertilizers

Using micronutrient fertilizers

There are many different fertilizers that are marketed as micronutrients. Usually, micronutrients are mixed with fertilizers containing N, P, and/or K. Because there are so many brands of micronutrients, it is important to read the label to determine the source of the micronutrient in the fertilizer.

The three primary classes of micronutrient sources are:

- inorganic
- synthetic chelates
- natural organic complexes

Because micronutrients are needed in such small amounts, the best method to correct a micronutrient deficiency is usually by application of the micronutrient through foliar fertilization. It is important to remember that there is a strong relationship between micronutrient availability and soil pH; therefore, micronutrient availability can be maximized by keeping the soil pH in the correct range.

Some common types of micronutrient fertilizers are shown in Table 8.2.

Table 8.2. Micronutrient fertilizer materials.

Element	Name of Material	% Element in Material
B	Borax	11.3
B	Borate 46	14.0
B	Borate 65	20.0
B	Boric acid	17.0
B	Solubor	20.0
B	Boron frits	2.0-6.0
Cu	Copper sulfate	22.5
Cu	Copper frits	variable
Cu	Copper chelates	variable
Cu	Other organics	variable
Fe	Iron sulfates	19-23
Fe	Iron oxides	69-73
Fe	Iron ammonium sulfate	14.0
Fe	Iron frits	variable
Fe	Iron chelates	5-14
Fe	Other organics	5-10
Mn	Manganese sulfates	26-28
Mn	Manganese oxides	41-68
Mn	Manganese chelates	12
Mn	Manganese chloride	17
Mn	Manganese frits	10-25
Zn	Zinc sulfates	23-35
Zn	Zinc oxides	78
Zn	Zinc carbonate	52
Zn	Zinc frits	variable
Zn	Zinc phosphate	51
Zn	Zinc chelates	9-14
Zn	Other organics	5-10
Mo	Sodium molybdate	39-41
Mo	Molybdic acid	47.5

Applying fertilizers

Solubility of fertilizers: liquid vs. dry

It is sometimes assumed that nutrients will be more available to plants if fertilizer is applied in a liquid form than if it is applied in a dry form. Research has shown, however, that there is generally no measurable difference in crop/plant response between a dry and a liquid fertilizer, as long as the two fertilizers are supplying the same amount of soluble nutrient.

For example, research has shown ammonium nitrate or urea (both dry fertilizers) will provide the same crop response as UAN (urea ammonium nitrate) solutions as long as the products are compared at the same rate of N. This should not be surprising considering the amount of water that is present in soils. The surface four inches of a silt loam soil at field capacity will normally contain more than 30,000 gallons of water. Therefore, if a dry fertilizer that is nearly 100% water soluble is applied to this soil, the nutrients in the fertilizer will quickly be dissolved in this very large amount of water.

A more important issue to consider when comparing fertilizer products is the **water solubility** of the product. If two products are being compared and one product has much greater water solubility than the other product, it would be expected that the product with the greater water solubility would provide a more rapid crop/plant response. Most common N, P, and K products are usually 90 to 100% water soluble, so little difference in response would be expected among these products, regardless of whether the products are in a liquid or dry form.

When evaluating micronutrient fertilizers, the solubility of products should be evaluated carefully because there can be a great deal of variation in the solubility of micronutrient fertilizers. If a fertilizer with low water solubility is applied to a soil, it may take several months, or even years, for the nutrient to dissolve and become available to plants.

When making decisions on the best fertilizer material to apply, the following questions should be considered:

- What is the solubility of the product?
 - Based on the available equipment, does a dry or liquid product best fit the operation?
 - What products are available from local fertilizer dealers?
 - What is the cost of those materials that are available?
-

Fertilizer placement and application methods

There are many methods that can be used for applying fertilizers. It is important to understand the relative merits of each before deciding the most cost effective and efficient method for application. For some nutrients and situations, multiple methods can be equally effective when applying fertilizers.

