SOIL RESOURCE EVALUATION FOR A GROUP OF SIDEWALK STREET TREE PLANTERS

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Abstract. Urban street-tree-planter soils provide inadequate growing space for root systems of trees and are subject to increased concentrations of pollutants not typically found in native soils. An examination of planting media in selected Geneva, Illinois street tree planters revealed physical and chemical soil properties that only the most stress-tolerant species could endure. The planter soils generally consisted of brick rubble, gravel, sand, and cinders. Drainage in the planters was impeded due to textural discontinuities. Soil pH and sodium values were high enough to classify these soils as sodic. Sodic soils naturally occur in arid and semi-arid regions where evapotranspiration exceeds precipitation. Planter soils need testing for physical and chemical characteristics before being used for trees. They can then be modified, if necessary, to provide the plant with the best possibilities to survive the urban environment.

Résumé. Les plantations d'arbres en sol urbain fournissent un espace de croissance inadéquat pour les systèmes racinaires des arbres et sont soumises à l'augmentation des concentrations de polluants qui ne sont pas typiques des sols d'origine. Une examen des moyens de plantation sélectionnés parmi les plantations d'arbres de rues à Geneva en Illinois a révélé des propriétés physiques et chimiques du sol que seules les espèces les plus tolérantes au stress pouvaient endurer. Les sols de plantation étaient constitués générallement de débris de briques, gravier, sable et de cendres. Le drainage dans les plantations était gêné par les discontinuités texturales. Le pH du sol et les taux de sodium étaient assez hauts pour les classifier parmi les sols sodiques. Ces sole se retrouvent naturellement dans les régions arides et semi-arides où l'évapotranspiration dépasse la précipitation. Les sols de plantation ont besoin d'être testés pour les caractéristiques physiques et chimiques avant d'être utilisés pour les arbres. Ils pourront alors être modifiés, si nécessaire, pour fournir le plant dans les meilleurs conditions pour sa survie dans l'environnement urbain.

Survival of street trees in urban planters is dependent upon preparation and management of their root-system environments. In planters, several soil and atmospheric factors are drastically different compared to the environmental conditions trees are adapted to in their native habitats (4, 12). Physical and chemical soil conditions which exist in street tree planters are the result of direct and indirect anthropogenic influences. The physical attributes of a soil, including texture, structure, bulk density, temperature, and water movement are generally at environmental extremes in street tree planters.

Soil particle size distribution (texture) controls the type of aggregation, drainage characteristics, pore space, and water-holding capacity of soil materials. Man-influenced soils have widely heterogeneous particle size distributions within relatively small areas (2). These commonly are abrupt changes in texture associated with material changes in the urban soil profile. Thus, wide variations in aggregate type and stability as well as soil water and drainage characteristics are common. The abrupt changes in materials and textures create conditions favorable to the formation of perched water tables which may be discontinuous in the profile (6, 7).

Alkaline soils have reactions (pH) greater than 7.0 and are dominated by the basic cations calcium, magnesium, potassium, and sodium. Urban soils commonly have chemistries that are alkaline which can be *in situ* from the planter soil materials or as a result of runoff from concrete structures which contain calcium carbonate (11). The chemistry of alkaline soils is such that micronutrient deficiencies may occur in sensitive species.

Urban soils sometimes accumulate salts to the degree that they classify as saline or sodic (sodium-affected soils) which is in stark contrast to the nursery conditions in which the plants developed (10). Typically saline and sodic soils are present in arid and semi-arid regions where evapotranspiration exceeds precipitation; thus, salts are not leached from the soil profile. Sodium-affected soils generally exhibit poor soil aggregate stability and lack structure as a result. This strongly inhibits air and water movement through the soil due to the lack of pore spaces.

Chemical contamination of urban soils occurs from a myriad of sources. Planter soil parent materials, *the materials in which the soil has* developed, may be contaminated before being brought to a site. These contaminants may include inorganic chemicals, fertilizers, pesticides, petroleum, and petroleum by-products. These types of contamination generally render a soil unusable for woody plant growth. Unfortunately, these contaminants are not generally recognized until plant death occurs (8).

