Fertilization of Container-Grown Nursery Stock
Michigan State University Extension Service
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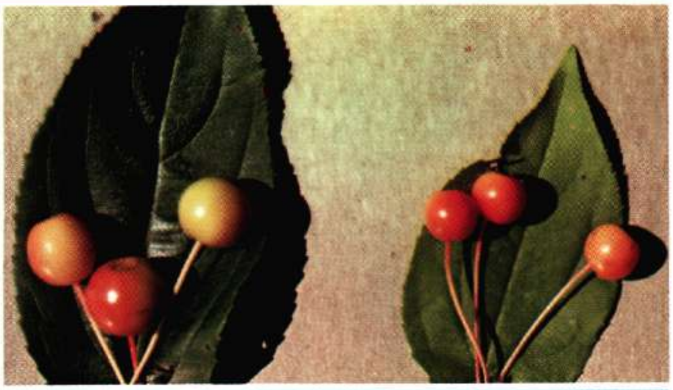
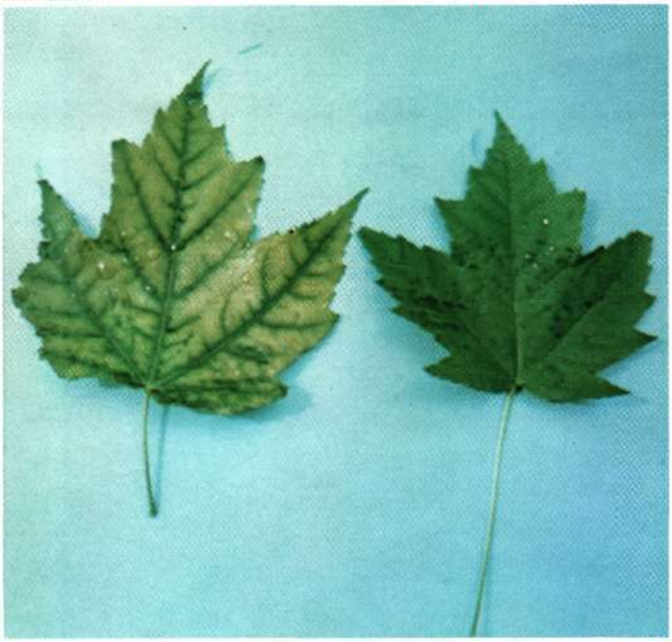
Cooperative Extension Service
The Ohio State University

ESSENTIAL ELEMENT DISORDERS





Sweet Gum
Top — Iron Treated; Bottom — Untreated

See back cover for more photos.

Top
Flowering Crabapple
Left-Nitrogen Treated; Right-Nitrogen Deficiency

Bottom
Manganese Deficiency on Leaves of Red Maple
Left — Untreated; Right — Treated

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Front Cover Photo: Iron Deficiency in Rhododendron

FERTILIZATION OF CONTAINER-GROWN NURSERY STOCK

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Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Roy M. Kottman, Director of the Cooperative Extension Service, The Ohio State University.

INTRODUCTION

Nursery stock production is rapidly escalating throughout the United States. Nursery producers in the north are increasing production without increasing the actual acreage due to increased production of container plants on acreage formerly in field production.

With container plant production, there are many questions concerning fertilization including: When to apply fertilizer? How much fertilizer should be applied? What type of fertilizer is preferred? How should the nutritional program be evaluated?

Currently available data on fertilization of container grown nursery stock has been compiled in this publication to assist nurseymen in improving their fertilization program. Recommendations for fertilizing plants in field nurseries and in the landscape are available in Bulletin 650 titled, "Fertilizing Landscape and Field Grown Nursery Crops."

MEDIA

Container nutrition is directly related to the physical and chemical characteristics of the medium in which the plant is grown. Numerous articles are available on the desirable characteristics of a good potting medium; therefore, only the characteristics affecting nutrition will be discussed in this bulletin.

CHEMICAL PROPERTIES

Cation Exchange Capacity

One chemical characteristic of a medium that directly affects container nutrition is cation exchange capacity (CEC); or the nutrient holding capacity. The CEC is the ability of a negatively charged particle to hold positively charged ions: potassium, ammonium, calcium, magnesium and others. Since the reserve capacity of a container is limited with respect to volume, the availability of nutrients to the plant is dependent upon the frequency of fertilization and the CEC. A medium with a high CEC requires less frequent application of fertilizer than a medium with a low CEC. Leaching of negatively charged nutrients (anions) is also greater where the medium has a low cation exchange capacity. Cation exchange capacity is expressed on soil test reports as milligram equivalents per 100 grams of medium or meq/100 g.

Carbon/nitrogen Ratio

Another chemical characteristic that affects container nutrition is the carbon/nitrogen (C/N) ratio of the potting mix and its effect on nitrogen availability. Fresh hardwood bark has a C/N ratio of 150/1; if plants are grown in these media, applied nitrogen is "tied-up" in the medium. However, after composting for 3-6 months, the C/N ratio declines to approximately 40/1, and nitrogen "tie-up" is almost eliminated. Pine bark when used fresh has a C/N ratio of 300/1; however, research has shown little difference in nitrogen utilization between composted and non-composted pine bark. Presently, composting of pine bark is not recommended. In recent tests, plants grown in non-composted pine bark grew best at 150 ppm nitrogen while similar plants grown in composted hardwood bark grew best at 300 ppm nitrogen. Knowledge of the C/N ratio and its effect on nitrogen utilization are necessary for proper management of container-nutrition.

Composting Procedure

The following procedure for composting of hardwood bark is suggested:

- ▶ Locate a reliable source of hammermilled bark with particles ¾ inch or smaller.
- ▶ Keep wood content (including sawdust) as low as possible.
- ▶ Add nitrogen — 6 pounds of ammonia nitrate per yd^3; phosphorus - 2½ pounds per yd^3 of treble superphosphate; sulfur - 1 pound per yd^3; iron sulfate - 1 pound/ yd^3.
- ▶ Add water to reach a moisture level of 60 to 70%.
- ▶ Mix with a shredder, modified manure spreader, rotating drum or other suitable equipment.
- ▶ Stockpile in windrows (6 ft. high x 8 to 10 ft. wide) and turn every 4 weeks to expose all parts to high rates of decomposition. Continue this process for 2 to 3 months.
  Add water if necessary.
- ▶ Provide adequate drainage to avoid free water in the bottom of windrows.
- ▶ After the pH is lower than 6.8 to 7.2 and soluble salts are in a safe range (2 months during summer and 3 months during winter conditions) the compost is ready for use even though temperatures may still be above 100°F.
- ▶ composted bark can be stored for 1 year without a significant loss in particle size distribution.
- ▶ To prepare container media, add peat, sand, perlite or other aggregates to adjust bulk density, cation exchange capacity and soil moisture characteristics to optimum levels for each crop. Do not use high pH peat or muck. Peat and other additives, including lime (only if peat is added), may be added before composting to yield a "pathogen free" medium.
- ▶ In practice, Canadian peat does not need to be sterilized (even though it contains low levels of watermolds) if added to hardwood bark after composting.

Optimum plant growth is not the result of using an "ideal" medium, but proper management of the medium that best fits your system. Almost any media with proper management can produce quality plants. Generally, when a grower has poor results with a particular medium, the management system is at fault and not the medium.

pH

The pH of a medium also influences the nutrition of container-grown crops. Most crops can be grown over a wide range of pH values as long as a proper balance of nutrients is provided. Nutrient availability is directly related to pH. In mineral soil the optimum pH for nutrient availability is 6.0 to 7.0; however, in an organic potting media the optimal pH for nutrient availability is in the range pH 5.0 to 6.0, Fig. 1. The pH of the medium should be adjusted prior to potting. If the medium pH is lower than the desired range, an application of 6 to 8 pounds per cubic yard of either limestone (calcium carbonate), dolomite or dolomitic limestone (calcium magnesium carbonate) is suggested. The finer the particles applied, the faster the rate of reaction occurs. Also, limewater prepared with 1 pound of hydrated lime per 100 gallons of water, can be used to raise the pH after planting. When using limewater, stir, allow to settle and apply the resultant solution. Nitrogen fertilizers should not be applied within 7 days of liming because subsequent chemical reactions result in the gaseous loss of ammonia.

Lowering the medium pH is necessary occasionally. This may be accomplished with either sulfur or iron sulfate. When lowering the media pH prior to planting, sulfur or iron sulfate should be used at approximately one pound per yd^3. When sulfur is used, the complete lowering of the pH will not occur for about 6 weeks. Iron sulfate is a fast acting compound and is used at the rate of 1 ounce per 2 gallons of water as a post-plant treatment. Allow about 1 to 2 weeks for acidification to occur. Repeated applications may be necessary, depending on the desired pH.

