Bulletin 650
Agdex 270/10

FERTILIZING LANDSCAPE AND FIELD GROWN NURSERY CROPS

OCES
Ohio Cooperative Extension Service
The Ohio State University

Fertilizing Landscape and Field Grown Nursery Crops

Author

Elton M. Smith
Extension Specialist
Landscape Horticulture
Department of Horticulture
The Ohio State University

Contents

Photos by K. Smith and E. Smith

For Sale Publication

Ohio Cooperative Extension Service
The Ohio State University

3/86—2M

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, J. Michael Sprott, Director of the Ohio Cooperative Extension Service, The Ohio State University.

INTRODUCTION

Soil fertility practices represent an important segment of the cultural program necessary for successful growth of woody ornamental plants. Satisfactory plant growth is dependent on proper nutrition as well as proper light, temperature, moisture and pest management. Fertilizer applications are necessary to supplement the naturally occurring soil mineral elements in order to maintain an optimum supply available for plant growth.

Observation through frequent assessment of growth combined with soil and foliar analysis are the keys necessary for the grower to develop the most effective fertilizer program for a given crop. Using the results from soil and foliar reports along with plant growth responses will enable the grower to optimize plant growth without under or over fertilizing.

The purpose of this publication is to assist landscapers, nurserymen, commercial grounds maintenance personnel and the gardening public in making the best decisions possible regarding nutrition of their woody ornamentals. A separate publication is available for nurserymen producing container grown woody plants.

Included in this publication is a review of soil properties, soil pH adjustment, fertilizer materials, suggested fertilizer programs for optimum plant growth and soil and foliar testing procedures.

PROPERTIES OF SOIL

Growth of woody plants is affected by the physical and chemical properties of soils. Soil properties that should be considered before selection of cultural practices include organic matter content, surface texture and soil drainage.

Organic Matter

Most Ohio soils, excluding the mucks and peats, range from 1½ to 7% in organic matter. The organic matter content of the light-colored soils ranges from 1½ to 3% while the dark colored soils contain between 3 and 7%. There is a definite decrease in organic matter content with depth.

Organic matter in soil is a source of nutrients for crop production including nitrogen, phosphorus and some micronutrients. Organic matter contributes to desirable soil structure and increases total water available to crops. The addition of organic matter increases the water holding capacity of sandy soils while increasing aeration of clay soils. As the organic matter breaks down into humus, it becomes colloidal in nature, and cation exchange and adsorbtion take place similar to clay colloids.

The level of organic matter in the soil cannot be easily changed. Most crops produce less than 5 tons of dry matter annually on a per-acre basis and this is less than 0.5% of the total soil volume in 6⅔ inches depth of an acre. Only a small portion of this actually becomes organic matter. Organic matter in the form of mulches can affect the nutrient status of soils. Competition for available nitrogen results when residues having a high C:N ratio such as corn cobs or fresh sawdust are added to soils. When microbes decompose plant and animal residues with high C:N ratios, they incorporate all the inorganic nitrogen into their bodies. A serious competition with higher plants for nitrogen is initiated. Thus the C:N ratio, through its selective influence on soil microorganisms, exerts a strong control on nitrification and the presence of nitrate nitrogen in the soil. Mulch with shredded or chipped bark, peat moss, compost or other materials with a low C:N ratio to avoid these problems.

Soil Texture

Soil texture is determined by the relative amount of sand, silt and clay in the soil. Some common soil textural classes are sandy loam, silt loam and clay loam with silt loam predominant in Ohio.

The surface area of soil particles is important and varies with the size of these soil particles. Clay particles have 100 times the surface area as the same volume of sand particles, therefore, clay has a greater capacity to attract soil nutrients. Sandy loam soils must be fertilized more often than clay loam soils due to the lower capacity to attract and hold soil nutrients.

In addition to a large surface area, clay contains negative charges which may be measured to indicate the exchange capacity for cations such as Ca^{++}, Mg^{++}, K^{+} and others. This is called cation exchange capacity (CEC) and appears on all soil test report forms from The Ohio State University. The CEC is an important indicator of the soil's capacity to provide nutrients for plant use and as a measure of potential leaching of nutrients.

Natural Soil Drainage

Most Ohio soils can easily absorb from 1 to 2 inches of water before any of the water moves to a greater depth. When the rate of water movement is restricted by fine-textured, hard pan or other impervious material, a saturated zone may develop in the top 3 to 4 feet of soil. Voids in the soil, normally containing air, are filled with water.

Saturated soil or poor drainage causes problems and limits the use of the soil. About 60% of the soils used for cropland in Ohio need improved drainage and the figure is considerably higher for long term nursery crops and when landscaping new construction sites.

For crop production programs to be effective, including fertilizing, soil moisture problems must be solved by using appropriate drainage measures such as surface or internal drainage. When poor drainage occurs roots are injured, fertilizer uptake is limited and plant growth is reduced. Contact the County Soil Conservation Service for assistance with soil drainage or water problems.

Soil Property Sources

In managing landscape or nursery plantings, it is beneficial to learn as much as possible about soil properties before planting. Additional data is available from several sources including: (1) The Agronomy Guide, Ohio Cooperative Extension Service, (2) The Division Of Lands And Soil, Ohio Department of Natural Resources and (3) The USDA Soil Survey Reports from The Soil Conservation Service.

SOIL pH ADJUSTMENT

The term pH is used to measure the chemical reaction of soil on a 0 to 14 scale. Values below 7 are considered acid and values above 7 are alkaline.

Optimum plant growth occurs when the soil pH has been adjusted to the range specific for the crop(s) in question. A number of plants such as certain conifers, most broadleaf evergreens, maples and oaks should be grown on acidic soils from 5.0 to 6.0, while other plants such as those in the legume family — viburnum, hydrangea and lilac — do best at pH values neutral to slightly alkaline. Adjusting the soil pH one way or the other is quite often necessary in both landscape and field nursery soils.

When the pH of mineral soil is 4.5 or below, aluminum, iron and manganese are so soluble that they may become toxic to certain plants. Other mineral elements such as nitrogen, phosphorus, potassium, sulfur, calcium and magnesium may become limiting for plant growth at low pH. In addition, the activity of bacteria is markedly curtailed at the acidic end of the pH scale.

As the pH increases, ions of Al, Fe and Mn precipitate and the availability of these elements decrease. If the pH becomes alkaline, deficiencies of Fe, Mn, B and Mo are likely to occur. Phosphorus complexes with Ca under alkaline conditions to form insoluble calcium phosphates.

