Fertilizer Guide

Part I:

Fertilizers and How They Work

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Plants require at least 16 elements for proper growth and development. Three of the elements—carbon, hydrogen, and oxygen—are provided by air and water; the other essential elements are obtained from the soil.

The macronutrients; nitrogen, phosphorus, potassium, calcium, sulfur, and magnesium; are used in greater quantities than the other mineral elements absorbed from the soil.(see Table 1) Nitrogen, phosphorus, and potassium are often called the primary nutrients because of the amount used by the plants and their importance in supplemental fertilizers.

The micronutrients; iron, manganese, copper, zinc, boron, molybdenum and chlorine; are required in smaller quantities but are no less important. The so-called "acid-loving" plants have a relatively high requirement for certain micronutrients, and chlorosis caused by an iron deficiency is a common ailment when these plants are grown in alkaline soils (over pH 7.0). Because of reserves normally found in the soil, the addition of supplemental micronutrients is not often necessary unless the soil is excessively alkaline or sandy.

Table 1. The amount of Essential Elements Contained in Higher Plants*

Element	Percent of Plant Tissue**
Oxygen	45
Carbon	45
Hydrogen	6
Nitrogen	1.5
Potassium	1.0
Calcium	0.5
Phosphorus	0.2
Magnesium	0.2
Sulfur	0.1
Iron	0.01
Chlorine	0.01
Manganese	0.005
Zinc	0.002
Boron	0.002
Copper	0.0006
Molybdenum	0.00001

* Adapted from: B. R. Stout, 1961. Proceedings of 9th Annual California Fertilizer Conference, pp 21-23.

** These percentages vary from different species and for the same species grown under different conditions.

Fertilizers

Fertilizer is any material that supplements the soil's supply of elements required for plant growth and development. Fertilizers may be categorized as natural organic, synthetic organic, or inorganic based on their source and chemical structure.

Organic fertilizer consists of nutrient elements derived from compounds with a carbon structure. The term organic when applied to fertilizer should include only organic materials that are insoluble in water.

All living matter—plant or animal—is composed of compounds with a carbon structure. Proteins, fats, carbohydrates and other compounds synthesized by an organism have one common factor—a carbon structure. Any of these materials could be considered as organic fertilizers when placed in the soil. Common examples of **natural organic** fertilizers are animal manure, bonemeal, sewage sludge and plant refuse.

Scientists have synthesized compounds with a carbon structure which are also organic. Examples of **synthetic organic** fertilizers are ureaformaldehyde and isobutylidene diurea.

Inorganic fertilizers are nutrient elements derived from

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sources which are not organic, those which have neither a carbon structure nor which have been derived from living matter. Examples of inorganic fertilizers are ammonium nitrate, ammonium phosphate, potassium nitrate and potassium chloride.

A complete fertilizer contains sources of nitrogen, phosphorus, and potassium. An incomplete fertilizer contains one or two of these elements in any combination, but never all three. Other fertilizer nutrients such as iron or magnesium may be present but are not considered in the definition of "complete" and "incomplete" fertilizers.

Analysis and Ratio

Fertilizer analysis or grade is the minimum guaranteed percentage by weight of nitrogen(N), phosphorus (expressed as P_2O_5 equivalent), and potassium (expressed as K_2O equivalent), and is printed on the container in that order.

For example, a 100 lbs. bag of 20-10-5 fertilizer is formulated from a nitrogen source(s) that contains 20 lbs. of elemental nitrogen, a phosphorus source(s) that contains the equivalent of 10 lbs. of P_2O_5, and a potassium source(s) that contains the equivalent of 5 lbs. of K_2O. Any of these elements missing from the formulation would be represented by a zero in the analysis. Ammonium nitrate, for example, which does not contain phosphorus or potassium, has an analysis of 33-0-0.

In addition to the total nitrogen, water insoluble nitrogen(WIN), if present, is also printed on the label as a percent of the total weight. For example, if half of the nitrogen of a 20-10-5 fertilizer is in a water insoluble form, the WIN content is 10%. Although WIN indicates the portion of nitrogen in a controlled-release fertilizer that is slowly soluble, it is not appropriate for coated fertilizers that encapsulate soluble nitrogen. In this case, the controlled-release nitrogen may be expressed in terms of dissolution rate. See Slow-Release Nitrogen for a more detailed description.