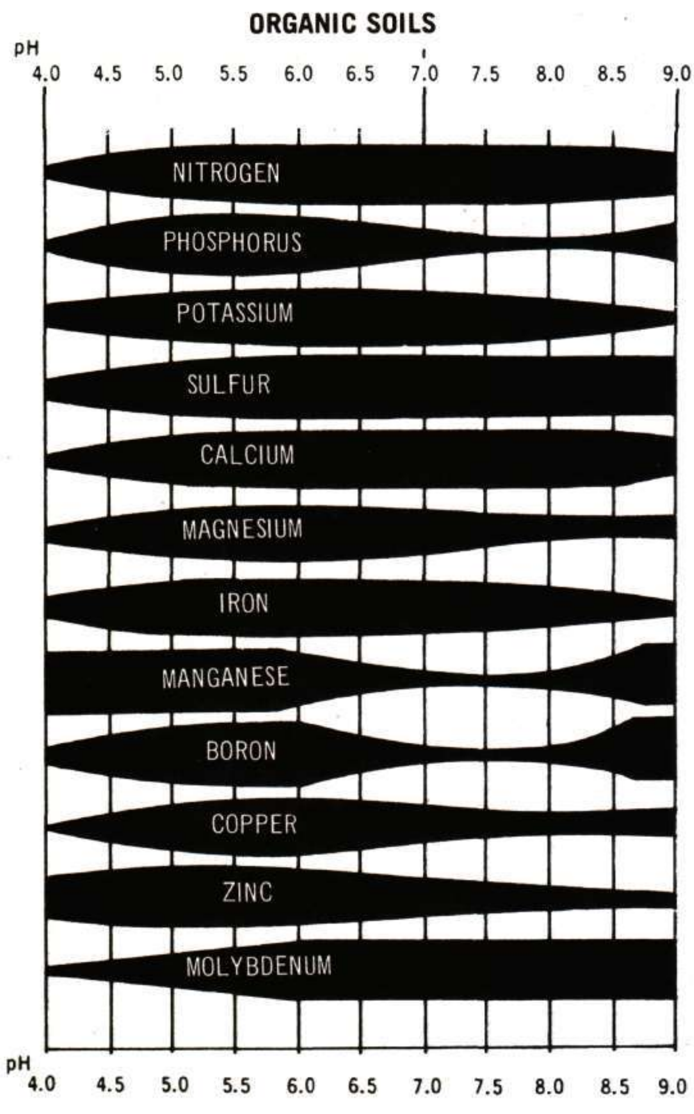


Fig 1: Relative availability of essential elements at different pH levels for an organic medium.

If the water supply has a high pH, there are several methods to lower the pH. These methods include: ion exchange columns, acid neutralization and use of acidifying fertilizers. The use of an ion exchange column is too costly, except in cases where small volumes of water are required. For example, an ion exchange column may be economical in the propagation house where there is high intensity production per unit of space. Acid neutralization of the irrigation water with phosphoric acid is a relatively safe and economical method of reducing pH. It is important to use a food grade phosphoric acid, because other grades of phosphoric acid may contain toxic levels of arsenic. Phosphoric acid is generally applied at the rate of 1 ounce per 100 gallons, which supplies about 30 ppm phosphorus, depending on purity of the acid. The third method of reducing pH of the irrigation water is use of acidifying fertilizers. Ammonium sulfate and ammonium nitrate are the most widely used acidifying fertilizers. Generally, any ammonium based fertilizer will result in increased acidification. The amount of acidification obtained with ammonium fertilizers depends on the rate, frequency of application, water pH and compounds present in the water.

Physical Properties

The physical characteristics of container media also affect the nutrition program. Drainage and water holding capacity are two physical properties that affect container nutrition. It is generally recommended that a container medium has about 20 to 25% air filled pore space at field capacity. Water-logged conditions may cause damage to the roots, reduce growth and result in eventual death of the plant. Growers may determine the percent aeration of their medium, using the following procedure.

1. Slowly add water to a container that has drainage holes plugged until the top of the medium glistens with water. No free water should be standing. Slow wetting of the medium avoids the trapping of air in the medium.
2. After water is glistening on the surface, weigh the container and its contents, either in ounces or grams. Call this weight, W_1.
3. After weighing, remove the drainage plugs from the container and allow it to drain about 4 hours.
4. After 4 hours, reweigh the container with drainage plugs. Call this weight, W_2; ounces or grams.
5. Determine the volume of medium in the container. One way of determining the volume is as follows: Estimate the soil line on a clean container, same size as used above, plug the drainage holes and fill with water and weigh. Call this weight W_3. Empty water from the container and reweigh with drain plugs. Call this weight W_4, ounces or grams.
6. Compute the percent air filled pore space by dividing the loss in weight (W_1 - W_2) by the volume (W_3 - W_4), and multiply by 100.

EXAMPLE: (a) Weight of saturated 2 gallon container of Rhododendron and bucket = 51 grams (W_1).
(b) Weight of container and bucket after draining 4 hours - 4300 grams (W_2).
(c) Weight of drained water = 800 grams (W_1-W_2).
(d) Weight of container plus water up to the soil line = 5250 grams (W_3).
(e) Weight of container without water = 600 grams (W_4).
(f) Divide drained weight (800 grams) by volume (4650 = W_3-W_4) 800 ÷ 4650 = .17. Multiply by 100 for percent air-filled pore space of 17%.

ROLE OF ESSENTIAL ELEMENTS

Nitrogen

Nitrogen is the mineral element needed in the greatest quantities by the plant. It forms between 1.5 and 4 percent of the dry weight of the average woody plant. It is an essential component of chlorophyll, the green pigment involved in photosynthesis. Nitrogen also occurs in amino acids, proteins, enzymes and other important compounds in the plant.

When nitrogen is deficient, plants are usually tall and spindly with the older leaves turning to a pale yellow color as the available nitrogen is transported to the newer foliage. Nitrogen utilized in new growth is derived primarily from storage nitrogen in the tissue. Consequently , deficiency symptoms for nitrogen appear on the older leaves first.

Nitrogen is utilized by the plant in two forms: ammonium (NH_4+) or nitrate (NO_3-). Generally, there is no preference by woody plants for one or the other; however, with specific plant species there are exceptions. Ericaceous plants such as azaleas are good examples of plants that respond better to ammonium than nitrate. This beneficial response to ammonium fertilization is associated with decreased pH of the plant tissue; however, when nitrates are used as the N source pH increases, which inactivates iron in the leaves.

When using liquid fertilization, ammonium toxicity may be a problem during the winter. During the winter, the rate of photosynthesis is lower, and ammonium nitrogen combines rapidly with carbohydrates in the roots, leading to a depletion of carbohydrates. Ammonium nitrogen accumulates within the plant and is toxic in small concentrations. ammonium toxicity may be more pronounced on seedlings where the carbohydrate reserve is limited. Nitrate-nitrogen is safer to apply during the winter months, when conditions are conducive for ammonium toxicity.

When the medium pH is above 7.0, free ammonia (NH_3+) can occur. As the pH increases, the concentration of free ammonia increases rapidly. Ammonia is then free to enter the root cells where ammonia toxicity occurs at very low levels. For this reason, nitrogen fertilizers should not be applied within 10 days after the addition of lime.

Medium pH is influenced by the form of nitrogen applied. For example, use of ammonium fertilizer results in a lower pH, while use of nitrate nitrogen results in a pH increase, at least initially.

Once nitrogen is applied to the media, several reactions may occur other than plant uptake (Fig. 2).

It is important for nurserymen to be aware of the various fates of applied nitrogen. Denitrification, for example, occurs primarily under anaerobic conditions such as flooding. Thus, if container material is subject to poor drainage or localized flooding conditions, nitrogen losses may occur. Leaching losses of nitrates may be extensive in containers. This is especially true during the summer when plants are watered almost daily and replenishment of nutrients is necessary. Nitrogen immobilization may occur if mineral nitrogen is converted into organic nitrogen by micro-organisms within the medium.

Phosphorus

Phosphorus is a component of nucleic acids and sugars and is essential for many of the energy transfer processes in the plant. Phosphorus deficiency is often evidenced by small dark-green leaves with a purple or bronze tinge.

Phosphorus is commonly applied as triple (treble) superphosphate. This fertilizer contains about 3 times as much phosphorus as does single (ordinary) superphosphate. Phosphoric acid may be used by growers who have liquid feed programs to add phosphorus or to lower the pH of their irrigation water. Proper equipment selection is necessary to avoid corrosion by the acid.

Some slow release forms of phosphorus are available, the most common being magnesium ammonium phosphate sold as Mag-Amp. The rate of availability of Mag-Amp is dependent upon the size of the granule. Mag-Amp should be considered as a phosphorus fertilizer rather than as a nitrogen fertilizer.

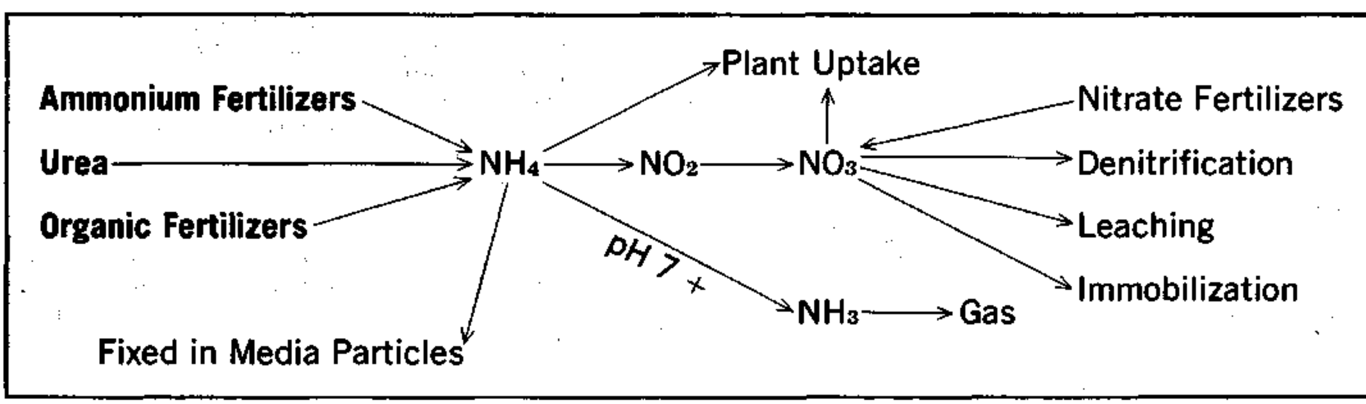


Fig. 2: Nitrogen transformations that occur in media.