- One common method of application is *broadcast applications*, which simply means that the fertilizer (either dry or liquid) is spread uniformly over the surface of the soil. This method of application is generally preferred for plants that are actively growing over most (or all) of the soil surface, such as turfgrasses, pastures, alfalfa, clovers, winter wheat, and winter barley. For certain situations where nutrients (e.g., P) can be fixed or tied-up by soils, broadcast applications can be an inefficient method of application because there is much greater soil to fertilizer contact resulting in more fixation or tie-up of the nutrient.
- *Band application* is another common method of applying fertilizers. Using this method, fertilizer is applied in a concentrated band either on the soil surface or below the soil surface. One common band application method is banding starter fertilizer near the seed to supply available nutrients as the seed germinates and the plant begins to grow. For row crops, banding is generally the most efficient method for applying micronutrient fertilizers.

Banding has been shown to be the most efficient method of applying P to row crops on soils that are low or deficient in P. On soils with low available P, it has been shown that only 50% as much band-applied fertilizer is required to get the same crop response as fertilizer applied broadcast. If P is simply being applied to maintain soil test levels and a direct crop response is not expected, little difference should be expected between broadcast or banded applications.

Another common form of banding is the application of sidedress N on corn where urea ammonium nitrate (UAN) fertilizers are applied in a band that is either injected into the soil or dribbled on the soil surface, or where anhydrous NH_3 is injected. Any time that anhydrous NH_3 is applied as a fertilizer it must be injected into the soil to prevent loss of the gaseous NH_3 . The UAN fertilizers are banded when sidedressed because UAN will cause severe burning of the plant leaves if applied directly to the leaves, and because broadcast applications of urea fertilizer have a greater risk of loss through NH_3 volatilization than banded applications.

- *Foliar application* of fertilizers is an efficient method of micronutrient application. If a visual micronutrient deficiency is observed, micronutrient fertilizers should be foliar applied as soon as possible. Typically, the greater the degree of the deficiency, the less likely it is that the deficiency can be

completely corrected with foliar fertilization. If a micronutrient deficiency occurs nearly every year in the same location, it may be cost-effective to either apply a band application of micronutrient at planting or apply a preventative foliar application of fertilizer before deficiency symptoms appear. Research has shown that foliar applications of macronutrients are generally not cost effective because plants' requirements for macronutrients are greater than the amount that can be taken up through the plant leaves.

- *Fertigation* is the application of fertilizers by injecting fertilizer into irrigation water. The most common use of fertigation is in applying N to crops that require significant quantities of N (e.g., corn). It is also possible to apply micronutrient fertilizers through fertigation. Applying N fertilizers through fertigation can be one of the most efficient methods of N application because this method applies a small amount of N to an actively growing crop. Because the crop is actively growing and because relatively small amounts of N are applied (i.e., 20 to 30 lb N/acre), the loss potential of N through leaching or denitrification is minimized. Efficient application of fertilizers through fertigation, however, assumes that the irrigation system is uniformly applying water and is not applying water at rates greater than needed by the growing crop.

Timing of application

Understanding crop nutrient-use patterns and nutrient/soil interactions are important for optimizing fertilizer timing. If soils are low in P or K and have a tendency to fix these nutrients, it is important to apply these nutrients as close to planting as possible to minimize fixation. If fixation is of no concern, timing of application for P and K is generally not that important.

Timing of application can be critical for optimal efficiency of N fertilizers. Soils that are prone to leaching (i.e., coarse-textured sandy soils) or denitrification should receive applications of N just prior to rapid N uptake by the plant for optimal efficiency. For example, corn usually begins rapid uptake of N when it is 12 to 18 inches tall. Applying N as closely as possible to the time of rapid uptake will minimize the risk of N loss to the environment and maximize nutrient-use efficiency by the corn crop.

Calculating fertilizer rates

- **Calculating how much N, P, or K is in a particular fertilizer:**

A fertilizer label identifies the percent by weight of N, P₂O₅, and K₂O in the fertilizer.

