1984 Guide to Turf, Tree and Ornamental Fertilization

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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 and potassium, are often called the primary nutrients because of the amount used by the plants and their importance in supplemental fertilizers. Magnesium is also considered a macronutrient.

The **micronutrients**, iron, manganese, copper, zinc, boron, molybdenum and chlorine, are required in smaller quantities but are no less important. Because of reserves normally found in soil, the addition of supplemental micronutrients is not often necessary unless the soil is excessively alkaline or sandy.

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. All living matter—plant or animal—is composed of compounds with a carbon structure. Compounds synthesized by organisms have one common factor—a carbon structure. Any of these materials could be considered as organic fertilizers

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.

Urea is technically an organic fertilizer since it contains one carbon. It is both naturally (bird manure) or synthetically produced. Although technically organic, it has the quick-release properties of inorganic fertilizers and should not be considered an organic fertilizer.

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

Fertilizers may contain both organic and inorganic components. Generally, organic compounds are insoluble in water while inorganic compounds are water soluble. Therefore organic compounds release elements more slowly. An exception, urea, is an organic material that releases nitrogen fairly rapidly.

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-pound bag of 20-10-5 fertilizer is formulated from nitrogen source(s) that supply 20 pounds of elemental nitrogen, phosphorus source(s) that supply the equivalent of 10 pounds of P_2O_5, and potassium source(s) that supply the equivalent of 5 pounds 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.

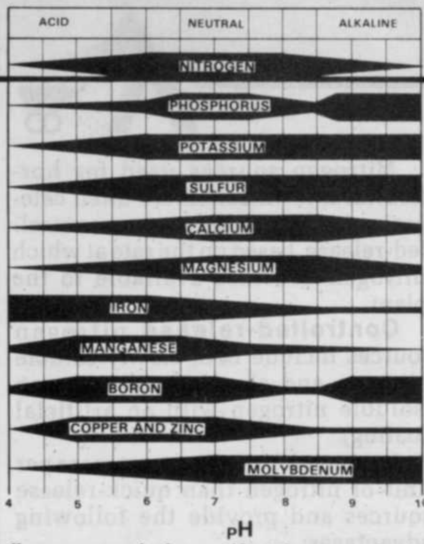
In addition to the total nitrogen, water insoluble nitrogen (WIN), if present, is also printed on the label as a percent of the total weight. For

Salt Indexes of Common Fertilizer Sources*

	Fertilizer	Formula	% N	% P_2O_5	% K_2O	Salt Index	Partial** Salt Index
Nitrogen	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		4.0	—	—	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	Superphosphate	$Ca(H_2PO)_2 + CaSO_4$	—	20.2	—	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	$(NH_4)_2HPO_4$	—	53.8	—	34.2	0.64
	Monopotassium phosphate	KH_2PO_4	—	52.2	—	8.4	0.16
Potassium	Potassium chloride	KC1	—	—	60.0	116.3	1.94
	Potassium nitrate	NO_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, OF K_2O.



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, such as sulfur coated urea. Instead, results of a coated slow release nitrogen (CSRN) test are listed on the bag. For a more detailed discussion, see Slow-Release Nitrogen.

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.

Absorption

All fertilizer nutrients, regardless of the source, are absorbed by plant roots as charged atoms or groups of atoms called ions—the nutrient salts. 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 or decomposed by soil microorganisms from complex compounds to the same nutrient salts provided by inorganic fertilizers. The rate of decomposition is dependent upon many 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 through the root cell membrane is regulated by the concentration of dissolved fertilizer salts in soil solution outside the cell relative to the concentration of dissolved salts within the cell. The cell membrane tries to control the concentration of salts on both side of it by allowing water (and dissolved salts) to flow from one side of the membrane to the other.

Normally, the plant cell takes in both water and salts. If too much fertilizer is applied to the soil and is dissolved by soil water, the high concentration of salts outside the plant cell will cause the membrane to stop the inflow of water or to let water flow out of the cell. The result is known as fertilizer burn or physiological drought.

Salt index values are a measure of a fertilizer's relative tendency to increase the concentration of salts in 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 cause burn.

Because some nutrient sources are more concentrated than others (that is, have a higher percentage of N, P_2O_5 or K_2O) 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 relative burn potential of fertilizers based on equal amounts of nitrogen or P_2O_5 or K_2O equivalents.

Soil pH

The term pH expresses the relative concentration of hydrogen (H¢) and hydroxyl (0H-) 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 indicates the soil solution contains more hydrogen ions than hydroxyl ions and is said to be **acid**. Similarly, a pH above 7.0 means the solution is **alkaline**, containing more hydroxyl than hydrogen ions.

The 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 soluble to be available for root absorption. Each nutrient has a pH of maximum availability simply because within this range it forms a large proportion of soluble compounds. The relationship between soil reaction and nutrient availability for 12 of the essential elements is shown in a table in this article.

Plant species differ in their response to soil acidity because of differences in nutrient requirements. For most plants the conditions of nutrient availability, without toxic amounts, are **best near pH 6.5**. 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 about pH 5.5.

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

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 successful, 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 amounts of water percolated through the soil. Water dissolves minute quantities of mineral and organic matter which commonly move with the water. Since soil and weather conditions vary throughout the United States, leaching affects soils of humid regions more, on the whole, than it does most soils of dry regions.

All nutrients are subject to leaching, although not to the same degree. Calcium losses are the greatest of any nutrient known. Nitrate salts—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 NUTRIENTS

Nitrogen, phosphorus and potassium are the three macronutrients required in the greatest quantity from the soil and are commonly applied for turfgrass and landscape plants. In addition to the primary fertilizer elements, the micronutrient iron is most likely to be found deficient in soils. Other elements which are sometimes deficient may be determined by soil and tissue analysis or by testing plant response.

