CRITICAL EFFECTS OF FERTILITY ON ROOT AND SHOOT GROWTH OF SELECTED LANDSCAPE PLANTS[1,2]

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Abstract. In the transition from a production nursery to the landscape, the percentage survival of woody trees and shrubs is sometimes small due to limited root growth. It is important to nurserymen and arboriculturists that proper fertility programs be determined that will maintain a proper balance in growth between shoots and roots. Studies with *Cotoneaster divaricata* showed that root growth was not increased by N addition up to 500 mg/l of soil mix. High N levels actually had negative effects on root growth, whereas P slightly stimulated growth. Mycorrhizal inoculation of *Liriodendron tulipifera* did not promote root or shoot growth without application of fertilizer.

The impetus for these studies came from popular promotion of containerized plants for use in street plantings and as major components in urban landscapes by nurserymen and arboriculturists instead of field-grown plants. However, recent production trends have minimized the importance of root development and stressed vigorously growing shoot systems, both in containers and in the field.

It is known that the extent of the root system will influence the ability of a plant to take up nutrients and ultimately grow and establish in the landscape. In fact, while root development may not be a limiting factor to growth during production, it may be limiting once a plant reaches the landscape. The most obvious attribute to salable trees and shrubs is a well-developed shoot system. During production little attention is given to fertilization programs to maximize both shoot and root growth. It has been shown that very few roots are actually needed to supply water and nutrients to an actively-growing shoot during production. In the nursery frequent applications of water and nutrients further minimizes root development.

Trees and shrubs grown under nursery conditions are going to have very high shoot/root (S:R) ratios. Although the most desirable (S:R) ratio has not been determined, it is known that the higher the (S:R) ratio the less tolerant the plant to stress in the landscape. Practices during nursery production leading to high S:R ratios include: frequent application of root-inhibiting herbicides, frequent watering and fertilization, frequent root pruning (increases fibrosity but decreases total root mass), harvesting techniques and containerized production. Thus, an important limiting factor to landscape survival may be root development during production.

The greatest portion, and in some cases all, of the shoot growth of woody plants under natural conditions in temperate regions occurs during a relatively short period in the spring and early summer. Perhaps because of this growth pattern, it is common practice both during commercial production and in the landscape to apply nutrients to woody plants during the spring and early summer in an attempt to influence the growth during this period (Meyer and Tukey, 1967).

However, most woody plants with one annual flush of shoot growth normally exhibit root growth throughout spring and again during fall. There is usually a period of rest in roots in midsummer and winter due to environmental extremes such as low temperatures and deficient soil moisture (Meyer, 1969). Recently, however, root growth of some woody plant species has been found less con-

trolled by climate or soil conditions and more dependent upon internal factors or rates of shoot development. For example, changes in rates of root growth during the growing season in selected pines (*Pinus* sp.), and 'Helleri' holly (*Ilex crenata*) were found correlated to rate of shoot elongation, nutrient content of the plant, as well as a combination of environmental factors (Wareing, 1971, Gilliam and Wright, 1978).

Whenever woody plants undergo a period of rapid root and/or shoot expansion considerable quantities of both inorganic and organic substances are required. These may be derived from either externally absorbed substances or internally redistributed substances. It has long been accepted that applications of fertilizer to woody plants results in taller trees, larger leaves with a much deeper green color and generally healthier plants than unfertilized plants. Root development measured in terms of size, spread and number of roots has also been found three to five times greater in fertilized than in unfertilized trees (Gessel and Walker, 1956). However, limited information is available on the timing and rate of fertilizer applications to coincide with flushing of shoot and root growth during the growing season.

Generally, the root system constitutes the primary organ of ion (nutrient) absorption. Although the foliar application of nutrients may be a satisfactory method of dealing with certain problems of mineral element deficiencies that are not readily corrected by other means, such applications have not been successfully adopted profitably for continuous nutrient supply for growth of trees and shrubs. Thus, despite the fact that the root sytsem is not the only site of nutrient uptake, it still remains, from a physiological and practical standpoint, the primary site of ion uptake and water absorption.

