Agricultural Extension Service
The University of Tennessee

PB1637

Fertilizers and Their Use

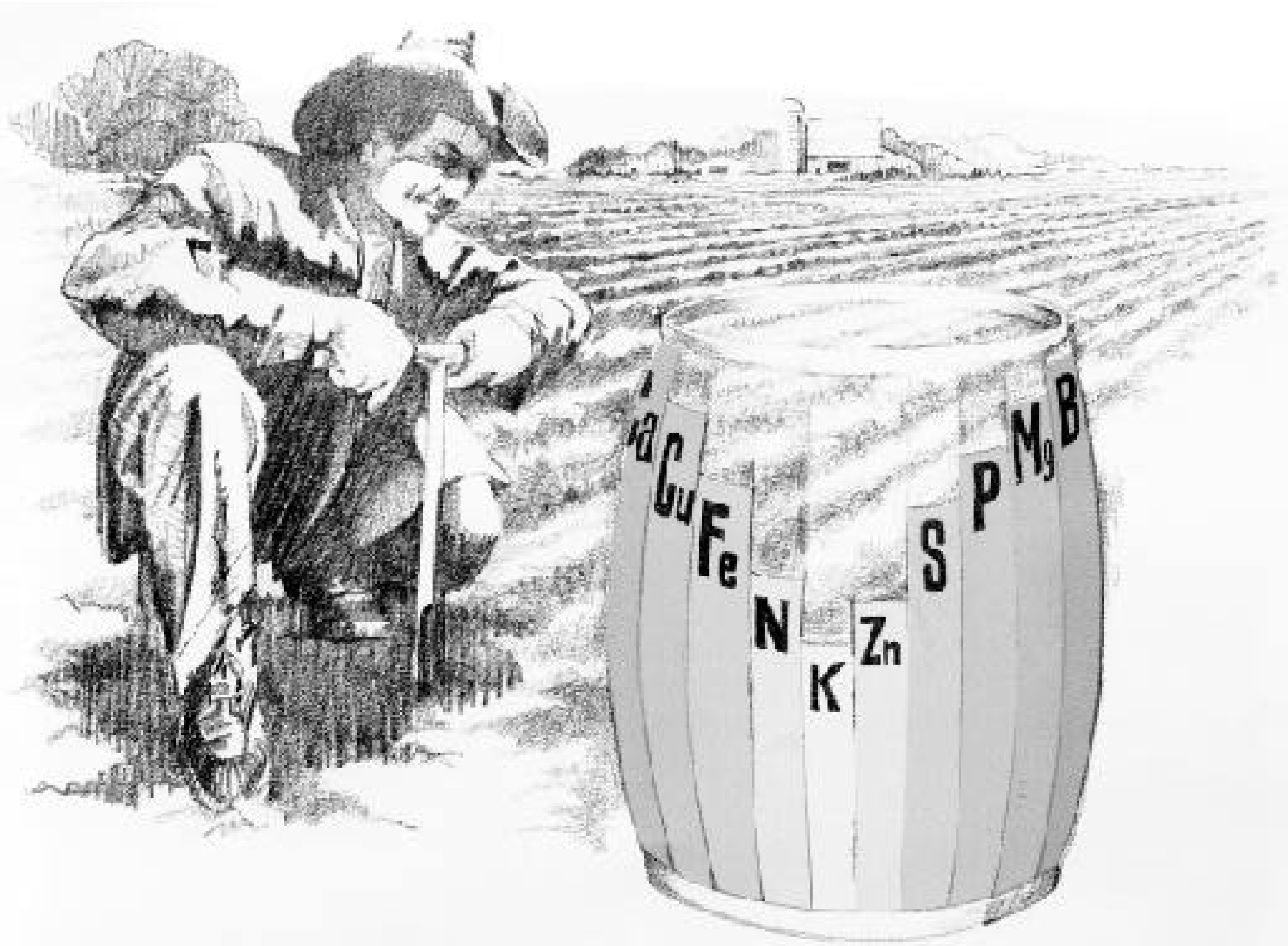


Table of Contents

List of Tables

Fertilizers and Their Use

Hugh Savoy, Associate Professor
Extension Plant and Soil Science

Introduction

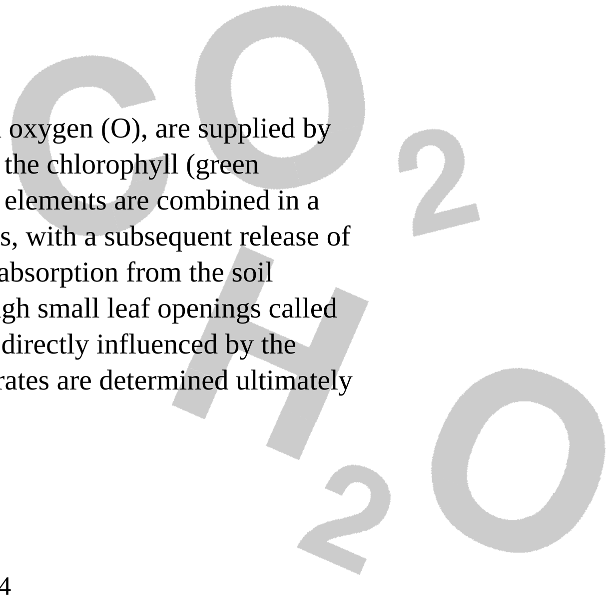
An understanding of soil chemical properties is important because of their effect on nutrient availability to plants. Also, these properties may usually be favorably altered with the use of lime and/or fertilizer materials. Many plants need 18 elements (see Table 1) for normal growth and completion of their life cycle. These elements are called the essential plant nutrients. Soil amendments containing the essential plant nutrients or having the effect of favorably changing the soil chemistry have been developed and used to enhance plant nutrition. These amendments are our lime and fertilizer materials.

With the development of these modern lime and fertilizer materials, as well as equipment for handling and application, amending soil chemical properties became a cheap and easily accomplished task relative to the high returns often achieved. Soil testing developed as a means for answering questions about need for a particular amendment (status of the soil's fertility) and uncertainty about how much to add. The two basic questions answered from the soil testing results of modern laboratories are: (1) Which soil amendments (specific types of fertilizers and/or liming materials) does this soil need? (2) How much of the amendments are needed to get the most return on dollars spent? Our lime and fertilizer materials are developed primarily from finite and non-renewable resources. Therefore, these preceding questions are extremely relevant to our concerns about the efficient and environmentally sound use of such resources.

Other diagnostic techniques, such as plant analysis, may sometimes be useful as a supplement to soil test information or for "troubleshooting" and monitoring applications. The mineral components of the plant (essential plant nutrients) are supplied to the plant by and through the mediums of air, water and soil.

Essential Plant Nutrients

Three elements, carbon (C), hydrogen (H) and oxygen (O), are supplied by air (in the form of carbon dioxide) and water. When the chlorophyll (green pigments) of plants are exposed to light, these three elements are combined in a process called photosynthesis to make carbohydrates, with a subsequent release of oxygen. The water is brought into the plant by root absorption from the soil system. Carbon dioxide (CO_2) enters the plant through small leaf openings called stomata. The rate at which photosynthesis occurs is directly influenced by the water and nutritional status of the plant. Maximum rates are determined ultimately by the genetics of the plant.



