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ROOT REGENERATION OF *TILIA CORDATA* CULTIVARS AFTER TRANSPLANTING IN RESPONSE TO ROOT EXPOSURE AND SOIL MOISTURE LEVELS

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Abstract. *Tilia cordata* cultivars 'Glenleven' and 'Greenspire' were exposed to drying for various lengths of time between digging and planting and also subjected to four levels of available soil moisture after transplanting into large pots. The exposure between digging and planting reduced initial shoot growth but had no effect on root regeneration. Decreasing available soil moisture after transplanting significantly reduced the quantity of root regeneration. There was no difference between cultivars in response to the treatments. A treatment that maintained 100% available soil moisture in the root zone maximized root regeneration.

Tilia cordata, littleleaf linden, is a widely used landscape tree both in its native Europe and in North America. A densely branching and uniform, pyramidal growth habit make it a very desirable tree for urban plantings. In 1971, approximately 37% of all trees planted in five representative southern Ontario municipalities were *T. cordata* (7). By 1980, the planting rate had fallen to only 11% of total trees planted. This reduction in use is of concern to both nurserymen and arborists who appreciate the value of this tree to the urban environment.

A large percentage of the reduction in use of *T. cordata* may be attributed to the poor transplant survival of bareroot transplanted trees experienced by the industry and reported in the literature (5, 8). The decline of trees has been characterized by the development of stem cankers after transplanting. The canker symptoms appeared only in trees weakened by stress resulting from an apparent inability is to form new absorbing roots (8).

The removal of a large portion of the root system at digging predisposes a bareroot transplanted tree to internal water deficits. At the time of digging, the root system of a tree may be reduced by up to 98% of its original volume (11). The physiological responses of the shoot cannot sufficiently reduce transpiration to compensate for the loss of absorbing roots. Stress levels may be further increased by exposure of the root system during the transplant process (3). This experiment was initiated to study the effects of both exposure of the roots during the transplant process, and varying levels of available soil moisture after transplanting, on root regeneration and growth of *T. cordata* cultivars 'Glenleven' and 'Greenspire.'

Materials and Methods

Three-year-old, budded, 250 cm trees of *Tilia cordata* cultivars 'Glenleven' and 'Greenspire' were selected for uniformity and dug bareroot in May, 1983. The trees were subjected to a drying period prior to transplanting by leaving the roots completely exposed in a room at 22°C and 50% relative humidity for 0, 12, 24, and 48 hours. The trees were then planted in 55 liter plastic bag pots containing a soil:peat:perlite mix (2:1:1 v/v).

Four cyclic moisture level treatments were maintained after planting for trees from each of the pre-plant exposure treatments. Trees were watered after they had reached the desired soil moisture level. The levels of post-plant soil moisture were 100%, 50%, and 40% available moisture. The fourth level was obtained by allowing the trees to visibly wilt before watering. Percent available moisture was measured using gypsum Bouyoucos blocks and a Bouyoucos moisture meter (Beckman Instruments, Cedar Grove, N.J.).

When necessary, the soil surface was covered with a removable plastic shield to prevent the entry of rainwater. The shield could be easily lifted to facilitate drying of the soil. The trees were staked to prevent wind shifting. For each of the 100%, 50%, and 40% treatments, the mean of four trees per treatment group was taken as the available soil moisture level for that treatment. The trees that were allowed to wilt before watering were monitored individually. Soil temperature was monitored by copper-constantan thermocouples placed at various positions in the soil.

Five shoots were randomly chosen at the midpoint of the canopy of each tree and measured over the course of the experiment. The experiment was terminated at leaf drop in the fall. The soil-root mass was removed from the bag and the soil was carefully washed from the roots. New root growth was distinguishable by its lighter colour and point of origin on the old root system. All new root growth was removed and the dry weight was recorded.

The experiment was a 2×4×4 factorial arrangement in a completely randomized design. There were two cultivars, four levels of pre-plant exposure, and four levels of post-plant soil moisture levels with four replicates per treatment combination for a total of 128 trees in the experiment. Mean separation was by LSD at the 5% level of significance.

Results and Discussion

Drying exposure periods applied between digging and planting had no effect on subsequent root growth. The only exception was the death of one tree early in the experiment that had been subjected to the longest exposure period. There was no difference between the two cultivars in response to the treatments applied, nor was there any significant interaction between the treatments.

Exposure of Sitka spruce and white pine seedlings to drying conditions for only two hours resulted in the death or damage of most of the plants (1, 6). The trees in our experiment were able to withstand the amount of exposure allowed prior to planting. Since the rate of root regeneration was not measured over time, it is not known whether exposure had any deleterious effect on the initial emergence of roots. At the time new root growth was measured, there was no evidence of reduced root regeneration as a result of exposure. It must be noted that air movement over the plants during exposure was minimal and sun exposure was nil. Actual drying conditions in the field are characterized by wind and/or sun induced dehydration either as a result of improper protection during transport or by natural weather conditions (3). Thus, caution must be used in extrapolating these results to actual field drying conditions.