Potassium

Potassium is necessary for enzyme formation and proper water balance within the plant. Deficiency symptoms appear as partial chlorosis of the most recently matured leaves in the interveined area, beginning at the tips; followed by necrosis. Relatively few chemicals are suitable for use as potassium supplying fertilizers. Potassium is commonly applied as potassium sulfate (K_2SO_4), potassium chloride (KCL) or potassium nitrate (KNO_3). Generally, these fertilizers are safe to apply; however, when potassium chloride is applied in large quantities, chloride toxicity is a possibility. Also, potassium chloride has a salt index of 116, and when used, soluble salts should be closely monitored.

Calcium

Calcium is required by the plant for the formation of calcium pectate, which is found in the cell wall. Deficiency symptoms are expressed as stunting of plant growth, leaf curling, death of growing points and restriction of root growth. New leaves may be yellowish-green in color. Because calcium is a non-mobile nutrient element, it accumulates in the older tissue first.

In addition to its function within the plant, calcium is important to plant growth because of its effect on pH and availability of other nutrients. Also, calcium has been shown to reduce toxicity damage from a number of other nutrient elements when they are applied in excess.

Common forms of calcium are hydrated lime, ground limestone and gypsum. Hydrated lime is water soluble and fast acting within the medium. The speed of reaction of ground limestone is determined by the particle size; the smaller the particle, the faster its effect. Gypsum is used whenever it is desirable to add calcium without affecting the pH; only under extreme acid conditions will gypsum raise the pH.

Magnesium

This element is a component of the chlorophyll molecule and a deficiency leads to a reduction in the rate of photosynthesis. Magnesium is transported within the plant from older leaves to younger leaves, resulting in deficiency symptoms first appearing on the older leaves. The symptoms include a yellow-green interveinal chlorosis. In the early stages of magnesium deficiency, irregular areas of interveinal chlorosis develop. These areas may enlarge and merge to cover all interveinal areas as the deficiency advances.

Two compounds are generally used to provide magnesium to the growing medium: Epsom salts (magnesium sulfate) and dolomite or dolomitic limestone. For growing plants, Epsom salts can be applied in the injection water at the rate of 2 pounds per 100 gallons. Do not mix Epsom salts with other nutrients because precipitation may occur. For the preplant media, dolomite is generally used to supply magnesium. Dolomite is composed primarily of calcium and magnesium carbonates in nearly equal proportions. Dolomitic limestone contains at least 50 percent dolomite, the rest being calcium carbonate. If dolomite is unavailable for the preplant mix, dolomitic limestone should be used.

Sulfur

Sulfur, another macroelement, is generally available as impurities in fertilizers and is seldom deficient in woody plants.

Micronutrients

Micronutrients are elements required in very small amounts; however, they are just as important to plant growth as any of the macronutrients. Generally, plants cannot tolerate high levels of micronutrients. Toxicities with micronutrients present as many problems as do micronutrient deficiencies. In an organic medium, both micro and macronutrients are most available around a pH of 5.0 to 5.5; this is 1 to 1.5 pH units lower than the optimal value for mineral soils. As the pH increases, micronutrients availability decreases, with the exception of molybdenum.

Iron

In woody plants, iron deficiency occurs more commonly than other micronutrient deficiencies. Iron is essential for chlorophyll synthesis, functions in photosynthesis, NO_3- and NO_2- reductions and in nitrogen fixation. Deficiency symptoms are expressed as a yellowing of the new foliage, which may eventually turn cream-colored, then almost white. Usually there is a sharp distinction between the chlorotic interveinal area and the green veins.

Iron deficiency may be caused by a number of different factors other than low iron supply. High levels of phosphates, heavy metals and nitrates may contribute to iron deficiency. Over watering, or poor aeration and high calcium carbonate or bicarbonate levels may contribute to iron deficiency until new roots are regenerated.

When iron is low and pH is high, iron sulfate may be applied at the rate of 3 pounds per 100 gallons. If the pH is in the correct range 5.0 to 6.0, chelated iron can be used to supply iron without any change in the pH of the medium. Iron chelate can be applied through injection equipment while iron sulfate cannot be applied in the injection system. For the preplant medium mix there are several commercially available sources of slow release iron.

Manganese

Manganese is essential for chlorophyll formation and is present in high concentrations in chlorophyll containing tissues. Deficiency symptoms are similar to iron deficiency except that a gradual gradation of chlorotic tissue to the green veins is present instead of the sharp distinction in iron deficiency. Deficiency of manganese can be corrected by the addition of chelated manganese or manganese sulfate. Manganese toxicity can be relieved by the addition of chelated iron.

Boron

Low boron levels are expressed as chlorosis of the new growth, since boron functions in chlorophyll formation. Also, the terminal growth may die and the resultant lateral growth has sparse foliage. The leaves may be small, thick, misshapen and brittle.

A deficiency of boron can be eliminated by the application of Borateen, Solubor, or Twenty Mule Team

Borax. These materials can be applied in the liquid feed system.

Recently, boron toxicity has been reported on Taxus. Symptoms of boron toxicity are first seen as necrosis around the edges of the leaves or on the tips of narrow leaf evergreens.

Zinc

Zinc is required in the plant for maintenance of auxin in an active state. A deficiency results in failure of the internodes to elongate with plants often being described as "little-leaf" or "rosetted." Zinc chloride or zinc sulfate can be used to overcome zinc deficiency.

Molybdenum

Molybdenum is required for the reduction of nitrate nitrogen within the plant before nitrogen can be used by the plant. One to five ppm Molybdenum is satisfactory for growth of most woody plants, and frequently healthy plants may have less than one ppm Molybdenum in the tissue.

Copper

Copper is a component of several enzymes involved in respiration and oxidation reduction reactions. While copper deficiency is seldom reported with ornamentals, copper toxicity may be more likely to occur. Symptoms are usually expressed as interveinal chlorosis and stunting of new growth.

Chloride

Chloride is involved in photosynthesis and is required in minute amounts by plants. Chloride toxicity is a much greater concern than deficiency, and is expressed as scorching of the leaves and premature defoliation.

Deficiency Symptoms

Deficiency symptoms are important to nurserymen to aid in identifying mineral element shortages; however, more evidence is usually needed to determine the specific element that is deficient. For example, similar symptoms may result from deficiencies of different elements such as nitrogen and sulfur which cause the same general symptoms on plants. Yet, knowledge of deficiency symptoms allows the grower to narrow the range of elements that are lacking.

Other problems may be associated with the reliance on deficiency symptoms alone to pinpoint the deficiency of a particular element. For example, the concentration of a particular element may be present in amounts that prevent visible deficiency symptoms, yet the deficiency can be severe enough to reduce yields. Another problem with use of deficiency symptoms to pinpoint deficient elements involves multiple deficiencies. When multiple deficiencies are present, it is almost impossible to determine a particular deficiency. The use of deficiency symtoms in diagnosis is further complicated by conditions that are not nutrient related, but may be mistaken for deficiencies. For example, bacteria and virus infections may cause symptoms that look like the deficiency symptom of a particular nutrient element. Overwatering or high soluble salts may induce similar symptoms. Root damage, regardless of the cause, may be expressed as deficiency symptoms.

General symptoms are presented in Table 1 for deficiencies of individual elements on woody plants.

Table 1: Nutrient Element Deficiency Symptoms Of Woody Plants

Elements	Symptoms
Nitrogen (N)	Small, pale young leaves. Uniform yellowing beginning with older leaves. Leaf abscission of older leaves may occur.
Phosphorus (P)	Small, dark-green leaves with bronze to purple tinge.
Potassium (K)	Partial chlorosis of most recently matured leaves in interveinal area beginning at tips, followed by necrosis.
Magnesium (Mg)	Marginal chlorosis on older leaves, then interveinal chlorosis.
Calcium (Ca)	Death of terminal buds, tip dieback, chlorosis of young leaves, root injury first apparent sign.
Sulfur (S)	Uniform chlorosis of new leaves. Older leaves usually are not affected.
Iron (Fe)	Interveinal chlorosis of young leaves (sharp distinction between green veins and yellow tissue between veins).
Manganese (Mn)	Interveinal chlorosis beginning at margins and progressing toward midribs, followed by necrotic spots between the veins.
Zinc (Zn)	Whorls of small, stiff and mottled leaves near the tip of current seasons growth.
Boron (B)	Terminal growth dies; lateral growth that develops has sparse foliage. Leaves are small, thick, misshapen and brittle.
Copper (Cu)	Terminal growth dies, preceded by rosetting. Leaf symptoms are not usually pronounced as with Fe, Zn or Mn. Veins lighter than blades.
Molybdenum (Mo)	Leaves show cupping, interveinal chlorosis preceded by marginal chlorosis.

To assist in determing specific nutrient deficiencies, refer to the following key. By combining results from using the key to nutrient deficiencies with soil and foliar analysis, one should be able to identify deficiency symptoms in most situations.

A KEY TO NUTRIENT DEFICIENCIES OF ORNAMENTAL PLANTS

This key is divided into 3 sections: (A) Oldest leaves first affected, (B) Youngest leaves first affected and (C) Terminal bud affected. After one has determined the specific location of the affected tissue, go to the appropriate section, either A, B, or C.