Aerosol deposition on urban soils can have negative long-term impacts on the growth and culture of woody plants, but these are difficult to identify and quantify. Deicing compounds, alkaline aerosols, and dust are the more common aerial contaminants reaching soils (14). Clark and Kjelgren (1) identify aerial contaminants as seasonal concerns more than long-term problems in deciduous species, but only in relation to deposition on foliage as opposed to soil contamination. Surface water runoff contributes much more quickly than aerosols to modifying soil chemistry. Alkaline water, deicing compounds, heavy metals, and greases and oils are among the contaminants deposited by surface runoff onto the root zones of urban trees (3, 5, 11).

Methods

Seventeen existing planter vault soils in Geneva, Illinois were evaluated for adequacy to support new tree plantings following removal of the old trees. The planters are located along the main thoroughfare through the central business district. The study was initiated to determine what amount of each existing planter soil might be reusable for new tree plantings after being in place approximately 20 years. Surface soil samples were gathered from each 1.2 m square planter vault using a 6.4 cm diameter soil auger. Soil morphological characterizations were performed in the field for texture, structure, color, and drainage conditions. Samples were analyzed in the laboratory for pH, electrolytic conductivity (EC), elemental concentrations, cation exchange capacity (CE), and base saturation. Sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were calculated for each site. These calculations are necessary for determining saline and sodic soils and are given below.

(Eq. 1) $SAR = NA^{+}/([Ca^{++} + Mg^{++}]/2)^{1/2}$.

(Eq. 2) $ESP = (Exch.\ Na^{+}/CEC) \times 100\%$.

Results and Discussion

Physical properties. The planter soils had physical attributes which would have been limiting to all but the most stress-tolerant species. many of the ginkgos *(Ginkgo biloba)* and sycamores *(Platanus occidentalis)* which were in these soils were stressed and declining, but few had perished. Topsoil material was lacking in most planters or, if present, consisted of compacted silty clay loam soil mixed with the other planter soil materials.

Soil textures in the planters usually ranged from clay loam to sandy loam; however, the soil materials were often mixed with either gravel, brick rubble, cinders, or sand. The problems with foreign materials such as these are many. The coarse materials and fragments do not provide a nutrient base for the plant and they have little, if any, water-holding capacity. They also lack structure and encourage material discontinuities within the planting soil. These restrict adequate root proliferation and disrupt drainage patterns in the planter by either providing voids in which the water will flow through too fast, not allowing for uptake by the plant, or by perching water. Materials such as cinders or bricks may have been contaminated before being placed in the planter. This could lead to unforeseen chemical problems as these slowly break down.

Many of the aforementioned drainage problems were noted in the planters during sampling and were attributed to the foreign materials. In addition, soil materials which were adequate texturally were often compacted and lacked any structural integrity. Aeration in those soils was minimal and perching of water was evident. Macro-structure destabilization, which reduced infiltration and permeability, was attributed to excessive sodium levels.

Chemical properties. Laboratory data for the Geneva street tree planter sites were aggregated *into three data sets: one for the north side of the* street, one for the south side, and an analysis of the data set as a whole. The direct impact man has on such tree planters is obvious visually. The planters are surrounded by concrete and have limited root space. The geographic separation of planters by north and south, however, reveals chemical impacts that would not have been so evident otherwise.

Soil pH can be used as general evidence of potential chemical imbalances in the soil system. The pHs found in the planter vaults indicate the potential for severe nutritional imbalances for virtually any tree planted (Table 1). The mean soil pH for all the sites was 8.5 but several had pHs between 9.0 and 9.9. Soil pHs above 8.3 are an indication of a sodium carbonate controlled soil chemistry instead of calcium carbonate, which is normally found in this area (15). The pHs found on the south side were more extreme than the north side (Table 1). The mean pH on the south was 8.8 compared to 8.3 on the north. These pHs, however, were not significantly different.

The elemental analyses of the planter soils also showed dramatic differences on north and south (Table 2). Phosphorus, potassium, magnesium, and sodium were all higher on the south side of the street than the north. Phosphorus levels were much lower overall than native soils of northeastern Illinois (9). Levels were twice as high on the south as the north but were so variable from planter to planter that the differences were not significant.

