Plant Establishment and Root Growth Research at the Urban Horticulture Institute

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The Urban Horticulture Institute was founded as part of the Department of Floriculture and Ornamental Horticulture of Cornell University, Ithaca, New York, in 1980 because of increasing concern over the livability of our urban environments. The Urban Horticulture Institute (UHI), under the program leadership of Dr. Nina Bassuk, conducts research, disseminates information through the New York State Cooperative Extension system and coordinates workshops. In addition to Dr. Bassuk, the UHI consists of Dr. Tom Whitlow and eight graduate students under their direction.

Research at the UHI mainly concerns plant establishment in urban and community areas. Our philosophy of plant establishment is diagramed in Figure 1. The first step in establishing plants is site assessment. Planting sites have little resemblance to the adjacent woodland or field since the soil has been disturbed and the above-ground environment has altered. A detailed on-site evaluation of soil conditions (pH, compaction, texture, etc.), radiation patterns (reflected heat, shade, etc.), pedestrian patterns, deicing salt damage potential, etc. is needed at the start. The next step in the plant establishment process can be planned only after growing conditions have been evaluated.

Poor growing conditions can often be alleviated somewhat by site modification techniques. For example, poor drainage can often be overcome by the installation of subsurface drainage systems or the redirection of surface water. Compacted soil can often be replaced with better soil, or subsoiling may prove to be effective. The installation of curbing may help alleviate the harmful effects of deicing salts. Unfortunately, the ability of site modification to improve growing conditions often limited because of the nature of the site or budget constraints. Alteration of pH, for example, is not a good permanent solution for long-lived plants with far reaching root systems such as trees. Subsoiling is really only effective if you can break through to freely draining soil, and it can be very destructive to the root systems of existing plants. Subsurface drainage may be impractical, and it only removes water moving by gravitational forces. Fine textured soils may remain too wet for many species, therefore, even when the drainage system is installed. In these cases, a redesign of the project and the selection of tolerant species is appropriate. For example, the grouping of plant material in common planting areas promotes a more efficient use of the available soil volume than if plants are confined in individual

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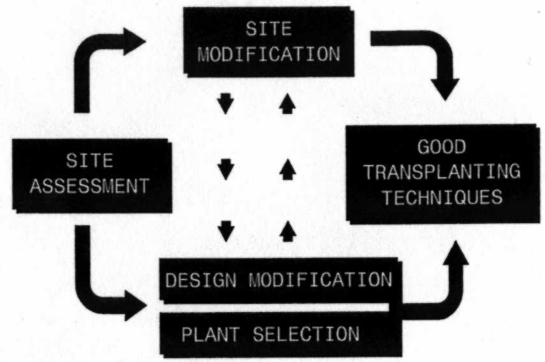

Figure 1 — UHI method for plant establishment

planting pits. In addition, a 'forest effect' can be achieved when plants are grouped, creating a more favorable above-ground environment. Planting areas can be moved away from the high pH found around buildings and sidewalks.

The selection of plant material that will tolerate specific conditions after final modifications and design alterations are made is essential. In other words, one should only choose plant material which will tolerate the specific site conditions. Selection for aesthetic qualities should only be made from that list of plants. Finally, good planting techniques are essential, but only after a detailed site assessment has been made, feasible site modifications have been implemented and the selection of species which will tolerate the final conditions compiled. Research at the UHI involves all phases of this process.

Some of the past research projects have included research on the physiological basis of drought resistance in trees (5), the description of the urban environment and associated stresses on street trees (7), the propagation of desirable urban tree species (4,6), the development of an easily implemented street tree inventory method (2) and the determination of soil volume needs for street trees (3). Some of the current research projects are summarized below.