Shoots and roots together constitute the entire higher plant structure, and in the economy of the whole plant, are in constant competition for available energy for their development. The resultant pattern of differential growth of the two organs, the shoot:root ratio (S:R), can thus provide an index for performance in a certain growth environment. For example, if nutrient supplies favor shoot growth at the expense of root growth,

the plant in question will exhibit a relatively high S:R value. Conversely, if root growth is favored over shoot growth, the plant will have a lower S:R value. The S:R ratios may thus help to ascertain how environmental and chemical factors affect and modify the growth of the shoot relative to the root. It should be noted, however, that the S:R ratios of plant species differ, and for a particular species the S:R value may vary with chronological age, stage of morphological development, and the kinds of growing environments. Both indirect and direct evidence indicates that the growth of roots depends upon sources of assimilates such as carbohydrates from the shoots, while nutrients such as nitrogen derived from absorption by roots are translocated upward and accumulated in leaves and seeds.

Achieving optimum nutrient levels that will maintain a proper balance between shoot and root growth often is difficult. Part of this difficulty may be attributed to a marked periodicity of shoot and root growth. In some woody plants root growth can be detected before shoot growth in spring. Other studies have shown that the root activity frequently appears to be inhibited during the period of active flushing of the shoots (Mertens and Wright, 1978). This inhibitory effect of shoot growth on roots appears to be due to the fact that while shoots are extending rapidly, they monopolize most available photosynthates and nutrients. Consequently, root growth can be limited if nutrient balance is improper. Translocation of photosynthate to roots is very much influenced by the extent of root development. Trees with poorly-developed root systems translocate low photosynthates poorly.

Several studies have been undertaken with selected woody plants to determine the effects of nutrient levels on:

(a) shoot and root growth rates,
(b) foliar nutrient composition,
(c) growth periodicity of shoots and roots,
(d) shoot and root growth following mycorrhizal inoculation.

Plants studied include species of *Acer, Liriodendron, Cotoneaster, Forsythia, Elaeagnus,* and *Quercus.*

Experiment 1

The main objective of this study was to determine the effect of nitrogen (N) and phosphorus (P) on root and shoot growth of *Cotoneaster* (Graca and Hamilton, 1981). In this experiment, single-stemmed cuttings of *Cotoneaster* were taken from stock plants propagated under greenhouse conditions and transplanted into polyvinyl chloride (PVC) pipes, two inches in diameter by one foot long, with a medium composed of peat and perlite (1:1v/v).

In order to measure the root system, a section was cut from one side of each length of pipe. The section was then replaced and secured with electrician's tape. A sheet of transparent acetate plastic was rolled and inserted into each pipe and a piece of saran shade cloth was wired to the bottom of each pipe to retain the growing medium. The pipe sections with transplanted cuttings, were then placed at 45° angles against a shelf with the window side down.

In this experiment, nitrogen was applied as NH_4NO_3, weekly, at levels of 0, 250, and 500 mg/l (ppm). Phosphorus was applied once as H_3PO_4 at levels of 0, 5, and 50 mg/l. Potassium, as KCl, was maintained at 150 mg/l level.

Shoot and root growth were determined weekly. After nine weeks, the plants were harvested with shoots separated from the roots. Fresh and dry weight of the components were obtained. Percent tissue N, P, and K was determined. Root length was measured by the Tennant (1976) method.

Patterns of shoot and root growth of *Cotoneaster divaricata* showed shoot growth consistently greater than root growth except for the ninth week (Fig. 1). Rapid increases observed for shoot growth were due to nitrogen (N). However, within N treatments there was no improvement of growth from 250 to 500 mg/l (Fig. 2).