Potassium and magnesium levels were higher than in native soils but were not considered to be at toxic concentrations (Table 2). North and south side differences were not statistically signficant. Calcium was much lower on the south than on the north; however, these values were not significantly different because of the high degree of variability in these urban settings. The levels of calcium on the north were somewhat high on average in comparison to native soils. The maximum on this side (14,000 ug/g) was extremely high (Table 2). The high values of magnesium and calcium could probably be attributed to excessive amounts of limestone gravel and rubble in the planter soil.

Sodium levels were elevated in all planter soils compared to native soils (9). High sodium levels in the soil affect plants by competing with exchangeable cations on soil colloids and thus impeding the balanced uptake of nutrients (13). The concentrations of sodium on the south side were signficantly higher than on the north side and are a result of sodium chloride deicers (Table 2). The low winter sun places the south side sidewalk and street in shade all day, thus requiring the use of more deicing salt. Precipitation in northeastern Illinois averages about 90 cm a year which normally is more than adequate to leach sodium through the soil. Next to busy streets or sidewalks, however, so much deicer is added that this amount of precipitation is not adequate for leaching (5, 10).

Sodium adsorption ratios and ESPs calculated for this study revealed most planter soils to be sodic. Sodic soils have an EC less than 4.0 mmhos/cm, an ESP greater than 15.0, and a pH greater than 8.5 (13, 15). All south side planters had sodic soils (Table 1). The mean SAR on the

Table 1. Chemical properties of planter soils on the north and south sides of the street.

Property	Mean	Std. dev.	Max.	Min.
pH (N)	8.3	0.9	9.9	7.3
pH (S)	8.8	0.7	9.8	7.5
EC (N) [mmhos/cm)	1.2	0.9	2.5	0.3
EC (S) [mmhos/cm]	1.3	1.9	2.4	0.6
SAR (N)	10.5 a	6.6	25.9	1.4
SAR (S)	28.1	13.8	58.1	2.8
ESP (N)	9.6 a	6.2	22.2	0.7
ESP (S)	23.6	10.4	42.8	2.9

(N) - North side of street
(S) - South side of street

a = Statistically signficant difference at 95% confidence using Student's t-test.

Table 2. Elemental concentrations in planter soils on the north and south sides of the street.

	ug/g			
Element	Mean	Std. dev.	Max.	Min.
Phosphorous (N)	12	8	30	3
Phosphorous (S)	24	29	112	4
Potassium (N)	236	145	700	98
Potassium (S)	253	214	790	70
Magnesium (N)	133	117	420	20
Magnesium (S)	194	109	790	70
Calcium (N)	4,030	3,617	14,000	1,600
Calcium (S)	1,823	577	2,850	1,400
Sodium (N)	381 a	217	740	87
Sodium (S)	846	480	2,000	105

(N) - North side of street
(S) - South side of street

a = Statistically signifcant difference at 95% confidence using Student's t-test.

south side was 28.1, well above 12.0 which is the ratio considered to be adverse to plant development (5). Mean north side SARs (10.5) were nearly at the threshold.

