COPING WITH CLAY: TREES TO SUIT SITES, SITES TO SUIT TREES[1]

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Abstract. Soils high in clay content are subject to widespread springtime wetness and poor aeration for tree root systems. Selection of kinds of trees tolerant of soil adversities and preparation of planting places for better accommodation of the selected trees are concurrent needs that must be meshed if there are to be enduring urban landscapes. Selection of better urban trees should be based primarily upon ecological attributes, including geographic and edaphic origins. Planting places should be conducive to rapid root proliferation and establishment following transplanting.

The coping with problems associated with clay soils is a difficult challenge commonly confronting those who deal with tree planting and tree health in the Chicago region. Clay soils are widespread in northern Illinois, having developed from alkaline glacial till on landscapes that are commonly flat to slightly rolling. Northern Illinois has some of the most fertile agricultural areas in North America, with soils that generally supported prairie in presettlement times; but such soils may pose difficulties for root growth of planted trees. Though descriptions and examples presented herein deal mainly with the Chicago region, the information and ideas may have applicability to urban areas elsewhere.

Flatness of landscapes and high clay content of soils provide conditions that produce slowness of drainage and persistent saturation of soils. Common in northern Illinois are perched water tables on the impermeable glacial till which underlies the soil surface at a depth of less than three feet. In large-scale construction projects, surface and deeper materials are mixed, producing at the manmade surface a clay-rich "non-soil" — a dense and inhospitable medium for tree root growth. Such re-shaping of the surface configurations of the landscape may facilitate runoff, especially through the creation of mounds, berms, and steep banks of retention ponds, but serious adversities in the tree-root environment still remain.

Molded landscapes, comprised of a mixture of substrates from different depths, have little of the porosity associated with undisturbed soils, in which valuable organic matter and mineral aggregates formed through the centuries are present. In "fill soil" there is root growth impedence, poor regulation of soil water, poor gaseous diffusion, and greatly fluctuating surface temperatures. Prolonged retention of moisture may lead to anaerobic conditions and accumulation of toxic substances, inhibitory or even lethal to roots (Craul, 1982).

Another problem in northern Illinois has to do with alkalinity. When highly calcareous glacial material is mixed with surface material, there is produced a root-growth medium with pH values too high for certain tree species. Moreover, runoff from concrete surfaces (streets, sidewalks, parking lots, driveways, etc.) appears to increase soil pH values. In the Chicago region, soil pH values between 7 and 8 are quite common in lawns and other grassy open areas. In a study at University Park, Pennsylvania, Halvorson et al (1982) found that precipitation pH (3.99) was raised dramatically (7.64) after the water had run across paved urban surfaces such as roads and parking lots.

To develop a harmonious tree/site relationship, the planting of a tree on an urban site 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 accommodate the special needs of the tree chosen. Initially, the selection of the kind of tree should be based on general advantages of the site and the feasibility of ameliorating site limitations. Site selection or preparation should take into account the functional capabilities of the chosen tree to tolerate any site adversities. By matching and meshing the functional attributes of the tree with

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the soil and topographic qualities of the site, a harmonious tree-site system can be produced. There are, of course, other considerations such as visual qualities; however, if in the completed project there is not proper physiological and ecological attunement of tree to site, other desirable qualities, including amenities and aesthetics, may never materialize. Tattar (1983) outlines stress models for urban trees wherein he proposes using the "natural forest" ecosystem as an ideal model; by taking cues and clues from nature, a "forest-like" urban environment can be developed, in which environmental extremes and people-pressures are moderated or minimized. He adds that, "we must also consider tolerance of urban stress a major desirable trait when selecting shade trees for planting."

Trees to Suit Sites

The best prepared planting medium high in clay will accommodate successfully only certain species of trees. It has been pointed out that floodplain and swamp species are generally successful urban trees (Curtis, 1959, Van Camp, 1970). Not only do these species tolerate spring soil wetness but they also tolerate prolonged summer dryness, actually possessing a broad amplitude of endurance of environmental adversity. American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica* var. *subintegerrima*), and silver maple (*Acer saccharinum*) are the main components of the floodplain forests of many of the rivers of the eastern United States. All are widely planted in towns and cities. Indeed, the widespread planting of American elm set the stage for Dutch elm disease devastation. Less common floodplain species are river birch (*Betula nigra*), swamp white oak (*Quercus bicolor*), hackberry (*Celtis occidentalis*), and sycamore (*Platanus occidentalis*). These four are also commonly used as urban trees (Ware, 1980a).