Phosphorus increased shoot growth only at highest N levels. Root growth was not increased by either N or P (Tables 1 and 2). However, as N application increased, root length was slightly reduced (Table 1) suggesting that root growth varies inversely with N concentrations. Conversely, as P application increased, a slight stimulation on root density was observed suggesting that root
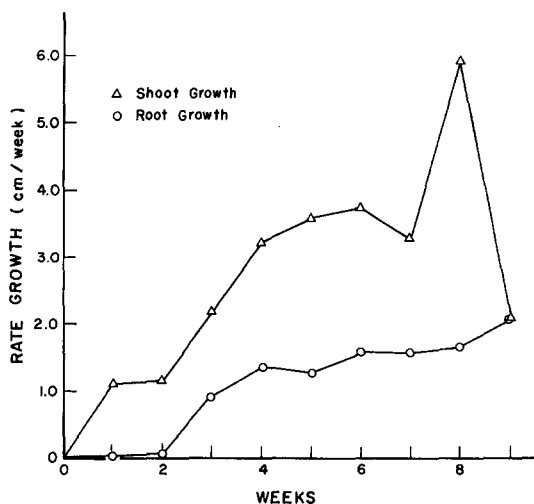

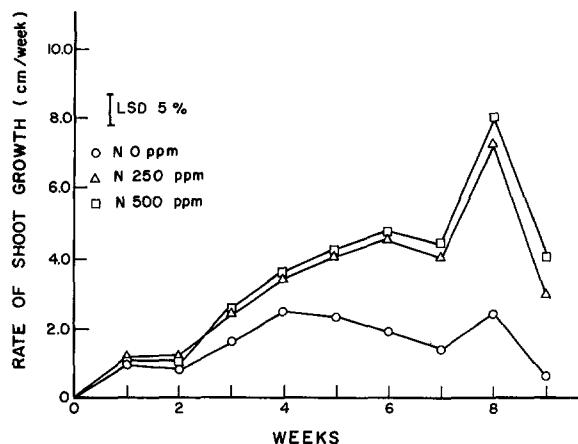Figure 1. Average effects of nitrogen and phosphorus on shoot and root growth of *Cotoneaster divaricata.*

Figure 2. Effect of nitrogen on rates of shoot growth of *Cotoneaster divaricata.*

development is more dependent upon P than N. A major point seems to be that high levels of N currently used for fertilization during production may have negative effects of root growth.

Experiment 2

The main objective of this study was to examine effects of mycorrhizae inoculation on growth of *Liriodendron tulipifera* (tulip poplar) at three

nutrient levels (Verkade and Hamilton, 1981).

Seedlings of tulip poplar were treated with controlled-release fertilizer (19N-6P-12K), and half of the seedlings were inoculated with the fungus *Glomus fasciculatus*. Mycorrhizal and non-mycorrhizal plants were grown under greenhouse conditions at three fertility levels (0, 2, and 4 gms N/l soil medium) to determine if mycorrhizal in-

oculation could be used to increase the root/shoot growth of tulip poplar at different fertility levels during production. Inoculated plants grown at the medium and high fertility levels (4 gms/l) were tallest and had the longest and most dense root systems (Table 3). Mycorrhizal inoculation only promoted growth of plants when fertilizer was applied.

Table 1. Effects of nitrogen on shoot and root growth of *Cotoneaster divaricata*.

| Nitrogen | Fresh Weight[xy] | | Root Length Per g of | | |
	Shoot	Root	Root	Plant	Density
ppm (mg/l)	g		m/g		cm/cm3
0	3.33^a	3.70^a	13.18^a	6.80^a	30.25^a
250	7.33^b	4.91^a	12.56^a	5.11^{ab}	39.84^a
500	7.87^b	3.72^a	11.39^a	3.72^b	27.02^a

[x]Mean separation with columns by Tukey test at 5% level.
[y]Values are the means of 4 replications.

Table 2. Effects of phosphorus on shoot and root growth of *Cotoneaster divaricata*.

| Phosphorus | Fresh Weight[xy] | | Root Length Per g of | | |
	Shoot	Root	Root	Plant	Density
ppm (mg/l)	g		m/g		cm/cm3
0	5.94^a	3.91^a	12.08^a	5.05^a	31.65^a
5	6.39^a	4.55^a	10.94^a	4.68^a	32.15^a
50	6.19^a	3.89^a	14.11^a	5.90^a	33.30^a

[x]Mean separation with columns by Tukey test at 5% level.
[y]Values are the means of 4 replications.