Fifteen of the essential nutrients are supplied by the soil system. Of these, nitrogen (N), phosphorus (P) and potassium (K) are referred to as primary or macronutrients. This is because (1) they are required by the plant in large amounts relative to other nutrients (see Table 2) and (2) they are the nutrients most likely to be found limiting plant growth and development in soil systems.

Table 1. Essential plant nutrients and their elemental (chemical) symbol

Nutrients Supplied by Air and Water	Nutrients Supplied by the Soil System		
Non-Mineral	Primary or Macronutrients	Secondary	Micronutrients
Carbon - C	Nitrogen - N	Calcium - Ca	Zinc - Zn
Hydrogen - H	Phosphorus - P	Magnesium - Mg	Chlorine - Cl
Oxygen - O	Potassium - K	Sulfur - S	Boron - B
			Molybdenum - Mo
			Copper - Cu
			Iron - Fe
			Manganese - Mn
			Cobalt - Co
			Nickel - Ni

Calcium (Ca), magnesium (Mg) and sulfur (S) are termed secondary nutrients because they are less likely to be growth-limiting factors in soil systems. Calcium and magnesium are added in liming materials when soil pH is adjusted and sulfur is added continually by rainfall and release from the soil organic matter. It is estimated that some 10 to 20 pounds of sulfur per acre may be deposited annually in precipitation.

Zinc (Zn), chlorine (Cl), boron (B), molybdenum (Mo), copper (Cu), iron (Fe), manganese (Mn), cobalt (Co) and nickel (Ni) are termed micronutrients because (1) they are found in only very small amounts (see Table 2) relative to other plant nutrients in the average plant and (2) they are least likely to be limiting plant growth and development in many soil systems. There is a much finer line between "enough" and "too much" for the micronutrients than for other plant nutrients. Use of micronutrient fertilizer materials should only be undertaken with very clear objectives (i.e., correction of clearly identified Zn deficiencies of corn grown on soils high in pH or P) in mind and with a knowledge of previously successful rates of application. Indiscriminate use of micronutrients is more likely to result in undesirable effects than similar use of other nutrients.

Table 2. Average concentrations of 13 soil-derived (mineral) nutrients in plant dry matter that are sufficient for adequate growth (Epstein, 1965)

Element	mg/kg (ppm)	%	Relative Number of Atoms
Molybdenum	0.1	--	1
Copper	6	--	100
Zinc	20	--	300
Manganese	50	--	1,000
Iron	100	--	2,000
Boron	20	--	2,000
Chlorine	100	--	3,000
Sulfur	--	0.1	30,000
Phosphorus	--	0.2	60,000
Magnesium	--	0.2	80,000
Calcium	--	0.5	125,000
Potassium	--	1.0	250,000
Nitrogen	--	1.5	1,000,000

Functions of the Essential Nutrients in Plants

Table 3 provides a brief description of the various functions of essential plant nutrients within the plant and lists the form(s) of the nutrient that the plant is able to obtain from the soil solution complex. Some nutrients are present in the soil solution complex as positively charged cations and others as negatively charged anions.

Table 3. Functions and available forms of nutrients

Nutrient Element	Functions in Plants	Plant Available From Soil Solution Complex	
		Form(s)	Symbol(s)
Nitrogen	Promotes rapid growth, chlorophyll formation and protein synthesis.	Anion and Cation	NO_3^- NH_4^+
Phosphorus	Stimulates early root growth. Hastens maturity. Stimulates blooming and aids seed formation.	Anion	$H_2PO_4^-$ HPO_4^{--}
Potassium	Increases resistance to drought and disease. Increases stalk and straw strength. Increases quality of grain and seed.	Cation	K^+
Calcium	Improves root formation, stiffness of straw and vigor. Increases resistance to seedling diseases.	Cation	Ca^{++}
Magnesium	Aids chlorophyll formation and phosphorus metabolism. Helps regulate uptake of other nutrients.	Cation	Mg^{++}
Sulfur	Amino acids, vitamins. Imparts dark green color. Stimulates seed production.	Anion	SO_4^{--}
Boron	Aids carbohydrate transport and cell division.	Anion	H_3BO_3 $H_2BO_3^-$ HBO_3^{--} BO_3^{---} $B_4O_7^{--}$
Copper	Enzymes, light reactions.	Cation*	Cu^{++}
Iron	Chlorophyll formation.	Cation*	Fe^{++} Fe^{+++}
Manganese	Oxidation-reduction reactions. Hastens germination and maturation.	Cation*	Mn^{++}
Zinc	Auxins, enzymes.	Cation*	Zn^{++}
Molybdenum	Aids nitrogen fixation and nitrate assimilation.	Anion	MoO_4^{--}
Cobalt	Essential for nitrogen fixation.	Cation	Co^{++}
Nickel	Grain filling, seed viability	Cation	Ni^{++} Ni^{+++}
Chlorine	Water use.	Anion	Cl^-
Oxygen	Component of most plant compounds.	Obtained from air and water.	
Hydrogen	Component of most plant compounds.		
Carbon	Component of most plant compounds.		

* Also available to plants in chelate form (a nutrient form having the essential nutrient linked to an organic compound so that it stays available for plant use within certain ranges of soil pH).

Cations are attracted to and held by the negatively charged surface area of clay and organic matter. Anions move more freely with the soil solution.

Visual Diagnoses of Plant Nutrient Deficiencies

Sometimes the soil chemistry is such that the soil is not able to supply sufficient nutrients to the plant. Toxic conditions such as excessive soil acidity may prevent plant roots from growing (see figure 1) or perhaps nutrients are simply in low supply. When these conditions are severe enough, plants will exhibit nutrient deficiency symptoms. The symptoms expressed by the plant are often used to somewhat subjectively diagnose plant nutrient problems. Some common symptoms shown by plants are:

(1) Chlorosis — A yellowing, either uniform or interveinal, of plant tissue due to a reduction of the chlorophyll formation processes.

(2) Necrosis — The death or dying of plant tissue. It usually begins on the tips and edges of older leaves and also may be caused by drought, herbicides, disease, foliar application of fertilizer or animals marking territorial boundaries.

(3) Rosetting — A cluster of leaves crowded and arising from a crown, resulting from a lack of new terminal growth.

(4) Anthocyanin (pigment) accumulation — This results in the appearance of reddish, purple or brownish coloration. The pigment anthocyanin forms due to sugar accumulation.

(5) Stunting or reduced growth, with either normal or dark green coloring or yellowing.

The symptom location on the plant depends on how well the nutrient moves from older plant tissues to younger developing parts. Nutrients that can be moved readily by the plant (mobile nutrients) to younger developing tissue are nitrogen, phosphorus, potassium and magnesium. Deficiency symptoms for these nutrients are usually first expressed in the older leaves. The entire plant may develop symptoms if the deficiency is severe. Nutrients that are not easily moved by the plant from older, developed plant parts into younger tissue are sulfur, calcium and all of the micronutrients. Deficiency symptoms for immobile nutrients are usually first expressed in the growing points and youngest leaves. The following is a generalized key to commonly expressed nutrient deficiency symptoms.