Nitrogen

Nitrogen is required in larger amounts than other elements supplied by the soil and is formed into compounds that comprise up to 50% of the dry weight of plant cells. It is more often deficient in soils than any of the other essential nutrients.

Plants can absorb nitrogen as either the ammonium (NH_4^+) or nitrate (NO_3^-) ions. Urea or inorganic forms of nitrogen are converted to ammonium which is subject to volatilization when surface applied. Where conditions favor volatilization, 25% or more of the applied nitrogen may be lost in the atmosphere.

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.

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

Controlled-release nitrogen sources include both slowly soluble nitrogen and slow release nitrogen (soluble nitrogen with an artificial coating).

In general, both types cost more per unit of nitrogen than quick-release sources and provide the following advantages:

1 supply nitrogen gradually which reduces the number of applications necessary
2 reduce nitrogen leaching and volatilization which increases efficiency
3 reduce risk of burn which allows higher application rates.

Slowly soluble nitrogen includes natural and synthetic organic fertilizers which are slowly soluble (not urea) 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. Milorganite (6% N) is a granular sewage sludge produced by the City of Milwaukee, WI, since 1926. Milorganite has been the most widely used natural organic for turfgrass fertilization.

Low analysis natural organic fertilizers are less prone to damage turf or plants through incorrect equipment calibration than other fertilizers.

The most common synthetic organic nitrogen sources are ureaformaldehyde (UF) and isobutylidene diurea (IBDU).

Ureaformaldehyde Reaction Products are synthesized by reacting urea with aldehyde. Formaldehyde is the most common aldehyde used.

UF reaction products range from those which are predominantly soluble, short-chained methylol urea, to those which contain short- (soluble) and long- (insoluble) chained methylene ureas.

All longer-chained methylene ureas depend on **microbial decomposition** for release of nitrogen. Factors such as **soil temperature**, which affects microorganism activity, may then also affect the rate at which nitrogen is released from these products. UF reaction products which contain water insoluble nitrogen are particularly sensitive to changes in microorganism activity.

Since 1977, several liquid forms of UF reaction products have become available for liquid fertilization. Hawkeye's Formolene (30% N) and Georgia Pacific's 4341 (30% N) are two fertilizers which contain soluble methylol urea as the predominant UF compound. In addition, both products contain approximately 50% free urea.

C.P. Chemical's Nitro-26 (26% N) is a solution of methylene urea and approximately 15% urea. Cleary's Fluf (18% N) is a suspension liquid (a liquid containing microfine particles) which, like Nitro-26, contains methylene urea as its predominant UF compound and approximately 15% urea. In addition to soluble, short-chained methylene urea, Fluf contains 20% water insoluble, long-chained methylene urea.

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

Products which contain water insoluble nitrogen and/or are predominantly methylene urea would have a lower potential to burn than those containing methylol urea. Liquids which have a lower urea content would also have a lower potential to burn.

For these reasons, Fluf would have the least potential for burn, followed by Nitro-26 and then Formolene and GP4341. Although field tests have verified the burn potential of these products in the order given, the magnitude of the difference between the products is not great.

Tests have shown that all UF reaction products have a substantially lower potential to burn than urea. Research has also demonstrated little difference between these products and urea regarding the rate at which nitrogen releases.

Another UF reaction product which is available in both a powder and a granular form is O.M. Scott and Sons' methylene urea fertilizers. Scotts first introduced methylene ureas into their fertilizer products in 1958.

Scotts' fertilizers include both water soluble and water insoluble methylene ureas. The water soluble portion ranges from approximately 40% for nursery stock to 70% for turfgrass fertilization. Although Scotts produces both complete and incomplete fertilizers containing methylene ureas, the fertilizers containing nitrogen only range from 38% to 41% nitrogen. Length of nitrogen release is up to 2 months for turfgrasses and from 2-6 months for container grown nursery plants.

Nitroform marketed by Nor-Am

Chemical Company, qualifies as a ureaformaldehyde fertilizer and not just simply as a UF reaction product. This is because Nitroform has at least 60% water soluble nitrogen (actually 66%) and the water insoluble nitrogen does not test less than 40% active by the nitrogen activity index (actually 40%).

Activity index indicates the amount of water insoluble nitrogen which is soluble in boiling water. An activity index of 40 means that 40% of the methylene ureas are soluble in hot water, while the remaining 60% are insoluble in hot water. Length of nitrogen release is 2 years. Lebanon Chemical also manufactures a ureaformaldehyde.

Isobutylidene Diurea(IBDU) was first marketed by Estech, Inc. in the late 1960's. IBDU is produced by reacting urea with isobutyraldehyde. For turfgrass fertilization, IBDU is sold as a granule in 2 sizes, fine (0.5-1.00 mm diameter) and coarse (0.7-2.5 mm). For container-grown and landscape plants, "briquettes" of IBDU are also available, called Woodace. They last in the soil from one to three years depending upon size, and are complete fertilizers.

Urea is released from IBDU through the hydrolytic action of water. The primary factors which influence the rate at which nitrogen is released from IBDU are **soil moisture and particle size**. Increasing soil moisture and decreasing particle size will increase the rate at which nitrogen is released.

IBDU in granular form contains 31% nitrogen of which 85-90% is insoluble.

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(SCU) is produced by coating granular or prilled urea with molten sulfur. The manufacturing process may also include the application of a sealant (microcristalline wax) and a conditioner (diatomaceous earth).

Degradation of the coating and diffusion of nitrogen through pores or imperfections in the coating are responsible for release of nitrogen. Because of varying coating thicknesses and imperfections, the rate at which nitrogen releases also varies. **Soil moisture** is the major factor which influences release of nitrogen. Increasing soil moisture will speed nitrogen release.