Table 3. Effects of inoculation with *G. fasciculatus* on increase in height, dry weight of shoots, dry weight of roots, and estimated root length of *L. tulipifera* grown at three fertility levels (0, 2, and 4 gms N/l of soil media) of Osmocote 19N-6P-12K slow release fertilizer.[z]

Plant Response	Fertility (gms N/l)	Inoculated	Noninoculated
Height increase (cm)[y]	0	0.84 c	0.79 c
	2	36.85 a	13.39 b
	4	40.66 a	16.42 b
Dry weight of shoots (gms)[x]	0	0.18 d	0.15 d
	2	7.07 b	0.67 c
	4	9.41 a	1.80 c
Dry weight of roots (gms)[x]	0	0.16 c	0.21 c
	2	2.48 a	0.48 b
	4	3.10 a	0.81 b
Root length (cm)[x]	0	566.41 b	489.72 b
	2	5012.84 a	1411.79 b
	4	5937.86 a	1768.76 b

[z]Separation of means by the Newman-Keuls test of significance, 1% level.   [y]Mean of 13 values.   [x]Mean of 6 values.

Current Landscape Fertilization Practices

Current landscape fertility practices have not been correlated with research findings such as those mentioned but hopefully will be in the future. However, disagreement exists on what is the best fertility program for a landscape specimen. Trees and shrubs that are maintained in a healthy vigorously growing condition are less susceptible to attack by insects and diseases and are able to tolerate other temporary environmental stresses (Carpenter, et al. 1975, Pirone, 1972, Totter, 1978).

Too often, landscape maintenance programs ignore nutrient requirements of trees and shrubs. The old adage that trees can grow where nothing else will is not valid. Although a tree may survive, it will probably not develop into the fine specimen presented in the original landscape design, unless a sound fertility program is provided. Fertilizers are not a substitute for light, water, etc., but make up a portion of the environmental factors, that must be in balance if the landscape plants are to fully develop (Smith and Gilliam, 1979).

Growth rate will vary somewhat among different species and from season to season, but generally, young, healthy trees should produce nine to twelve inches of terminal growth per year. Large, mature trees usually average six to nine inches of annual growth. The amount of growth for the current year can be measured from the tip of the twig to the first ring of bud scale scars; for previous years, the distance between one ring of bud scale scars and the next ring measures growth (Kvaalen and Carpenter, 1979). By comparing the growth of several seasons, growth rate for an individual tree can be determined. If growth rates are less than those mentioned, plants would probably benefit from additional fertilizer.

Fertilizing can quicken growth of young plants and can help stimulate growth of slow-growing species. Under proper nutritional care, even the so-called slow-growing species may grow as rapidly as many other species. Although mature trees and shrubs that have reached full size need less fertilizing than young plants, regular low rates of fertilizing will maintain good color and health while limiting excessive growth (Smith and Gilliam, 1979).

It is important to determine whether a fertility program is needed for mature landscape plantings. For example, a shade tree in a backyard, typically without stress conditions, will usually respond to less fertilizer and fewer applications than a tree planted between a sidewalk and street. The root zone of the latter is reduced and likelihood of soil compaction, exposure to highway salts and the road dirt, and air pollution is greater. However, in the landscape, if a complete fertilization program is being carried out for turf, the trees and shrubs may not need additional fertilizer so long as fertilizer is also applied to plant beds. Note: *Fertilizer-herbicide mixes designed for turf should never be used in plant beds* (Kvaalen and Carpenter, 1979).

Not all species of plants will respond to the same fertilizers or rates. For example, *Tilia* species typically respond to nitrogen, *Quercus* to iron, and *Acer* to manganese (Smith and Gilliam, 1979). Certain plants grown out of their native habitat may have specific nutritional needs.

A soil test should be used to determine pH and whether or not adequate levels of phosphorus and potassium are present in the soil. Usually with woody plants, nitrogen is the nutrient in short supply. Nitrogen readily leaches out of the root zone and must be replaced annually or at least every two years.