Mineral soil pH values between 6.0 and 7.0 result in the greatest number of mineral elements available in proper amounts for plant growth. In most situations, micronutrient deficiencies can be avoided by proper management of soil pH.

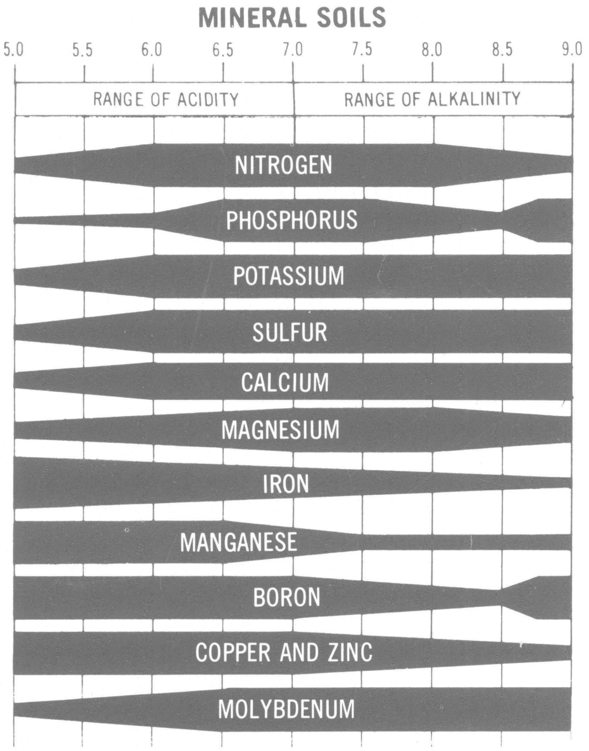


Fig. 1. Relative availability of essential elements to plant growth at different pH levels for mineral and organic soils.[1]

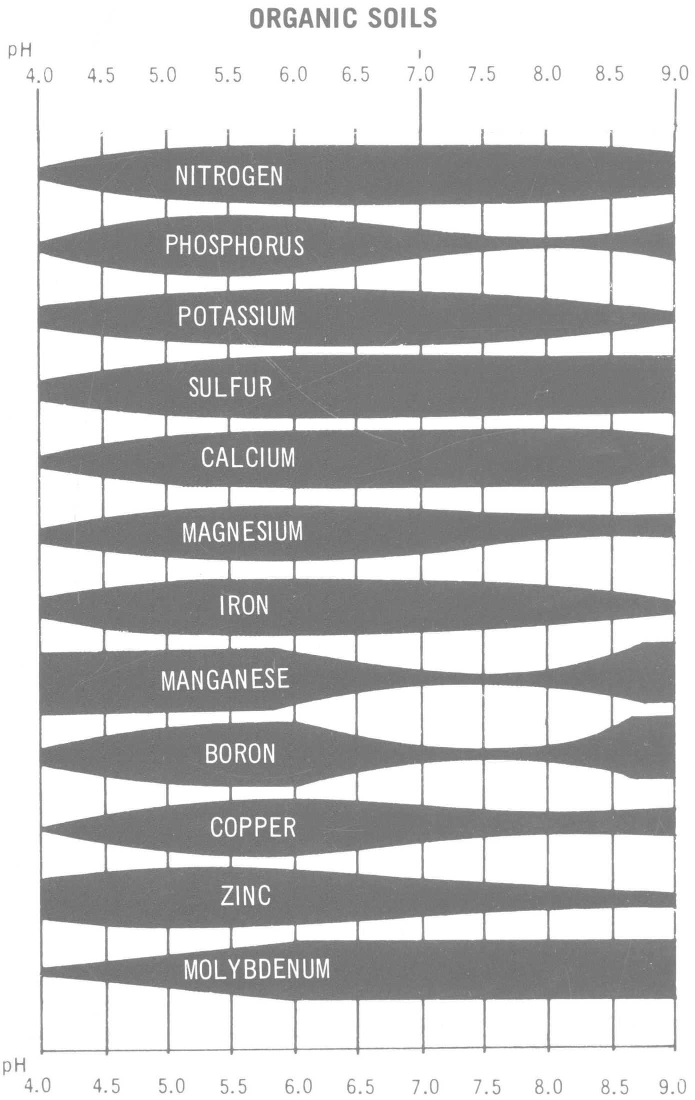
pH of the Subsoil

Naturally occurring alkaline parent materials become acid as a result of leaching over long periods of time. Water moving through the soil, particularly in late winter or spring, removes soluble bases. After free carbonates have been leached, the removal of bases exceeds the rate of production by weathering, thus the soil becomes acid. Degree of acidity in the soil is a function of the reaction of the soil parent material, amount of water moving through the soil and length of time the water has been moving through the soil.

The parent materials in western and northwestern Ohio have high pH ranges and contain as much as 50% calcium carbonate or its equivalent. Eastern and southwestern Ohio soils have been developed from acid sandstones and shales which commonly have pH values as low as 5.0.

Increasing Soil pH

Liming soil, in addition to increasing the pH, has several advantages including: (1) supplying Ca and Mg, (2) increasing P, Mo and Mg, (3) reducing harmful concen-



trations of Al, Mn and Fe, (4) increasing favorable microbial activity releasing elements necessary for plant growth and (5) improving soil structure and tilth.

Nutrient availability is the single most important factor which pH influences, as shown for mineral and organic soils in Figure 1. Note that optimum pH in mineral soils is between 6.0 and 7.0 and for organic soils is between 5.0 and 6.0.

Field Soils (Lime)

The lime requirement is determined by the lime test index which measures total exchangeable soil acidity. The lower the lime test index is below 68, the higher the lime requirement. Data in Table 1 shows the relationship between lime test index and lime requirements to different soil pH levels.

If plowing will be to a depth other than 8 inches, a lime adjustment will be required to react with the larger or smaller volume of soil involved. Depth of plowing or tilling adjustments will be made on The Ohio State University soil test report form, if the depth of plowing is noted on the soil information sheet sent to the Research-Extension Analytical Laboratory in Wooster.

Bench, Or Bed Grown Crops

For most bench or bed grown crops when the pH is somewhat lower than desirable (5.5 to 6.0), an application of 5 lbs. per 100 sq. ft. of either lime (calcium hydroxide) limestone (calcium carbonate), or dolomitic limestone (calcium-magnesium carbonate) is suggested. If the pH is between 5.0 and 5.5, two 5 lb. applications spaced at 2-week intervals are recommended.