A prediction of the rate at which nitrogen is released from SCU is known as dissolution rate. Dissolution rates range from 20% to more than 80%. Nursery grade SCU has a lower dissolution rate than turf grade. For SCU coated with microcrystalline wax a dissolution rate of 25-40% has given good initial turfgrass response. Ask the manufacturer for the dissolution rate of SCU to determine an accurate N release rate.

Although a 2-4 month residual is claimed for surface applications to turfgrass, the nitrogen release rate may be as great as one year, depending on placement and product used. Commercial products range from 32% to 38% nitrogen. SCU is available from Canadian Industries Ltd., Ag Industries Manufacturing Corporation (a division of Lesco Inc.), and O.M. Scott and Sons.

Osmocote® has been available to the horticultural and landscape industry since 1967. Osmocote is manufactured by the application of a plastic, semiporous coating to prilled soluble fertilizer sources such as ammonium nitrate, ammonium phosphate, urea and calcium phosphate.

Nutrients are released from Osmocote by diffusion. Water enters the plastic shell, dissolves the soluble nutrients which then diffuse into the soil for plant uptake. **Soil temperature** will significantly influence the rate at which nutrients are released. Warmer soil temperature increases the release rate, while cooler soil temperatures decrease the release rate.

Nitrogen release rate varies from three months to one year plus, depending on the nitrogen source(s) used and placement of the fertilizer. Osmocote is available through Sierra Chemical Company.

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 (sources which do not contain carbon) such as ammonium nitrate and ammonium sulfate are quick-release. Urea, although technically organic, is soluble and possesses many of the same characteristics as inorganics.

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
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. A discussion of these products is included in the section on Ureaformaldehyde Reaction Products.

New products

Oxamide—Current projections by Estech, Inc. are that Oxamide will be marketed in 1985. Oxamide, which is a diamide of oxalic acid, is made from hydrogen cyanide. Tests have been conducted with both powder and granular forms.

The method by which nitrogen is released from Oxamide is chemical hydrolysis by water. **Particle size** influences the rate at which nitrogen is released from Oxamide—the larger particle releases more slowly.

Research has shown that Oxamide has a residual of from 60 to 100 days although the larger particle has shown nitrogen release up to six months. Oxamide contains 31% nitrogen.

Triamino-triazine/urea under development by Melamine Chemicals, Inc. is a homogeneous granule of triamino-triazine (66% nitrogen) and urea (46% nitrogen). Triamino-triazine is a crystalline powder produced by heating urea under pressure in the presence of a catalyst.

Both microbial decomposition and chemical hydrolysis are responsible for the release of nitrogen. **Soil temperature, moisture and pH** all influence the rate at which nitrogen becomes available from this product. The triamino-triazine portion of the fertilizer is slowly broken down in the soil. There is an initial lag of over 60 days before nitrification followed by a controlled release for a period of one to two days.

A triamino-triazine/urea product with an analysis of 60-0-0, containing ⅓ urea, ⅔ triamino-triazine by weight, is currently available for forest and rice fertilization. Although still being tested, this new source of nitrogen may prove to be a valuable alternative to conventional nitrogen sources used in fertilizing turfgrasses and landscape plants.

Nitrification Inhibitors—As mentioned previously, substantial losses of nitrogen can result from volatilization and leaching. A concept that has been practiced with fertilization of field crops is the use of a nitrification inhibitor.

The objective is to slow the nitrification process for sources of quick-release nitrogen which are ammonium-based or ammonium-forming such as ammonium nitrate, ammonium sulfate and urea.

Nitrification is a two-step process where ammonium is converted to nitrite then nitrate by soil bacteria. The nitrification inhibitor reduces the bacteria responsible for the conversion process which keeps the nitrogen in the ammonium form. In the ammonium form, the nitrogen is less subject to losses by leaching. Likewise, maintenance of nitrogen in the ammonium form reduces the potential for denitrification (which is loss of nitrate as a gas) which improves the overall efficiency of the nitrogen source.

Nitrapyrin, marketed as N Serve by Dow, is a nitrification inhibitor which is currently registered for use in corn, wheat, sorghum, cotton and rice. Because nitrapyrin is volatile, it must be incorporated into soil during or following application. Dow is currently testing nitrapyrin as a nitrification inhibitor for turfgrass. Lebanon also has an inhibitor for turf.

Another interesting concept developed to reduce the loss of nitrogen from volatilization is the addition of soluble magnesium or calcium to urea.

When applied to soil, urea is converted into ammonium carbonate. In this form, the ammonium ion can be changed to ammonia and lost as a gas. When magnesium chloride is included with urea, ammonium chloride—instead of ammonium carbonate—is formed and is less susceptible to ammonia loss.

Although still being evaluated, NVN is a urea-magnesium solution marketed for turfgrass fertilization in 1984 by Great Salt Lake Minerals and Chemicals Corporation. Further testing and experience with this product should help to document the practical application of this product.

Phosphorus

Phosphorus is especially important in seedling growth and is utilized in carbohydrate conversions, energy transfer and is a constituent 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 no more than a few inches in 50 years. Plants take up phosphorus primarily in the

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

Phosphorus availability 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, $CA_3(PO_4)_2$. 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%. Soluble phosphorus sources include monoammonium phosphate (11-48-0) which is 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, but high cost of production has limited its use.

Potassium

Potassium is found in all plant parts in relatively large quantities and functions in catalyzing 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 resistance to heat, cold, drought, and 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 carbohydrates 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 absorbed by clay particles which prevents excessive leaching except on sandy soils.

The most common potassium fertilizer is potassium chloride (0-0-62), although potassium sulfate (0-0-54) is often used in arid regions where chloride is a problem or in liquid fertilization 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.