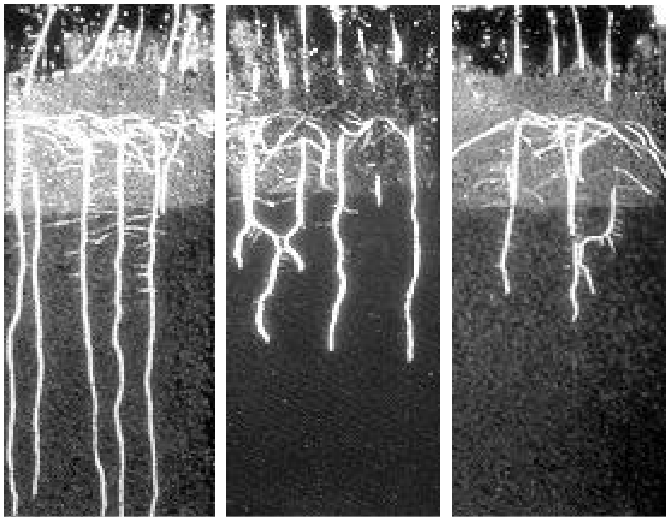
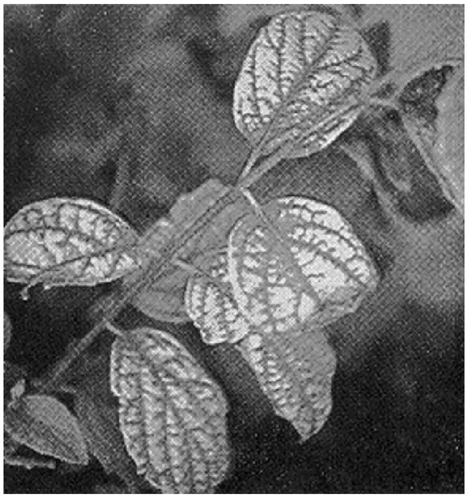

pH 6.5 pH 5.5 pH 5.2

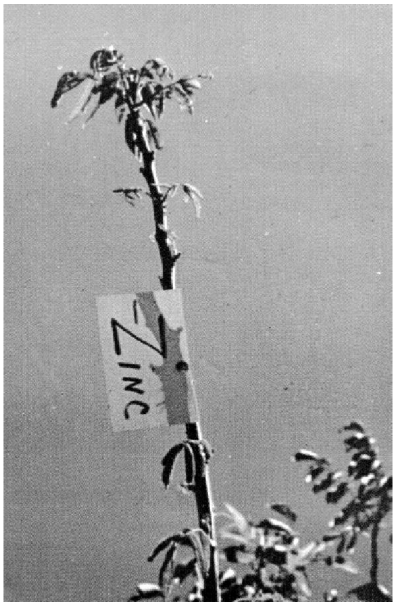
Figure 1. Soil pH effect on plant roots.

(1) Chlorosis



(1) Chlorosis

(2) Necrosis



(3) Rosetting

(4) Anthocyanin
(pigment) accumulation

(5) Stunting or
reduced growth

Generalized Key to Plant-Nutrient Deficiency Symptoms

I. Effects occur mostly on older or lower leaves of plant; effects generalized or localized.

A. Whole plant more or less uniformly affected; may exhibit drying or firing in lower leaves.

1. Plants light green; chlorosis in lower leaves (progresses down the midrib), more or less drying or firing of lower leaves; plants may be stunted or woody; stalks short and slender if element is deficient in later stages of growth ______________________ **NITROGEN**

2. Plants dark green, young leaves appearing abnormally dark green; stems and leaves usually highly pigmented with purplish red, especially near end of shoots; stalks short and slender if element is deficient in later stages of growth. Fruiting often delayed. Vegetative growth less than normal ______________________ **PHOSPHORUS**

B. Effects on plants localized; mottling or chlorosis with or without spots of dead tissue on lower leaves; little or no drying up of lower leaves.

1. Mottled (often prominently) or chlorotic leaves; may redden as with cotton; **sometimes with dead spots**; tips and margins turned or cupped upward; stalks slender ______________________ **MAGNESIUM**

2. Mottled or chlorotic leaves **with large or small spots of dead tissue.** Plants perhaps not particularly stunted; stalks may be slender; leaves, especially the older ones, scorched and dying at tip and outer margins. Leaf margins often crinkled and curled. Corn stalks may be brittle (browning of tissue evident in split joints, especially toward base of plant) with cobs not filled to the ends ______________________ **POTASSIUM**

II. Terminal buds or younger leaves affected; symptoms localized.

A. Terminal bud death common, following appearance of distortions at tips or bases of younger leaves.

1. Young leaves of terminal bud at first typically hooked, finally drying back at tips and margins, so that later growth is characterized by a cut-out appearance at these points; stalk finally dies at terminal bud. Tips of unfolding leaves gelatinize, sticking together when dry as in corn ____ **CALCIUM**

2. Young leaves of terminal bud becoming light green at bases, with final breakdown here, in later growth, leaves become twisted; stalk finally dies back at terminal bud. Sometimes a distinct cupping of young leaves. With fleshy tissues, often internal browning and death ______________ **BORON**

B. Terminal bud commonly remains alive.

1. Young leaves permanently wilted (wither tip effect), without spotting or marked chlorosis; twig or stalk just below tip and seedhead often unable to stand erect in later stages when shortage is acute ____________ **COPPER**

2. Young leaves not wilted; chlorosis is present with or without spots of dead tissue (necrosis).

> **a. Necrosis not commonly present.** Plants not particularly stunted. Leaves pale green, veins often somewhat lighter in color than interveinal area. Often difficult to distinguish from nitrogen deficiency ______________________________ **SULFUR**
>
> **b. Necrosis commonly present, in spots scattered over the leaf,** Interveinal tissue yellowish, veins green ________ **MANGANESE**
>
> **c. Necrosis may be present, often confined to leaf tip or margins,** Interveinal tissue yellowish, veins often green but may become lighter in color later ______________________ **IRON**
>
> **d. Necrosis may be present, generally within interveinal tissue surrounding midrib**, veins remain green, younger leaves yellow ish (striping in grasses) or even white (white bud in corn) ___ **ZINC**

Amending Soil Chemical Properties

Fertilizer Materials

The term "fertilizer material" means a commercial fertilizer containing one or more of the recognized plant nutrients, which is used primarily for its plant nutrient content. Fertilizers are derived from a wide variety of natural and manufactured materials and are sold in solid, liquid and gaseous form (anhydrous ammonia). These materials are designed for use or claimed to have value in promoting plant growth or increasing plant-available nutrient levels in soils.