After liming, no nitrogen fertilizer should be applied for 10 days. Free lime will react with ammonium nitrogen causing release of gaseous ammonia which may burn the foliage and is a loss of valuable fertilizer. Liquid fertilizing will be satisfactory, because the nitrogen levels are usually much less than granular applications.

Decreasing Soil pH

The pH of mineral soils should be in a range 5.0 to 6.0 for optimum growth of certain plants. Trees in the group include sour gum, sourwood, sweet gum, hemlock, magnolia, white pine, dogwood, most maples and oaks. Shrubs include nearly all the broadleaf evergreens, enkianthus, photinia and azaleas. A number of ground covers respond best in acidic soils including daphne, epimedium, wintergreen, partridgeberry and pachistima.

Field Soils (pH)

The pH of soils can be lowered by the addition of sulfur. The approximate amount of sulfur to add to 1000 sq. ft. and to an acre of a silt loam soil are listed in Table 2. Heavier applications will be needed in clay-loam soils and less in sandy-loam soils.

Aluminum sulfate can be used for acidification, but

Table 1: Lime Requirements To Increase Soil pH To Four Levels

(In terms of of T/A Ag-Ground Limestone, T.N.P. 90+, 8 inch Plow Depth)

Lime Test Index	pH Levels							
	Mineral Soils						Organic Soils	
	7.0		6.5		6.0		5.2	
	Tons/ A	Lbs/ 1000 sq. ft.	Tons/ A	Lbs/ 1000 sq. ft.	Tons/ A	Lbs/ 1000 sq. ft.	Tons/ A	Lbs/ 1000 sq. ft.
68	1.4	65	1.2	55	1.0	45	0.7	30
67	2.4	110	2.1	95	1.7	80	1.3	60
66	3.4	155	2.9	135	2.4	110	1.8	85
65	4.5	205	3.8	175	3.1	145	2.4	110
64	5.5	255	4.7	215	3.8	175	2.9	135
63	6.5	300	5.5	255	4.5	205	3.5	160
62	7.5	345	6.4	295	5.2	240	4.0	185
61	8.6	395	7.2	330	5.9	270	4.6	210
60	9.6	440	8.1	370	6.6	305	5.1	235
59	10.6	485	9.0	415	7.3	335	5.7	260
58	11.7	540	9.8	450	8.0	370	6.2	285
57	12.7	585	10.7	490	8.7	400	6.7	310
56	13.7	630	11.6	535	9.4	430	7.3	335
55	14.8	680	12.5	575	10.2	470	7.8	360
54	15.8	725	13.4	610	10.9	500	8.4	385
53	16.9	770	14.2	655	11.6	535	8.9	410
52	17.9	825	15.1	695	12.3	565	9.4	430
51	19.0	875	16.0	735	13.0	600	10.0	460
50	20.0	920	16.9	775	13.7	630	10.5	485
49	21.1	970	17.8	820	14.4	660	11.0	505
48	22.1	1000	18.6	855	15.1	695	11.6	535

These values must be adjusted for type of liming material and plow depth.

the quantity necessary to decrease the soil pH to the same degree is 4 to 5 times greater than the amount of sulfur required. The use of aluminum sulfate should be considered only for small areas or individual trees or shrubs.

Table 2: Approximate Amounts Of Sulfur Necessary To Lower The pH Of A Silt Loam Soil

From	Pounds per 1000 sq. ft.	Pounds per acre
8.0 to 6.5	30	1300
8.0 to 6.0	40	1750
8.0 to 5.5	55	2400
8.0 to 5.0	70	3000
7.5 to 6.5	20	870
7.5 to 6.0	35	1525
7.5 to 5.5	50	2175
7.5 to 5.0	65	2830
7.0 to 6.0	20	870
7.0 to 5.5	35	1525
7.0 to 5.0	50	2175
6.5 to 5.5	25	1090
6.5 to 5.0	40	1750

THE ROLE OF THE ESSENTIAL ELEMENTS

Through the years scientists have determined that a number of nutrient elements are essential for plant growth. To be an essential element for plant growth, the nutrient element must be either directly involved in the metabolism of the plant or it must be necessary for the plant to complete its life cycle.

Nine essential elements required in relatively large amounts by the plant are called macronutrients. Included in the list of macronutrients are nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, carbon, hydrogen and oxygen. The latter three are readily available in air and water.

Seven other essential elements required in small amounts by the plants are called micronutrients and these include iron, manganese, zinc, boron, molybdenum, copper and chlorine.

If an insufficient amount of any of these 16 essential elements are lacking or in excess, plants will not grow properly. Metabolic dearrangements eventually become visible as deficiency symptoms when any one of these essential elements are lacking. More or less distinct symptoms occur for individual nutrient element deficiencies because of the role each individual element plays relative to growth of the plant. Once a deficiency or toxicity symptom is visible, plant growth has been and will continue to be reduced until corrected.

Macronutrients

Nitrogen (N), the macroelement other than carbon (C), hydrogen (H) and oxygen (0) needed in the greatest quantities within the plant, is a constituent of proteins, growth regulators, chlorophyll and other essential components of the plant. Nitrogen enters the plant for the most part in the nitrate (NO_3) and ammonium (NH_4) forms. One of the early signs of nitrogen deficiency is a general yellowing of the leaves due to an inhibition of chlorophyll synthesis. Since N is a mobile element in the plant the deficiency symptoms usually are evident on the older leaves first. This would be true for the deficiency symptoms of the other mobile elements such as K, Mg and P.

Phosphorus (P) plays a key role in the energy system of a plant. It is a constituent of compounds which provide energy for synthesis of sucrose, starch and proteins. Phosphorus is also known to be involved in photosynthesis and transfer of hereditary characteristics. Phosphorus enters plant roots in inorganic phosphate forms.

Potassium (K), like nitrogen, is required in relatively large amounts by the plant, although no potassium containing compounds have been isolated from plants. Potassium, like Ca and Mg, is absorbed into the plant as the inorganic metal ion. The primary function of potassium is as an activator enzyme. Other potassium functions include involvement in regulation of transpiration and photosynthesis. Leaf margin chlorosis and browning are the typical deficiency symptoms.

Magnesium (Mg) is a constituent of chlorophyll and activates a number of enzymes which affect the transfer of energy. A deficiency of magnesium affects a wide range of metabolic functions. Foliar chlorosis is an early symptom of magnesium deficiency.