Actually, recommendations about the time and rate of application vary greatly. There are two basically different determinations about the best time for tree fertilization. Some research suggests that for northern climates, an April or May application will make the most efficient use of nitrogen supplied, with October and November being suggested as second best. The reverse order has also been suggested based on soil temperatures in the root zone. Soil temperatures are warmer in the fall, and more absorption of fertilizer will occur when temperatures are warmer. In southern or west coast climates where the temperatures are mild the year round, applications should be made before the growing season starts. As long as soil temperatures are above 40-45°F, roots can absorb nutrients. An added advantage is that in spring and midfall, soil moisture conditions also favor plant nutrient uptake.

If fertilizer was not applied during the spring or autumn, applications can be made up to about July 1 in northern and midwestern climates. Applications of fertilizers in late summer could promote a late flush of growth which may not acclimate before freezing temperatures occur.

Several methods of applying fertilizer are commercially practiced, including liquid soil injection, soil drill holes or deep-root feeding, surface application, foliar sprays and tree injection or implantation. Each serves a specific role depending upon the site and plant condition. Research has indicated generally that surface applications will provide the same benefits to a tree or shrub as deep-root feeding (also called punch bar system or soil drill holes). However, surface applications have certain disadvantages. The turf is often stimulated under a tree and the turf will be much greener than in surrounding areas. However, for fertilization of shrub beds and trees where high absorption rates are not needed or where the stimulaton of the turf area is not disadvantageous, the surface application is easier to make and it can be done with less labor, and consequently, less cost (Neely *et al.* 1970).

Dry fertilizers may be broadcast by hand or spread by push-type or rotary distributors. Avoid uneven distribution by dividing the fertilizer to be applied in half, then applying one-half lengthwise over the area, the remainder crosswise over the area. If isolated trees within a landscape are being fertilized with a dry fertilizer, avoid the so-called "oasis effect" by extending the area treated beyond the trees cover. Water the area thoroughly after application to remove it from grass or ground cover and move it down into the soil.

In the drill-hole method of application, holes may be punched with a crowbar or "punchbar" or drilled with an auger attached to an electric drill. The latter method is preferred in heavy soils since it does not compact the sides of the holes and permits dissolved fertilizer to move more freely from the hole. Such drilling has the added bonus of improving aeration of heavy compacted soils.

The drill holes can be placed on a concentric circle in the soil around the plant outward one to three feet beyond the drip line or they can be laid out in a rectangular area extending past the drip line (Fig. 3). Holes in either pattern should be evenly drilled or spaced on two-foot centers with approximately 250 holes per 1,000 square feet. Depth of holes should not be much greater than fifteen to eighteen inches since most of the feeder roots of many trees are within two feet of the surface. Diameter of the holes should be approximately two inches. Turf plugs should be kept intact so that they may be used or replaced after the fertilizer is added. Do not drill holes within two feet of the trunk of trees with a twelve-inch trunk diameter or within three feet of trees with an eighteen-inch diameter. The required amount of fertilizer, based on the area to be covered and the rate of application, should be divided equally to fill the total number of holes, and can be applied with a funnel or can with the top edge bent to form a pouring spout. After the fertilizer has been added, water thoroughly. The holes can be filled following fertilization with sand, topsoil, peat moss, calcined clay, perlite, small crushed stone or other soil amendment and the turf plug is then replaced on the top. If there is no danger to pedestrians, the holes may be temporarily left open to facilitate air and water penetration. This technique is time consuming and expensive, but it does eliminate the problem of a green turf oasis under the tree.