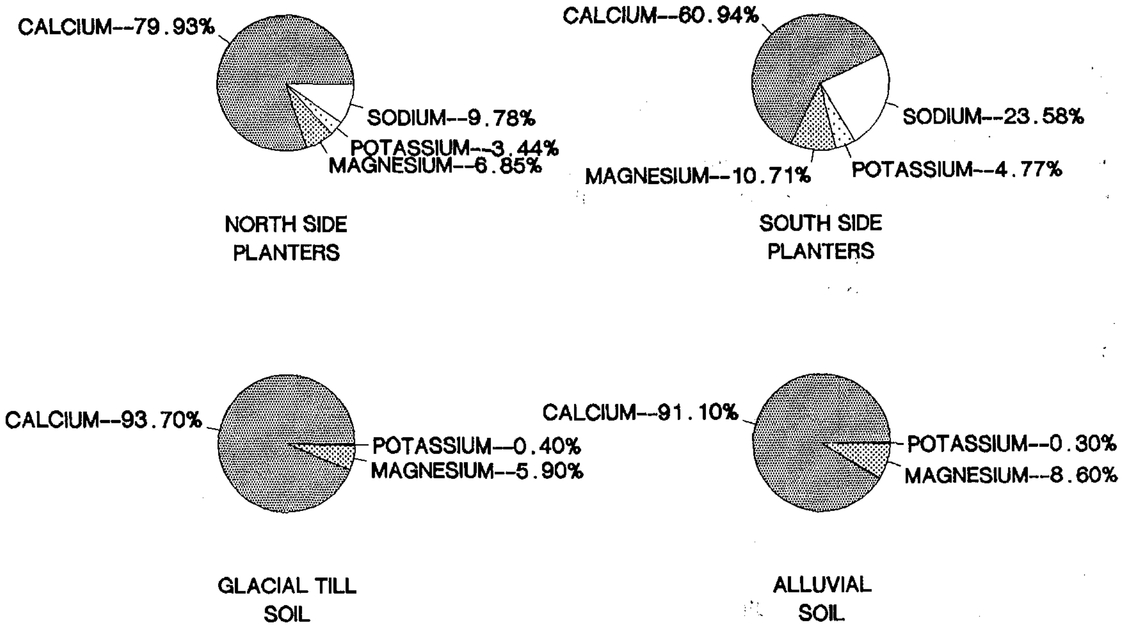
Electrolytic conductivity test results from the planter soils would not have indicated a sodium or salt problem. Only 25% of the sites showed soluble salt levels limiting to woody plants and the mean values of the sites were well below the limit threshold of 2.0 mmhos/cm (Table 1). Linear regression data showed very low correlation of SAR to EC ($R^2 = 0.0073$) and ESP to EC ($R^2 = 0.0285$). This suggests that SAR and ESP should be used instead of EC for evaluating soil sodium problems.

Base saturation data for selected native soils of northeast Illinois and soils in the street tree planters of this study are provided in Figure 1 and highlight the severe chemical imbalances of these planter soils. Native soils have base saturations dominated by calcium while magnesium is a moderate percentage and potassium a small percentage (9). The Geneva planter soils had base saturations dominated by calcium; however, sodium and potassium were very high, especially on the south side of the street.

Summary

The street-tree-planter soil is often taken for granted as being a tolerable planting medium. Soils are usually not examined to any extent unless a tree is declining severely and no cause above the soil surface can be identified as the problem. New planting soils are usually deemed acceptable as long as they are dark in color and seem to be somewhat granular in nature. Many times those planting the trees do not understand what is involved with providing a good planting medium. Soils in the native and urban environment are very complex and should be examined physically and chemically for any properties that may be deleterious to the establishment and development of woody plants.

Sodium is often a contributing factor to the decline of plantings next to roads and highways. Decline from sodium is most often due to foliage



Data for planter soils from Geneva, Illinois.
Data for natural soils from Lake Co., Illinois.

Figure 1. Mean base saturation levels in Geneva planter soils and native glacial till and alluvial soils.

damage but in severe instances may be a result of imbalanced soil chemistry or modified soil structure. Methods of reducing or eliminating sodium chloride as a deicer are many, however, most have their drawbacks. Raising street tree planters eliminates sodium-laden runoff from moving into the soil and would reduce some road splash but not eliminate spray onto foliage. Alternative deicers are available but are too expensive for most government agencies to justify. Many of the more popular ones, primarily calcium chloride, contain chloride which can be as much of a problem as sodium for vegetative damage (3).

Soils in the urban environment should be evaluated before plantings are established. Many factors of urban plantings cannot be controlled easily, such as temperature extremes, aerial contimants, pollutants in runoff, and restricted rooting environments. The soil material that is used, however, can be modified to fit the requirements of the plant so that it has the best chance of survival in the harsh urban environment. Conversely, the selection of woody ornamentals appropriate for harsh sites can also reduce the negative impacts common to urban planters (16).

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