MICRONUTRIENTS

With the exception of sandy soils, micronutrients are more likely to be unavailable in the soil than low in total amount.

Deficiencies of iron, manganese, zinc, copper and boron are sometimes found in certain plant species, especially in sandy or alkaline soils.

Micronutrients commonly deficient in sensitive species should be included in the regular fertilization program. Once deficiency symptoms have developed, however, foliar sprays or trunk injections and implants may be necessary to correct the deficiency.

Iron is the micronutrient most likely to be deficient throughout much of the United States and Canada. Iron is most commonly deficient in alkaline soils, although excessive levels of phosphate, manganese, zinc, and copper can produce iron deficiency. Waterlogged soils also reduce the availability of iron.

Soil applications to prevent or correct micronutrient deficiencies include inorganic salts, chelates and sulfur. Results have not always been satisfactory due, in part, to insufficient applications of the amending agent, severity of the deficiency symptoms, and soil problems such as excess alkalinity or poor drainage.

Micronutrients in the form of nitrate or sulfate salts are often included in fertilizer formulations but not in sufficient amounts to correct a deficiency. In addition, micronutrient salts may become insoluble quickly in alkaline soils and, therefore, unavailable for absorption by plants.

Inorganic salts of micronutrients may injure turfgrasses at the rate recommended for woody plants and should be applied during the dormant period, preferably by subsurface application. Ferrous sulphate and ferric nitrate are available from agricultural and horticultural distributors.

Chelates remain more soluble in alkaline soils than inorganic salts and can be applied to the soil surface or injected into the soil. Chelates also are less likely to cause injury to plants than inorganic salts and last longer in the soil. However, the cost for chelated micronutrients is considerably higher than for inorganic sources.

Chelates are marketed under various trade names with formulations for different conditions and purposes. Sequestrene® from Ciba Geigy, Ferriplex® from Miller Chemical & Fertilizer Corporation, and XL Iron Chelate from Doggett Corp. are three chelated iron products. Recommended rates usually vary from 2 to 6 pounds per 1,000 square feet. Eagle-Iron®, produced by Eagle-Picher Industries, is effective for iron deficiencies in crops and is being tested for turf and woody plants. Select the proper product for a particular situation and follow directions on the label.

Acidifying agents, such as sulfur and sulfuric acid, are normally injected into the soil or placed in vertical holes. Depending upon the soil texture and pH, large amounts of sulfur may be required over a number of years to correct the pH of calcareous soils. To minimize the potential for injury to woody plants, 20 pounds per 1,000 square feet should be the maximum amount of sulfur applied at one time.

Turfgrass injury has been reported at rates above 5 pounds per 1,000 square feet. Attempts to acidify large areas of soil with existing landscape plants have generally been unsuccessful. Foliar sprays are especially effective on ericaceous plants, such as rhododendrons, to correct iron deficiencies. Not all plant species, however, respond to foliar-applied micronutrients.

Applications are recommended just prior to or during active shoot growth in the spring, although applications later in the season may also be effective. Response to foliar treatments will vary depending upon the species, age and condition of the plant; time of year; micronutrient applied; and severity of the deficiency.

For best results, the plant should not be suffering from moisture stress, the leaf surfaces should be thoroughly covered and the humidity should be high enough to allow the spray to remain on the leaf in soluble form long enough to be absorbed. Both chelated and inorganic micronutrients are recommended.

Trunk injections and implants are recommended to correct micronutrient deficiencies in trees over 4 inches in diameter which do not respond satisfactorily to soil treatments. For trees which have begun to decline, the best results are usually obtained from trunk treatments in conjunction with soil applications of fertilizer. Once the deficiency has been corrected in the trees, attempts should be made to maintain adequate micronutrient levels in the soil to avoid repeated wounding of the trunks.

Injections or implants should be spaced 4 to 5 inches apart and as low as possible on the trunk. Since the outermost xylem (wood) rings are actively transporting water and dissolved minerals, capsules should be placed or injections made in this area. Capsules or materials which seal the injection hole should be inserted just below the bark tissue to facilitate proper wound closure.

The best results and the most rapid callusing occur when the treatments are made before growth starts in the spring.

In addition to commercially available injection and implant products, micro-nutrients can be injected with the same equipment recommended for Dutch Elm Disease, which is inexpensive and simple to use. For iron-deficient pin oaks, dissolve 1.5 to 2 grams of ferric ammonium citrate in one to two cups of water for each injection. Trees under moisture stress should not be treated with trunk injections or implants.

Companies making tree injection and implant products include Creative Sales Inc. and J.J. Mauget Co.

FERTILIZER/PESTICIDE COMBINATIONS

The use of fertilizer/pesticide combinations has become an accepted practice among most turfgrass managers whether applying fertilizers in a dry or liquid form. In combining both fertilization and pest control in one application, both time and labor savings can be realized.

Fertilizer/pesticide combinations can include herbicides, insecticides and fungicides along with fertilizer. In dry form, a popular combination is a broadleaf herbicide(s) (ie 2,4-D, MCPP) impregnated on fertilizer. To optimize results, the label of dry fertilizer/broadleaf herbicide combinations will frequently recommend making the application following rain or irrigation or when a dew is present. This improves the adherence of the herbicide to the leaf surface of weeds and maximizes absorption.

Two important factors which can reduce the effectiveness of fertilizer/pesticide combinations applied in liquid form are **incompatibilities and alkaline hydrolysis**.

In addition to checking the pesticide(s) label, a wise precaution to tank mixing is to conduct a jar test for the compatibility of the components. **Incompatibilities** can lead to an unstable mixture and/or a chemical reaction between 2 or more tank mix components. These can result in one or more of the following: failure of the equipment to apply the tank mix, poor pest control or turf response, and phytotoxicity.