Aggregate Mixes for Use Under Pavement

Jason Grabrosky, Graduate Student

Many of the problems associated with the decline of street trees can be attributed to inadequate soil volumes. Tree roots are seldom able to penetrate beneath the streets and sidewalks of our downtown environments because of the compaction levels required for the soil underneath pavement. Tree roots are instead confined to usually no more than a $4 \times 4 \times 3 = 48\ ft^3$ volume of soil. A medium-sized shade tree in reasonably good soil would instead require 300 - 400 ft^3 of soil without additional irrigation in the northeastern United States (3). A tree whose root system approaches fully exploiting the 48 $ft.^3$ volume of soil found in a typical tree pit would be increasingly vulnerable to attack by insects, diseases and people pressure and therefore increasingly susceptible to decline. The intent of this research is to develop a soil mix that will meet engineering standards for compaction yet retain characteristics which will be favorable for exploitation by tree roots. Such a mix is not intended for the primary growing media, but for a 'breakout zone'. A mix that meets the engineering standards for compaction, yet provides for sufficient aeration and lack of impedance requires that the mix be a solid matrix of aggregates (such as gravel). Tests are therefore underway which tests different types of aggregates combined with different amounts and compositions of media. Engineering specifications are being developed for many combinations. The combinations which meet the engineering specifications are then being tested for plant response by compacting the mixes in containers and planting with trees. The mixes which hold the most promise will be further screened in a full-sized tree pit and pavement test.

pH Tolerance Trials

Tony Dufour, Graduate Student

Most literature on plants and pH is observational and only states what is best, or what is 'preferred' for the particular plant in question. In order to make meaningful plant selections, we instead need to know the limits of pH tolerance for tree species. The pH in most urban plantings is elevated (more alkaline) due to the leachate from mortar used in the making of concrete and cement. Trees which can tolerate these high pH levels are needed for urban plantings. The goals of this research are to 1) Develop a protocol for testing the pH tolerance of trees; and 2) Identify species or populations of species which are tolerant of high pH.

The first trees to be evaluate are eight species of Quercus (oak). Acorns are being collected this fall from trees known to be growing on elevated pH sites from many parts of the country and from trees known to be growing on sites with a pH more typical for the particular species. Acorns from these trees will be grown and tested for tolerance to high pH. The research will expand to other species when the testing protocol has been satisfactorily established

Vegetative Propagation and Production of Desirable Plants for Urban Landscapes

Anna Perkins, Graduate Student

Many species which are most resistant to urban stress or have very desirable aesthetic qualities are also very difficult to propagate vegetatively (e.g. Nyssa, Corylus, Stewartia). Selection for tolerance to urban conditions within species therefore cannot be easily accomplished. A method of cutting propagation utilizing an etiolation technique was developed by previous UHI research (4,6). The purpose of this research is to expand the number of species tested using this propagation method and to develop methods for growing the rooted cuttings through the first overwintering and up to the lining out stage. Some species propagate readily, but post-rooting survival is low. The effect of several growth regulators as well as the effect of various storage conditions are being evaluated.

The Effect of Provenance on Flooding Tolerance of Red Maple

Lou Anella, Graduate Student

Acer rubrum (red maple) has a natural range from Canada to Florida, and it can be found growing in low flooded areas as well as on dry ridge tops. The purpose of this research is to determine if a difference in tolerance to flooding between those populations (provenances) growing in flooded areas and those growing in dry areas exists. Another objective is to identify the physiological basis for such a difference, if it exists. A better understanding of the physiology behind the ability to tolerate adverse conditions such as flooding will increase our ability to choose plant material for potentially stressful landscape situations.

One isolated population of trees growing along the bank of the James river in northern Virginia and another growing on a mountain ridge top in western Virginia were identified for testing. Seeds were collected from each provenance in 1990 and sown in a greenhouse. Seedlings were then grown in containers until testing for flood tolerance began in 1993. Trees from each provenance were flooded and photosynthesis rate, stomatal conductance, and morphological changes were recorded.

Trees from the wet provenance quickly reacted to flooding. Photosynthesis rates and stomatal conductances quickly dropped, whereas reactions were much slower in the trees native to the dry habitat. Photosynthesis rates eventually dropped to lower levels in the dry site trees, however. Abscisic acid (ABA), a plant hormone, is being investigated as a possible root-to-shoot signal on the wet site trees. In addition, the wet site trees developed raised lenticels (hypertrophy) along the lower trunks, but trees native to the dry sites did not. It is thought that hypertrophied lenticels and an accompanying increase in the air filled porosity of stems act as a conduit of oxygen to flooded roots. The anatomy of the stems are being studied to determine if wet site trees developed larger internal conducting areas after flooding.