Sulfur (S) like nitrogen, is a component of protein, and causes deficiency symptoms similar to nitrogen, although seldom deficient in Ohio soils.

Calcium (Ca) functions in the formation and maintenance of cell membrane systems and imparts rigidity to the cell wall. Another function of calcium appears to be detoxificiation of other ions.

Micronutrients

Iron (Fe) deficiency occurs more commonly than most micronutrients in woody plants. Iron is essential for chlorophyll synthesis, functions in photosynthesis, NO_3 and NO_2 reductions and in nitrogen fixation. Iron is a nonmobile element within the plant, and deficiency symptoms occur on new foliage as interveinal yellowing. Iron as well as Mn, Cu and Zn are taken into the plant by inorganic metal ions.

Manganese (Mn) closely follows iron in terms of commonly occurring micro-nutrient deficiencies. Manganese plays an essential role in photosynthesis and respiration. Manganese deficiency symptoms are often confused with iron and zinc because the chlorosis symptoms are similar.

Zinc (Zn) is required for maintenance of auxin in an active state. A deficiency of Zn results in the failure of internodes to elongate. Plants with Zn deficiency are often described by terms like "little-leaf" or "rosetted".

The remaining 4 micronutrients including boron, molybdenum, copper and chlorine are seldom deficient in woody plants.

Deficiency Symptoms

Deficiency symptoms are important to nurserymen and landscapers 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 symptoms 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 3 for deficiencies of individual elements on woody plants.

To assist in determining 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.

Table 3: Nutrient Element Deficiency Symptoms Of Woody Plants

Element	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 prounounced as with Fe, Zn or Mn. Veins lighter than blades.
Molybdenum (Mo)	Leaves show cupping, interveinal chlorosis preceded by marginal chlorosis.

A KEY TO NUTRIENT DEFICIENCIES OF ORNAMENTAL PLANTS

This key is divided into 3 sections: (A) Older 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.**

FERTILIZER

Analysis Or Grade

The analysis or grade refers to the minimum amounts of N, P_2O_5 and K_2O 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 is 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 0.436, one can obtain the pounds of actual P in a fertilizer. The percentage of K in K_2O is 83.0 and by multiplying the pounds of K_2O by 0.83 the actual K in a bag of fertilizer can be determined.

If any of these elements are not present in the formulation, a zero would appear in the analysis. For example, ammonium nitrate, which has no phosphorus or potassium, has an analysis of 33-0-0.

To compute the number of pounds of nitrogen in a 100 pound bag of ammonium nitrate (NH_4NO_3) multiply 100 x .33 which results in 33 pounds of nitrogen. Dividing 33 by the unit cost yields costs per pound of nitrogen. Relative costs of several fertilizers are shown in Table 4.

Organic And Inorganic Sources

Fertilizers may be divided into 2 broad groups, namely organic and inorganic or chemical. An organic fertilizer is derived from a living plant or animal source. Nitrogen in an organic fertilizer is slow in becoming available for plant use because the organic nitrogen (NH_2) must be reduced by micro-organisms to ammonium (NH_4) or nitrate (NO_3). Generally, organic fertilizers are used by the gardening public rather than commercial production due to their high cost per pound of actual nutrient element. However, urea at 45% N, a synthetic organic fertilizer is available at a low cost. In moist media at a temperature above 60°F, it takes about 3 to 5 days for the complete conversion of urea to ammonium.

Another organic fertilizer that may soon be used in greater quantities is sewage sludge. Plants have been shown to respond favorably when sewage sludge was applied to the soil. Further research is needed before specific recommendations will be made.

Chemical fertilizers are either mixed or manufactured and have the advantage of lower cost. Consequently, most fertilizers used today are from chemical sources. High analysis, rapid solubility and availability necessitate caution when applying chemical fertilizers. See Table 4 for a comparison of several chemical fertilizers relating to cost, composition and effects on soil pH.

Slow Release Fertilizers

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

The most common element in a slow release fertilizer is nitrogen. There are several fertilizer categories of slow release nitrogen fertilizers commercially available including:

(1) Urea-formaldehyde (UF) (38-0-0). Released by microbial degradation.
(2) Isobutylidene diurea (IBDU) (31-0-0). Released by soil moisture and particle size.
(3) Sulfur coated urea (SCU) (36-0-0). Release rate controlled by coating thickness.
(4) Plastic coated fertilizers (Various formulations). Release dependent on temperature and coating thickness.
(5) Natural organics—sewage sludge, composted municipal sludge, process tankage and fish scrap.

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

Liquid Fertilizers

The application of soluble fertilizers has gained importance over the years as a maintenance and production fertilizer and in preventing and correcting minor element deficiencies. Soluble fertilizers are applied either on the foliage or to the soil.

Liquid fertilizers are important in production of nursery stock particularly as an additive in spray operations. Landscape and grounds personnel utilize this method of fertilization extensively for deep root feeding of trees and shrubs.

Many soluble formulations are available for almost any specific need from plant starter, high nitrogen fertilizers to minor element formulations. The most popular formulation has been 20-20-20 for spring and summer use. Chelated iron is used extensively for the prevention and control of iron deficiency of many plants such as azaleas, rhododendron, oaks, sweet gum and other plants susceptible to iron deficiency.

Table 4: Analysis and Effects of Soil pH of Some Chemical Fertilizers

Name of Fertilizer	Analysis	Soil Reaction
Anhydrous Ammonium	82-0-0	Acid
Ammonium Nitrate	33-0-0	Acid
Urea	46-0-0	Acid
Ammonium Sulfate	20-0-0	Acid
Calcium Nitrate	15-0-0	Alkaline
Superphosphate	0-20-0	Neutral
Treble Superphosphate	0-46-0	Neutral
Mono-Ammonium Phosphate	11-48-0	Acid
Di-Ammonium Phosphate	18-46-0	Acid
Potassium Nitrate	13-0-44	Neutral
12-12-12	12-12-12	Varies with N sources
10-10-10	10-10-10	Varies with N sources
Potassium Chloride	0-0-60	Neutral
Potassium Sulfate	0-0-60	Neutral

A FERTILIZER PROGRAM FOR PLANTS IN THE LANDSCAPE

Many factors influence the fertilization program of plants in the landscape. Unlike similar plants growing in the nursery, landscape plants are often growing under greater stress and fertilization practices must be taken into account based on these stresses for satisfactory plant growth.