Alkaline hydrolysis is the degradation of a pesticide due to a high pH (greater than 7.0) of the water used to apply a pesticide. Some common lawn care pesticides which are subject to alkaline hydrolysis include organophosphate insecticides (Dursban, diazinon and Dylox), herbicides (bensulide), carbamate insecticides (Sevin), and certain systemic fungicides such as benomyl.

To determine if alkaline hydrolysis will effect the pesticide application, have the pH of the water source tested by using a pH meter or litmus paper. Should the water prove to be alkaline, check with the manufacturer of the pesticide(s) used for their suggestions on pH correction.

FERTILIZATION OF TURFGRASS

Traditionally, turfgrass managers have applied fertilizer during spring and fall using color and the amount of leaf growth as a guide to the rate and frequency of application.

Although promoting good color and stimulating shoot growth are important objectives, frequently overlooked are nutrient influences on carbohydrate reserves, root growth, and the plant's ability to tolerate disease and environmental stress. An understanding of the impact of fertilizer applications on these factors can give refinement to a fertilization program.

Timing applications

An important objective in timing fertilizer applications should be to build carbohydrate reserves and promote root development. The response of warm-season and cool-season turfgrasses differ in this respect.

The predominant **cool-season** turfgrasses (bluegrass, perennial ryegrass, fescue and bentgrass) initi-

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ate and develop their root system in the early spring and fall. For this reason, **fall** application of nitrogen is paramount to a fertilization program because it will increase carbohydrate reserves and root growth. Fall fertilization will also improve turf density by promoting greater rhizome and tiller growth.

In addition to regular fall fertilization (September-early October) a relatively new concept known as **late fall** or late season fertilization is being included in many maintenance programs. Late fall fertilization is applied when shoot growth slows or approximately at the time of the last regular mowing of the season.

Nitrogen applied at this time greatly enhances the photosynthetic production of carbohydrates. These carbohydrates are stored for use the following growing season, providing earlier spring greenup and an energy source for turfgrasses to recuperate from environmental and mechanical stress.

Another advantage of late fall fertilization is that it reduces the need for high amounts of spring-applied nitrogen. Excessive **spring** fertilization can actually reduce carbohydrate reserves and root development by stimulating rapid shoot growth. This is because growing shoots take priority over roots for carbohydrate utilization.

Both spring and summer fertilization should be used to maintain the color and density produced with fall fertilization the previous year. Fertilization at these times should not produce succulent plant tissue which can increase the severity of turfgrass disease and reduce the plant's ability to withstand heat, drought, mowing or wear stresses.

Applications of **potassium** will greatly contribute to the hardiness of the plant and help to "temper" the stimulating effects of nitrogen applications.

In contrast, most of the root growth in the **warm season** grasses, such as Bermudagrass, zoysiagrass and St. Augustinegrass, occurs during the spring and summer. Fertilization during these periods will stimulate root growth. However, only moderate applications of fertilizer should be made in early spring in areas where warm-season grasses experience winter dormancy.

Bermudagrass and St. Augustinegrass are subject to **spring root dieback** following spring greenup. Heavy fertilization during early spring may result in an additional stress during this critical survival period.

Like cool-season turfgrasses, warm-season turfgrasses accumulate carbohydrate reserves in the fall when shoot growth activity slows. Care must be taken with the timing of fall fertilization since it may decrease low temperature hardiness if applied late. Maintaining adequate potassium levels in fall will increase the tolerance to low temperatures.

As with cool-season turfgrasses, indiscriminate use of nitrogen fertilization in the summer can increase injury of warm-season grass subjected to disease or environmental stress. As mentioned previously, maintaining adequate soil potassium levels will aid warm-season turfgrass in their tolerance of heat, cold, mowing and wear stresses, and reduce their susceptibility to turfgrass diseases.

Rate of fertilization

The annual nitrogen requirement (pounds per 1,000 square feet) for turfgrass should be determined by considering several factors including the length of growing season, level of quality desired, purpose for which the turf is used, and the species and cultivars present .

The **length of growing season** or number of days (months) between the last killing frost in the spring and the first in the fall will vary greatly depending on location within the United States. Along the Gulf of Mexico and in certain areas of Arizona and California, the average growing season is in excess of eight months.

In contrast, northern portions of Maine and Minnesota have as little as three and a half months of growing season. Obviously, the longer the length of growing season, the greater the amount of nitrogen needed to maintain turfgrass quality.

Because the **level of quality** desired is subject to human interpretation, the rate of fertilization can be tailored to meet the expectations of the user. A home lawn maintained for aesthetic purposes, for example, can range from a weed-free turf of acceptable color and density to a season-long turf of premium appearance.

The **purpose** for which the turf is used, whether it be for an aesthetic or recreational function, will also influence the nitrogen fertility level. The rate of fertilization of bentgrass, for instance, can vary from four to ten pounds of nitrogen per 1,000 square feet. Lower rates may be used to provide a pleasing appearance on a home lawn while higher rates may be applied to maximize the playability on the golf course putting green.

Turfgrass species and cultivars can vary in amount of nitrogen required to maximize quality. Within the cool-season grasses, sheeps, hard and red fescues require a low level, Kentucky bluegrass a medium level, and bentgrass a high level of fertility. Improved cultivars of bermudagrass will require more nitrogen than common bermuda.