Evaluation of Effect of Tree Pit Construction on Tree Growth

Barbara Neal, Graduate Student

Tree pits were designed and installed with ultimate tree health in mind on Pennsylvania avenue and adjacent highly visible areas in Washington, D. C. in the late 1970's. The expense of mixes and pits were of less concern than the effect on tree health because this is the street on which the presidential inaugural parade is centered. Street trees were therefore intended to become a showpiece and a source of national pride. The purpose of this research is to measure the effect of this 'first class' treatment on the trees which were planted into these areas. Incremental growth patterns will be determined by cores into the center of the trunks so that yearly growth can be assessed. Comparisons between these various designs and standard designs can then be made

Remediation Techniques for Trees in Compacted Soil

Susan Day, Graduate Student

Soil compaction is a perennial problem on most landscape sites. Compaction usually occurs because of heavy equipment traffic during construction. Soil compaction destroys soil macropores by compression, thus reducing drainage and increasing resistance to root penetration. Slow drainage decreases oxygen diffusion to roots since oxygen travels much more slowly through water than through air. This slowed oxygen diffusion limits the active respiration which is required for normal growth and health of roots. The reduced root extension caused by high penetration resistance and lower growth rates results in trees which are more susceptible to drought and mineral deficiencies.

The purpose of this research was to test several method for effectiveness of alleviation of the adverse effects of soil compaction. A field of silty clay was compacted to a bulk density of 1.5 g/cm^3 by making repeated passes with a large tractor. Two species of landscape-sized trees were then planted into an experimental design consisting of five treatments. Callery pear (*Pyrus calleryana*) was chosen for its reported tolerance to compacted soil, and sugar maple (*Acer saccharum*) was chosen for its reported sensitivity to compacted soil. All trees were approximately 2 M tall and were planted bare-root into the following treatments in the spring of 1991: 1) Backfilled with existing soil (control); 2) Backfill amended with 50% v/v spaghnum peat (amended backfill); 3) Four trenches 0.3 M deep and 1 M long filled with sandy loam soil radiating in a spoke-like pattern from the planting hole (soil trenches); 4) Four 0.6 M long X 10 cm diameter perforated ADS drain pipes installed vertically 1 M away from the trunk and equidistant from each other (vertical drains); and 5) Four drainage panels 0.3 M wide X 0.6 M long X 1.5 cm thick placed on the long edge in the ground but with contact with the surface air, installed equidistantly in a spoke-like pattern around the planting hole (Enkadrain®). The effect of the treatments on soil oxygen concentration was measured periodically, and shoot extension was measured after the 1992 and 1993 growing season. Sugar maple trees suffered high mortality and low shoot growth on all treatments, so only results for callery pear are discussed below. The vertical drain and Enkadrain® treatments produced a significant aeration effect on the nearby soil, whereas the amended backfill and soil trenches did not. This aeration effect did not result in an increase in shoot growth when compared to controls or the other treatments, however. Shoot growth of those treatments designed with a root 'break-out zone' to reduce resistance to root penetration (amended backfill and soil trenches) had significantly more shoot growth than other treatments (vertical drain and control) (Fig. 2). Resistance to root penetration of the surrounding compacted soil was only below the threshold which limits root growth when the soil was very wet (Fig. 3). Only trees which can tolerate prolonged soil wetness, would therefore be able to make significant root growth into the compacted soil.

Root and Shoot Growth Periodicity

Roger Harris, Graduate Student

Shoot growth is easily observed, but the determination of root growth is much more difficult since roots are hidden from view. Knowledge of root growth patterns of trees is important to arborists since it may indicate the best time to transplant trees, fertilize, apply deicing salts, etc. Moreover, if root growth correlates with shoot growth, then periods of high root growth can be predicted by the observance of shoot growth. The purpose of this research was to determine root growth patterns for landscape trees in upstate New York and to determine if root growth can be predicted from observance of shoot growth. In order to determine the relationship between shoot growth and root growth, four species with two distinct types of shoot growth habit were chosen. Green ash (*Fraxinus pennsylvanica*) and scarlet oak (*Quercus coccinea*) grow with more than one flush of shoot growth during the growing season if conditions are favorable. Turkish hazelnut (*Corylus colurna*) and tree lilac (*Syringa reticulata*) commonly grow with only one flush of shoot growth during the growing season. Both groups consist of an easy to transplant tree (green ash or tree lilac) and a difficult to transplant tree (scarlet oak or Turkish hazelnut). This combination of plant material resulted in four possible root growth patterns.