Location

The location of plants in the landscape may influence its fertilizer practices. For example, a shade tree in the backyard, typically without stress conditions, will usually respond to less fertilizer and fewer applications than a tree planted between the sidewalk and street. The root zone area of the latter is reduced, likelihood of soil compaction, exposure to highway salts and road dust or dirt and air pollution is greater. All these factors contribute to the need for greater attention to plant care practices, including regular fertilizing to maintain healthy growth.

Species

Not all plants respond to the same fertilizers or rates, thus it is advantageous to recognize species differences. For example, linden trees typically respond to nitrogen, oaks to iron and maples to manganese. It is important to recognize that certain plants, particularly when grown out of their native habitat, as in the case in many landscape situations, may have specific nutritional needs. Plants with shallow fibrous root systems such as Azalea and Rhododendron are sensitive to high rates of fertilizer. Fast growing species such as willow, certain elms and silver maple require less

Norway Maple—Healthy plant, left; nitrogen deficient plant, right. Note brighter green and smaller foliage of tree that lacks nitrogen.

fertilization than slower growing species.

The purpose of fertilizing landscape plants the first year or two following transplanting is to increase height, width and caliper. However, once the plants are established and growing well the function of fertilizing is to maintain satisfactory growth and health but not necessarily to produce optimum height or caliper as the commercial nurserymen is seeking.

At Planting: Fertilization at transplanting is recommended to supply phosphorus, because that element moves slowly in soils, as well as to assist in plant establishment. Apply 10 lbs. fertilizer per cu. yd. in the backfill of 0-20-0, 4-12-4, 5-10-5 or similar high phosphorus fertilizer. The rate of 10 lbs. per cu. yd. is about equal to 0.5 lb. fertilizer per bushel of backfill material.

After Planting: Research in Ohio has shown that about 3 lbs. of actual nitrogen, the mineral element most responsible for vegetative growth, per 1000 sq. ft. per yr. or 6 lbs. every other year is all that is needed to maintain the health of woody plants in most landscape situations. If foliage color, annual growth or general vigor is not normal, increase the rate to 5 or 6 lbs. of N per 1000 sq. ft. per yr. If soil or foliar tests are available, follow those recommendations; otherwise, the suggested rate above could be used as a guide.

The surface area under the branch spread of a tree can be calculated as follows. Surface area — Radius^2 X 3.14. The radius is the distance from the trunk to the edge of the branch spread. As an example, a 6 inch DBH (diameter tree) with a total branch spread of 36 feet would have a radius of 18 feet. The area, according to the formula would equal 18 X 18 X 3.14 or 1017 sq. ft. Considering the recommendation of 3 lbs. of actual nitrogen per 1000 sq. ft., one would apply about 17 lbs. of 18-5-9 fertilizer (3.0 ÷ 0.18 = 16.6 lbs.).

Another formula for determining fertilizer needs for trees is based on diameter breast height (DBH). Apply ¼ lb. actual N per inch DBH of trees under 6 inches in diameter. The rate is increased to ½ lb. N per inch DBH for trees over 6 inches DBH. Fertilizing trees using this formula results in quantities similar to the surface area basis.

Using the same 6-inch DBH tree as above and fertilizing with ½ lb. actual N per inch DBH would require 16.7 lbs. of 18-5-9. [6 (dia.) × 0.5 (rate) = 3.0 amount of N] [3.0 (amount of N) ÷ 0.18 (%N in 18-5-9) = 16.7 lbs. of 18-5-9]

Woody plants respond well to fertilizers with a 3-1-2 or 3-1-1 ratio such as 24-8-16, 18-6-12, 18-5-9, 15-5-5, 12-4-4 or similar formulations. Trees and shrubs respond to 3 times as much nitrogen as phosphorus and twice as much potassium as phosphorus. An application of 3 lbs. of actual nitrogen per 1000 sq. ft. applies 1 lb. of P_2O_5 and 2 lbs. of K_2O when using a 3-1-2 ratio.

The trend in recent years by fertilizer formulators has been to use higher analysis in the fertilizer package. Often the nitrogen content is 30% or more and is 4 or 5 times the phosphorus level. These formulations, although promoted for turf, can be satisfactorily used around woody plants. Avoid use of fertilizer and herbicide combinations.

Timing Fertilizer Applications

In the landscape, plants are fertilized at varying intervals, depending on growth and vigor. Fertilizing once a year is preferable to the common practice of every 2 to 3 years. Applications twice a year in certain site situations would be advised.

The best time to fertilize is autumn, generally between the first hard freeze in October and December.

The next best time would be prior to growth in early spring, usually between February and early April. If fertilizer was not applied during the autumn or spring season, applications may be made up to July 1. Fertilizer applied after July 1 could promote a late flush of growth, which may not acclimate before freezing temperatures of autumn and injury could occur. Forcing late growth is most frequently a problem with broadleaf evergreens such as Pieris and Rhodendron.

Methods Of Fertilizer Application

Several methods of applying fertilizer are commercially practiced, including liquid soil injection, soil drill holes, surface application, foliar sprays and tree injection or implantation. Each serves a specific role, depending on the site and plant condition.

Liquid injection of fertilizer into the soil is rapidly taken into the plant by the roots and is an excellent method to correct deficiencies of specific mineral elements. Also, the addition of water to dry soil is desirable in summer or during periods of drought, Injection sites should be 2 to 3 feet apart, depending on pressure and 8 to 12 inches deep for trees.

A major advantage to the drill hole or punch bar system is the opening of heavy compacted soils which allow air and fertilizer to penetrate the soil. This technique and liquid injection avoid the excess grass growth in turf areas from surface applications.

The drill holes should be placed in concentric circles in the soil around the plant, beginning 2 to 3 feet from the main stem and extending 1 to 3 feet beyond the dripline. Space holes 2 feet apart and drill them 8 to 12 inches deep. The recommended rate of fertilizer should be uniformly distributed among the holes. Depending on the diameter of the hole, it can be filled following fertilization with peat moss, calcine clay, perlite, small crushed stone or other soil amendment.

Fertilizing via surface application is as effective in providing a positive plant response with most woody plant species as other methods. This method requires the least application time, is the least expensive but should be avoided in high quality turf areas.

Fertilizer stakes or spikes that are driven into the soil contain satisfactory fertilizer materials. Unfortunately, the spacing of the spikes is such that very little of the fertilizer comes in contact with the root system. Thus, this method is not as effective as other methods. One or two stakes per inch diameter of tree trunk does not represent adequate fertilizer distribution because lateral fertilizer movement is limited.