A. Older leaves affected first:

A1. General chlorosis progressing from light green to yellow; stunting of growth, excessive bud dormancy; necrosis of leaves, followed by abscision in advanced stages — **Nitrogen.**

A2. Marginal chlorosis or mottled leaf spots which occurs later; tips and margins may become necrotic, brittle and curl upward — **Magnesium.**

A3. Interveinal chlorosis with early symptoms resembling N deficiency; leaf margins may become necrotic and may roll or curl — **Molybdenum.**

A4. Leaf margins may become brown or mottled and curl downward — **Potassium.**

A5. Leaves accumulate anthocyanins causing blue-green or red-purple coloration; lower leaves may turn yellow—**Phosphorus.**

B. Youngest leaves affected first:

B1. Light green color of young foliage, followed by yellowing; tissue between veins lighter colored — **Sulfur.**

B2. Distinct yellow or white area between veins; initially veins are green, becoming chlorotic under severe deficiency, followed by abscision — **Iron.**

B3. Necrotic spots on young chlorotic leaves, with smallest veins remaining green — **Manganese.**

B4. Chlorotic leaves abnormally small; shortened internodes in severe cases, becoming rosetted — **Zinc.**

B5. Young leaves permanently wilted, becoming chlorotic, then necrotic — **Copper.**

C. Terminal bud dies:

C1. Brittle tissue, young or expanded leaves becoming chlorotic or necrotic and cupped under or distorted; terminal and lateral buds and root tips die — **Boron.**

C2. Growing points damaged or dead; tips and margins of young tissue distorted; leaves may become hard and stiff — **Calcium.**

Fertilizers

The analysis or grade of a fertilizer refers to the minimum amounts of materials in the fertilizer. A 10-10-10 fertilizer would represent 10 percent nitrogen (N), 10 percent P_2O_5 equivalent and 10 percent K_2O equivalent. In 50 pounds of 10-10-10, there are 5 pounds of N, 5 pounds of P_2O_5 equivalent and 5 pounds of K_2O equivalent.

In the future, fertilizers will most likely be expressed entirely in the elemental form; N-P-K versus N-P_2O_5-K_2O used today. When this is accomplished, the conventional 10-10-10 fertilizer will be expressed as a 10-4-8 fertilizer. The percentage of P in P_2O_5 is 43.6. Thus, by multiplying the pounds of P_2O_5 by .436, you can obtain the pounds of actual P in a fertilizer. The percentage of K in K_2O is 83. Thus, by multiplying the pounds of K_2O by .83, you can obtain the pounds of actual K in a bag of fertilizer.

If any of these elements are not present in the formulation, a zero would appear in the analysis. For example, ammonium sulfate, which has no phosphorus or potassium, has an analysis of 20-0-0.

To obtain the number of pounds of nitrogen in a 50 pound bag of ammonium sulfate ($(NH_4)_2SO_4$), multiply .20 x 50. Thus, there are 10 pounds of nitrogen in 50 pounds of ammonium sulfate.

Fertilizers may be divided into 2 broad groups: organic and inorganic (chemical). An organic fertilizer is derived from a living source; either plant or animal. Nitrogen in an organic fertilizer is slow in becoming available for uptake by the plant because the organic nitrogen (NH_2) must be reduced by micro-organisms to ammonium (NH_4). Generally, organic fertilizers are not used because of their high cost per pound of actual nutrient element; however, urea, a synthetic organic fertilizer, is available at a low cost. Urea is very high in nitrogen (45%). In moist medium at a temperature above 60°F, it takes about 3 to 5 days for the complete conversion of urea to ammonium.

Another potential organic fertilizer is sewage sludge. Plants have been shown to respond favorably when sewage sludge was applied to the medium. Further research is needed in this area before recommendations can be made.

Chemical fertilizers are either mixed or manufactured, and have the advantage of low cost. Consequently, most fertilizers used today are from chemical sources. High analysis, rapid solubility and availability necessitate caution when applying chemical fertilizers. See Table 2 for a comparison of several chemical fertilizers on the composition and effects on soil pH.

Slow release fertilizers may be either chemical or organic. They are characterized by a slow rate of release, long residual, low burn potential, low water solubility and high cost.

The most common element in a slow release fertilizer is nitrogen. There are five fertilizer categories of slow release nitrogen fertilizers available today.

Table 2: Chemical fertilizers, composition, effects on soil pH and salt index

NAME OF FERTILIZER	ANALYSIS	SOIL REACTION	SALT INDEX
Ammonium Nitrate NH_4NO_3	33-0-0	Acid	104.7
Urea	46-0-0	Acid	75.4
Ammonium Sulfate $(NH_4)_2SO_4$	20-0-0	Acid	69.0
Calcium Nitrate $Ca(NO_3)_2$	15-0-0	Alkaline	52.5
Superphosphate	0-20-0	Neutral	7.8
Superphosphate (Treble)	0-46-0	Neutral	10.1
Mono-Ammonium Phosphate	11-48-0	Acid	29.9
Di-Ammonium Phosphate	18-46-0	Acid	34.2
Potassium Nitrate KNO_3	13-0-44	Neutral	73.6
12-12-12	12-12-12	Varies with N sources	—
10-10-10	10-10-10		—
Potash KCL	0-0-60	Neutral	116.3
Potassium Sulfate K_2SO_4	0-0-60	Neutral	46.1

1) Urea-formaldehyde (UF)
2) Isobutylidene diurea (IBDU)
3) Sulfur coated urea (SCU)
4) Plastic coated fertilizers
5) Natural organics: sewage sludge, process tankage, fish scrap, etc.

These slow release fertilizers utilize water insoluble nitrogen (WIN) primarily, which results in a slow rate of release. This is in contrast to the water soluble nitrogen (WSN) in most granular fertilizers. Today, most of the slow release fertilizers have both rapid initial release and long term release of nitrogen.

A brief description of the 5 categories of slow release nitrogen fertilizers follows.

1. Urea formaldehyde (UF) - Nitrogen is released from water insoluble nitrogen (WIN) as a result of microbial degradation. This is enhanced by (1) warm medium temperature above 55°F, (2) adequate soil moisture, (3) adequate soil oxygen, and (4) pH ranging from 5.5 - 6.5.

   UF's vary in the rate of release. The rate of release is also dependent on the length of the UF chains; shorter chains being more soluble. Some examples of UF's, their analysis and release duration are listed below.

	Analysis N-P-K	Release Duration
Agriform (A)	14-4-6	4.6% in 45 days - 9.4% in 3-4 months
Agriform (B)	20-10-5	7% in 45 days - 13% in 24 months
Nitroform	38-0-0	14% in 45 days - 24% in 12 months

   Urea formaldehyde slow release fertilizers are safe to apply in overwintering structures during the winter months.

2. Isobutylidene diurea (IBDU) - Nitrogen release rate is controlled by two factors:
   (a) **soil moisture** - the more moisture available, the more rapid N release and
   (b) **particle size** - smaller particles release more rapidly. Temperature and microbial activity have limited effects on the N release rate.

	Analysis N-P-K	Release Duration
IBDU	31-0-0	Isobutylidene diurea 8-12 mo. water soluble (7.75% **water sol. 23.25%** WIN)

3. Sulfur Coated Urea (SCU) - The nitrogen release rate is based upon the **thickness** of the sulfur coating and **temperature.** Also, acidity favors release. These factors cause accelerated degradation of the sulfur coating.

   One drawback to the use of SCU is the rapid release of nitrogen under high temperatures, which could be damaging to plants in a storage house in the early spring.

	Analysis N-P-K		Release Duration
SCU-A	36-0-0	Urea	10% in 7 days, 4-5 months
SCU-B	36-0-0	Urea	26% in 7 days, 3-4 months

4. Plastic Coated Fertilizers

   Release of nutrients occur when water dissolves the fertilizer salts, followed by diffusion of the salts out of the granule. The thickness of the coating and temperature, (increased release with higher temperatures) are the governing factors controlling the release rate. Microbial activity, soil pH and soil moisture have no effect on the release rate of N, with one exception. When soil moisture conditions are excessively droughty, N release will be halted unless the coat is damaged to drying. Damage to the coating results in a rapid release of nitrogen.

	Analysis N-P-K		Release Duration
Osmocote	14-14-14	NH_4NO_3	3 months
Osmocote	18-6-12	NH_4NO_3	8-9 months
Osmocote	18-5-11	NH_4NO_3	12-14 months

5. Natural Organics

   Sewage sludge, process tankage, fish scrap, etc.

   Release occurs through natural decomposition dependent on temperature, moisture, pH and other factors.

See Table 4 for a listing of slow release fertilizers, rates of applications, period of effectiveness, mechanism of release and source of nitrogen.

FERTILIZER PROGRAMS FOR CONTAINER-GROWN ORNAMENTALS

Since containers have a limited volume, it is necessary to provide adequate nutrients necessary for satisfactory plant growth. The fertilization program is comprised of two components; preplant and postplant fertilization.

PrePlant Fertilization

The preplant incorporation of fertilizer into the medium has 3 primary purposes. These purposes are: (1) to provide initial fertilizer for plant establishment, (2) to incorporate fertilizer elements that move slowly through the medium, and (3) to adjust soil pH to optimum levels for nutrient uptake. Generally, nitrogen and potassium cannot be incorporated in quantities large enough to sustain growth throughout the season. All other nutrients may be provided with a preplant fertilization in sufficient quantities to meet the needs of plants throughout the growing season. Incorporating too much fertilizer before potting may produce toxic concentrations of soluble salts or elemental toxicities that inhibit growth or kill the plant. Suggested preplant mixes are presented in Tables 3 and 4. Generally, slow release forms of potassium have not been entirely satisfactory. Thus, some type of postplant application of potassium is necessary after planting. The rates depend on the percentage of each element in the fertilizer. If the recommended preplant mix is used, then the slow release fertilizer need not be high in phosphorus. The medium should be used 2 to 3 days after pre plant incorporation of slow release fertilizers. If the medium is stored, soluble nitrogen may accumulate and become toxic.