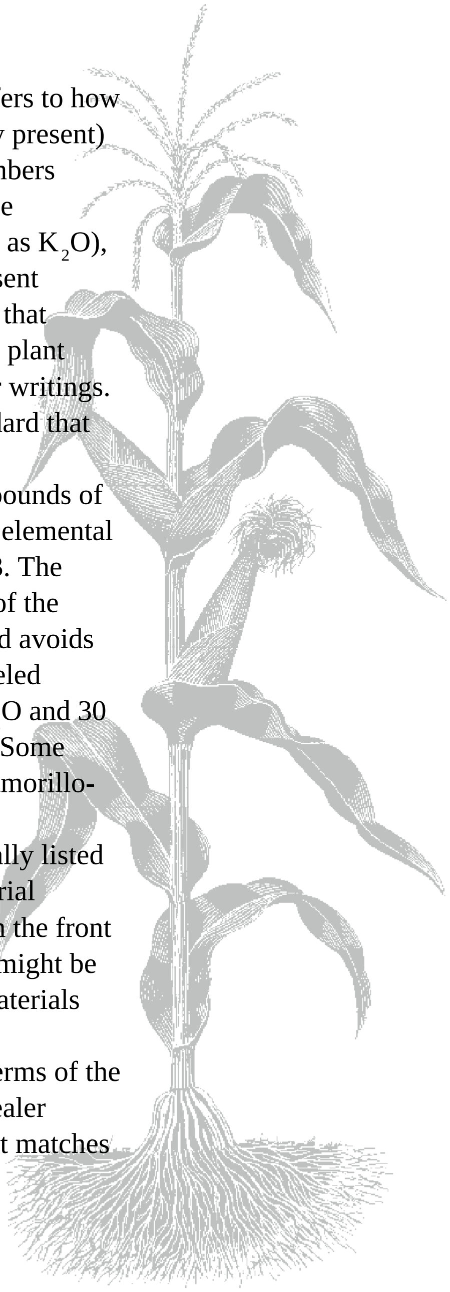
Fertilizer Label

The fertilizer **guaranteed analysis** or **grade**, stated on the bag, refers to how much of an element is in the material (the guaranteed minimum quantity present) based on percentage by weight. All fertilizers are labeled with three numbers which give the percentage by weight of total nitrogen (N), citrate-soluble phosphorus (expressed as P_2O_5) and water-soluble potassium (expressed as K_2O), respectively. Often, to simplify matters, these numbers are said to represent nitrogen, phosphorus and potassium (N, P, K). It should be remembered that actually it is not N-P-K but N-P_2O_5-K_2O. The first chemists who studied plant nutrition expressed phosphorus and potassium as the oxide form in their writings. This practice continued and was eventually adopted as an industry standard that continues to this day.

For example, if we have a 50-pound bag of 10-10-10, there are 5 pounds of N, 5 pounds of P_2O_5 and 5 pounds of K_2O. To convert the P_2O_5 to actual elemental P, multiply it by 0.44; to convert the K_2O to actual K, multiply it by 0.83. The other 35 pounds of the fertilizer material is filler or the carrier material of the fertilizer ore. The filler or carrier helps to evenly spread the fertilizer and avoids burning plants with too much fertilizer. A 50-pound bag of fertilizer labeled 0-20-20 would have 0 pounds of N, 10 pounds of P_2O_5, 10 pounds of K_2O and 30 pounds of filler or carrier material. Various materials are used as fillers. Some common ones are: pelleted biosolids, attapulgite clay, vermiculite, montmorillonite, fuller's earth and diatomaceous earth.

The secondary and micronutrient grade of a fertilizer blend is usually listed on the back of the bag. It is also expressed as a percent of the total material weight. Infrequently, it is expressed as a part of the grade designation on the front of the bag. For example, a 10-10-10 blend containing 15 percent sulfur might be labeled as 10-10-10 +15 S. The type and amount of primary fertilizer materials used in the blend are also usually listed on the back of the fertilizer bag.

Most soil testing laboratories give fertilizer recommendations in terms of the amount of N, P_2O_5, and K_2O needed on a per acre basis. The fertilizer dealer assists the producer in choosing or blending a fertilizer material that best matches this nutrient recommendation in a cost-effective manner.



State laws require that the manufacturer or blender guarantee what is claimed on the label. In some instances, a fertilizer may contain secondary nutrients or micronutrients not listed on the label because the manufacturer or blender does not want to guarantee their exact amounts. For this reason, some fertilizers (especially organic fertilizers) may have a higher total nutrient content than what is listed on the label. Often, the N, P, K and micronutrients tied up in various organic compounds are not claimed by the manufacturer on the label. One method used to indicate the presence of these organic nutrients has been to use the terms W. I. N. (water-insoluble N) and W. S. N. (water-soluble N) on fertilizer labels. Water-soluble N dissolves readily and is usually in a very simple form such as ammoniacal-N or nitrate-N. Nitrogen that will not dissolve readily may exist in other forms in fertilizer. These are usually the organic forms of N (except urea) that must be broken down into simpler forms before the plant can use it. Water-insoluble N is referred to as a slow-release nitrogen source and delivers nitrogen at different rates according to the amount and kind of material in its composition.

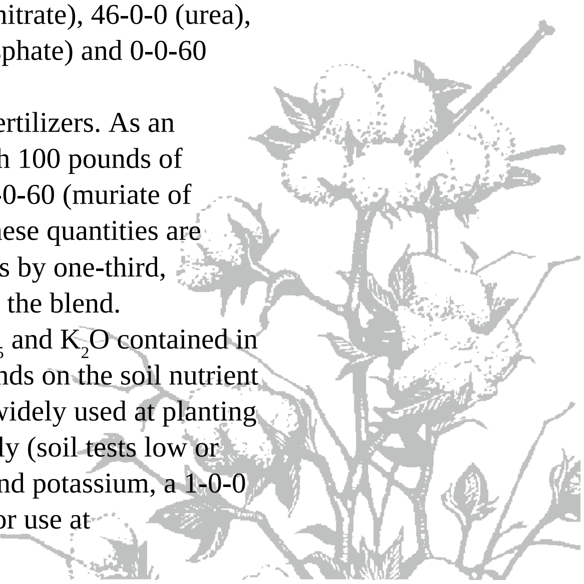
The best fertilizer grade to use depends on the current soil test levels in your field and what nutrients are most needed to ensure that no nutrient will limit production level of the crop to be planted. Sometimes only nitrogen is required, but only a good soil testing program can provide you with that information. Availability of fertilizer materials and costs are also always a consideration in planning your fertility program.

Complete versus Incomplete Fertilizer

A fertilizer is said to be a **complete or mixed fertilizer** when it contains nitrogen, phosphorus and potassium (the primary nutrients). Examples of commonly used complete fertilizers are 6-12-12, 10-10-10, 15-15-15 and 20-10-10. An **incomplete** fertilizer will be missing one or more of the major components. Examples of incomplete fertilizers are: 34-0-0 (ammonium nitrate), 46-0-0 (urea), 18-46-0 (diammonium phosphate), 0-46-0 (triple super phosphate) and 0-0-60 (muriate of potash).

Incomplete fertilizers are blended to make complete fertilizers. As an example, if 100 pounds of 46-0-0 (urea) were combined with 100 pounds of 0-46-0 (concentrated super phosphate) and 100 pounds of 0-0-60 (muriate of potash), a fertilizer grade of 15-15-20 would result. When these quantities are combined, each quantity is diluted by the other two materials by one-third, provided each fertilizer material contributed equal weight to the blend.