– Example: 60 pounds of a 21-5-7 fertilizer would contain 13.2 pounds of N (60 X 0.21), 3 pounds of P₂O₅ (60 X 0.05), and 4.2 pounds of K₂O (4.2 X 0.07).

- **Calculating how much fertilizer to apply for a specific amount of nutrient:**

The basic formula for calculating how much fertilizer to apply to a given area for a specific amount of nutrient is the following:

$$\text{Amount of fertilizer} = (\text{Amount of nutrient needed} \div \text{Percent nutrient in the fertilizer}).$$

– Example 1:

How much 34-0-0 is needed to apply 30 pounds of N?

It would take 88 pounds (30 ÷ 0.34) of 34-0-0 to apply 30 pounds of N.

– Example 2:

If 15-8-10 was used to apply 45 pounds of N, how much P₂O₅ and K₂O would be applied with this application?

It would take 300 pounds (45 ÷ 0.15) of 15-8-10 to apply 45 pounds of N. Therefore, a 300 pound application of 15-8-10 would supply 24 pounds of P₂O₅ (300 X 0.08) and 30 pounds of K₂O (300 X 0.10).

- **Calculating rates of liquid fertilizers:**

When doing fertilizer calculations with liquid fertilizers, the calculations are similar but the density of the liquid fertilizer must be known before doing any calculations.

– Example: If a jug contains 2 gallons of a 9-18-6 liquid fertilizer that weighs 11.1 pounds per gallon, how much N, P₂O₅, and K₂O would be in this jug of fertilizer?

First, calculate how much fertilizer is present in the 2 gallons. There would be 22.2 pounds of fertilizer (11.1 lb/gal X 2 gal). So, there would be 2 pounds of N (22.2 X 0.09), 4 pounds of P₂O₅ (22.2 X 0.18), and 1.3 pounds of K₂O (22.2 X 0.06) in this 2 gallon container of fertilizer.

• **Calculating the amount of fertilizer needed for a specific area of land:**

– Pounds per acre:

For example, how much urea (46-0-0) is needed to apply 135 pounds of N to 30 acres of land (1 acre = 43,560 square feet)?

Begin by calculating how much urea is needed to provide 135 pounds of N per acre. This would be 293.5 pounds ($135 \div 0.46$). So, the total urea needed for 30 acres would be 8,804 pounds (293.5×30) or 4.4 tons (there are 2,000 pounds in a ton).

– Pounds per 1000 square feet:

For turfgrasses or horticultural crops, fertilizer is often applied in pounds of nutrient per 1000 square feet. For example, how much ammonium sulfate (21-0-0) is needed to supply 1 lb N per 1000 square feet to a lawn that is 7,500 square feet?

It would take 4.76 pounds of ammonium sulfate to supply 1 lb N ($1 \div 0.46$). Therefore, it would take 35.7 pounds ($(7,500 \div 1000) \times 4.76$) of ammonium sulfate for this lawn.

**Calculating
fertilizer costs**

Bulk fertilizer is often sold by the ton; therefore, it is important to know how to convert the cost per ton to the cost per unit of a specific nutrient so that price comparisons can be made between various fertilizer choices.

– Example 1:

Urea (46-0-0) is currently selling for \$340 per ton, ammonium sulfate (21-0-0) is selling for \$240 per ton, and UAN (30-0-0) is selling for \$204 per ton. What is the price of each of these fertilizers when priced per unit of N?

There are 920 pounds (2000×0.46) of N in a ton of urea, 420 pounds (2000×0.21) of N in a ton of ammonium sulfate, and 600 pounds (2000×0.3) of N in a ton of this UAN. This means that the cost per pound of N is \$0.37 for urea ($\$340 \div 920$), \$0.57 for ammonium sulfate ($\$240 \div 420$), and \$0.34 for UAN ($\$204 \div 600$).

– Example 2:

Diammonium phosphate (18-46-0) is currently selling for \$280 per ton. What is the cost per pound of N and per pound of P_2O_5 ?