If the medium pH is excessively alkaline, it may become necessary to add phosphoric acid through the irrigation system at the rate of 2 ounces per 100 gallons or drench with iron sulfate at 1 ounce per 2 gallons of water.

Table 3: Fertilizer applications to hardwood bark before composting

Source	Rate/yd.^{3}
Ammonium nitrate (other nitrogen sources can be used)	6 lbs.
Superphosphate or	5 lbs.
Treble Superphosphate	2½ lbs.
Sulfur	1 lb.
Iron Sulfate	1 lb.

The application of fertilizer to hardwood bark mixes following composting and immediately prior to planting should consist of slow-release fertilizer at manufacturers suggested rates. Examples would be:

Osmocote ....18-6-12 @ 7-9 lbs./cu. yd.
Lakeshore ....18-5-9 @ 7-9 lbs./cu. yd.
Ureaform ....38-0-0 @ 2-3 lbs./cu. yd.

(Additional potassium will be needed with UF)

Table 4: A suggested pre-plant fertilizer mix for pinebark

Source	Rate/yd.^{3}
Dolomitic Limestone	6-8 lbs.
Superphosophate (Treble)	2½ lbs.
Micro-nutrients-	Rate depends on source
Perk, Esmigran FTE	Read the label
Gypsum	2 lbs.
Wetting Agent - Aqua-Gro	1 lb. (For organic media, without peat moss)

If the medium pH is very acid it is necessary to raise the pH and reduce the acidity. This may be accomplished by use of dolomitic limestone, $CaMg(CO_3)_2$, or hydrated lime, $Ca(OH)_2$. The former product is normally used when growing woody ornamentals in containers; however, if a rapid adjustment in pH is required, hydrated lime would be more suitable. The finer the particles, the more rapid the material will dissolve; thus, because of its fineness, hydrated lime would dissolve more rapidly than dolomitic limestone.

The natural form of phosphorus breaks down slowly due to its low chemical solubility. In the fertilizer industry, phosphate rock is treated with sulfuric acid to form superphosphate, a more readily available form of phosphorus. The high analysis treble superphosphate (40-47%P_2O_5) differs from the ordinary superphosphate (16-21% P_2O_5) in that it contains more phosphorus and no gypsum. Production of ordinary superphosphate has declined significantly in recent years, and as a result growers are using treble superphosphate primarily. Superphosphate has almost no effect on pH when the pH ranges from 5.5 - 7.5. At a low pH, superphosphate tends to reduce acidity, whereas with a pH of 7.5 to 8.5, it tends to reduce alkalinity. Since phosphorus moves slowly in the medium and reportedly contributes to root growth, it should be mixed in the medium for early plant development.

Gypsum ($CaSO_4 \cdot 2H_2O$) is used to provide both calcium and sulfur to the medium. Large amounts of calcium can be added to the medium without effecting pH by the use of gypsum.

Micronutrients, essential elements required in small amounts, should be mixed into the medium. The rates will vary according to the brand used. Follow the label recommendations.

Use of various bark media necessitates the preplant incorporation of a wetting agent into the medium. This is expecially true for pine bark media which may actually resist water entering the medium when it becomes dry. Successful plant growth in containers is dependent on proper watering, which the wetting agent enhances.

Previously it was mentioned that nitrogen and potassium could not be added preplant in sufficient quantities necessary to sustain plant growth throughout the growing season. This is especially true for nitrogen. Growers should use a slow release fertilizer at potting or soon after and periodically supplement with a liquid fertilizer throughout the growing season.

Most of the potassium can be supplied with slow release forms of potassium. To add more potassium during the growing season, use potassium nitrate as one of the supplemental nitrogen fertilizations.

Postplant Fertilization

Supplemental fertilizer during the growing season is necessary for optimum growth of most container grown woody ornamentals. Limited volume of containers, low cation exchange capacities of the more commonly used media, limited nutrient reserve, and rapid leaching of nutrients all contribute to the need for supplemental fertilization.

Nitrogen cannot be incorporated pre-plant in sufficient quantities for adequate growth throughout the season and it must be added during the growing season.

Suggested fertilizer programs for nitrogen include selecting from 1, 2, or 3 below.

1. Complete slow release fertilizer at manufacturer's recommended rate (Table 5), or
2. A slow release fertilizer-applied in combination with soluble fertilizer at 150 ppm N (weekly), or
3. When no other form of nitrogen is applied in slow release or granular form then soluble N at 250-300 ppm N (weekly) is suggested.

These recommendations may vary with plant species, stages of plant growth, environmental conditions and the concentration of other essential elements. The above recommendations are intended to be general guidelines only.

While it is almost impossilbe to determine the exact nutrient concentration to apply to each species or genera, broad ranges of plants can be grown under similar fertility ranges. For instance, if nurserymen will group their plants (taxus together, hollies together, etc.) fertilization within a genus usually varies less than between two genera. Satisfactory growth can be obtained by fertilizing at a particular level within a genus. Further grouping according to plant size within species enhances more efficient fertilization, watering and pruning.

Table 5: Slow release fertilizers commonly used in container-production

Type of Fertilizer	Rates of Application	Period of Effectiveness	Mechanism of Release	Source of Nitrogen
Agriform Tablets 14-4-6	1-2 tsp/gal 3-4 tsp/3 gal 4-5 tsp/5 gal	2-4 months	Temp. and bacterial activity	Ureaformaldehyde (U.F.)
Lesco 20-6-12+ Fe	1 tbsp/gal	4-6 months	Moisture and coating thickness	Sulfur coated urea and ammoniacal nitrogen
MagAmp 7-40-6 plus 12% Mg	1½ tbsp/gal 12-15 lbs/cu. yd. of course granules	4-12 months (Additional nitrogen needed)	Moisture	Magnesium ammonium phosphate
Osmocote 18-6-12	7-9 lbs/cu. yd. or 1 tbsp/gal	8-9 months	Temp. and coating thickness	Plastic coated Ammonium nitrate and Ammonium phosphate
18-9-9	4 tsp/3 gal	3-4 months		
14-14-14	2 tbsp/5 gal	3-4 months		
18-5-11	1 tbsp/gal or 7-11 lbs/cu. yd.	One year		
Precise 12-6-6	1 tbsp/gal	3-4 months	Moisture and Temp.	U.F.
Pro Grow 31-5-6	1 heaping tsp/gal	3-4 months	Bacterial activity	Urea and Methylene Ureas
25-10-10	1 heaping tsp/gal	3-4 months		
24-9-9	1 heaping tsp/gal	4-6		
Sta-Green	1 tbsp/gal	6-8 weeks	Moisture and Temp.	U.F.
Sulfur Coated Urea 36-0-0	1 tsp/gal	Up to 6 months	Moisture and Coating thickness	Sulfur Coated Urea
Ureaform 38-0-0	1 tsp/gal 2-3 lbs/cu. yd.	6-8 months	Temp. and bacterial action	U.F.

With hardwood bark, good results have been obtained by adding slow release fertilizer at potting (follow recommended rate), plus liquid feed at 200 ppm N weekly. A pine bark medium may require slightly less fertilizer to produce the same amount of growth that occures in a hardwood medium depending on the amount of composting at the higher fertility rate. Also, some genera respond to heavy fertilizer applications while others will not. Holly, cotoneaster, weigelá, forsythia and others respond favorably to relatively high nitrogen rates, while azaleas and rhododendrons and others cannot tolerate the higher nitrogen levels.

For most container grown plants, satisfactory growth will occur with slow release fertilizer plus supplemental liquid fertilization at 150 to 200 ppm nitrogen. Urea and ammonium nitrate are the most commonly used nitrogen fertilizers for supplemental feeding. Both of these fertilizers are soluble in hot water.

Additional micronutrients may be needed during the growing season, especially iron. Use of highly soluble liquid fertilizers has reduced the amount of micronutrients availabale to the plant. When dry fertilizers were used, they generally had enough micronutrients as impurities for adequate plant growth. Micronutrients may be added either through the injection system or as a top dressing. The key to proper management of micronutrients is to have the pH between 5.0 and 6.0. Once the pH rises above 7.0, most micronutirents become tied up in the medium.

Methods of Postplant Fertilizer Application

Commercially used methods of container fertilization include dry, liquid or foliar fertilization. Each of these methods may be used successfully with proper management. The key to a successful fertilization program is selecting a method that fits your system.

Dry application of fertilizer may be utilized effectively in small container operations because of the low investment initially in equipment. Use of the dry fertilizer application method allows the grower to select from a wider range of fertilizers.

There are disadvantages with the dry method of fertilizer application. These materials are usually applied by hand, which requires high labor input and they may require 2 applications annually. The difficulty of uniform application has developed with the advent of high analysis fertilizers. When a high analysis fertilizer is used, less material is required per container. It becomes difficult to spread the fertilizer material uniformly across the surface of the container when a small amount is applied.

Liquid application is a common method of applying fertilizers in containers. The limiting aspect of liquid fertilization is the high initial cost for injection equipment or for the labor when a hose-on applicator is used. Liquid applications provide uniform dosage, automation and easy distribution.