The **fertilizer ratio** indicates the proportion of N, P_2O_5 and K_2O contained in the fertilizer. The specific fertilizer ratio you will need depends on the soil nutrient level. For example, a 1-1-1 ratio (10-10-10 or 15-15-15) is widely used at planting time when both phosphorus and potassium are in short supply (soil tests low or medium). When soils test high or very high in phosphorus and potassium, a 1-0-0 ratio (34-0-0 or 46-0-0) may be a more appropriate choice for use at or near planting.



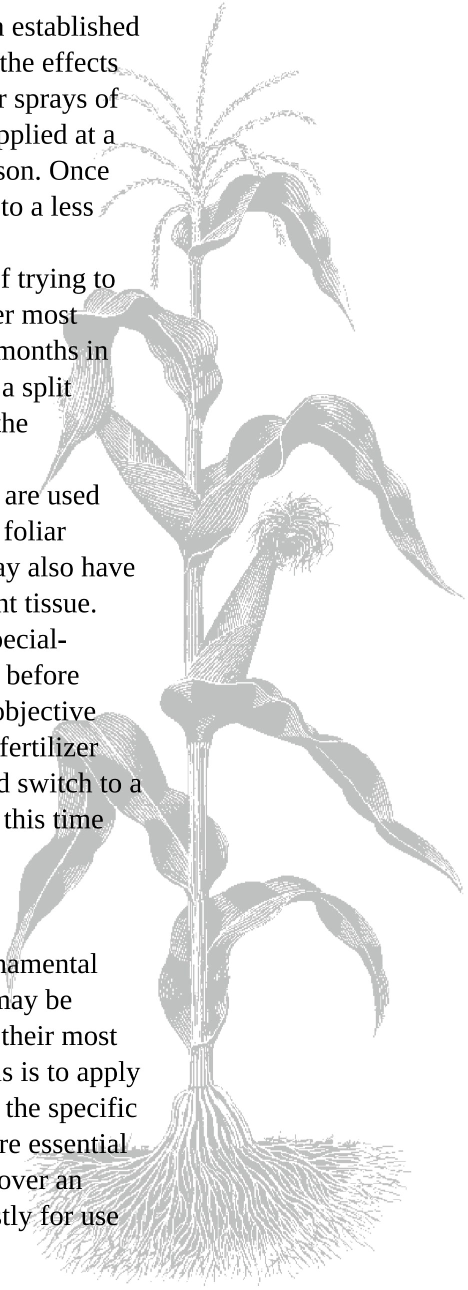
Special Purpose Fertilizers

Special purpose fertilizers are primarily used in the small fruit and nursery industries. When shopping for fertilizer, you will find that some are packaged for very specific uses, such as blueberry food. The blueberry (sometimes called rhododendron or azalea fertilizer) food is one example of these specialty materials and belongs to an old, established group, **the acid-plant foods**. Some of the compounds (ammonium sulfate is usually the acidifying ingredient) used in these fertilizers are chosen because they have an acid reaction and may benefit acid-loving plants when the soil pH is too high. These materials are appropriate for use when small-fruit producers are trying to slowly lower the soil pH in an established blueberry orchard that is showing symptoms of iron deficiency due to the effects of a high soil pH. They are often used in combination with dilute foliar sprays of iron or soil applications of iron chelates. These materials are usually applied at a rate that will meet the nitrogen requirement of the orchard for that season. Once the soil pH is lowered to the desired level, the producer should switch to a less acidifying nitrogen source such as urea or ammonium nitrate.

Ideally, soil pH is adjusted to the correct range well in advance of trying to establish a blueberry orchard. Elemental sulfur is the specialty fertilizer most appropriately used for this purpose. It should be applied at least three months in advance of plant establishment. If the initial soil pH is very high, then a split application of sulfur over a six-month period may be needed to reach the desired range.

In some agronomic cropping systems, special-purpose fertilizers are used when applying nutrients through irrigation systems (fertigation) or for foliar application. These are generally highly water-soluble materials and may also have a relatively low salt index to minimize the potential for burning of plant tissue.

It is difficult to make a blanket statement that a certain type of special-purpose fertilizer is best for some plants. Be sure to perform a soil test before purchasing any special-purpose fertilizer materials to provide a more objective basis for application. Once the objective for using the special purpose fertilizer (i.e., soil pH lowered to correct range) is achieved, the producer should switch to a more appropriate material. Continued use of a specialty fertilizer after this time can result in fertility problems.



Slow-release Fertilizers

Slow-release fertilizers are used primarily in the turf, sod and ornamental nursery industries. Since plants can take up nutrients continuously, it may be beneficial to provide them with a somewhat steady supply throughout their most active periods of growth. Perhaps the most efficient way to achieve this is to apply a slow-release fertilizer designed to release nutrients at rates matching the specific plant nutrient requirements. Slow-release fertilizers contain one or more essential nutrients. These elements are released or made available for plant use over an extended time period. The slow-release materials are generally too costly for use in agronomic cropping systems. Ongoing research efforts explore the potential for use of these materials as in-furrow starter fertilizers because of their relatively low salt index.

Organic Fertilizers

In Tennessee, certification of materials for use as **organic fertilizers** is currently handled by the Tennessee Land Stewardship Association. The word organic applied to fertilizers usually means that the nutrients contained in the product are derived solely from the remains of a once-living organism. If these products are registered with the Tennessee Department of Agriculture as fertilizers, they will have the fertilizer grade stated on the package labels. These labels may or may not include the total nutrient value, but only what is guaranteed.

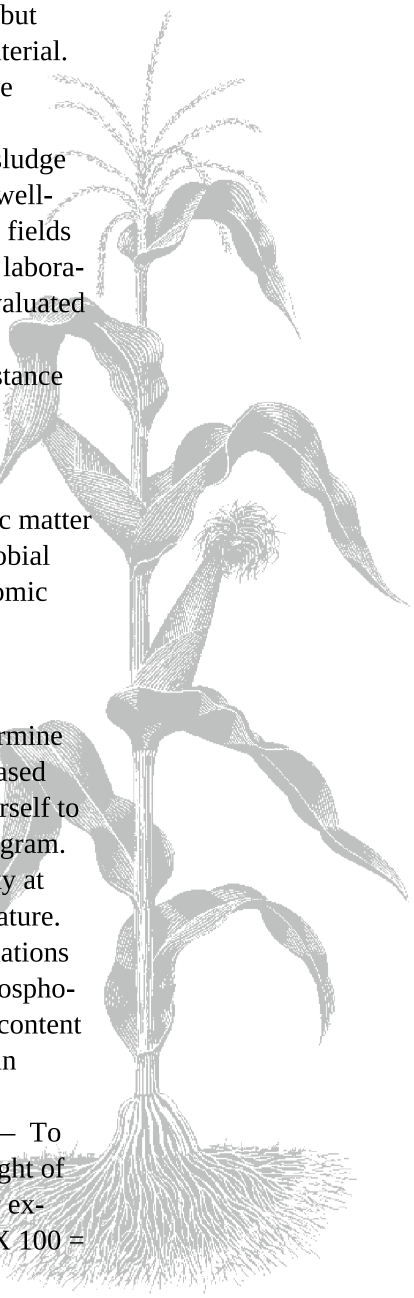
Some organic materials, particularly composted manures and sludges, are often registered and sold as **soil conditioners** instead of fertilizers. Soil conditioners do not have a nutrient guarantee, even though various amounts of plant-available nutrients are usually present. Soil conditioners are materials having properties that may improve the soil's physical condition. Those soil conditioners with substantial nutrient value have much greatest potential for use in a cost-effective manner.