Fertilization at transplanting is recommended to supply phorphorus, because that element moves slowly in soils, as well as to assist in plant
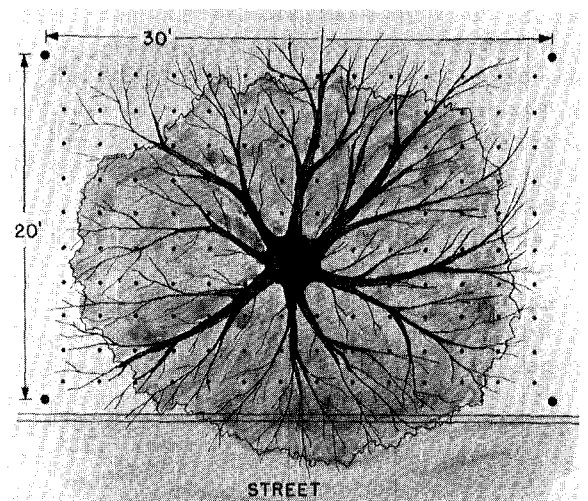

Figure 3.

establishment. At planting, apply ten pounds fertilizer per cubic yard of backfill of 0-20-0, 4-12-4, 5-10-5 or similar high phosphorus fertilizers. The rate of ten pounds per cubic yard is about equal to 0.5 pound fertilizer per bushel of backfill material. Water-soluble fertilizers, such as 8-32-16 and 10-52-8, are recommended at planting.

Calculate the size of the planting bed or lawn area containing the landscape plants. A rate of two to four pounds of actual nitrogen per 1,000 square feet of soil per year or six to eight pounds every other year is considered optimal. If foliage color, annual growth or general vigor is below normal, use the higher rates up to five or six pounds nitrogen yearly, per 1,000 square feet of soil. To reduce risk of fertilizer injury, this total yearly amount may be divided into two or more applications during the growing season. Even at one application, four pounds per 1,000 square feet is not considered excessive for well-established plantings in beds. For plants growing in turf, however, split applications may be used to avoid damage to turf. If soil tests or foliar analyses are available, follow those recommendations, otherwise, the suggested rates can be used as guides.

Another recommendation often made is to feed trees two pounds total nitrogen for each inch of trunk diameter or caliper. When following this recommendation, take care not to apply the fertilizer at a rate more concentrated than two pounds total nitrogen per 1,000 square feet of surrounding turf. When applying a complete fertilizer, it is suggested that a ratio of 2:1:2, 3:1:2 or 3:1:1 be used; again, the rate based on the amount of nitrogen in the analysis. Trees and shrubs respond to two or three times as much nitrogen as phosphorus and twice as much potassium as phosphorus. An application of three pounds of actual nitrogen per 1,000 square feet applied one pound of P_2O_5 and two pounds of K_2O when using a 3:1:2 ratio.

So-called "food spikes" or "food stakes" that are driven into the ground at intervals beneath and around trees and shrubs contain satisfactory fertilizer materials and are sometimes used as an alternative to drilling and filling holes, but they are even more expensive than other methods of fertilization. Unfortunately, the spacing of the food 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 provide adequate fertilizer distributon because lateral fertilizer movement is limited.

Dry fertilizer is also sometimes injected by blasts of air — a technique requiring specialized equipment. Sand is used as a carrier; the technique has the additional benefit of improving soil aeration.

The use of liquid injection can be made if the equipment, a special injector wand, is available. 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 two to three feet apart, depending on pressure and fifteen to eighteen inches deep for trees. Approximately 200 gallons of water is recommended per 1,000 square feet. The holes should be spaced two-one-half feet from center to center; approximately thirty pounds of 20-20-20 analysis fertilizer is recommended per 200 gallons of water. In an area of 1,000 square feet, there will be approximately 160 injection sites; one and one-half gallons of solution should be injected into each hole. Some caution should be taken in using liquid injection methods. Apply no more than one and one-half gallons per hole, and do not force the liquid into the hole at great pressure, for this may create air holes around the root system of the tree being fed.

Special Cases

Deciduous trees. Mature trees sometimes require little fertilization as long as they have good leaf color and grow reasonably well. Stimulating increased growth may increase foliage density to the point that interior foliage and plants growing beneath the trees may be weakened by heavy shade.

For trees growing in confined areas where roots are restricted by pavement, buildings or other construction, fertilizer rates should be based on the area in which the roots are confined and not

upon the branch spread when using the punchbar or auger method. Applying too heavy a rate can result in damage to roots.