Root growth was determined using two separate devices. The first device was a rhizotron. Two 1 M wide X 1 M deep by 8 M long ditches were excavated, and the sides were fitted with clear 0.6 M wide Lexan plates. The Lexan plates were held by pressure

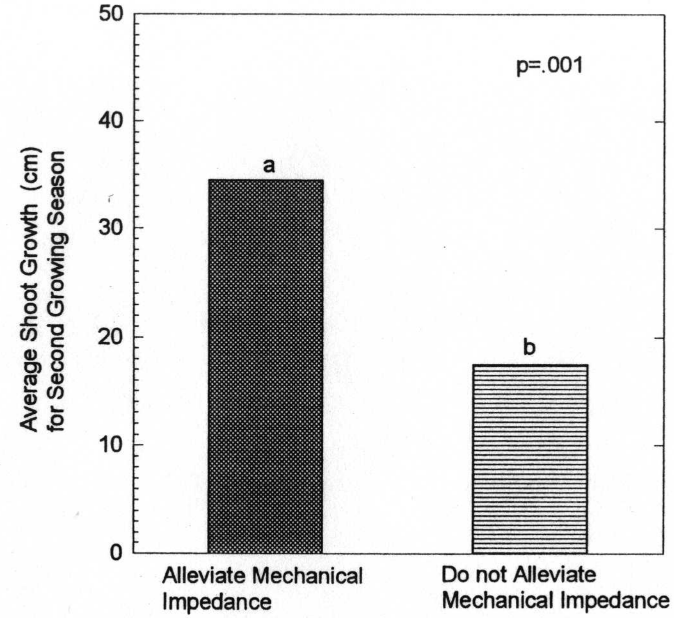

Figure 2 — Shoot growth of treatments that alleviate mechanical impedance (amended backfill and soil trenches) and treatments that do not alleviate mechanical impedance (vertical drain and control). Enkadrain® was considered intermediate and was therefore not considered.

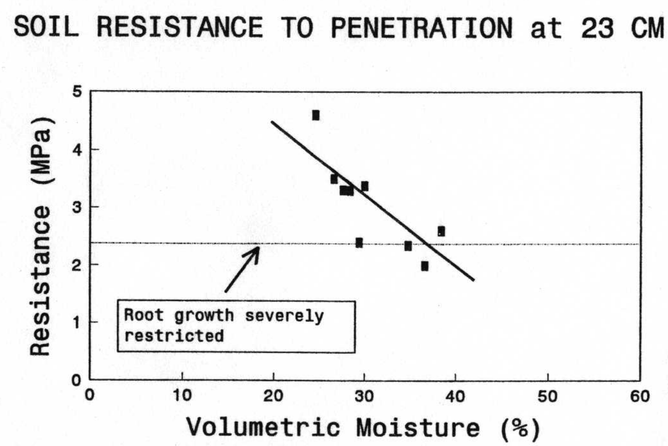

Figure 3 — Soil resistance at different moisture levels.

treated wooden frames, and the frames were supported by a series of posts and beams. The rhizotron was then fitted with plywood covers. Foam insulation was placed against the Lexan plates during the winter. Trees were planted along the edge of the rhizotron and

