CONSTRAINTS TO TREE GROWTH IMPOSED BY URBAN SOIL ALKALINITY[1]

by George Ware

Abstract. Soil alkalinity is commonly a limitation to tree growth in urban soils of the Chicago region. Associated chlorosis may sometimes be successfully treated, but longer term modification of the root environment is desirable. Selection and use of trees tolerant of soil alkalinity (calciphytes) are urgent needs. Planning a harmonious tree/site system requires simultaneous consideration of the limitations of both elements. Alkalinization of urban soils from runoff from concrete and limestone surfaces appears to be widespread.

Résumé. L'alcalinité du sol est communément une limitation à la croissance de l'arbre dans les sols urbains de la région de Chicago. La chlorose qui en découle peut quelquefois être traitée avec succès, mais des modifications à long terme de l'environnement racinaire sont souhaitables. La sélection et l'utilisation d'arbres tolérants à l'alcalinité du sol sont ardemment désirées. L'alcalinisation des sols urbains causée par l'écoulement des surfaces de béton et calcaire paraît être répandue.

The selecting of trees for urban planting in the Chicago region requires attention to two serious limitations—soil alkalinity and clayiness. This region has extensive areas of soil derived from alkaline glacial till. Urbanization often brings about a mixing of surface and deeper material producing a tree-root environment scarcely conducive to proper growth. The following discussions deal mainly with situations in the Chicago area, but information and ideas are thought to have applicability to urban areas elsewhere.

It has been stated that more than 80 percent of urban tree problems begin in the soil (7). This premise is the basis for giving special attention to understanding how root systems can grow satisfactorily in adverse urban soils. Underground problems for trees planted in urban situations are attributable to poor drainage and root drowning, summer dehydration of roots, roots outgrowing the soil volume available to them, increasing of water and nutrient needs, and alkalinization or salinization of the soil (12). Hightshoe (2) lists major urban soil limitations as droughtiness, coarse textures, claypans, wetness, acidity, shallow depth, nutrient imbalances, compaction, toxicity, salinity, and alkalinity. All of these limitations indicate environmental extremes of one kind or another. Proper performance of urban trees requires that environmental conditions, especially those of soil environments, have qualities of eveness in which detrimental extremes rarely occur.

Attaining a harmonious urban tree/site relationship requires two interdependent and concurrent considerations: the selection of the kind of tree to be planted and the selection and/or preparation of the site to accomodate the special requirements of the tree chosen. Initially, the selection of the kind of tree should be based upon assessment of the general qualities of the site and the feasibility of modifying and ameliorating site limitations. Site selection or preparation should take into account the functional capabilities of the chosen kind of tree to tolerate site adversities. By matching and meshing the functional attributes of the tree with the topographic and soil qualities of the site, a harmonious tree/site system can be produced. The selection of the right tree for the right place should be based upon possibilities for survival and enduring health. Attractive trees can be selected from lists of rugged, durable, and ecologically appropriate trees, but lists of aesthetically appealing trees provide little basis for selecting trees with good survivability (10).

Many shade tree species have their natural origins in forest or woodlands, wherein soil building is a part of a system of recycled leaves and nutrients. Decomposition of leaves and incorporation of organic matter into soil bring about pH levels below 7. Tree species tolerating soil pH levels above 7 usually are those with special natural origins—limestone areas, savannas, mountain ranges, or stream valleys of grassland regions. The driest portions of the geographic range of a forested region may have localized populations that tolerate higher pH levels than the trees of the main body of the forest. An example is

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black maple *(Acer nigrum)*, sometimes called Iowa sugar maple, which is quite different from New England sugar maple *(Acer saccharum)*. Black maple has leathery leaves and an extensive root system and is highly tolerant of the hot summers of Iowa (11). It appears to tolerate pH levels much higher than 7.0.

Plants that in nature are associated with alkaline soils are designated by several terms: calcicole, calciphile, calcipete, and calciphyte. All of these terms denote plants that grow in soils rich in calcium salts (3). The term "calciphyte" is perhaps most self-explanatory and is used in the following discussions.