Trees with very narrow crowns will have a broader root spread than crown spread. Fertilizer should be applied throughout the estimated root zone, not merely beneath the branch spread.

Deciduous shrubs. Surface application is preferred to the punchbar method for small or shallow-rooted shrubs. Fertilizer should be scattered evenly beneath and slightly beyond the shrub's foliage mass or applied to the entire bed if plants are close together. Care should be taken to avoid contact between the stems or trunks of plants and the fertilizer, and application should be followed with a thorough watering. If the shrubs are known to be deep rooted, the fertilizer may be worked into the soil.

While plants are small and rapid growth is desired, higher rates of nutrients can be applied. As plants reach desired size, reduce or eliminate fertilizer to limit growth.

Newly planted trees or shrubs. Damage to roots can occur when too much inorganic fertilizer is incorporated into soil or backfill used in transplanting. Surface application of fertilizer is preferred and should be watered in extremely well. Many landscape nurserymen avoid using fertilizer the first year, although this is not always desirable. Slow-release fertilizers may be worked into soil deep in the planting hole if several inches of backfill are added before the plant is placed in position.

Evergreens. Evergreen trees and shrubs appear to require lower rates of nutrients than their deciduous counterparts. Overfertilizing coniferous trees leads to open growth with widely-spaced branches. Narrowleaved evergreen shrubs generally need only enough fertilizer to maintain good foliage color, especially if used in small scale plantings.

Many broadleaved evergreens have shallow root systems which are easily burned by highly concentrated chemical fertilizers. These plants need an acid soil pH for an efficient nutrient uptake. Most garden centers stock special acid-based fertilizers formulated for broadleaved evergreens. These fertilizers contain both an in-organic source of acid-type nitrogen, which is quickly available to a plant, and an organic source, which will supply nitrogen over a period of time. Lime, wood ashes, and bone meal will raise soil pH and should be avoided. The punchbar method of fertilizer application should not be used with broadleaved evergreens, nor should surface applications be worked into soil.

An acid-type organic mulch, such as peat moss or rotted oak-leaf mold, will help conserve moisture, keep weeds down, and protect roots from excessive summer heat.

Minor elements. The major concern thus far has been with the major nutrients, principally the nitrogen requirements, of the woody plants. Generally, few of the minor elements are limiting to the growth of most woody species. However, an exception is true with high-pH soils. Iron chlorosis can develop in many species grown in such soils. Common examples are the ericaceous plants and pin oak, *Quercus palustris.* Iron chlorosis is generally throught to be due to the low solubility of iron in high-pH soils. However, damage to root systems such as that caused by low oxygen levels in water-logged soils may also cause chlorosis symptoms.

There are several solutions to iron chlorosis and generally these can be classified as permanent, semipermanent, and temporary. Of course, a permanent solution is to correct the problem of high pH in the soil before planting. Foliar analysis and/or soil tests are recommended to determine specific causes of chlorosis. Growing side by side in similar soil conditions a pin oak may be chlorotic due to iron deficiency and a red maple, *Acer rubrum* chlorotic due to manganese deficiency. However, as stated, corrections before planting are desirable. The area treated should encompass enough soil to allow future root development of the plant. Too often, the soil pH is adjusted only for the backfill in the planting hole, or in an area only slightly beyond the hole, without any regard for growth and development of the tree or shrub. Iron chlorosis can develop five to ten years after planting as tree roots grow out into areas where high pH has not been treated.

To lower soil pH, use sulfur and acidic fertilizers. In limestone base soils, changing soil pH at depths

from eighteen to twenty-four inches with fertilizers is nearly impossible; in these soils, the trees should be fed by the deep-root method, with ferrous sulfate (iron sulfate) and sulfur (Hamilton, 1981). Chelated iron may give more satisfactory results in any kind of soil if used in a soil injector or in a deep root-feeding than it will if applied to the surface. The response to these techniques is slow, but fairly permanent.