To correct minor element deficiencies, spraying liquid fertilization on the foliage should be considered, especially for iron deficiency using chelated iron. This method should not be considered adequate as a means of providing all the necessary mineral elements required by plants in the amounts necessary for satisfactory growth.

Micro-nutrient spray applications are most effective when made just before or during a period of active growth, usually from spring to early summer. Response as indicated by greening of chorotic foliage and normal growth coming from buds on affected shoots is usually observed from 2 to 8 weeks after treatment but response time varies, depending on species, age of plant and its parts, time of year, severity of the deficiency and soil conditions under which plants are growing. Using one or two applications during the year will prevent or control deficiencies but under some conditions it may be necessary to make several treatments annually to maintain healthy growth.

Tree trunk injection, infusion of liquid or implants of fertilizer salts is often the most satisfactory method of applying minor elements such as iron, manganese and zinc. Due to adverse soil pH, high moisture relationships and other soil conditions, this method is often more satisfactory than liquid fertilization of the foliage especially with iron deficiency.

Chlorosis

Chlorosis of foliage may be caused by one or more different environmental factors. Usually, chlorosis occurs when a mineral element is deficient in the plant. Elements may be leached from the soil, particulary in acidic soils, or elements may be "fixed" in unavailable forms such as iron and manganese in highly calcareous soils. Crop removal may reduce the availability of an element. The native content of previously uncultivated soils may be in the deficiency range for certain plants. Excessive levels of one element in the soil may induce deficiency symptoms of a heavy metal such as iron deficiency induced by excessive copper or copper deficiency inducted by excessive phosphorus. When certain elements such as boron are present in toxic amounts, a general chlorosis may occur. Insect, disease or nematode injury to root systems, poor drainage or over watering reduces the ability of the roots to remove nutrients from the soil and may cause a general chlorosis.

Most symptoms are exhibited by foliage discoloration. The degree of chlorosis is dependent on the factors mentioned above and species susceptibility. Growing side by side in similar soil conditions a pin oak may be chlorotic due to iron deficiency and a red maple chlorotic due to manganese deficiency. Foliar analysis and soil tests are recommended to determine specific causes of chlorosis.

For certain element deficiencies and, in particular iron, the most effective treatment is trunk injection and implants. Injection of iron sulfate has been effective for one season with oaks and other species. Implants of ferric ammonium citrate capsules are extremely effective in the control of iron deficiency in a number of plants including pin, white, scarlet, willow and pin oak, Japanese black and white pine, sweet gum, star magnolia and oriental photinia.

Implants of manganese sulfate have been successful in controlling Mn deficiency in Norway, sugar and red maple, to a limited extent silver maple and flowering cherry.

The capsules should be implanted as low as possible on the trunk and in a spiral fashion around the trunk Implant in early spring before growth starts for best results. Wound closure is most rapid from spring treatment. All species above will close or nearly close in one season with a ½ inch diameter hole with the exception of sweet gum, which requires two seasons for complete closure.

Trunk injections and implants are less expensive than foliar and soil treatments but recommended for landscape plantings rather than nursery treatments.

A FERTILIZER PROGRAM FOR FIELD GROWN NURSERY STOCK

Pre-Planting

It is usually necessary to apply fertilizer to a planting site prior to planting. If the needed mineral elements are applied to cover crops one or two years ahead of planting, the soil should be at a much more desirable fertility level at planting time. A combination cover crop program of rye sown in late summer followed by Sudan-Sudex hybrids planted in the spring and plowed in August over a two year period between nursery crops, provides organic matter, some soil pest control and a source of nutrients. The combination of fertilizer and cover crops will improve both the nutrient level and the structure of the soil, thus creating a more desirable rooting medium for new plantings. Fertilizer applications should be based upon soil test results and kind of cover crops grown. Definitely, a high phosphorus fertilizer such as 0-46-0, 0-20-0, 4-12-4, etc. should be applied prior to planting nursery stock to provide a source of phosphorus for several years. Nitrogen fertilizers must be applied annually due to leaching and crop use.

To correct low phosphorus and potassium levels prior to planting, the guidelines suggested in Table 5 can be used as a point of reference; however, a soil test is strongly advised.

Table 5. Corrective applications of phosphorus and potassium to non-planted soils

Phosphorus Soil Test Values lbs/A	lbs/A 0-20-0	lbs/A 0-46-0	lbs/A 15-15-15
0-9	1500	645	2250
10-19	1000	430	1500
20-29	500	215	750
30 +	0	0	0

Potassium Soil Test Values lbs/A	lbs/A 0-0-60	lbs/A 15-15-15
0-99	600	2250
100-149	500	1500
150-199	425	750
200 +	0	0

Post Planting

The rates of fertilizer application suggested below are general and should be adjusted by the grower according to leaf color, terminal growth, trunk caliper as well as results of soil and foliar reports.

Ratios of 3-1-2, 3-1-1 or 4-1-2 fertilizer, as described under the section on a fertilizer program for plants in the landscape, are most satisfactory for the growth of plants in the nursery.

The rates suggested in Table 6 based on nitrogen requirements will, in most situations, provide the necessary maintenance phosphorus nad potassium particularly if adequate amounts were applied prior to planting. If phosphorus and potassium were not incorporated prior to planting, annual applications of both will undoubtedly be necessary.

To compute the required rate of a given fertilizer formula, divide the lbs. N per A or sq. ft. by the percent nitrogen of the analysis. Example: To determine the rate of 12-4-4 required per A, based on a recommendation of 264 lbs. of actual N per A, divide 264 by 0.12, which equals 2200 lbs. of 12-4-4.

To adjust levels of phosphorus and potassium after planting woody ornamentals, the suggested rates of complete fertilizers in Table 6 should be satisfactory.

Table 6. Nitrogen Fertilizer Rates For Existing Field Grown Nursery Stock

Plant Groups	lbs. N/1000 sq. ft.	lbs. N/A	Examples of Fertilizers	Application Rates lbs/A
Deciduous Trees and Shrubs	5-6	220-264	12-4-4	1830-2200
			18-6-12	1220-1470
			24-8-16	920-1100
			30-10-10	730-880
			38-0-0	580-690
			45-0-0	490-590
Narrowleaf Evergreens	4-5	176-220	12-4-4	1470-1830
			18-6-12	980-1220
			24-8-16	730-920
			30-10-10	590-730
			38-0-0	460-580
			45-0-0	390-490
Broadleaf Evergreens	2-3	88-132	12-4-4	730-1100
			18-6-12	490-730
			24-8-16	370-550
			30-10-10	290-440
			38-0-0	230-350
			45-0-0	200-290

Methods of Application

Granular: Generally, field nurseries are using inorganic granular fertilizers which are applied via the broadcast method using hopper drop type spreaders, rotary spreaders or by aircraft. Band fertilizer treatment, particularly in tree and large shrub blocks, is becoming more popular with the increased price of fertilizers.