In general, organic fertilizers release nutrients over an extended period of time. They act much like the slow-release fertilizers. Potential drawbacks include the uncertainty of releasing enough of their principal nutrient at the proper time, costs, odors, commercial availability of the products and relatively low nutrient contents. Some products may also attract animals after application. Cotton-seed meal, blood meal, bone meal, fish emulsion and all animal manures are examples of these materials.

Animal manures are probably the most commonly available organic material used for their fertilizer value. Animal manures sometimes can't be certified as an organic fertilizer because of some feed additives that might have been used to enhance animal performance. Animal manure is essentially a complete fertilizer. It varies in nutrient contents, but a fertilizer ratio of 1-1-1 is typical. Animal manures make outstanding soil conditioners. Commonly available manures include cow, swine and poultry. The highest nutrient values are generally found in the fresh manures and decreases as the material ages or is composted. Although fresh manures have higher available nutrient contents, an aged or composted material is sometimes more appropriately used to facilitate spreading, minimize burn potential or the presence of excess salts.

Other organic-like materials (sewage sludge products, urea) are commonly available but usually not approved for use in the certified organic production systems.

Sewage sludge is a recycled product of municipal sewage treatment plants. Forms commonly available are activated, composted and lime-stabilized. Activated sludge has higher concentrations of nutrients than composted and is sometimes registered with the Tennessee Department of Agriculture as a fertilizer material, and sold in a dry, granular form. Composted sludge is primarily used and registered as a soil conditioner. Lime-stabilized sludge may change the soil pH a great deal more than it does soil nutrient content. The liming value varies, but producers should always be aware of this liming effect when using this material. Overuse may result in raising soil pH higher than might be desirable for the current crop.



There is some question about the long-term effects of using sewage sludge products, especially in the vegetable production systems. This resource is well-suited for use in the nursery or sod production industries. Pastures and hay fields may benefit from judicious applications of the lime-stabilized materials. A laboratory analysis of the product should be completed and results thoroughly evaluated prior to use.

Urea is an example of a **synthetic organic fertilizer**, an organic substance manufactured from inorganic materials.

Compared to synthetic fertilizer formulations, organic fertilizers are relatively low in concentrations of actual nutrients, but may perform other soil-conditioning functions. These functions include: increasing the organic matter content of the soil, improving soil physical properties and increasing microbial activity. They are sometimes not economical to use in conventional agronomic production systems.

Calculations of Application Rates

Your fertilizer dealers have computer programs that can quickly determine the most cost-effective fertilizer blend and amount needed for your field based upon a soil test report. You may want to make some basic calculations yourself to better understand this process and make decisions on your fertilization program. Computing the amount of a fertilizer needed for a given area is rather tricky at first, but after a few times, the logic falls into place and becomes second nature. The University of Tennessee Soil Testing Laboratory provides recommendations to agricultural producers in amounts of nitrogen, potassium as K_2O and phosphorus as P_2O_5 to use per unit area. The next step is to determine the nutrient content of the fertilizer material to be used. The following example may help you in calculating the fertilizer nutrient content.

Example 1. Calculating nutrient content of dry and liquid fertilizers — To determine the N, P_2O_5 and K_2O content of a dry fertilizer, multiply the weight of the material by the percentage (percent/100) of each fertilizer nutrient. For example, 100 pounds of 3-9-18 contains: 0.03 X 100 = 3 pounds of N; 0.09 X 100 = 9 pounds of P_2O_5; and 0.18 X 100 = 18 pounds of K_2O.

To calculate the N, P_2O_5 and K_2O content of a liquid fertilizer, it is necessary to know both the grade and the weight of the material per gallon. One gallon of liquid 3-9-18 weighing 11.1 pounds would contain: 0.03 X 11.1 = 0.33 pounds of N per gallon; 0.09 X 11.1 = 1.0 pound of P_2O_5 per gallon and 0.18 X 11.1 = 2.0 pounds of K_2O per gallon. Therefore, 9 gallons of the 3- 9-18 liquid would supply the same amount of available plant food as the 100 pounds of dry fertilizer with the same grade.

Knowing the recommended amount of nutrient per acre (from your soil test report), the nutrient content of the material to be used and the number of acres to be treated, you can then readily determine how much of a given material will be required.

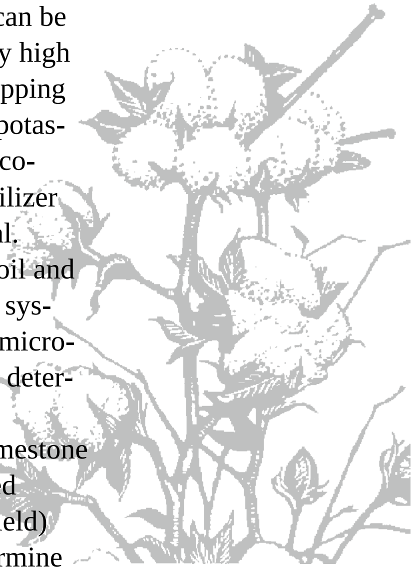
Frequency of Fertilizer and Lime Applications

Nitrogen is the most frequently applied nutrient in non-legume cropping systems. It must be added each year; multiple applications of nitrogen during the period of crop production may sometimes be needed. For example, in hay systems, nitrogen fertilizer is added after each harvest during the growing season. Also, in many of the vegetable crop production systems, a split application of nitrogen is suggested. Your soil test report will provide a suggested frequency of nitrogen application needed for the crop of interest, and amounts to apply. Multiple applications of nitrogen are also sometimes needed when soil conditions favor nitrogen loss (i. e., prolonged periods when fields are saturated with water).

In addition to nitrogen, potassium fertilization is usually needed every year in the continuous hay and silage cropping systems. This is because potassium is taken up by plants in larger amounts (termed luxury consumption) than are actually needed to result in the maximum dry matter production. Adding potassium fertilizer above recommended amounts usually results in higher levels of potassium in the plant tissue, but not higher yield of the hay or silage. Removal of the total plant as hay or silage takes large amounts of potassium out of the field. This makes it unlikely that soil test potassium levels in these cropping systems can be increased above the low testing level except when adding cost-prohibitively high levels of potassium fertilizer. Increasing the soil test level of K in these cropping systems is not needed to maintain high yields “ if ” recommended rates of potassium fertilizer are applied every year in a one-time application. The most economical approach is to add, “each year,” just that amount of potassium fertilizer that the continuous hay or silage system will need to meet its yield potential.