Fertilizer ratio is the relative amounts of nitrogen, phosphorus and potassium. A fertilizer with an analysis of 20-10-5 would contain four times as much nitrogen as potassium and twice as much phosphorus as potassium.The ratio then would be 4:2:1.

Table 2. The essential elements and the forms available to green plants.

Elements		Available forms
1. Macronutrients		
Nitrogen	(N)	NO_3-, NH_4+, Urea (some)
Phosphorus	(P)	HPO_4--, H_2PO_4-
Potassium	(K)	K+
Calcium	(Ca)	Ca++
Magnesium	(Mg)	Mg++
Sulfur	(S)	SO_4--, SO_3-
2. Micronutrients		
Iron	(Fe)	Fe++, Fe+++
Manganese	(Mn)	Mn++, Mn+++
Copper	(Cu)	Cu+, Cu++
Zinc	(Zn)	Zn++
Boron	(B)	BO_3---
Molybdenum	(Mo)	MoO_4--
Chlorine	(Cl)	Cl−

Absorption

All fertilizer nutrients, regardless of the source, are absorbed by plant roots as charged atoms or groups of atoms called ions—nutrient salts (see Table 2). These ions exhibit either a positive or a negative charge which is essential for root absorption by electrical attraction.

Inorganic fertilizers form ions readily when dissolved in water and therefore are quickly available for root absorption. Organic fertilizers—both natural and synthetic—must be hydrolyzed(decomposed) by soil microorganisms from complex compounds to the same nutrient salts provided by inorganic fertilizers. The rate of decomposition is dependent upon soil factors such as temperature, moisture and pH.

Burn

Fertilizer burn is the visible symptom of insufficient water in a plant associated with an overapplication of fertilizer salts.

The movement of water across the root cell membrane is regulated by the concentration of dissolved fertilizer salts in soil solution relative to the dissolved salts within the cell. As fertilizer salts dissolve in water, they raise the osmotic pressure of the solution. Water always moves from the side of the membrane with the low osmotic pressure to the side with higher osmotic pressure. Root cells actively absorb fertilizer salts from soil solution, and under normal conditions, maintain a higher osmotic pressure.

If excess fertilizer salts are applied and raise the osmotic pressure of soil solution, water cannot enter the cell and may actively move out of it. The resulting injury is known as fertilizer burn or physiological drought.

Salt index values are a measure of a fertilizer's relative tendency to increase the osmotic pressure of the soil solution. Sodium nitrate has been given a salt index value of 100 and the value for all other fertilizers is relative to an equal weight of sodium nitrate. The higher the salt index, the greater the potential for a fertilizer to raise the osmotic pressure of soil solution and, thus, cause burn. See Table 3 for salt indexes.

Because some nutrient sources are more concentrated than others(have higher percentages of N,P,or K) the actual increase in burn potential is affected by the application rate as well as the salt index. The partial salt index is calculated per unit of each nutrient and compares the rela-

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Table 3. Salt indexes of common fertilizer sources*

Fertilizer	Formula	% N	% P_2O_5	% K_2O	Salt Index	Partial** Salt Index
Nitrogen sources						
Ammonium nitrate	NH_4NO_3	35.0	—	—	104.7	2.99
Ammonium sulfate	$(NH_4)_2SO_4$	21.2	—	—	69.0	3.25
Sodium nitrate	$NaNO_3$	16.5	—	—	100.0	6.06
Potassium nitrate	KNO_3	13.8	—	—	73.6	5.34
Urea	H_2NCONH_2	46.6	—	—	75.4	1.62
Natural organic		5.0	—	—	3.5	0.70
Monoammonium phosphate	$NH_4H_2PO_4$	12.2	—	—	29.9	2.45
Diammonium phosphate	$(NH_4)_2HPO_4$	21.2	—	—	34.2	1.61
Phosphorus Sources						
Superphosphate	$Ca(H_2PO)_2+CaSO_4$	—	20.0	—	7.8	0.39
Triple superphosphate	$Ca(H_2PO_4)_2$	—	48.0	—	10.0	0.21
Monoammonium phosphate	$NH_4H_2PO_4$	—	61.7	—	29.9	0.49
Diammonium phosphate	$(NH_4)_2HOP_4$	—	53.8	—	34.2	0.64
Monopotassium phosphate	KH_2PO_4	—	52.2	—	8.4	0.16
Potassium Sources						
Potassium chloride	KC1	—	—	60.0	116.3	1.94
Potassium nitrate	KNO_3	—	—	46.6	73.6	1.58
Potassium sulfate	K_2SO_4	—	—	54.0	46.1	0.85
Monopotassium phosphate	KH_2PO_4	—	—	34.6	8.4	0.24