Disadvantages of liquid fertilization, in addition to the high investment cost, include: (1) a limited number of fertilizers can be used (ureas and ammonium nitrate are most commonly used), (2) during periods of frequent rainfall a possible deficiency may occur when irrigation is not needed.

Two basic methods of liquid fertilization are: hose-on application and injection application. With hose-on application, the desired concentration is mixed and applied through a hose. Economically, this is an inexpensive method of fertilization in terms of needed equipment. It does provide for uniform application, easy distribution and combines fertilization with irrigation. However, this method does require considerable labor.

The second method of liquid fertilization is injection into the irrigation system. Concentrated fertilizer solutions are forced into the irrigation system. Automation, low-labor requirement, and uniformity of application are advantages of this method. The high initial investment is usually offset by savings in labor within a few years.

Foliar applications are also used on a commercial basis. Spray equipment for pest management is used to apply a combination of pesticides and fertilizers. Generally, foliar applications are limited to micronutrients and possibly nitrogen. Urea is the only safe source of nitrogen that may be used in moderately high concentrations; usually 5 pounds of urea per 100 gallons of water. Foliar fertilization should be considered where some soil conditions may inhibit root absorption for a period of time, where quick response is needed, or when minor element deficiencies exist.

If a grower decides to use a liquid fertilization system, he will usually need some type of proportioner. A proportioner is a device through which concentrated fertilizer is introduced into the water line used for watering crops. There are 2 basic types of fertilizer proportioners on the market: positive injection and displacement types. Displacement proportioners operate on the principle that a measured amount of stock solution is injected into the irrigation water which is also measured. To function satisfactorily, the incoming water must not mix with the concentrated stock solution and dilute it. A flow control value may be necessary to avoid fluctuations in the rate of water flow. Otherwise, the uniformity of the dilution ratio depends on maintaining a uniform water flow.

The positive injection or venturi-type proportioners operate by injecting a set amount of the concentrated fertilizer solution into the water line. With positive injectors, the rate of injection may be controlled by the rate of water or have a constant injection rate regardless of the rate of water flow. The greatest accuracy for nursery crops may be obtained with proportioners whose injection rate is controlled by the rate of water flow, which provides a constant ratio over a wide range of pressure.

Examples of positive injection proportioners are:

1. Commander Proportioner, Merit Industries, Inc., P.O. Box 8075, Cranston, Rhode Island 02920.
2. Fert-O-Jet, Fert-O-Jet Co., 4701 Old San Jose Road, Santa Cruz, California 95060.
3. HPA Metering Systems, T. H. Baggaley Ltd., 34 Rothschild Street, London S.E. 27, England.
4. Hydrocare Injector, Hydrocare Products, Inc., Northfield, Illinois 60093.
5. Smith's Measuremix, Smith Precision, 1299 Laurence Drive, Newbury Park, California 91320.

Venturi-type proportioners with metering values also provide accurate application of liquid fertilizaiton where small ranges of pressure change occurs in the irrigation system. Some examples of venturi proportioners with metering values are:

1. Gewa, Herman A. Wirth (U.S. Importer), P.O. Box 25, Sayville, New York 11782.
2. Mixer-Proportioner, Young Industries, Box 943, Los Altos, California 94022.

When selecting a proportioner, several factors should be considered. First, the capacity of the watering system should be determined along with an estimate of the area to be watered and the time available to water a given area. Secondly, the mobility of the proportioner should be evaluated relative to the nursery layout. A nursery that is spread out may require a portable proportioner, while a nursery that has all of its growing space concentrated in a given area may require a nonmovable proportioner. Other factors to consider include the dilution ratio, a smaller ratio proportioner requires a larger stock solution, and solubility of fertilizers to be used. Proportioners may also have alternative functions; fungicide and insecticide application.

Soluble fertilizers are necessary for satisfactory operation of a proportioner. Usually, it is more convenient to dissolve the fertilizer in hot water (150°F). Stir until all solids dissolve. For highly insoluble materials, it may be necessary to heat the water until the material dissolves.

A separate container, fiberglass or plastic, should be used for mixing to avoid possible damage to the proportioner from foreign particles in the solution. The screened siphon hose in the proportioner should be kept at least 1 inch from the bottom of the tank to prevent the uptake of foreign particles that may damage the proportioner.

Use of dyes for monitoring the liquid fertilization program are recommended, especially for displacement type proportioners. Dyeing the stock solution allows the applicator to determine when the stock solution has been depleted and whether or not mixing of the stock soultion with the displacement water is occurring. Dyes are also important in that the grower can actually see that fertilizer is coming out of the irrigation nozzles. If nurserymen are using more than one fertilizer for injection purposes, they should consider color coding the various fertilizers. Fertilizer dyes are available from nursery and greenhouse supply dealers.

The color of the fertilizer solution should not be used as a method to check the accuracy of the proportioner. The accuracy can be checked with a conductivity meter (solu-bridge). Each fetilizer used in the liquid fertilization has its own salinity or electrical conductivity value, which can be determined on a solubridge. A grower can make a small volume of fertilizer containing the concentration of fertilizer which will be applied to the plants, then measure the electrical conductivity of samples from the proportioners collected from the irrigation nozzles. An acceptable bridge is manufactured by Beckman Instruments, Inc., 89 Commerce Road, Cedar Grove, New Jersey 07009.

Parts Per Million (ppm)

Nurserymen who use a liquid fertilization program are faced with the problem of how much fertilizer to mix in the stock solution to achieve a desired concentration. One simple formula for determining the pounds required per gallon is as follows:

$$\frac{\text{ppm required} \times \text{dilution factor} \div 1000}{\text{\% Nutrient Content} \times 120} = \text{lbs/gal of stock solution}$$

For example: You want to apply 150 ppm nitrogen to 1-gallon containers. You have a 55-gallon container for your stock solution, and a 400:1 injector. How many pounds of urea (45% N) should be mixed in one gallon of stock solution?

$$\frac{150 \times 400 \div 1000}{.45 \times 120} = \frac{60}{54} = 1.11 \text{ lb/gallon of stock solution and}$$

for 55 gallons = 61.11 lbs. of Urea

A second formula will provide the answer in ounces required per gallon of stock solution.

$$\text{ozs./gal.} = \frac{\text{ppm required} \times \text{dilution factor}}{75 \times \text{\% nutrient content}}$$

$$= \frac{150 \times 400}{.45 \times 75} = \begin{array}{l}17.7 \text{ ozs/gal of stock solution} \\ 17.7 \text{ ozs.} = 1.11 \text{ lbs.}\end{array}$$

When urea, ammonia nitrate or other colorless compounds are used, a colored dye should be mixed with the fertilizer. This provides visible proof that the fertilizer is being applied.

Timing Of Fertilizer Applications

Most recommendations for fertilization of container-grown nursery stock suggest that fertilizer be maintained in the medium at a constant level as near as possible throughout the growing season. New research is demonstrating that maintenance of these constant fertility levels may not be necessary. The key to understanding the reason why plants may not need constant fertilization is in observing the type of growth characteristic to particular plants. For example, some plants have only one flush of growth per year; euonymus, spruce, fir and others. This spring flush of growth is primarily a result of stored carbohydrates and nutrients in the roots and stems. These nutrients must be in the plant prior to the beginning of the spring growth flush. This may best be accomplished by fall fertilization after growth has hardened off or by an early spring application. Fall fertilization is recommended, especially for plants that are entering the winter in a nutrient deficient condition. Once shoot growth begins, nutrient uptake is not as effective, due to root inactivity. Since these plants will not have another growth flush until the following spring, constant levels of fertilization may not be necessary. In fact, a low maintenance level of available fertilizer throughout the growing season with supplement fertilizer applied after plants have hardened off in the autumn will produce as much growth as currently recommended levels of fertilization.

Other plants have more than one growth flush during a single growing season. Plants included in this category include: taxus, holly, cotoneaster, rhododendron and many shade trees. The spring growth flush of these plants is identical to the spring growth flush of those plants having only one growth flush. The second flush of growth occurs as a result of rapidly accumulating nutrients. For example, Figure 3, shows that tissue nitrogen in holly accumulates rapidly before the second growth flush begins, and that the time between growth flushes is dependent on the level of N applied. This figure also shows that the tissue nitrogen is accumulating while shoot growth is inactive. In other words, root growth occurs first, then shoot growth follows. Thus, accumulation of nutrients is more efficient when nutrients are applied after shoot elongation has ceased. Subsequent research has shown that holly plants fertilized twice during active root growth flushes had growth equal to plants fertilized weekly. Furthermore, plants fertilized only during active root growth had greater root growth than plants fertilized through out the growth flush. Thus, proper timing of fertilizer applications have been shown to reduce total applied fertilizer and to enhance root growth in container grown holly.

Research has not been undertaken with crops other than holly; however, many other plants have growth flushes similar to holly and should respond in the same manner.

In view of the previously mentioned information, fertilization after transplanting should begin when the roots start to grow. Initiation of root growth will be dependent on the severity of root pruning at transplanting.

Many growers are also concerned about how long fertilization should continue into the autumn. Recent research indicates that fertilization can be continued late into the autumn if adequate winter protection (minimum heat or microfoam) is available; however, plants grown under single or double layer poly should be fertilized no later than October 1 in a normal year. It is important that plants are in a good nutritional state before overwintering. This will insure a good spring growth flush.