The other essential nutrients can build up to very high levels in the soil and so may not need to be added every year. Except in hay and silage cropping systems, potassium also can build up to very high soil test levels. Most of the micronutrients are always present in adequate amounts. A soil test can be used to determine which nutrients are needed for your crop and how much to apply.

Soil pH generally only has to be adjusted upward with agricultural limestone every three to five years. This may occur more often in intensively managed cropping systems (high rates of fertilizer and total crop removal from the field) and when soils have a low clay content. Soil testing is the best way to determine



when additional lime is needed and should be done every year in very intensively managed and high-value cropping systems (i.e., tobacco, vegetable crops) or for sandy soils.

Timing of Fertilizer and Lime Applications

Nitrogen should be applied near crop establishment, as a side-dress application, or both. Phosphorus and potassium may be applied in the fall or spring if the soil pH is properly adjusted and soils are not subject to severe erosion or flooding. Micronutrients should be applied where recommended at planting. Agricultural limestone may be applied anytime prior to crop establishment.

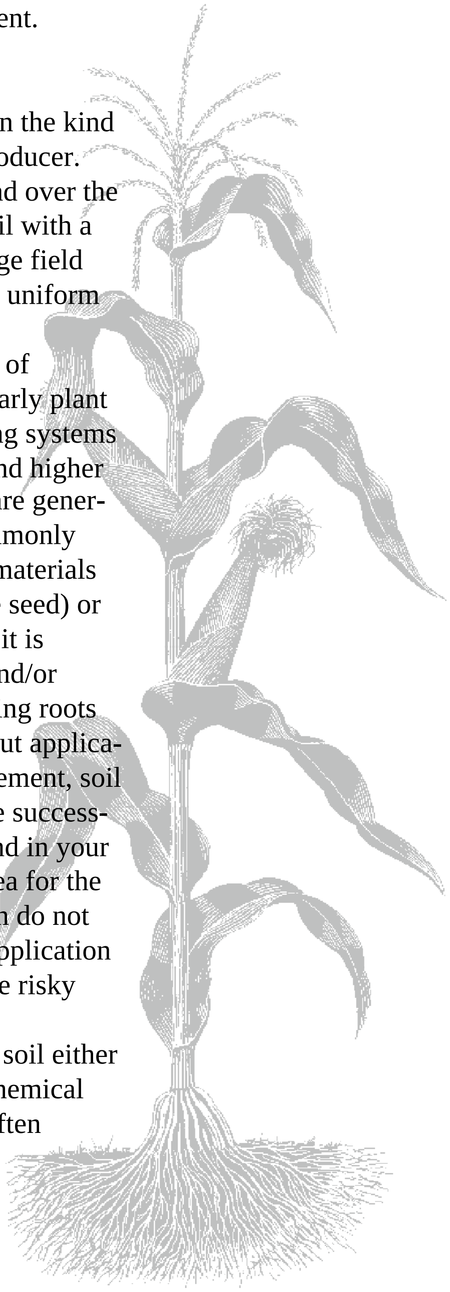
Application Methods

There are different methods of fertilizer application depending on the kind of fertilizer material, the cropping system and equipment used by the producer.

Broadcasting: A recommended rate of lime or fertilizer is spread over the growing area and left to filter into the soil, or is incorporated into the soil with a cultivator. Broadcasting is the application method generally used for large field areas, when time or labor are limited, or when it is important to obtain a uniform distribution of the soil amendment, as with a liming material.

Banding: This method is primarily used to apply small amounts of fertilizer as a plant starter. Starter fertilizer applications may stimulate early plant growth and increase yield. This is especially important in no-till cropping systems where crop residues or winter covers result in lower soil temperatures and higher moisture levels that may reduce plant vigor. Narrow bands of fertilizer are generally applied in furrows 2 to 3 inches from and 1 to 2 inches deeper (commonly called a 2 X 2 application) than the seeds or plants are planted. Starter materials have also been successfully applied in-furrow (in direct contact with the seed) or in about a 4-inch wide band over the surface of the planted furrow after it is sealed. Careless placement of the fertilizer band too close to the seeds and/or excessive application rate can often reduce germination rate, burn seedling roots and result in loss of stand. It is difficult to make a general statement about application rate. This depends on the type of fertilizer material, method of placement, soil texture and the sensitivity of the crop. Be familiar with what others have successfully done under soil and environmental conditions similar to those found in your farm fields. Get into the program only one step at a time. Try a small area for the first couple of years to be sure that the materials and rates of application do not adversely affect seed germination or yield in your soil type. In-furrow application of starters (in direct contact with the seed) is a less costly but much more risky method than the surface band or 2 X 2 application.

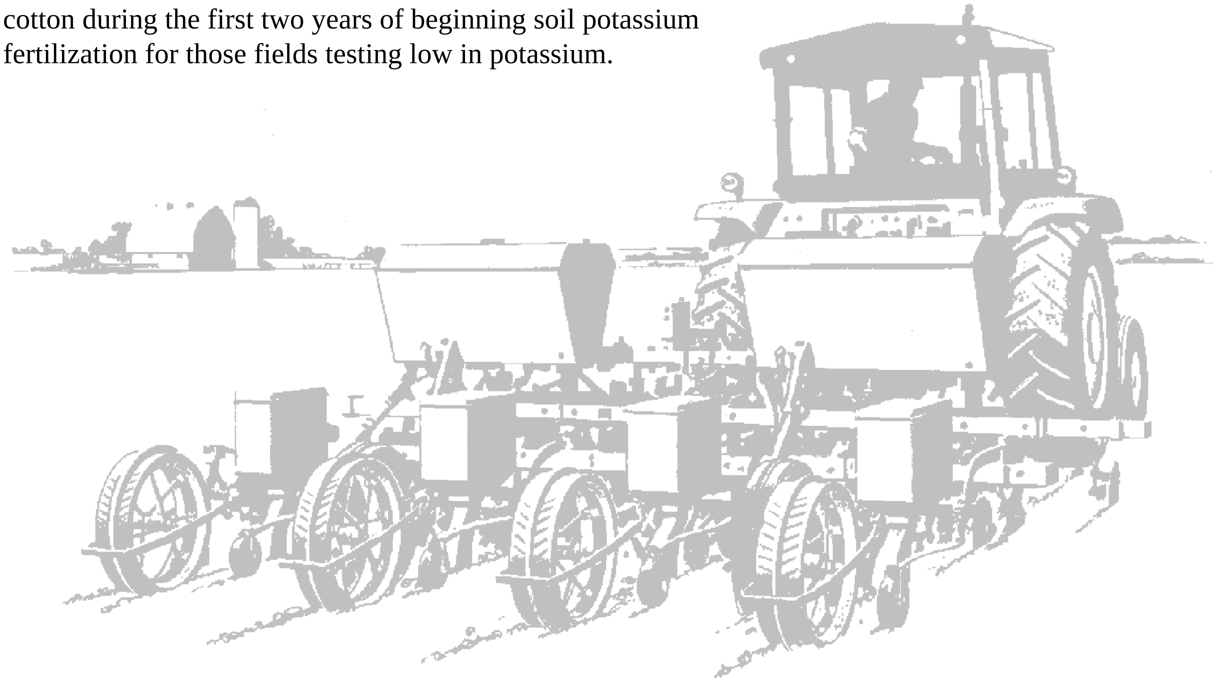
Anhydrous ammonia must be applied as a band injected into the soil either at planting or as a sidedress application. This is simply because of the chemical characteristics of that fertilizer material. Liquid nitrogen materials are often applied in a surface or injected band.