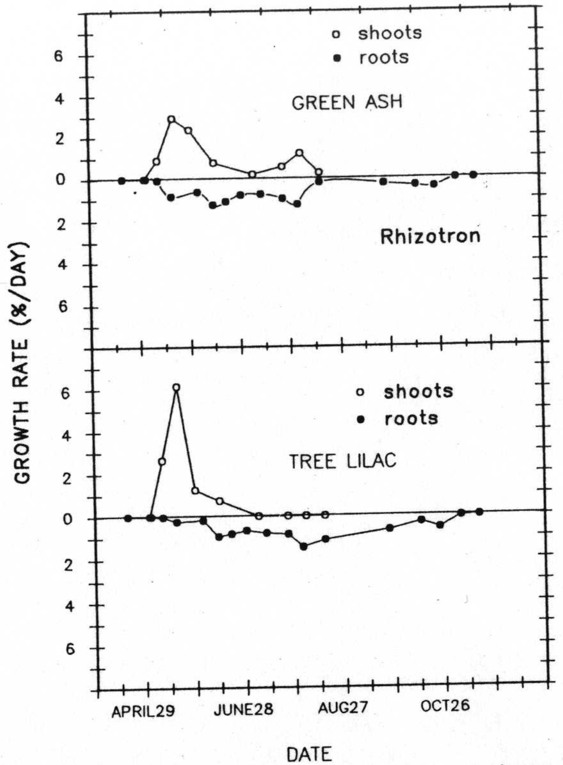

Figure 4 — Shoot and root growth of green ash and tree lilac measured on a rhizotron. Each data point is the mean of 4 trees.

allowed to grow for one year before measurements were made. Root growth was then determined by following the growth of larger individual roots over the growing season.

The second device was a minirhizotron. The minirhizotron consisted of one clear 5 cm diameter acrylic tube per tree placed 0.6 M into the ground at a 4° angle. The tubes entered the ground 0.6 M from the trunks of the trees and sloped toward the tree under the ground. Root growth was determined by slowly lowering a miniature movie camera down the tube and recording the roots present on a video tape.

Ease of transplanting had no relationship to root growth patterns when root growth was assessed by either method, and root growth had no relationship to shoot growth when root growth was determined as described above on the rhizotron (Fig. 4). Alternating root and shoot growth was evident, however, when root growth was determined using the minirhizotron (Fig. 5). This seeming contradiction was because of the different types of roots measured with each method. The rhizotron method measured only the laterally growing, larger, more rapidly expanding roots. The minirhizotron, however, measured all diameters of laterally and vertically growing roots. This indicates that root growth can be predicted by shoot growth when all types of roots are considered. The smaller roots which were included in the measurements made on the minirhizotrons are likely the ones most important for water or mineral absorption. It was interesting that measurable root growth did not begin before budbreak on any of the four species tested.

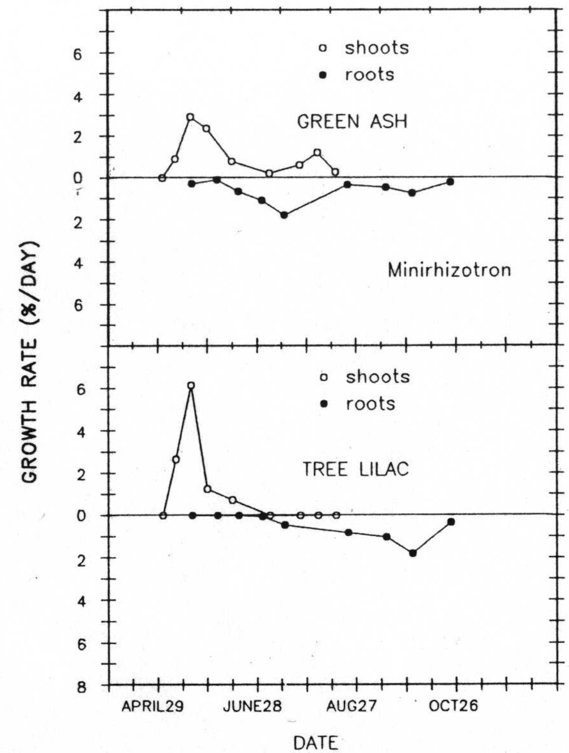

Figure 5 — Shoot and root growth of green ash and tree lilac measured on a minirhizotron. Each data point is the mean of 4 trees.

This was unexpected and contrary to popular thought. This was probably a function of the cold upstate New York soils and the species tested.

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