A ton of 18-46-0 contains 360 pounds of N (2000×0.18) and 920 pounds of P_2O_5 (2000×0.46); therefore, the cost per pound of N is \$0.78 ($\$280 \div 360$), while the cost per pound of P_2O_5 is \$0.30 ($\$280 \div 920$). This

example demonstrates that if N is the only nutrient needed, diammonium phosphate would be an expensive fertilizer choice. However, if P and N are both needed by the crop, then diammonium phosphate would be an excellent fertilizer choice because the P and some of the N required by the crop would be supplied by the same fertilizer. Diammonium phosphate is typically used to meet the P need rather than the N need of a crop. The N supplied by diammonium phosphate application is then deducted from the crop's N requirement.

– Example 3:

If liquid ammonium sulfate (8-0-0-9) is selling for \$90 per ton and UAN (30-0-0) is selling for \$204 per ton, what is the cost per gallon of each of these products knowing that 8-0-0-9 weighs 10.14 pounds per gallon and 30-0-0 weighs 10.84 pounds per gallon?

One ton of 8-0-0-9 would consist of 197.2 gallons ($2000 \div 10.14$), while a ton of 30-0-0 would consist of 184.5 gallons ($2000 \div 10.84$); so, one gallon of 8-0-0-9 ($\$90 \div 197.2$) would cost \$0.46 and one gallon of 30-0-0 would cost \$1.11 ($\$204 \div 184.5$). The cost per pound of N for each of these products would be \$0.57 [$0.46 \div (10.14 \text{ lb/gal} \times 0.08)$] for the 8-0-0-9 and \$0.34 [$\$1.11 \div (10.84 \text{ lb/gal} \times 0.3)$] for the 30-0-0.

Liming materials

Introduction

Maintaining soil pH in the proper range is important to the optimal growth of plants. If soil pH drops below about 5.5, aluminum begins to become soluble in soils. The amount of soluble aluminum increases dramatically as the soil pH continues to drop. Many plants do not grow well when large amounts of aluminum are present in the soil solution, so lime must be added to these soils to prevent soil pH from getting too low. An understanding of liming materials is important when deciding the type of lime to use.

Limestone is a naturally occurring mineral resulting from the deposition and compression of the skeletal remains of marine organisms (e.g., coral, shellfish, etc.), and it contains high amounts of calcium and magnesium carbonates. Because limestone is a naturally occurring mineral, there are varying degrees of purity and chemical composition. Pure calcium carbonate (CaCO_3) has been assigned an arbitrary index of 100 to define its neutralizing value. All liming materials are then compared to pure CaCO_3 and rated on their neutralizing ability relative to pure CaCO_3 . This rating, referred to as the *calcium carbonate equivalency* (CCE), is assigned to all liming materials. A CCE greater than 100 indicates that the material is capable of neutralizing more acidity on a weight basis than pure CaCO_3 , and vice versa.

The property that distinguishes lime from other calcium or magnesium bearing materials is that lime contains calcium and/or magnesium in forms that, when dissolved, will neutralize acidity. Lime components which reduce acidity are the carbonates contained in limestone and marl, the oxides contained in burned lime, and the hydroxides found in slaked lime. Not all materials that contain calcium and magnesium can be used for liming purposes. For example, calcium and magnesium sulfates and chlorides will supply calcium and magnesium, but will not reduce soil acidity.

The carbonates, oxides, and hydroxides of calcium and magnesium are only sparingly soluble in water. These materials require soil acidity in order to react, and the reaction is fairly slow due to their low solubility. Burned lime and hydrated lime are highly reactive and react quickly with soil acidity. To obtain the greatest benefit from these materials, especially at higher rates of application, they should be thoroughly mixed with the soil by disking and/or plowing.

Calcitic and dolomitic lime

Calcitic and dolomitic limes are made by grinding or crushing mined limestone rock to a certain fineness. The degree of fineness must be specified when sold. In order to be useful as an agricultural liming material, crushed limestone must react with soil acids within a reasonable length of time. The rate of reaction or dissolution of crushed limestone is largely determined by its fineness or mesh size.