* Adapted from: Rader, Jr., L.F., L.M. White and C.W. Whittaker. 1943. The Salt Index—A Measure of the Effect of Fertilizers on the Concentration of the Soil Solution. Soil Science Volume 55, pp 201-218.

** Calculated per unit of N, P_2O_5, or K_2O.

tive burn potential of fertilizers based on equal amounts of nitrogen or equivalents of P_2O_5 or K_2O.

Effects of Soil pH

The term pH expresses the relative concentration of hydrogen(H+) and hydroxyl (OH-) ions in solution. A pH of 7.0 means the hydrogen and hydroxyl ions are equal and the solution is said to be neutral. A pH below 7.0 means the solution contains more hydrogen ions than hydroxyl ions and is said to be acid. Similarly, a pH above 7.0 means the solution contains more hydroxyl ions than hydrogen and is alkaline.

Soil pH may influence nutrient absorption and plant growth through the effect of hydrogen ions and their indirect influence on nutrient availability. In most soils the latter effect is the most significant.

The presence of an element in the soil is no guarantee that it is in a soluble form available for absorption. The concentration of hydrogen and associated ions affects soil reaction and the formation of soluble and insoluble compounds. All nutrients must be

> The presence of an element is no guarantee it is available to plants.

soluble to be available for root absorption.

Each nutrient has a pH where it is most available because it forms a large proportion of soluble compounds at that particular pH range. See Figure 2 for pH ranges and availability of nutrients.

Plant species differ in their response to the soil acidity

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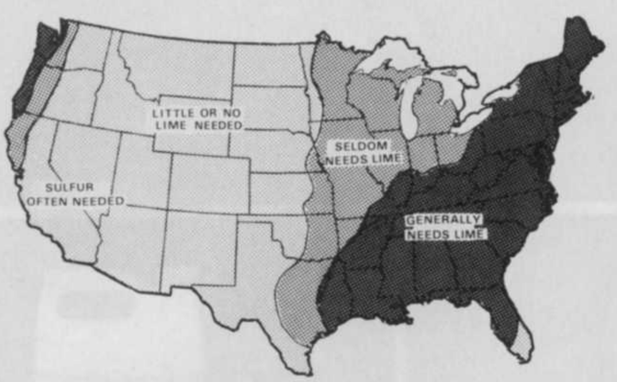
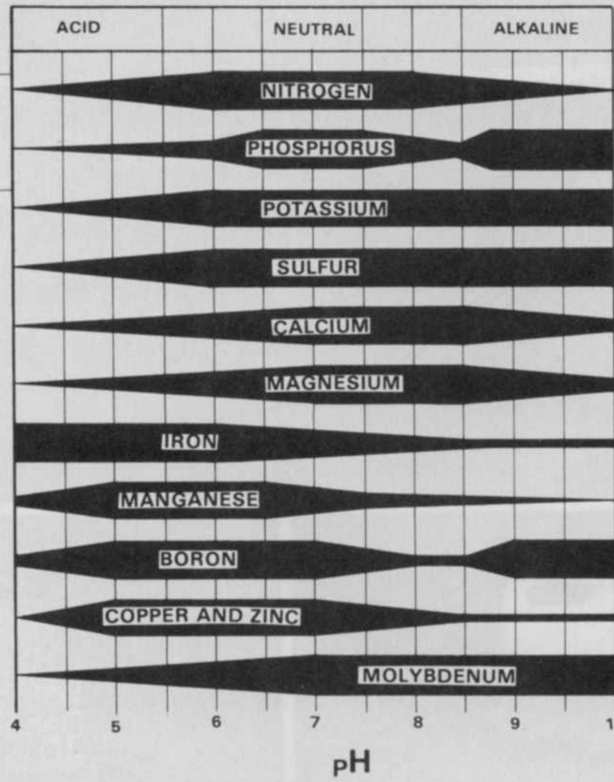