Hightshoe (2) and Berrang and Karnosky (1) rate trees on the basis of tolerance of soil alkalinity. Some of the calciphytes that tolerate soils pH 8 or higher are: hackberry *(Celtis occidentalis)*, sycamore *(Platanus occidentalis)*, black locust *(Robinia pseudoacacia)*, American elm *(Ulmus americana)*, catalpa *(Catalpa speciosa)*, honeylocust *(Gleditsia triacanthos)* blue ash *(Fraxinus quadrangulata)*, Kentucky coffeetree *(Gymnocladus dioica)*, bur oak *(Quercus macrocarpa)*, chinquapin oak *(Q. muhlenbergii*, Fig. 1), Shumard oak *(Q. shumardii)*, and many hawthorn species. David elm *(Ulmus davidiana)* is a promising but little known calciphyte from northern China (Fig. 2).

In contrast to calciphytes, numerous kinds of trees cannot tolerate alkaline soils and often manifest the problem by developing pale green to yellow foliage (chlorosis). Chlorosis in midwestern states is most commonly seen in the foliage of pin oak *(Quercus palustris)* and red maple *(Acer rubrum)* but also may be seen in quite a number of other species, including: river birch *(Betula nigra)*, white oak *(Quercus alba)*, red oak *(Q. rubra)*, scarlet oak (Q. coccinea), sweet gum *(Liquidambar styraciflua)* sourgum *(Nyssa sylvatica)*, beech *(Fagus grandifolia)*, bald cypress *(Taxodium distichum)*, and tuliptree *(Liriodendron tulipifera)*.

Neely (6) lists 28 shade tree species that may show iron-deficiency chlorosis induced by soil alkalinity. Seven oak species are on this list. Smiley (8) notes that chlorosis owing to manganese deficiency in red maple and sugar maple is usually associated with disruptions of natural soil profiles. Smiley observes that chlorosis of these two maple species is seldom seen in natural woodland situations.

Throughout northeastern Illinois the glacial till underlying the natural soils contains countless fragments and particles of dolomitic limestone. In areas of urbanization, calcareous glacial material is commonly mixed with surface soil materials when large-scale landscape modifications are made. Urban soil often has pH values too high for proper growth of many tree species. Downtown areas appear to have soils progressively alkalinized by runoff from limestone and concrete surfaces that dominate the city center. The recent perceptible loss of sculptural detail on the facades of downtown buildings suggests that acid rain may be accelerating the dissolution of limestone and

Figure 1. Chinquapin oak *(Quercus muhlenbergii)* occurs in nature on calcareous soils.

Figure 2. David elm *(Ulmus davidiana)* is an elm from northern China that thrives on calcareous clayey soil.

concrete, some of which ends up in the soil. Alkalinization of urban soils owing to acid rain is a little-noted phenomenon.

The widespread prevalence of soil alkalinity in the Chicago area is evidenced by the fact that for soils of suburban lawns and parkways, 80 to 90 percent of analyses give pH readings of 7.0 or higher. Water from dolomite aquifers and granular lawn fertilizers tend to elevate pH levels. Readings of 8.0 to 8.5 are common in lawn soils of Chicago suburban communities. Unmodified natural soil profiles of meadows, prairies, and forests usually have surface soil readings somewhat lower than 7.0.

During rainstorms in 1984 and 1985, surface runoff water flowing from a parking lot at the Morton Arboretum showed a pH range of 7.5 to 8.0. During this time the pH of intercepted rainfall ranged from 4.3 to 5.9. Downslope from parking lots and roadways, Messenger (5) demonstrated that white oaks were greatly deficient in foliar manganese and were generally chlorotic. Healthy green upslope trees had far higher levels of foliar manganese. Messenger concluded that over a period of time alkalinization of previously acidic soils had been induced from drainage from lime-containing surfaces of roads and parking lots. Chlorotic white oaks adjacent to roads, driveways, and parking lots are common in the Chicago region.

In wooded neighborhoods, chlorotic white oaks appear to be more common in highly groomed front yards than in less well-tended backyards or in peripheral patches of oaks on large residential lots. Messenger (4) suggests that high levels of foliar phosphorus may be associated with low foliar concentrations of iron and manganese. He cautions against indiscriminate fertilization of lawns, especially around white oaks, pin oaks, red maples, and other species subject to chlorosis.