Sometimes, a tree has declined greatly because of iron chlorosis to such a great extent that a quicker response is needed. Trunk injections of ferrous sulfate or capsules containing iron chelate can provide a response in about three weeks. The treatment may last for up to five years. At the same time, soil treatments should also be made. Tree trunk injection, infusion of liquid or implants of fertilizer salts is often the most satisfactory method of applying not only iron but also zinc and manganese.

In early spring, when the new growth is expanding, a foliar spray with ferrous sulfate or iron chelate solution will provide a temporary response. It is only temporary, since the iron does not move in the plant beyond the foliage that has been sprayed; the new growth not treated will be chlorotic. This method should be used only to provide an immediate response, and a more permanent means of correcting the chlorosis should be initiated immediately.

Micro-nutrient sprays can be used to correct other minor element deficiencies quickly, but are more costly and less long-lasting than soil treatments. Foliar feeding of small and medium-sized shrubs can be done by the homeowner; proper coverage of trees and large shrubs will require services of a professional landscape nurseryman or arborist. Trunk injection methods may also require professional application.

pH

Soil pH, to a large degree, controls availability of many essential mineral elements. The pH of soil should be modified before planting to fit needs of the landscape plant. Although this is the most desirable practice, it may be necessary to adjust soil pH at a landscape site years after installation.

The need for soil testing before pH adjustments cannot be overemphasized. Too frequently, lime or sulfur is applied to soil without adequate knowledge of existing pH. In sections of the United States, such as the Northeast, soil pH is sometimes low, below 5.5 and adding surfur is unnecessary and could be harmful. Within a landscape site with a low pH soil, there may also be a high pH area. POINT: Do not unknowingly add lime or surfur to soils because of a general recommendation or because the practice is needed for an adjoining site. A soil test or pH determination is essential.

Increasing soil pH. The soil type determines the amount of lime required to change pH. Sandy soils have less buffer capacity, less resistance to acidity change, and require less lime per unit of pH change. The more clay present, the greater the buffer capacity, and the more lime required for increasing the soil pH. Highly organic soils have a very high buffering capacity and often it is not practical to try to change their pH. Lime is added to organic soils to supply calcium rather than to effect a change in pH.

Decreasing soil pH. The pH of mineral soils should be in a range of 5.0 to 6.0 for optimum growth of certain plants. Trees in this group include sour or black gum &(*Nyssa sylvatica*), sourwood or sorrell tree (*Oxydendrum arboretum*), sweet gum (*Liquidambar styraciflua*), hemlock (*Tsuga* sp., magnolia (*Magnolia* sp.), white pine (*Pinus strobus*), dogwood (*Cornus* sp.), most maples (*Acer* sp.), and oaks (*Quercus* sp.). Shrubs include nearly all the broadleaf evergreens bellflower tree or shrub (*Enkianthus* sp.), photinia (*Photinia* sp.), and azaleas (*Rhododendron* sp.).

The pH of soils can be lowered by the addition of sulfur. Again, the buffering capacity of the soil controls the amount of sulfur needed to decrease the soil pH by a given amount. Highly organic soils are nearly always acid and rarely need a decrease in pH. Soils with a limestone base have a high buffering capacity and it is very difficult to lower the pH in such soil. Generally, it is much easier to increase soil pH by adding lime than to decrease it by adding sulfur.

When applying sulfur over established turf, certain precautions should be followed. Sulfur can combine with water to form a dilute acid. If air

temperatures are above 80°F and the humidity is high, the formation of acid on turf grasses will cause burning of foliage. For safety, it is recommended that two pounds per 100 square feet (870 pounds per acre) be the maximum amount of sulfur applied at one time and that repeated applications be made several weeks apart.

Aluminum sulfate can be used for acidification, but the quantity necessary to decrease the soil pH to the same degree is four to five times greater than the amount of sulfur required. The use of aluminum sulfate should be considered only on a small scale.

Summary

Fertility programs for woody plants in the landscape should be carried out on a regular basis. Soil tests and growth observations should be used as a means of determining the fertility needs of plants. Rates should be based on the nitrogen level in the fertilizer and the P and K ratios.

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