Geographic trends *in soil pH amendment.*



because of differences in nutrient requirements. For most plants, a pH of 6.5 fits the availability of most nutrients, without toxic amounts of any nutrient.

However, certain plants—such as rhododendrons, azaleas, pines and camellias—require comparatively large amounts of nutrients that are soluble in acid solution. They are "acid-loving" plants and grow best in soils of pH 5.5.

Soil acidity, as such, is seldom toxic to plants, but below pH 5.5 certain elements such as aluminum and manganese may become soluble to levels toxic to plant growth.

It has also been shown that pH levels affect the rate of of thatch decomposition, since they influence the organisms which break down thatch.

In some cases, nutrient availability can be improved by correction of the soil pH as well as by supplemental fertilization. Sulfur and agricultural lime are the materials used most frequently to alter the soil reaction or pH.

Lime increases the pH (decreases acidity); sulfur lowers the pH (increases acidity).

Ideally, the pH of soil within the root zone of a plant should be measured every three to five years and, if necessary, adjusted to the most favorable range for that particular species. Unfortunately, lowering the pH of an alkaline soil is not always succesful, particularly if the soil is inherently calcareous with significant calcium reserves.

Leaching

Leaching is the removal of materials in solution from the root zone. Leaching is caused by percolation, the lateral and downward movement of water through soil. Loss of nutrients due to leaching is proportional to the amount of water percolated through the soil. Water dissolves minute quantities of mineral and organic matter. Soil and weather conditions affect leaching.

All nutrients are subject to leaching, but not to the same degree. Calcium losses are the greatest of any nutrient known. Nitrate salt—the form of nitrogen primarily absorbed by plant roots—moves with ground water and rapidly leaches from the root zone. Magnesium, sulfur and potassium are moderately leached, whereas only a trace of phosphorus is lost.

Primary Fertilizer Elements

Nitrogen, phosphorus and potassium are the three nutrients required in the greatest quantity from the soil. In addition to these, iron is most likely to be found deficient in soils. Soil and tissue analysis can be used to determine the deficiency of any nutrient.

Nitrogen

Nitrogen is required in larger amounts than other elements supplied by the soil. Compounds formed by the plant from nitrogen comprise up to 50 percent of the dry weight of the plant. Nitrogen is a component of proteins, chlorophyll, amino acids and enzymes.

Nitrogen is more often deficient in soils than any of the other essential nutrients.

Plants can absorb nitrogen as either the ammonium (NH4+) or nitrate (NO3-). Urea or inorganic forms of nitrogen are converted to ammonium which is subject to volatilization when surface applied. More than 25 percent can be lost to volatilization under certain conditions.The ammonium form of nitrogen may be taken up by plant roots or transformed to nitrate which is the form most nitrogen is absorbed by plants.

Since nitrate ions are negatively charged, they are not absorbed by soil colloids (negatively charged) and readily move with soil water. Thus, heavy rainfall or irrigation may move nitrate below the root zone.

Because of the transitory nature of nitrogen in mineral soils, soil analysis is not as useful in determining deficiencies as an observation of symptoms. Nitrogen deficiencies are observed as uniformly yellowish-green leaves or needles which are more pronounced in older tissue. Leaves are small, thin and may start dying at the tips. The growth rate is reduced.

Nitrogen sources used for horticultural fertilization are often categorized as quick-release or controlled-release, based upon the rate nitrogen becomes available to the plant.