Cultural practices such as irrigation and clipping removal may require the use of higher annual nitrogen rates to maintain the desired turfgrass quality. Supplemental watering of turfgrasses will increase the rate at which nitrogen is leached from the turfgrass root zone. Losses of nitrogen are substantial particularly

Annual Nitrogen Requirement of Turfgrasses*

Species	Length of Growing Season	Nitrogen per Season lbs./ 1,000 sq. ft.	Variations in Management
Cool-Season:			
sheeps & hard fescue	4- 8	0- 3	low maintenance; roughs
red fescues	4- 8	1- 3	low maintenance to good care
Kentucky bluegrass	5-12	2- 8	lawns, fairways
bentgrasses	4- 8	1- 4	medium care, lawn, fairways
bentgrass, greens	5-12	6-15	clippings removed, forced growth
Warm-Season:			
zoysia	6-10	1- 6	adequate cover
common bermuda	7-12	2- 8	most variable
St. Augustine, Bahia	10-12	2- 8	warm areas, lawns
bermudagrass, fairways and tees	5-12	4- 9	good management
bermudagrass, greens	8-12	8-20	may rest over winter

* Adapted from Turf Managers' Handbook by William H. Daniel and Raymond P. Freeborg, published in 1973 by Harvest Publishing Company, New York, NY.

when quick-release sources of nitrogen are applied to soils high in sand content.

Collection of clippings following mowing has been estimated to remove approximately 20% of the nitrogen applied to turfgrass. Should clippings be routinely removed from turf, as on a golf course green, additional nitrogen should be factored into the yearly total.

Phosphorus and potassium have been routinely applied along with nitrogen using fertilizer with ratios such as 3:1:2, 5:1:2 or 4:1:1. These ratios are based on the relative amounts of nitrogen, phosphorus and potassium found in turfgrass clippings but do not take into consideration the inherent levels found in the soil.

Rather than applying phosphorus and potassium each time nitrogen is applied, there use should be based on a **soil test**. The importance of determining inherent soil levels is exemplified when considering phosphorus application. Since many turfgrass soils contain high levels of phosphorus, little if any response is obtained when phosphorus is applied to established turf.

Two factors to be considered in making individual nitrogen applications are the nitrogen source used and the time of year. Applications using **quick-release** sources of nitrogen are commonly limited to no more then one pound of nitrogen per 1,000 square feet. This rule of thumb is observed in spring and fall to avoid overstimulating shoot growth. Likewise, summer fertilizer applications using quick-release sources are frequently limited to no more than one-half pound of nitrogen per 1,000 square feet. Lower rates of quick-release nitrogen sources will also minimize the potential to cause fertilizer burn.

In contrast, applications of nitrogen using **controlled-release** sources are generally made at rates from one to three pounds of nitrogen per 1,000 square feet. The longer residual of controlled-release nitrogen sources reduces the need for more frequent applications required when using quick-release sources. The need for less frequent applications is particularly desirable for turfgrass managers with labor and time restraints.

Method of application

Fertilizers can be applied in either dry or liquid forms. The choice of using either dry or liquid application equipment has been the subject of great controversy particularly in the lawn care industry.

Research has shown, however, that turf response is equal regardless of the method of application when considering a source of nitrogen such as urea. The choice of application method, then, may be decided on the turf manager's perception of productivity and personal preference.

Two types of spreaders are used to apply **granular** (dry) fertilizers; the gravity and the centrifugal. With the **gravity** (or drop) spreader, fertilizer is held in a trough and is agitated by a mixing bar connected to the wheels. The fertilizer is dropped by gravity through a series of slots to the turf below. The gravity spreader applies a defined swath of fertilizer which can avoid waste in confined turf areas.

The **centrifugal** (or broadcast) type of spreader is commonly used by commercial turf managers because the centrifugal applies a wider swath of fertilizer and can treat large areas more quickly than with the gravity spreader. The centrifugal spreader features a hopper from which the fertilizer falls from a hole (or series of holes) onto a spinning disk which propels fertilizer ahead and to the sides of the spreader.

With a liquid application method, fertilizer is either solubilized or suspended in water and sprayed on the turf. The amount of water used normally varies from 1 to 5 gallons per 1,000 square feet.

The equipment used to make **liquid** applications of fertilizer can be broadly classified into either low-pressure spray booms or high-pressure or hydraulic sprayers. Both types of sprayers feature a tank for holding the fertilizer and water, pump to build pressure so as to force the liquid from the tank to the nozzle, pressure regulator to keep the pressure at the level desired, strainers or screens to keep solids from clogging the pump (or nozzle), and nozzle(s) which deliver the spray to the turf in a particular pattern.

Low-pressure spray booms, as the name implies, are operated at low pressures, generally in the range of 15-60 pounds per square inch (psi) and deliver one gallon or less per 1,000 square feet of spray.

Low-pressure spray booms are designed to be driven over large areas delivering the spray from a series of nozzles in distinct swaths. This type of sprayer has been popularized by golf course superintendents who use it for making liquid applications to golf course fairways.

High-pressure sprayers can create spray pressure of several hundred pounds or more and use a hose and hand-held nozzle for directed applications of the spray. This type of spraying system is used by those companies in the lawn care industry who apply fertilizers using a liquid application technique.

FERTILIZATION OF TREES AND SHRUBS

Landscape trees and shrubs are often grown out of their native habitat and are subject to adverse soil and environmental conditions. Compacted soils, poor drainage, restricted root areas as well as highway salts, air pollutants and competition from turfgrass contribute to plant stress and increase the importance of regular fertilization to maintain healthy growth.

Vigorous, well-maintained trees are more resistant to many insect and disease pests, are more attractive, and are a greater asset to properties.

When trees are fertilized, only nitrogen, phosphorus and potassium are normally applied. However, supplemental micronutrients such as iron and manganese may be necessary for certain species growing in alkaline soils.

Plants generally respond to applications of nitrogen often with dramatic improvements in shoot growth and leaf color. Because of nitrogen's transitory nature in soils and the large amount extracted by plants, soil analysis is not particularly useful. Heavy applications of nitrogen alone may stimulate shoot growth more than root growth, disturbing the natural root:shoot ratio.