Pin oak (*Q. palustris*) is widely planted in the Chicago region even though problems seem to plague this species. It is a native of poorly drained flat areas that have acidic soils but also thrives in well-drained places; however, it often develops chlorosis in urban situations with alkaline soils. Because acidification of such soils is quite difficult, selection of oak species with more suitable ecological attributes seems to be a better approach to urban planting. Requirements for such an urban oak should include tolerance of both clay and alkalinitiy. Both Shumard oak (*Q. shumardii*) and its close relative Texas red oak (*Q. texana*) get along well on alkaline clay soils. Chinquapin oak (*Q. muehlenbergii*) is another oak at home on alkaline clay soils. Northern red oak (*Q. rubra*) does moderately well on slightly alkaline soils if drainage is adequate. Bur oak (*Q. macrocarpa*) is an excellent oak for clay soils, also tolerating some alkalinity. Hill's oak (*Q. ellipsoidalis*) is occasionally seen as a successful planted tree in northern Illinois (Figure 1).

A good example of a calciphile (a plant that grows best on calcareous soil) is white poplar (*Populus alba*), known for its spread by suckering (Figure 2). The calciphile concept is a useful one in the search for new urban trees.

Lists of recommended trees of the towns and villages of the Chicago region are usually quite short and show considerable similarity. Green ash, honey locust (*Gleditsia triacanthos*), Norway maple (*A. platanoides*), sugar maple (*A. saccharum*), red maple (*A. rubrum*), and hackberry are on most of the lists. 'Greenspire' and 'Redmond' lindens are on some of the lists, as are red oak, pin oak, and ginkgo (*Ginkgo biloba*).

Generally excluded are silver maple and Siberian elm (*U. pumila*). Still, in new neighborhoods the numbers of these trees are quite great, mainly because homeowners insist upon quickly produced shade. However, recent

Figure 1. A three-year-old planting of oaks on a berm made of clayey soil. The pin oak on the right is already in decline; the two Hill's oaks have vigorous dark green growth.

large-scale plantings seem to emphasize green ash, honey locust, Norway maple, and red maple. Experienced landscape contractors in the Chicago region consider red maple and pin oak most appropriate for those sites where the soil profile has been preserved intact, insuring a neutral to slightly acid topsoil. Both red maple and pin oak are subject to chlorosis on re-molded landscapes because of the predominantly alkaline clay root environment. The use of limestone gravel around pin oak and red maple ignores the natural soil requirements of the two species (Figure 3).

Some of the little-used and little-known tree species with considerable tolerance of clay soils and alkalinity are: blue ash (*F. quadrangulata*), pumpkin ash (*F. tomentosa*), Amur corktree (*Phellodendron amurense*), lace-bark elm (*U. parvifolia*), Japanese elm (*U. japonica*), Amur maple (*A. ginnala*), hedge maple (*A. campestre*), black maple (*A. nigrum*), and Peking tree lilac (*Syringa pekinensis*). Some suitable conifers are: European larch (*Larix decidua*), baldcypress (*Taxodium distichum*), and limber pine (*Pinus flexilis*).

Figure 2. An example of a calciphile. White poplar tolerates well the alkaline clayey soil and the restricted root-system soil volume. Countless suckering shoots are regularly mowed off.

The concept of provenance (the place of origin or source) is useful in the search for more suitable and more stress-tolerant urban trees. For tree species that have extensive natural ranges, it appears that those populations of plants indigenous to the most climatically rigorous parts of the range may provide the best urban trees. An example with special pertinence is the greatly variable sugar maple, which has a natural range extending over a large part of eastern North America. The sugar maples native to New England have leaf shapes quite different from the leaf shapes of those growing in Iowa (Desmarais, 1952). But leaf shape is only the most obvious of a number of dissimilar qualities in the natural populations of sugar maples in these two well-separated areas. The sugar maples of Iowa have thicker, more leathery, and more scorch-resistant leaves than the sugar maples of New England. The heavier root systems of Iowa maples seem to provide an adaptation for good tolerance of the periodically hot and droughty Iowa summers. Because of its evolutionary origin in a part of the nation with cold winters, hot summers, and much windy weather, the genetic make-up of Iowa sugar maple may equip this maple to tolerate urban adversities better than most of the sugar maples now being planted (Kriebel, 1957). Both 'Legacy' and 'Green Column' are new sugar maple cultivars originating in the Midwest and displaying visible characteristics and functional qualities that indicate successful performance in the Midwest.

The concept of provenance also may be applied to other parts of the world as sources of woody plants. China has large areas with climates similar to the climates of our Midwestern states. Certain commonly used urban trees have their origins in China, but the search for additional species has not been carried very far, especially with regard to trees native to places such as swamps, floodplains, and mountains. There appear to be many more tree species in northern China that have qualities needed for successful performance in urban situations in the United States.

Elms have especially good qualities for satisfactory performance on urban sites. Though the word "elm" often evokes negative responses, a significant consideration is that certain Asian elms are quite resistant to Dutch elm disease and phloem necrosis. For example, lace-bark elm, or true Chinese elm, is a highly promising elm with an extensive natural range in China. Its small, glossy, leathery leaves and its reddish mottled bark are some of its attractive features (Leopold, 1980). Certain selections of both lace-bark elm and Japanese elm resemble American elm and both could be used as substitutes (Ware, 1980b). Siberian elm is a well-known import from China, but its rampant growth and breakable branches are drawbacks that exclude it from consideration as a worthy urban tree.