Controlled-Release

Controlled-release nitrogen sources include both slowly soluble nitrogen, which is an inherent characteristic of the fertilizer, and slow-release nitrogen which is imparted to a soluble fertilizer by an artificial coating.

In general, both types cost more per unit of nitrogen than quick-release sources and provide the following advantages: gradual supply of nitrogen which reduces the number of necessary applications, reduced leaching and reduced volatilization, and lower risk of burning which allows higher application rates.

Slowly Soluble

Slowly soluble nitrogen sources release nitrogen as their chemical structure slowly breaks down. Both natural and synthetic organic fertilizers can be classified as slowly soluble and are broken down by hydrolysis and/or microbial activity into soluble forms of nitrogen.

Natural organics include sewage sludge and plant and animal wastes, generally low in nutrient content.

Because of the bulk required to provide sufficient nutrients, and storage and odor problems, natural organics are being replaced by synthetic organic nitrogen in many fertilization programs. The most common synthetic organic nitrogen sources are ureaformaldehyde(UF) and isobutylidene diurea(IBDU).

> Soil analysis is not as useful in finding nitrogen deficiencies as observing symptoms.

UF Reaction Products

Ureaformaldehyde reaction products are synthesized by condensing urea with formaldehyde. From this reaction a number of urea-type compounds are produced; urea, methylol urea, and methylene urea. UF reaction products are distinguished from each other by the relative amounts of these three compounds and solubility in cold and hot water.

Most of the new fertilizer products are UF reaction products. To help identify types of UF reaction products scientists look at the number of carbon lengths in the chemical chain which results from condensing urea with formaldehyde.

Solubility of UF reaction products decreases, along with nitrogen release and burn potential, as the number of carbon lengths increase. Urea contains the least number of carbon lengths and methylene urea contains the largest number. Methylol ureas fall in between.

Ureaformaldehyde(Nitroform), a product of BFC Chemicals, Inc., contains at least 35 percent nitrogen, mostly in insoluble and slowly soluble forms. At least 60 percent of the total nitrogen of UF is insoluble in cold water.

Hawkeye's Formolene and Georgia Pacific's GP4341 are two liquid products which contain soluble methylol urea as the UF compound. C.P. Chemical's Nitro-26 Plus is also a liquid, but methylene urea is the predominant urea compound. Cleary's Fluf is a flowable liquid(a liquid containing microfine particles) which contains methylene urea as the predominant UF compound. Scott's Polyform is a homogeneous granular form of methylene ureas.

Knowledge of the relative amounts of urea, methylol urea, and methylene urea contained in liquid UF reaction products can be used as a guide in predicting their potential to cause fertilizer burn.

Fluf would have the least burn potential because it contains less than 16 percent urea with methylene urea as the predominant UF compound and 20 percent of the total nitrogen is water insoluble.

Nitro-26 Plus, like Fluf, also contains less than 16 percent urea with methylene urea as the major UF compound. However, Nitro-26 Plus contains no water insoluble nitrogen and therefore could be considered intermediate in burn potential.

Formolene and GP4341 contain 50 percent urea with methylol urea as the primary UF compound and would have the greatest potential to cause burn of the liquid UF reaction products.

IBDU

Isobutylidene diurea(IBDU) is produced by reacting urea with isobutyraldehyde and is marketed in two size ranges, fine (0.5-1.0 mm) and coarse (0.7-2.5 mm). Urea is released from IBDU through the hydrolytic action of water.

Factors which increase the rate of nitrogen release from IBDU include: 1) decreasing particle size, 2) increasing soil moisture, 3) increasing soil temperature, and 4) increasing soil acidity (lowering pH).

IBDU (Par-Ex) is sold by Estech General Chemical Corp. and contains 31 percent nitrogen which is 85 to 90 percent insoluble, depending upon particle size.

Slow-Release

Slow-release nitrogen is produced by encapsulating quick-release nitrogen with an insoluble coating. The soluble nitrogen is released through tiny pores as the coating is broken down in the soil. A mixture of variable coating thicknesses provides continuous release of soluble nitrogen for a controlled period of time. Only two slow-release nitrogen sources are commercially available—sulfur coated urea and Osmocote.