Use of mulch around oaks has several possible benefits for the oaks: exclusion of grass, which competes for root-space; expansion of a surficial rhizosphere in which tree rootlets and mycorrhizae thrive; long-term acidification of the surficial rhizosphere; and a medium for receiving treatments for lowering soil pH. Experiments at the Morton Arboretum are testing the response of white oak root systems to "vertical mulches"—porous organic topsoil placed in shallow trenches radiating from points near the trunks of oaks. The idea is to induce fine-root proliferation in a favorable, aerated, and somewhat acidic medium. Such a medium may facilitate absorption of iron and manganese.

The tree owner with a chlorotic tree is likely to be more interested in correcting the condition than in how the condition came about. Short-term treatments involve supplying utilizable forms of iron or manganese through trunk injections or through absorption by rootlets. Because deficiencies are related to reduced availability, which is in turn related to high pH levels, reducing soil pH level should also be alleviative. But lessening alkalinity of urban soils of the Chicago region is difficult. Applications of sulfur and sulfur compounds are sometimes used. Applications of sulfuric acid quickly lower soil pH, but effects are usually localized and temporary. Accompaniments to various trunk and soil applications should be longer-term treatments, such as replacement of grass with mulch.

Soil alkalinity is only one of many adversities that may limit growth of urban trees. Approaches to addressing these problems are: correcting or ameliorating limitations of the soil environment of the root systems of existing trees, selection or preparation of favorable planting sites for new trees, and selecting trees that can tolerate alkalinity.

Changing the soil environment of existing trees may require a great deal of effort and time, perhaps years, but better preparation of planting

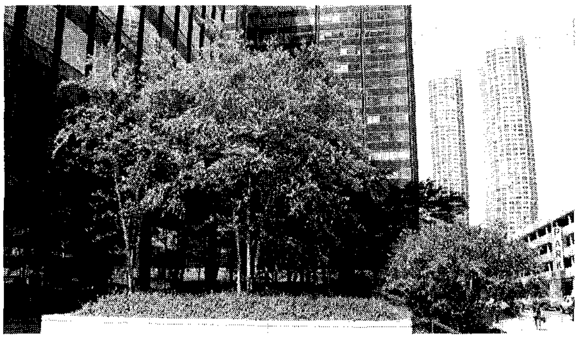

Figure 3. A group of river birches *(Betula nigra)* in a large planter box in downtown Chicago. River birch is not a calciphyte.

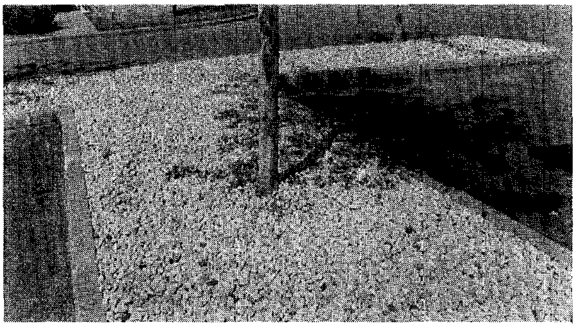

Figure 4. The limestone mulch surrounding a red maple *(Acer rubrum)* will slowly alkalinize the soil, creating conditions unfavorable to the root system of the maple.

places and proper selection of trees (calciphytes) are definite near-term possibilities for improvement of urban landscapes. For example, in downtown areas greater use of large planter boxes (Fig. 3) would permit utilization of non-alkaline soil and the use of groups of appropriate woody calciphytes. Finding, selecting, and development of additional trees tolerant of soil alkalinity are urgent needs for improvement of urban landscapes.

An overall perspective for handling urban tree problems is presented by Tattar (9), in which he uses the "natural forest" ecosystem as an ideal model. He notes that the natural processes of forest trees are largely ignored in many urban tree situations (Fig. 4). His list of things that work toward a forest-like environment includes: use of mulches, avoidance of soil alkalinity and salinity, protection of trees from bark damage, and better use of fertilizer. His view is that environmental extremes and people-pressures must be moderated. He adds that an important consideration is the selection and development of urban trees that can tolerate urban stresses.

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Abstract

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Honeylocust has become an increasingly popular shade tree. Honeylocust has had a reputation as a relatively "pest-free" tree. Unfortunately, numerous insect and mite problems, as well as various canker fungi, have become increasingly important on honeylocusts as the tree has grown in landscape popularity. Insects and mites that plague honeylocust include mimosa webworm, honeylocust plant bug, honeylocust podgall midge, leafhopper, treehopper, honeylocust spider mite, eriophyid (rust) mites, cottony maple scale, blister beetle and honeylocust borer.