The need for supplemental phosphorus and potassium is more difficult to determine than for nitrogen since phosphorus and potassium normally do not produce a noticeable, visible response except on young or newly transplanted trees and shrubs. In addition, results from field studies have been inconsistent because of differences in soil, the age, condition and location of test species, and the timing and method of application.

Where reliable soil tests are not available for phosphorus and potassium, most arborists fertilize all trees and shrubs with a complete fertilizer. Since arborists are concerned with the health of individual trees and shrubs growing in a wide variety of soil conditions, the most practical approach to fertilization is to provide an effective fertilizer formulation for trees and shrubs within a market area.

Specific soil/plant deficiencies may be addressed, if necessary, on an individual basis. In most cases, a **3:1:1** or similar ratio is satisfactory for landscape plants although additional potassium and/or micronutrients may be advisable in sandy soils.

Additional micronutrients may also be necessary in alkaline soils particularly for ericaceous or other so-called "acid-loving" plants.

Iron deficiency chlorosis is common on oaks, rhododendron and pine grown on alkaline soils and has been reported on sweet gum, ginko and birch as well as many other woody ornamentals. **Manganese deficiency chlorosis**, also induced by alkaline soils, is a common problem with maples.

Application rates

Most fertilizer recommendations are based on the number of square feet in the **growing area** for shrub beds or the **branch spread** for individual trees and shrubs.

Fertilizer recommendations based on trunk diameter can result in over-fertilization and damage to plants if the root system is restricted by paved areas, foundation walls, or other obstructions in the soil.

Three pounds of actual nitrogen per 1,000 square feet per year or six pounds every other year is satisfactory to maintain the health and vigor of deciduous trees and shrubs. If leaf color, annual growth or general vigor is unacceptable, six pounds of nitrogen per 1,000 square feet may be applied annually.

Broadleaf evergreens, small shrubs, flowering trees and recently transplanted or declining trees are more sensitive to fertilizer salts and should receive only about one-half the recommended rate, particularly when quick-release fertilizers are applied. The risk of injury to sensitive plants may be reduced by splitting the recommended amount into two or more applications.

The amount of fertilizer to be applied per 1,000 square feet of root areas can be calculated by dividing the percent nitrogen on the fertilizer bag into the desired nitrogen per 1,000 square feet. For example, to determine the amount of 30-1-10 fertilizer required to apply six pounds of nitrogen per 1,000 square feet, divide .30

into 6, which equals 20 pounds (.30/6 = 20).

Application timing

Although the roots of woody plants may elongate throughout the growing season, active root growth most often occurs in early spring and late fall when soil temperatures are relatively cool and there is little competition from leaves for water and nutrients.

Fertilization is most effective when supplemental nutrients are available during these periods of optimum root growth. Soluble nitrogen fertilizers, because of their short residual in soils, should be applied between October and December and/or between February and April. Controlled-release nitrogen ensures availability in the root zone for a relatively long period, depending upon the solubility of the nitrogen source. The application timing of these fertilizers may not be a major concern.

Application techniques

Supplemental nutrients can be supplied to landscape plants through foliar sprays, trunk injections or applications on or beneath the soil surface. Though each method has advantages in specific situations, woody plants in most cases respond best to soil applications.

Surface applications—Nitrogen fertilizers can be applied to the soil surface since nitrates are highly mobile in soil solution and will move downward into the root zone. However, since turfgrasses within the application zone may be injured or respond with undesirable succulent growth, trees and shrubs in quality lawns normally are fertilized with subsurface applications, either placed in vertical holes or injected below the soil surface.

When fertilizing woody plants in sodded areas, surface application should be limited to no more than three pounds of nitrogen per 1,000 square feet from a controlled-release source.

Fertilizer containing phosphorus should not be applied to the soil surface. Phosphorus is bound tightly to soil particles and does not move downward to contact the absorbing roots. Surface applications of phosphorus may also stimulate annual bluegrass which is undesirable in home lawns.

Drill hole technique—Fertilizer can be placed in the root zone by drilling holes in the ground and dividing the recommended amount of fertilizer equally among the holes. For trees, the holes should be drilled 12-18 inches deep and 18-24 inches apart, beginning 2 to 3 feet from the trunk and extending two to three feet beyond the drip line.

To prevent turfgrass injury, the fertilizer level should be at least 4 inches below the soil surface. Calcined clay, perlite or other soil amendments can be used to fill the top of the hole or, in quality lawns, a plug of grass can be removed before drilling and replaced after adding fertilizer.

Soil Injection—Liquid soil injection is a fast, economical alternative to the drill hole technique for applying nutrients within the root zone. The injection equipment consists of a hydraulic sprayer operated at 150-200 psi and an injector probe that inserts about 12 inches into the soil. The injections are normally in a grid pattern about 3 feet apart within and slightly beyond the tree canopy.

Soil injection provides more thorough nutrient distribution than the vertical hole technique and generally can be done in about one-fourth the time. Unfortunately, most soluble fertilizers have a relatively high burn potential and soluble nitrogen may be rapidly leached from the root zone. The actual amount of soluble fertilizer applied is often less than one pound nitrogen per 1,000 square feet because of factors such as drought and decline which increase the sensitivity of plants to fertilizer salts.

After application, soluble nitrogen may remain in the root zone for as little as six weeks, further reducing the amount of nitrogen available for absorption.

Because of the limitations of liquid soluble fertilizers, suspension fertilizers are rapidly gaining acceptance for soil injection. Ureaformaldehyde is particularly effective as a controlled-release nitrogen source in spraying systems since the release rate is not greatly affected by particle size. Suspended in water, powdered ureaformaldehyde can be injected into the soil and dispersed laterally by hydraulic pressure.