Sulfur-Coated Urea

Sulfur-coated urea is produced by coating urea with molten sulfur and then sealing the granule with oil or wax. The soluble nitrogen is released through tiny pores or imperfections in the coating.No two particles are coated the same.

The nitrogen release rate or dissolution rate is determined by placing sulfur-coated urea in water at 100 degrees F. for a seven-day period and is expressed as percent dissolved at the end of that time. Most SCU products have a dissolution rate between 20 and 30 percent. Factors which increase the release rate of nitrogen from SCU include: increasing soil temperature and increasing soil moisture.

Sulfur-coated urea is commercially available with 32 to 37 percent nitrogen from Canadian Industries Ltd., AG Industries Mfg. Corp.(a subsidiary of Lakeshore Equipment and Supply Co.), and O.M. Scott.

Osmocote

Osmocote is manufactured by encapsulating soluble fertilizer with a plastic, semiporous coating. Water enters the capsule, dissolves the nutrients, and then diffuses out into the soil for plant uptake. Osmocote is marketed by the Sierra Chemical Corp.

Quick Release

Quick-release nitrogen sources are all soluble in water and are either available for root uptake in their present form or are readily converted to available forms in the soil. Inorganic nitrogen fertilizers (do not contain carbon) such as ammonium nitrate and ammonium sulfate are quick-release. Urea, although technically an organic source of nitrogen, is soluble and possesses many of the same characteristics as the inorganics. Organic doesn't always mean slow-release.

> FAN's nitrogen release is similar to urea, but its burn potential is much lower.

In general, the quickly available nitrogen sources are less expensive than controlled-release sources and have the following characteristics: 1) readily soluble in water, 2) immediately available for absorption, 3) can cause growth flushes, 4) short soil residual, 5) leach and/or volatilize, and 6) high burn potential,

Recent developments in ureaformaldehyde reaction products have provided quick-release nitrogen with a burn potential much lower than for other soluble nitrogen sources.

New Products

A newcomer to the soluble nitrogen market is avaible from the W.A. Cleary Co. as a liquid product under the name FAN. FAN contains 20 percent nitrogen and is produced by reacting urea and acid aldehyde to form ethylidene urea. Although the nitrogen release rate is similar to that of urea, the burn potential is much lower. The markets for FAN should be the same as for the sprayable UF reaction products.

Melamine (triaminotriazine) is a relatively new controlled-release nitrogen source produced by Melamine Chemicals, Inc. Melamine is combined with urea in 1/3(urea):2/3(melamine ratio by weight. It is marketed under the trade name Super 60, which has a 60-0-0 analysis.

Super 60 is currently sold for forest and rice fertilization and is being tested for the nursery and tree and turf care industries. It has a possible application in both the granular and liquid fertilizer markets since the granules disburse in water releasing urea into solution, while the melamine powder remains in suspension.

Melamine is very slowly broken down in the soil with an initial lag of more than 60 days before nitrification, followed by controlled release of nitrogen for a period of one to two years. Depending upon the results of further laboratory and field studies, melamine and/or various combination products may be available in the near future as an alternative to UF, IBDU, and SCU.

Phosphorus

Phosphorus is especially important in seedling growth. It is utilized in carbohydrate conversions, energy transfer, and is a component of nucleoproteins and phospholipids. Phosphorus helps maintain a desirable pH in cells and contributes to root development.

Phosphorus deficiencies are most often encountered in seedlings. Leaves or needles turn a dull green becoming reddish-bronze to purple, especially along margins in cold weather.

Some Phosphorus is provided by soil minerals and soil organic matter but it is very slowly available from these sources. Since phosphorus moves very little through soil, supplemental phosphorus tends to accumulate near the application site, moving only a few inches in 50 years.

Fertilizer

Plants take up phosphorus primarily in the orthophosphate form (H_2PO_4-). Although soils normally contain relatively large amounts of phosphorus, much of it is in forms not available to plants.