Sidedressing: This term generally refers to those fertilizer materials applied to the soil, (after the crop is up), during the early to mid-growth period of the crop. Sidedressed fertilizer materials can be either broadcast on both sides of the row about 6 to 8 inches from the plants or banded down the row middles. Nitrogen fertilizers are more often sidedressed than phosphorus or potassium materials. This is usually to supplement nitrogen needs, but also to ensure more efficient use under cropping conditions that may favor nitrogen loss (sandy soils, wet soils, irrigated soils)

Fertigation: Nitrogen and potassium are sometimes sidedressed by application in the irrigation water that is applied to crop production systems at intervals during the growing season. This is termed fertigation. Phosphorus is not normally applied in this manner because it forms many insoluble compounds with other elements present in the irrigation water. This tends to clog up the irrigation system unless special care is taken to maintain the water pH at a level where most of these compounds will stay in solution. It is usually best to take care of phosphorus needs (if any exist; many soils contain more than adequate levels of phosphorus for crop production) by a broadcast application of concentrated super phosphate fertilizer prior to crop establishment.

Foliar Feeding: Foliar-applied nutrients are absorbed and used by the plant quite rapidly. Absorption begins within minutes after application and is completed within one to two days with most nutrients. Foliar nutrition can supplement soil nutrition at a critical time for the plant (i.e., to maintain iron nutrition for an established acid-loving plant during the time period of soil pH adjustment with acid-forming fertilizers), but it is not a substitute for soil application. This is especially true for the primary and secondary nutrients. In agronomic cropping systems, University of Tennessee research has shown benefit from foliar application of potassium in some cotton fields. Foliar feeding with potassium is indicated for cotton during the first two years of beginning soil potassium fertilization for those fields testing low in potassium.



A Listing of Commonly Available Fertilizer Materials

Nitrogen — Table 4 provides a listing and information on commonly available nitrogen sources.

Table 4. Nitrogen fertilizer materials

Material	Analysis	Physical form	Handling Precautions/ Comments
Anhydrous ammonia	82-0-0	gas	---Extremely irritating to eyes and respiratory system in concentrations up to 0.07 % by volume; 0.17 % causes convulsive coughing; 0.5 to 1.0 % is rapidly fatal after short exposure; --- Will burn if a source of ignition is present ----Flammable and explosive mix tures are formed with air in concen trations of 16 to 25 % NH3 by volume. ----Need specialized equipment for application, used primarily for agronomic crops on relatively level land.
Urea	46-0-0	solid (prills, granules, crystalline)	Good storage and handling properties
Ammonium nitrate	34-0-0	solid (prills or granules)	---Strong oxidizer; readily absorbs water;can be explosive when mixed with carbonaceous materials
UAN solutions	(28-32)-0-0	liquid	--Normally 33 to 35 % is urea and 45 to 47 % is ammonium nitrate.; weighs about 11.1 pounds per gallon; salting out may occur at 32 F.
Ammonium sulfate	21-0-0 + 24 S	solid (crystalline or granules)	-- Used primarily as an acidifying fertilizer or source of sulfur

Phosphorus -- Table 5 provides a listing of and information on commonly available sources of phosphorus.

Table 5. Phosphorus fertilizer materials

Material	Analysis	Physical Form	Citrate Soluble	Water Soluble	Handling Precautions
Diammonium phosphate	18-46-0	solid, granule	----	100	Avoid excess dust
Monoammonium phosphate	11-48-0	solid, granule	-----	100	Avoid excess dust
Triple superphosphate	0-46-0	solid, granule	13	84	Avoid excess dust
Ordinary superphosphate	0-20-0	solid, granule	18	78	Avoid excess dust
Ammonium polyphosphate	11-37-0 10-34-0	liquid	----	----	Eye irritant, dike to contain spilled material

Potassium -- Table 6 provides a listing and information on commonly available potassium sources.

Table 6. Potassium fertilizer materials

Material	Analysis	Physical Form	Handling Precautions
potassium chloride	0-0-60	solid,granule	Avoid excess dust
potassium sulfate	0-0-50 + 18	solid, granule	Avoid excess dust
potassium nitrate	13-0-44	solid, granule, crystal	Avoid excess dust

Complete and Mixed Fertilizers — Table 7 provides a listing of some of the more commonly available complete or mixed fertilizer materials.

Table 7. Some complete and mixed fertilizer materials

Mixed Materials	Percent (%)			Pounds of Fertilizer to Supply One Pound of Primary Nutrient		
	N	P_2O5	K_2O	N	P_2O_5	K_2O
19-19-19	19	19	19	5.3	5.3	5.3
15-15-15	15	15	15	6.7	6.7	6.7
10-10-10	10	10	10	10	10	10
6-12-12	6	12	12	16.7	8.3	8.3
12-24-24	12	24	24	8.3	4.2	4.2
5-10-15	5	10	15	20	10	6.7
18-46-0	18	46	0	5.5	2.2	NA
11-37-0*	11	37	0	9.1	2.7	NA

*Liquid material weighs about 13 lb per gallon or 167.2 gall

Secondary Nutrients and Micronutrients – Table 8 provides a list of some of the more commonly available secondary and micronutrient sources.

Table 8. A listing of some secondary and micronutrient fertilizer materials

Nutrient Material	Nutrient Content (%)	Pounds of Material for One Lb. Nutrient
Magnesium		
Magnesium Oxy-Sulfate (granular)	36	2.8
Dolomitic Limestone*	9	11.1
Magnesium Sulfate (Epsom Salts)	9	11.1
Magnesium-Potassium Sulfate	11	9.1
Sulfur		
K-Mag (Sul-po-mag)	21-22	4.5-4.7
Elemental Sulfur	85-100	1.0-1.2
Calcium Sulfate (Gypsum)	15-18	5.5-6.7
Ammonium Sulfate	24	4.2
Boron		
Borax	10-15	6.7-10
Solubor	20.5	4.9
Calcium		
Calcitic Limestone*	35	2.8
Calcium Sulfate (Gypsum)	22.5	4.4
Bone Meal	15	6.7
Iron		
Iron Sulfate	40	2.5
Iron Chelates (soluble powder)	20	5.0
Manganese		
Manganese Oxy-sulfate	28	3.6
Manganese Chelates (soluble powder)	20	5.0
Zinc		
Zinc Oxy-Sulfate	36	2.8
Zinc Chelates (soluble powder)	25	4.0

*Should not be used as a nutrient source unless there is a need for lime.

Visit the Agricultural Extension Service Web site at:
http://www.utextension.utk.edu/

PB1637-10M-11/99
E12-2015-00-117-00