At least 60% of the total nitrogen in ureaformaldehyde is water insoluble and becomes available over a one- to two-year period. Since the nitrogen salts are released gradually as the compounds degrade, ureaformaldehyde has a significantly lower burn potential than soluble nitrogen sources and can safely supply the recommended annual rate of three to six pounds of nitrogen per 1,000 square feet in a single application.

Soluble methylol and methylene ureas recently been introduced have a lower burn potential than urea or other soluble nitrogen sources. But their release characteristics and usefulness in tree care have yet to be determined.

Other methods

- The aero-fertil technique injects dry fertilizer by blasts of air into holes which have been previously drilled in the soil. This method is similar to drill hole application and provides additional aeration by fracturing heavy or compacted soils.
- Fertilizer stakes or spikes are driven into the ground at intervals beneath the drip line of trees and shrubs. Although they contain satisfactory

fertilizer materials, spikes are expensive and not as effective as other fertilization methods. One or two spikes per inch of trunk diameter provide only a small amount of fertilizer, very little of which comes in contact with the root system since very little lateral distribution occurs within the root zone of most soils.

Foliage sprays and trunk injections and implants can supply a limited amount of nutrients to woody plants and are recommended for micronutrients whose availability is reduced by alkaline soil conditions. These methods are most effective when a single micronutrient is deficient.

FERTILIZATION OF TREES AND SHRUBS IN CONTAINERS

The growing of trees and shrubs in landscape containers is becoming more common in locations where plants are desirable but suitable planting sites are limited.

Container-grown plants need more careful attention to maintain proper growth than landscape plants because the reservoir of available growing media, minerals and water is much smaller. In addition, the shallowness of many containers often results in soil conditions that are too wet and poorly aerated for plant growth, particularly when the soil has not been properly prepared.

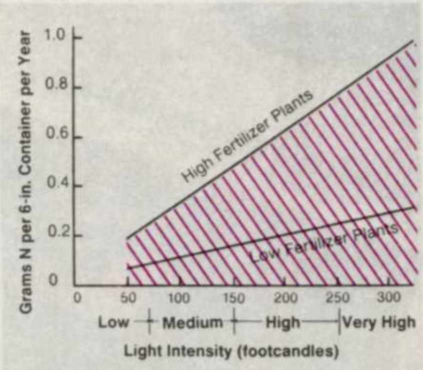
Container soils are subject to excessive leaching and require that a regular fertilization program be followed. In general, recommended **fertilizer rates** for landscape plants based on square footage have been successful in maintaining container-grown plants.

A complete fertilizer applied at an annual rate of 0.5 to 1 ounce of nitrogen per 10 square feet of container soil surface is commonly used. However, because of the wide selection in plant material, and variations in container design and growing media, fertilizer requirements are best determined through soil and tissue analysis.

Container fertilization includes dry, foliar and liquid application. Each may be used successfully with proper management. As with landscape plants, **foliar applications** are usually limited to micronutrients. Foliar fertilization should be considered where soil conditions may inhibit root absorption or where a quick response is desirable. Care should be taken to contain the spray since some micronutrient sources have staining properties.

Dry fertilizers may be applied effectively either in controlled-release or quick-release form. High analysis fertilizers may be difficult to evenly distribute because of the small amount required per container. Liquid applications of soluble or suspension fertilizers provide a uniform dosage and fast and easy distribution. Soluble fertilizers, however, will require more frequent applications due to the ease with which these materials may be leached from container media.

Suggested Fertilizer Rates for Plants in Interior Landscapes



FERTILIZING INTERIOR PLANTS

During the production phase, foliage plants are encouraged to grow as quickly as possible, utilizing considerable quantities of nutrients. These same plants grown indoors, however, are normally subjected to much lower light levels, and neither require nor will tolerate the levels of fertilizer typical in production.

Precise fertilizer requirements are difficult to predict in interiorscape maintenance without measuring the **light intensity** at strategic locations. The light level can vary significantly from one side of a room to another side, often within a distance of a few feet. In general, the stronger the light under which foliage plants are growing, the greater the amount of nutrients needed to meet the requirements for growth.

Recommended annual fertilizer rates can vary from as low as 0.3 grams of nitrogen per square foot for low light intensities to 3.0 grams of nitrogen per square foot for very high intensities.

A complete fertilizer with a nitrogen:phosphorus:potassium ratio similar to those recommended for landscape plants is suitable for indoor plants. The highest levels of nutrients should be coordinated with optimum growth periods. For most plants, this is during the spring and summer months, especially when natural light is the primary light source.

Micronutrients are seldom recommended but may be necessary when growing sensitive plants in soilless media. The rubber plant (*Ficus elastica* 'Decora') and the Areca palm (*Chrysalidacarpus lutescens*) are both sensitive to boron deficiency. In addition, the Areca palm reportedly is sensitive to zinc deficiency.

Care must be taken when applying micronutrients. Overapplications can quickly cause toxicity problems.

In addition to light levels, the proper amount of nutrients is determined by **plant species**. Plants which normally are grown under low levels of fertility include many ferns and fleshy plants such as Peperomia. High nutrient-requiring plants include rapid growing species and large-leaved plants such as Ficus and Schefflera.

A build up of salts, both from fertilizer and irrigation water, is possible unless the root area is periodically flushed with excess water which is allowed to drain away. This is particularly true when plants are over-fertilized during periods of low light and/or little growth.

Since visual symptoms such as stem rot and leaf necrosis in new growth are similar to those of over-watering, the soluble salts of the soil should be tested for confirmation.

Circle the number on the reader information card for more information on fertilizer products mentioned in this article

Company	Reader Service Number
American Pelletizing Corp	190
The Andersons. (Tee-Time)	191
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