Calcitic lime reacts somewhat faster than dolomitic lime of the same mesh size. Dolomitic lime contains both magnesium and calcium, whereas calcitic lime contains mainly calcium. The CCE of these limes is similar (Table 8.1).

Acid soils that are deficient in magnesium should be treated with dolomitic limestone. Calcitic lime should be used on acid soils where the ratio of soil test calcium to magnesium is less than 1.4. Either dolomitic or calcitic lime may be used in all other situations.

Calcium oxide or burned lime

Calcium oxide, or burned lime, is made by roasting crushed limestone in an oven or furnace. This process changes the chemical form of Ca from a carbonate to an oxide. Burned lime is also known as *unslaked* or *quick lime*. The CCE of burned lime depends on the purity of the limestone from which it is made but usually ranges from 150 to 175. No other liming material has such a high neutralization value. Approximately 1,140 pounds of burned lime with a CCE of 175 is equivalent to 2,000 pounds of calcitic lime with a CCE of 100.

Burned lime is usually sold in bags because of its powdery nature, unpleasant

handling properties, and reactivity with moisture in the air. This liming material neutralizes soil acids rapidly but is somewhat difficult to mix with the soil. Thorough mixing at the time of application is necessary due to a tendency for burned lime to absorb moisture, resulting in the formation of lime granules or aggregates.

Hydrated lime Hydrated lime is calcium hydroxide but is usually called *slaked* or *builders' lime*. This type of lime is made by reacting burned lime with water and drying the resulting calcium hydroxide. Hydrated lime is similar to burned lime in that it is powdery, reacts quickly, and is unpleasant to handle. The CCE ranges from 110 to 135 depending on the purity of the burned lime.

Marl Marls are found in beds, mixed with earthen materials, in the form of calcium carbonate. These calcium deposits are often found in the Eastern or Coastal Plain Region of Virginia, limestone valleys in the Appalachian Region, and other Atlantic Coast states. Their usefulness as a liming material depends on the CCE, which usually ranges from 70 to 90, and the cost of processing into usable material. Marls are usually low in magnesium, and their reaction within the soil is similar to calcitic lime.

Slags Slag is a by-product of the steel industry and consists primarily of calcium silicate minerals. Slags can make a good liming material, but most slags have a lower CCE than calcitic lime, requiring the use of a higher rate.

One important note about slags is that they can sometimes contain significant quantities of heavy metals. Thus, it is important to know the composition of the slag before using the material as a soil amendment.

Ground oyster shells Oyster shells and other sea shells are composed primarily of calcium carbonate. These materials can work well as liming materials. As with any lime, the fineness of the material and the CCE will determine the appropriate rate to apply to a soil for proper pH adjustment.

Particle size of liming materials Fineness, or mesh size, of applied lime is the main factor that influences the rate of reaction. All of the lime applied does not need to react with the soil immediately to be of maximum value. The coarser mesh sizes dissolve over a longer period of time and in so doing, tend to maintain soil pH.

A certain amount of lime should be sufficiently fine (pass an 80-mesh sieve) to react rapidly with the soil acidity. Part of the lime should be sufficiently fine (about 40 to 60 mesh) to react within one to two years, and the remainder

of the lime should be large enough (about 20 mesh) to react in a period of two to three years. For a liming material to react in this manner, it must be composed of lime particles of different mesh sizes. Research has shown that limestone that is pulverized to 100 mesh, or finer, will react rapidly with soil acids. On the other hand, 10- to 20-mesh limestone dissolves very slowly and, therefore, is only slightly effective in reducing soil acidity.

Burned and hydrated limes have a much finer mesh than the ground limestones and are therefore quicker acting. All lime particles in these materials are 100 mesh or finer. The quick-acting characteristics of these lime materials can be an advantage in certain situations.

References for additional information

Note: Although these references are not cited specifically in this chapter, information obtained from them was helpful in writing the chapter.

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