Phosphorus availabilty is influenced by soil pH. At a pH below 5.5, iron and aluminum form an insoluble complex with phosphorus that is not available to plants. At a pH above 7.5, calcium combines with phosphorus to form insoluble compounds such as calcium phosphate. Phosphorus is most available between pH 6.0 and 7.0.

The most common phosphorus sources for granular application are the superphosphates with a P_2O_5 equivalent of 20 to 48 percent.

Soluble phosphorus sources include monoammonium phosphate (11-48-0), recommended for alkaline soils, and diammonium phosphate (18-46-0).

Liquid ammonium phosphate (10-34-0) is often used where bulk tank storage is feasible. Monopotassium phosphate (0-52-34), a soluble, granular product, has an excellent potential as fertilizer because of its high analysis and low salt index. High cost of production has limited its use.

Potassium

Potassium is found in all plant parts in relatively large quantities and functions in catalyzing plant reactions, regulating transpiration, and aiding in the translocation of materials between cells. Although more research needs to be done with turfgrasses and woody plants, potassium is thought to influence rooting and increase heat, cold and drought resistance as well as enhancing resistance to disease.

The effects of potassium on plants are more subtle than the effects of nitrogen because they are not normally expressed visually in terms of growth rate or leaf color. Potassium deficiencies may restrict the translocation of car-

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bohydrates and nitrogen metabolism and are evidenced first as marginal and interveinal yellowing of older leaves. Leaf tips may roll, turn brown and wither. Growth is often stunted.

Potassium mobility in soils is less than that of nitrate but greater than that of phosphates. The available form of potassium(K+) is strongly adsorbed by clay particles which prevents excessive leaching except on sandy soils.

> Iron is the micronutrient most likely to be deficient in much of the U.S.

The most common potassium fertilizer is potassium chloride(0-0-62), although potassium sulfate(0-0-14) is often used in arid regions where chloride is a problem or in commercial lawn care programs because of its lower burn potential.

Potassium sulfate has a lower solubility and may contain insoluble silica fractions. Potassium nitrate(13-0-44) is an excellent fertilizer but generally is not priced competitively with the chloride or sulfate forms. Monopotassium phosphate(0-52-34), as mentioned earlier, has excellent potential as a fertilizer but its use is limited because of its high cost.

Iron

Deficiencies of micronutrients such as iron, zinc, manganese, copper and boron are sometimes found in certain plant species, especially when grown in alkaline or sandy soils. Iron is the micronutrient most likely to be deficient throughout much of the United States and Canada.

Iron is essential for the formation of chlorophyll and its deficiency is initially expressed as interveinal and marginal yellowing of the youngest leaves. Prolonged iron deficiency can result in decreased shoot and root growth because of a lack of chlorophyll to maintain photosynthesis.

Iron deficiencies do not usually result from a lack of iron but rather because the iron is tied up or "fixed" in insoluble compounds. Iron is most commonly deficient in alkaline soils although excessive levels of phosphate, manganese, zinc, and copper can produce iron deficiency. Waterlogged soils can also reduce the availability of iron.

Since iron deficiency is often the result of alkaline soil reactions, acidifying soils would appear to be a practical solution. Calcareous soils, however, may have large reserves of calcium to buffer attempts to lower the pH, particularly if the soil is fine textured. Relatively large amounts of sulfur may be required over a number of years to correct the pH of clay soils.

Compounds containing iron can be applied to the foliage, soil, or, for trees, injected or implanted into the trunk.

Materials for foliar and soil application include inorganic salts, such as ferrous sulfate and ferric nitrate, available from agricultural and horticultural distributors; and chelated forms, such as Sequestrene from Ciba Geigy and Ferriplex from Miller Chemical and Fertilizer Corp. An organic product called Eagle-Iron from Eagle-Picher Industries Inc., is effective for iron deficiencies in crops and is being tested for turfgrasses and woody plants.

Iron from inorganic salts is quickly combined into insoluble forms in alkaline soils and little remains available for plant use. Chelated irons react slower with soil components and improve the continued availability of iron.

For trunk injection or implantation of chlorotic trees, iron salts such as ferric citrate and ferric ammonium citrate are available from laboratory chemical distributors or may be ordered through a pharmacy. **WTT**