Foliar: Foliar sprays of certain nutrient elements are used for correction of minor element deficiencies. This method is also employed by some nurserymen every time a spray application is needed for insect or disease control. Compatability with pesticides should be known or nutrients should be applied separately. Foliar applications of urea (45% nitrogen) have been used successfully in cases where additional nitrogen was needed at a critical time. A rate of 5 lbs. per 100 gallons of water is satisfactory. Should potassium deficiency symptoms occur, either nitrate or sulfate of potash at 6 to 10 lbs. per 100 gallons of water should be applied.

Calcium deficiencies can be corrected with 3 lbs. of calcium nitrate or 2 lbs. of calcium chloride per 100 gallons of water. Calcium sprays have been added to most pesticide mixtures without compatability problems. Do not apply calcium sprays when the temperature is above 85°F. Proper pH control prior to planting should prevent calcium deficiencies in most soils.

Magnesium deficiency is frequently observed in plants in nurseries in eastern Ohio and in evergreens in acidic container mixes. Foliar application of magnesium sulfate (Epsom salts) is effective in overcoming this deficiency. A rate of 20 to 40 lbs. per 100 gallons is suggested, depending on severity of symptoms. Epsom salts should not be mixed with pesticides to avoid loss of pesticide effectiveness.

Chelated iron is effective in preventing iron deficiency of woody landscape plants in alkaline soils. Apply according to label rates as several brand name products are available. Any runoff will benefit the crop through root uptake.

Manganese deficiency of maple is common in Ohio and limited success has been obtained with manganese sulfate or chelated manganese sprays. Plant maples on the most acidic soils in the nursery if options exist.

To control boron deficiency, apply Solubor at ½ lb. per 100 gallons of water, Twenty Mule Team Borax at 1 oz. per 100 sq. ft. or ½ oz. per 1000 gallons of irrigation water. Boron deficiency is noted infrequently in woody ornamental plants.

Zinc, chlorine and molybdenum have not been observed to be deficient in plants in Ohio nurseries.

Micronutrients with the exception of iron and manganese, should seldom be applied to woody ornamentals except in cases of proven deficiency. The range between enough and too much is very small for these trace elements.

Injection Through Irrigation: The main advantages of fertilizing through the irrigation system are savings in time and labor of application, the ease of application at any time during the growing season and the opportunity for quick plant response. Relatively few producers use this system for field grown stock, although it is gaining importance in container and bedded stock.

The key to proper application is a proportioner which will permit accurate flow of the soluble fertilizer into the irrigation line. A number of proportioners with various capacities are available from irrigation supply firms. Uniformity of application will depend on the layout of the irrigation system, sprinkler pattern and the manner in which the material is injected into the irrigation line.

Use lower rates (1) early in the season before plants are fully developed, (2) for newly planted stock and (3) for ericaceous plants and slow growing narrowleaf evergreens.

Concentrations of 100 to 400 parts per million are generally used, depending on frequency of application.

Timing

Generally, very broad recommendations have been made concerning the timing of fertilizer application to trees and shrubs, with fall and spring being the recommended periods for fertilizer application. This is true for many species, but not all of them.

Some plants have only one flush of growth per year. Plants in this category include burning bush, most spruce, fir and others. The spring flush of growth is primarily a result of stored carbohydrates and nutrients in the roots and stems. Consequently, nutrients should be added prior to the beginning of growth in the spring. This may be accomplished by a fall application of fertilizer after growth has ceased or by an early spring application. Early spring applications should be made 4 to 6 weeks prior to the beginning of growth in the spring. Once shoot growth begins, nutrient uptake is not as effective, due to the relative inactivity of the roots.

Some reports have suggested that both fall and spring applications of fertilizer should be made to nursery crops. At this time, evidence would support use of fall fertilization on those crops exhibiting only one flush of growth annually. Avoid late autumn fertilization of sandy soils and use of nitrate fertilizers since they are readily leached.

While some plants have only one growth flush annually, the majority of plants have more than one growth flush. These plants include Taxus, Ilex, Cotoneaster, Rhododendron and many of the shade trees. With these plants, split applications of fertilizer are desirable for optimum growth. As with plants having only one growth flush, the spring growth flush is dependent on nutrients stored after the first growth flush. A second fertilizer application, about the time the shoots of the first flush are beginning to slow or cease in elongation, should induce a vigorous second growth flush. If the second fertilizer application is made no later than mid-late June, new growth will have adequate time to mature before a normal autumn freeze. A mid-late autumn fertilizer treatment would then be made in the same year, thus, two annual fertilizer applications, late spring or early summer and autumn. The recommended rates of fertilizer from soil test reports or as suggested in this bulletin should be divided between the autumn and spring treatments. Avoid applying the full rate of fertilizer with each application.

Research results have shown that maximum fertilizer uptake occurs while plants are in the "resting stage" of growth. This is a period when shoot elongation is not occurring and the plant appears to be inactive. However, root growth is occurring at this time; thereby, enhancing uptake of plant nutrients.

The late fall or early spring treatment should be a complete fertilizer. With late fall applications, after a hard freeze, nutrient uptake will continue until the moisture in the soil freezes. These absorbed nutrients will be stored in the roots and stems for spring growth. In addition to stems and roots, evergreen plants store nutrients in the leaves.

Plants with a continuous growth pattern such as juniper should have a more constant rate of fertilization. Perhaps the use of an organic, slow release or urea based fertilizer would be appropriate. Application should be made in early spring as well as late fall.

Late summer fertilizer application, especially nitrogen, may result in a late flush of growth of some plants if environmental conditions are satisfactory. This new growth will possibly be killed by freezing temperatures. The overall hardiness of plants can be decreased by a late flush of growth.

SOIL AND FOLIAR ANALYSIS

Soil Analysis

Once the nursery or landscape planting site has been selected, one of the first priorities prior to planting is to test the soil. The most significant aspect at this time is to determine the pH and lime test index as well as the fertilizer needs. It is much easier and more desirable to adjust the soil pH and nutrient status prior to planting. Ideally, the initial soil samples and corrective actions should be done a year or two prior to planting. This allows time for the needed soil amendments to produce their most desirable effects.