Timing of fertilizer applications are also important to rooted cuttings. Many cuttings are rooted in June and July. Often times these cuttings are not fertilized until the next spring when these plants are potted into larger containers, and as result they are the same size then as when they were propagated. Most rooted cuttings will respond to fertilization immediately after rooting. Rooted cuttings fertilized after rooting usually have a

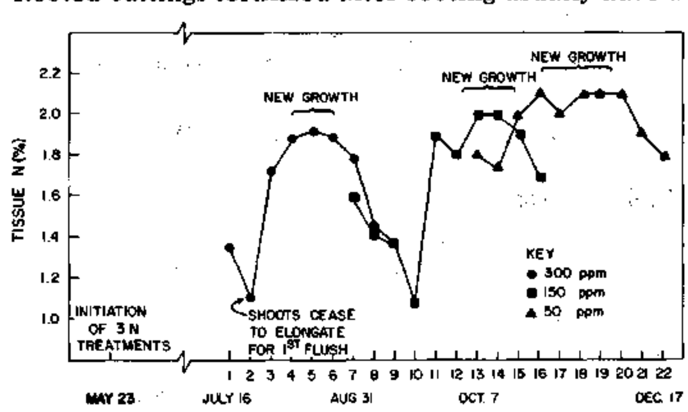


Fig 3. Effects of 3 nitrogen levels on tissue N fluctuations during a flush of growth on 'Helleri' holly.

growth flush the first autumn, and go into the winter in the proper nutritional condition. By the end of the first full growing season following propagation, these plants may be almost twice as large as rooted cuttings which were not fertilized immediately after rooting. Larger plant size is a result of a larger vegetative size of the plant from which the spring flush occurs, and consequently a larger spring growth flush. Softwood cuttings taken in June-July should receive either a slow release fertilizer or liquid feed immediately after root initiation. An additional growth flush can be obtained through proper fertilization immediately after propagation. When selecting a slow release fertilizer for newly rooted cuttings, management should select a slow release fertilizer that will provide nutrients through the autumn months.

If plants are purchased in September or October that are deficient in nutirents, a one-half rate of either a liquid or slow release fertilizer should be applied after hardening off the plants, but before December 15. Nitrate fertilizers are normally recommended for winter use.

When slow release fertilizers are used, they should be applied when the plant is potted. An application of a 3 to 4 month slow release fertilizer in the early spring should be followed with a midsummer application to insure adequate nutrients for autumn uptake or an 8 to 9 month application at potting is the alternative. Generally, slow release fertilizers should not be applied at full rate after August 1.

Winter application of slow release fertilizers is quite common because nursery labor requirements are low at this time. However, caution should be exercised when applying a slow release fertilizer in the winter whose release rate is dependent on temperature or moisture. High temperatures often occur in poly covered houses and may result in nutrient release at a time when little or no water is being applied to overwintering plants; resulting in soluble salt accumulation. A number of environmental factors may influence soluble salt damage or lack thereof, as well as plant tolerance to soluble salts. Thus, salt sensitive plants will have some degree of injury more frequently than salt tolerant plants when temperature or moisture dependent slow release fertilizers are applied in the winter months. Once ventilation and watering resume in the spring, slow release fertilizers should be applied, usually by April 1. If plants enter the overwintering period in a good nutritional status, the earliness of spring fertilization is not critical since spring growth is dependent on storage nutrients.

Regardless of the method of fertilization, proper timing of fertilizer applications are dependent on good management.

MEDIA AND FOLIAR ANALYSIS

Media Analysis

Soil testing enables the grower to monitor the fertilization program. A soil test will inform growers on the status of nutrients in the medium at the time of sampling. Because a container medium is an ever changing environment, a systematic sampling procedure must be utilized. This is especially true with respect to watering. A grower should take soil samples after the containers have received a predetermined amount of water after fertilization. By using this system, one can take into account the amount of rainfall received.

A soil test will also provide information on pH and soluble salt values. A pH value of 7.0 indicates a neutral soil, while pH values above 7.0 indicates an alkaline soil and below pH 7.0 an acidic soil. For most organic media, a pH value of 5.0 to 6.0 is adequate. This is in contrast to mineral soils where the optimum pH values are between 6.0 and 7.0.

For containers, about 10 plants that are representative of the plants being tested should be sampled. One-fourth inch of the surface media should be discarded and a small core taken through the entire depth of the media in the container. The medium is then blended for testing.

Each medium used in the nursery should have a complete analysis 2 or 3 times annually. These analyses are performed by the state laboratory (Research Extension Analytical Laboratory) or by a commercial laboratory. Recommended sampling times are (1) about 6 weeks after potting, (2) midsummer and (3) October 1. The midsummer testing is optional.

Container plant producers should own their own equipment to measure pH and soluble salts. Frequent sampling by the growers will avoid many conditions of under or over fertilizing. A good portable pH meter can be purchased for about $200 from most nursery and florist equipment supply firms. For soluble salts determination, a solu-bridge can be purchased for about $200. Growers with their own pH and soluble salt testing equipment should test the medium prior to canning and weekly or biweekly after the addition of predetermined amounts of water following fertilization.

Sequential soil tests are necessary to show what changes are occurring in the soil. This implies that careful record keeping and a review of these results are integral parts of a successful fertilizer program. Only a series of tests conducted over time will accurately evaluate nutrition and serve as a fertilizer guide for a particular nursery.

There are many different procedures that can be used to determine pH and soluble salts, and there is little agreement among soil testing specialists as to which method is the best.

Testing Procedures for pH

One procedure for determining pH is to make a suspension using 2 to 5 parts of distilled water per unit of air dried medium. Allow the mixture to stand 1 hour, stirring at 15 minute intervals; then extract the solution either through number 2 filter paper or cheese cloth. The pH meter should be calibrated prior to testing, and both the pH meter and the extracted solution should be at room temperature. Twenty-five percent of the electrode should be immersed in the extracted solution. The electrode should be rinsed with distilled water between each solution to be tested. As the amount of water increases in the suspension, so will the pH, until the pH reading is .5 to 1 unit higher than a "true" reading.

Another procedure for determining pH is to make a suspension using a weak electrolyte solution such as 0.01 molar calcium chloride $CaCl_2$-$2H_2O$ (6.7 grams $CaCl_2$-$2H_2O$ - reagent grade/gallon of distilled water). Place one part air dried medium (1 oz.) into a clean container and add 2½ parts of $CaCl_2$-$2H_2O$ solution (2½ oz. or 60 milliliters). The solution is extracted as previously mentioned. This procedure overcomes the soil-water relationship which causes high pH readings mentioned in the previous procedure. For further information on this topic, read **Modern Potting Compost** by A. C. Bunt, Penn State University Press.

It is necessary to properly maintain pH meters for accurate readings. Electrodes should be kept full of the internal solution. Battery operated pH meters should be checked regularly to insure a properly charged battery. To check the pH meter, measure a standard pH solution, used in calibrating the pH meter. If the pH value is low, the battery is probably weak.

For most media testing procedures, it is recommended to use a volume per volume measurement rather than a weight per volume. This will minimize the effects of varying bulk densities.

Testing Procedures for Soluble Salts (Salinity)

Soluble salts are an expression of the salt index in the potting medium. Current nursery practices include heavy fertilizer applications and frequent irrigation to compensate for the limited container volume. Occasionally, nutrients may accumulate in the medium and build up to levels that restrict plant growth; through either specific toxicities or general salinity. When excess salts are present in the medium, water availability to the plant is reduced. Salinity effects are amplified when environmental conditions are conducive for excessive transpiration. Thus, the potential for soluble salt damage is greater during the summer months than during winter. Damage from excessive soluble salts may be expressed as restricted plant growth, leaf burn, chlorosis, defoliation and stem dieback.

Because of the potential damage that can occur from excessive soluble salts, it is necessary for container growers to monitor the amount of salts present in the medium. Salinity measurements may be based on electrical conductivity (EC), which is directly dependent upon the concentration of dissolved salts in the medium. The success of this method depends upon the use of a procedure where the amount of water used for the EC determination is standardized and is related to the amount of water present in the medium. Many soil tests use a procedure based on suspensions due to greater ease and speed of preparation. Usually, either a ratio of 1 part of medium to 3 parts of distilled water or 1 part of medium to 5 parts of distilled water is used. With organic media, these methods may lack the accuracy of the saturated paste extract, because of the large differences in bulk density and water retention of the various organic media. These differences can be partially overcome by using a volume instead of a weight ratio.

For example, add one part air dried soil (1 oz. volume) to 3 parts distilled water (3 oz.). Stir the mixture and allow to stand for an hour. Extract the solution the same as for pH determinations.

The solu-bridge should be standardized after a warm up period of one-half hour. To standardize the solu-bridge, measure the conductivity of a .01 N KCL solution (.7456 g of KCL in 1 liter of distilled H_2O), which should read 1.41 mmhos per cm. To determine the soluble salt level of your sample, multiply the value indicated on the solu-bridge by the dilution value. Thus, for a 1:3 dilution, the mmhos value should be multiplied by 3.

A suspension or dilution procedure is the best method for growers who are determing their own soluble salts. The equipment required for this procedure will cost about $200 and includes a solu-bridge, distilled water, standard solution, filter paper and beakers. A solu-bridge is easily operated and may be obtained from a number of nursery or florist supply dealers. This equipment is inexpensive insurance, considering the potential damage that could occur. Growers should monitor soluble salts on a regular basis.