Shortcomings can be associated with virtually all prospective urban trees, but certain species have obvious problems, especially when clay soils and alkalinity are both prevalent. Both pin oak and red maple commonly become chlorotic. With the exception of river birch, birches are not at home on clay and usually fall prey to bronze birch borers within a few years. Certain *Prunus* species are detrimentally affected by waterlogged soils, owing to the conversion of naturally occurring cyanophoric glycosides to hydrogen cyanide, which is toxic to cells (Rowe and Catlin, 1971; Perry, 1982). Perhaps the Row and Catlin study provides insight on the problem-plagued and short-lived purple-leaved plums so frequently seen in group plantings. On the other hand, apples and pears (also in the Rosaceae) are relatively tolerant of soil wetness. 'Bradford' pear and related cultivars of *Pyrus calleryana* seem to get along well with clay soils.

Sites to Suit Trees

Lessons from the "natural forest" tree-stress model (Tattar, 1983) are appropriate in consideration of possibilities of site modification. Zimmerman and Brown (1971) state that "contrary to what many laymen believe, the bulk of the root system of most trees growing on medium-textured soils (loams and clays) is within three feet of the surface. The majority of the smaller absorbing roots lie in the upper six inches of forest soil." Porosity and good aeration are favorable factors conducive to root proliferation, and it is in the upper six to twelve inches where simulation of the favorable conditions of natural forest soil is most readily accomplished in man-made urban situations.

In undisturbed soils, the activities of roots and the myriad of associated organisms have favorably conditioned the soil as a medium for plant root growth. An associated phenomenon is the aggregation of mineral particles into structural units that facilitate the movement of water and oxygen, both vital to root health and growth. Preserving a natural and undisturbed soil system is highly desirable because it is a medium that has developed over a long period of time — a medium already prepared for tree planting. Unfortunately, undisturbed soil systems are seldom preserved in man-made urban environments (Perry, 1982).

Clayey urban soils are especially difficult substrates into which to transplant trees and amelioration of conditions for accommodating root systems in such soils is often insufficient. The roots from root balls may not readily enter the surrounding soil. There are actually two interfaces which roots must grow across to leave the root ball and enter the surrounding existing soil: root ball/backfill and backfill/existing soil. The frequently observed tendency for roots to proliferate within soil-root balls rather than to grow out of balls points up a need for better understanding of root growth patterns following transplanting.

Watson and Himelick (1983) call attention to the small amount of total root system that may be present in the root ball of a transplanted tree.

Figure 3. Red maples growing in soil completely covered with limestone gravel. The foliage is pale green, but chlorosis is not yet apparent.

They stress the importance of the regeneration of rootlets from callus formed at several root ends and the importance of keeping the peripheral portion of the root ball moist during transit. Equally emphasized is the injurious effect of overwatering and the saturation of both the ball and the soil medium surrounding the ball. It is vital that rapid proliferation of rootlets occur if there is to be sufficient rootlet/soil contact for the trees to survive environmental vagaries and the precariousness of the first year.

A broad disk of porous topsoil (as backfill) six or more inches deep tends to encourage rapid lateral growth of roots from the root ball of a newly transplanted tree. Of course, a broad excavation is necessary. The broad porous soil zone permits extensive lateral soil exploitation by rootlets, eliminating the second interface. Mulching of the surface soil lessens the possibility of surface heating and drying that might dehydrate rootlets near the soil surface.

The use of a mound or berm is another approach to facilitating tree-root establishment by lessening the constraints of poor soil aeration. Though the berm offers localized elevation and facilitates egress of water, problems may still exist if the berm is comprised of compacted fill or dense soil. The use of a narrow trench (French drain) with coarse gravel covered with sod is a good way to make a hidden lateral drain with a seep hole. Alternatively, trenching with a back-hoe from the planting spot to the edge of the berm and filling the trench with porous organic soil, not only will permit the exit of water but will also provide an elongate soil zone conducive to quick horizontal root growth and proliferation. These procedures can also be used on certain existing slopes.

In clay soils, there is great desirability for planting trees on slopes rather than on flat sites. This idea is applied to large-scale forest/farm landscapes by Edington and Edington (1978) who give guidelines for the placement of trees on land with marked topographic differences. They emphasize the tree-growth constraints of flat plateau-like upland sites where lateral movement of water is slow and waterlogging of soils is common. They recommend the planting of trees only on the border areas or crests of such plateaus and, of course, on the slopes, especially the lower slopes. The lesson from their examples seems to be "Don't plant a tree on a flat place if there is a slope available."

The selection of the right tree for the right place too often rests with considerations that do not attach enough importance to the survivability of the tree. Attractive trees can be selected from lists of rugged, durable, and ecologically appropriate trees, but lists of aesthetically desirable trees provide little basis for selecting trees with good survivability.

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