A soil analysis has its greatest value in established plantings when used in conjunction with foliar analysis. With woody plants, due to the vast depth and breadth of the root system, it is difficult to sample the soil to represent the area where the root system absorbs its nutrients. Thus, a poor correlation may exist between a soil test and a leaf analysis for a given nutrient. Because a foliar analysis does not indicate soil pH, both should be used to help diagnose suspected mineral deficiencies. Soil tests should always accompany foliar analysis of plants in tubs or planters, due to the rapidity of pH change in containers.

Soils in the landscape and field nurseries should be tested every 2 to 3 years and corrective action taken. A minimum of 6 to 8 sites should be sampled per field, combined and thoroughly mixed to provide greater uniformity. Dry at room temperature and place in a self-mailer, available from County Cooperative Extension Services Offices.

A soil analysis service is available in Ohio through each County Cooperative Extension Service Office. A questionnaire should be completely filled out and accompany the soil sample so the specialist can make valid recommendations.

The O.S.U. soil testing laboratory offers two groups of tests. The Standard Test includes soil pH, lime test index, available P, exchangeable K, Ca and Mg, cation exchange capacity and percent base saturation of Ca, Mg and K. The Greenhouse Test includes all of the above plus soluble salts and nitrates. Several tests are included on an individual basis, including organic matter, available manganese, boron and zinc but must be separately requested.

Nitrogen is not regularly tested by most laboratories, including the O.S.U. REAL Lab due to its unstable nature in soils. Nitrogen is readily leached from the root zone area of soils and is used in large amounts by plants. For these reasons, nitrogen applications are recommended on an annual basis according to the rates suggested under the sections on fertilizer programs for Landscape or Field Grown Nursery Stock.

Interpreting Soil Test Results

Soil Test Levels: Soil test values, for most crops and soils should be within or above the following ranges.

Soil pH

5.0-7.0 for mineral soils depending on plant species
5.0-6.0 for organic soils

Soil Nutrients

Available	P	30-100 lb/A
Exchangeable	K	200-400 lb/A
Exchangeable	Ca	800-16,000 lb/A[1]
Exchangeable	Mg	150-2,000 lb/A
Available	Mn	20-40 lb/A
Available	B	0.5 lb/A
Available	Zn	3 lb/A

[1] Limits vary depending on CEC, Ca-Mg ratio and % base saturation.

Cation Exchange Capacity (CEC)

CEC is a measure of the capacity of a soil to hold exchangeable cations including H+, Ca++, Mg++ and K+. In slightly acid to neutral soils, Ca and Mg account for 80% or more of the exchangeable cations, while K accounts for only a few percent. In acid soils a large part of the cations are hydrogen and aluminum in various forms. CEC is measured in terms of milliequivalents (Meg) per 100g of soil.

The CEC depends largely on the amount and type of clay present and the organic matter content. The larger this value, the more cations the soil is able to hold against leaching. It is not practical to attempt to increase the CEC of a soil, although liming will slightly increase the effective CEC.

The following is the normal range in CEC for different soil textures:

Soil Textures	**Common CEC Range** (Meg/100g of soil)
Coarse (Sands)	5-15
Medium (Silts)	8-30
Fine (Clays)	25-50
Organic Soils	50+

Base Saturation

Percent base saturation of the soil CEC will usually be within the following ranges, assuming proper pH range: Ca - 40 to 80%, Mg - 10 to 40% and K - 1 to 5%.

The Ca to Mg ratio is figured on the basis of percentage saturation of the soil CEC by each. This ratio should be considered when lime is added to the soil. If the ratio is 1:1 or less (less Ca than Mg), a low Mg limestone should be used. If the ratio is greater than 10:1, a high magnesium limestone should be used. Most plants grow well over a wide range of Ca: Mg soil ratios.

The Mg to K ratio should be greater than 2:1. The percent base saturation of Mg should be at least two times the percent base saturation of K. High K frequently results in reduced uptake of Mg by plants.

Foliar Analysis

Foliar or leaf analysis is a procedure in which the leaf tissue is analyzed to determine the mineral element content within a plant.

Foliar analysis is an important tool for establishing and maintaining a proper nutrition program in woody plants. Foliar analysis should be considered both to diagnose suspected mineral element deficiencies and as a check on the fertilizer program. The latter is especially important for those producing plants in containers with so many factors influencing the nutritional status. Regular analysis can indicate an approaching deficiency 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 reductions.

Grower use of foliar analysis is aimed at reaching optimum production within the limits of good nutrition. Using foliar analysis only when nutritional problems are suspected will not yield the greatest grower returns.

In general, leaf samples should be taken between mid-June and mid-September or later with evergreens and from plants that represent conditions within the planting whether normal or abnormal. Samples should include the most recently matured leaves which are about midway on shoots of current seasons growth. Approximately 30 to 100 leaves, depending on size, should be selected from trees, shrubs and broadleaved evergreens. About 50 terminal cuttings, 2 inches long, should be removed from narrow leaved evergreens from as many different plants as possible with the same condition. Comparison of health plant tissue with chlorotic plants is often a helpful technique in diagnosing plant nutrient problems.

County Cooperative Extension Service Offices have kits and detailed information on this program. Maximum benefit can be obtained only if sampling instructions are followed, the questionnaire filled out completely and recommendations incorporated into the cultural program.

Interpreting Foliar Analysis Results

The desired concentration of a mineral element should occur within the sufficient range. The figures in Table 7 indicate foliar mineral element ranges assembled through a compilation of research, survey data and industry samples.

Table 7: Foliar Mineral Element Ranges For Woody Ornamentals

	-Deficient-	-Low-	-Sufficient-	-High-	
N	0[*]	1.00	1.50	3.50	5.50
	0	1.50	2.00	4.50	7.00
P	0	0.10	0.20	0.60	1.00
K	0	1.00	1.50	3.50	6.00
Ca	0	0.20	0.50	2.50	4.00
Mg	0[*]	0.10	0.20	1.00	2.50
	0	0.20	0.30	1.00	2.50
Na	-	----	----	----	1.00
Mn	0	20	30	800	1000
Fe	0	30	50	700	1000
B	0	20	30	50	100
Cu	0	4	6	40	200
Zn	0	25	30	75	100
Mo	0	0.40	0.60	6	20
A1	----	----	----	----	800

[*] Levels for evergreens only.