Currently, the most accurate method of determining soluble salts in the laboratory is the saturated paste extract (ECe). The saturated paste extract is prepared by adding distilled water to the medium and stirring until the medium will not hold any more water. Then allow the medium to stand four hours or overnight and make final adjustments. The medium will glisten and reflect light when the saturation point is reached, but there is no free standing water on the surface. The water or filtrate is obtained from the medium by placing the prepared sample on dry filter paper in a Buchner funnel and applying suction until 20 to 25 milliliters of the filtrate is collected. The filtrate is transferred to a tube and a reading made with a Solu-bridge.

A major problem with the saturated paste extract method is the difficulty in determining the saturation point. Consequently, the results will be dependent on the consistency of the personnel making the extraction and their determination of the saturation point. This procedure may eventually prove to be the best method of determining soluble salts, but at this time use of this procedure is limited to soil testing laboratories.

Growers can monitor their fertilizer programs with a solu-bridge (see page 14). Since the ECe is an indication of the salts in the medium, including nutrients, maintenance of a satisfactory level of soluble salts through fertilization will aid in the development of a good fertilization program. Regular monitoring of the soluble salts in the medium will protect against both over and under fertilization.

Low soluble salts may be due to overwatering or under fertilization, not enough fertilizer, while high soluble salt levels may result from insufficient watering or overfertilization.

At a normal watering, enough water should be applied so that it runs freely from the soil or medium. Usually container mixes are formulated for rapid leaching of accumulating salts and irrigation manage-

Table 6: Interpretation of conductivity readings based upon saturated paste extract, 1:2 soil/water w/v and 1:5 soil/water/w/v.

Saturated Paste		1:2 OSU-REAL Lab		1:5 O.F.A. Lab			Interpretation
1-2*	100-200**	.15*	15**	.3*	30**		Low
2-4	200-400	.5 - 1.8	15 - 180	.3 - .8	30 - 80		Satisfactory
4-6	500-600	1	- 3.4	180 - 340	.8 - 1.5	80 - 150	
High							

* millimhos
** mhos

ment which includes the application of enough water to leach them away. The medium should be kept moist to reduce the moisture stress to a minimum. If the medium does dry out, do not apply a dry fertilizer or a strong fertilizer solution to the dry medium.

Foliar Analysis

Foliar or leaf analysis is a procedure in which the leaf tissue or other tissue is analyzed to determine the mineral element content. This procedure reveals the amount of mineral constituents within a plant and can be used with a wide range of soil mixes and climatic conditions.

Foliar analysis is an important tool for establishing and maintaining a proper nutrition program with woody plants. It should be considered both to diagnose suspected mineral element deficiencies or toxicities and as a check on the fertilizer program. The latter is especially important for those producing plants in containers where so many factors influence the nutritional status. Regular analysis particularly over a period of years, can indicate an approaching deficiency or toxicity of a nutrient element before the plant shows any visible symptoms. It's possible then, through proper corrective fertilizer applications, to prevent the deficiency from ever occurring in the plant. It's possible, also, to determine high concentrations before visual toxicity symptoms appear and prevent growth reduction. Also, use of foliar analysis may improve the efficiency of the fertilizer program by avoiding over or under fertilization.

Sampling Guidelines

Usually, the leaf samples are taken from the most recently matured leaves (about midway on shoots of current season growth). Representative samples should be taken from randomly selected typical plants. Generally, from 8 to 10 grams fresh weight (30 to 100 leaves, depending on leaf size) should be selected from the broadleaved evergreens and about 50 terminal cuttings from narrow leaved evergreens. Late June to September is the recommended time for sampling of deciduous and evergreen plants. Also, December to March is recommended for sampling of evergreens.

These samples should be washed with a .1 percent detergent solution and rinsed in distilled water; dust, spray or other contaminates may influence results, especially if microelement deficiency or toxicity is suspected. Leaves should be dried rapidly at a uniform temperature. Usually, leaves are dried at 70°C for 48 hours but drying at room temperature is acceptable for routine analysis.

Samples should be mailed to a plant analysis laboratory in a paper bag; use of plastic bags results in mold and mildew on the samples, which will influence the results.

Usually, the testing laboratories have mailers in which the sample is placed.

Interpreting Foliar Analysis Results

The desired concentration of a mineral element should occur within the sufficiency range. The data in Tables 7 and 8 indicate the low, sufficient and high ranges. Comparison of healthy plant analysis with chlorotic plant analysis often is a good indication of the nutrient problem, if one exists.

Table 7: Survey of nitrogen content of woody ornamentals in Ohio

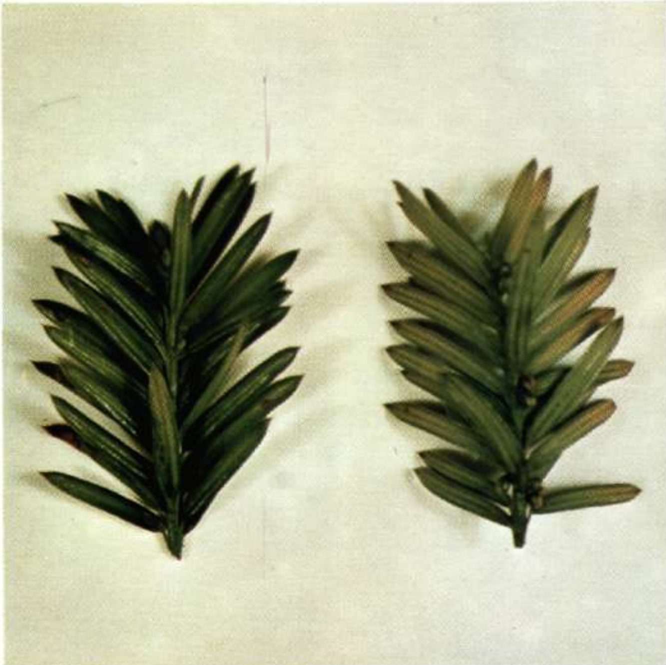
Deciduous Trees and Shrubs	N	Broadleaf Evergreens	N
Acer platanoides	2.6%	Euonymus	2.4%
Acer Saccharinum	2.3%	Ilex	2.3%
Malus	2.4%	Rhododendron	1.8%
Prunus	2.3%	Cotoneaster	2.2%
Cornus	2.2%	Pyracantha	2.2%
Lonicera	2.8%		
		Narrowleaf Evergreens	**N**
Viburnum	2.0%	Juniper	2.0%
Weigela	2.3%	Picea	2.0%
Spiraea	2.2%	Pinus	1.8%
		Taxus	2.0%
		Thuja	2.0%

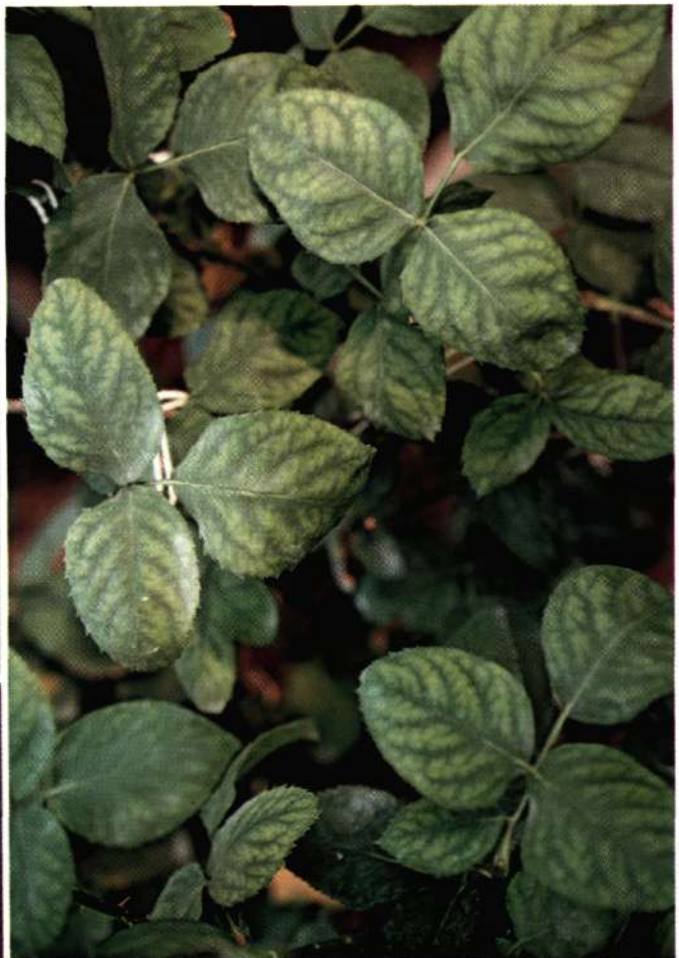
Table 8: Foliar mineral element ranges for woody ornamentals

	—Low—	—Sufficient—		—High—
N	1.00*	1.50	3.50	5.50
	1.50	2.00	4.50	7.00
P	0.10	0.20	0.60	1.00
K	1.00	1.50	3.50	6.00
Ca	0.20	0.50	2.50	4.00
Mg	0.10*	0.20	1.00	2.50
	0.20	0.30	1.00	2.50
Na	—	—	—	1.00
Mn	20	30	800	1000
Fe	30	50	700	1000
B	20	30	50	100
Cu	4	6	40	200
Zn	25	30	75	100
Mo	0.40	0.60	6	20
Al	—	—	—	800

* Levels for evergreens only.

ESSENTIAL ELEMENT DISORDERS





Top: Taxus — Magnesium Deficiency
Bottom: Taxus — Boron Toxcity

Top: Roses — Boron Deficiency
Bottom: Flowering Crabapple — Magnesium Deficiency

Additional photos on inside of front cover.