The pre-plant exposure had a significant effect on new shoot growth (Figure 1), but the reduction in shoot growth did not correlate well with the increasing severity of the preplant treatment. The trees subjected to the shortest exposure (12 hours) had the least amount of new shoot growth overall. Initially, all of the exposure treatments lagged behind the unexposed trees in amount of new shoot growth. At the last measurement date,

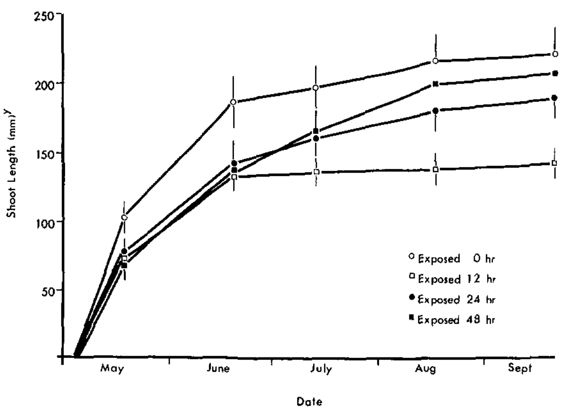

Figure 1. Shoot elongation of *Tilia cordata* cultivars exposed for varying lengths of time prior to planting. Bars at each point represent the standard error (overlapping bars omitted for clarity). y — sum of five shoots per tree

only the 12 hour exposure treatment was significantly different from the unexposed control. The initial lag of all the exposed treatments can be attributed to the stress induced by the exposure treatment. However, the apparent inability of the trees in the 12 hour exposure treatment to recover as successfully as the more severe exposure treatments cannot be readily explained. Previous research has shown that root exposure may reduce both shoot and root growth (1, 6).

Varying soil moisture levels applied after transplanting had a more pronounced effect on new root growth (Table 1 and Figure 2). Decreased soil moisture was accompanied by decreased amounts of new root growth. These results agree with the work of previous authors who observed decreased root regeneration and growth with increased water stress (2, 4). Water stress indirectly reduces the production of carbohydrate by limiting the amount of water available to the shoot (9). However, shoot growth was not affected by the soil moisture levels applied after transplanting.

Cyclic watering was used to induce the levels of soil moisture. After watering, root growth proceeds until sufficient water is extracted from the soil by the tree, or lost through evaporation, to induce stress in the plant. Roots become suberized under the stress and growth after subsequent watering is slow to commence (10). At a constant osmotic potential of −6 bars and below, red oak seedlings did not regenerate new roots (4). The cyclic soil moisture treatments used in this experiment mimic more closely the natural water relations in the soil after transplanting than the artificial maintenance of a low osmotic potential in the soil. Trees are usually watered at transplanting and then periodically receive water either by natural precipitation or by irrigation.

Summary

Based on this study, root exposure during the digging-transplanting process is less critical than often assumed. Maximum root growth after transplanting was achieved with a treatment that maintained 100% available moisture in a well aerated container soil mix. In soils that are poorly drained, excessive watering could cause waterlogging and anaerobic conditions resulting in reduced root growth and possible death (10). The results of this experiment indicate that in free draining soils, maximum root growth of *Tilia cordata* cultivars can be achieved by minimizing the interval between waterings to maintain a high level of soil moisture.

Table 1. Root regeneration of *Tilia cordata* cultivars subjected to different levels of available soil moisture after planting.

Percent available moisture	*Dry Weight of new root growth*[z]
100	9.59 a
50	7.67 b
40	7.27 b
Wilting Point	6.05 c

z — a data transformation was necessary to facilitate statistical analysis of the results. The number presented in the table equals the square root (dry weight of new roots (g) plus 0.5) and is thus dimensionless.

Mean separation in columns by LSD, 5% level of significance

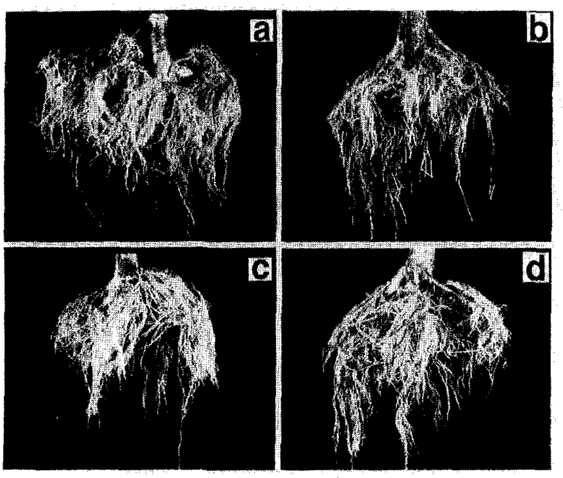

Figure 2. Root systems of trees grown in soil maintained at: (a) 100%, (b) 50%, (c) 40%, available soil moisture, and (d) allowed to visibly wilt before watering.

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Abstract

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The care and maintenance of a collection of mature trees is both a challenge and an opportunity to learn effective techniques of preservation and conservation. Three years ago we developed a conservation program to insure the best care possible. This approach is applicable to residential properties, as well as parks and arboreta. The key to the Morris tree care program is the use of priority tree lists. Each tree is assigned to a maintenance category. Only ten are included on our top priority list. These are routinely inspected, fertilized, pruned, watered during drought, and sprayed when insects or diseases threaten. Our secondary tree list includes approximately 130 trees that receive annual inspection, fine pruning, and other care as required. They are fertilized every three years, or more frequently if they require. The tertiary list is divided into thirds receiving regular care every three years. Trees on this list receive medium pruning and are fertilized less frequently. All other trees get major dead-wood removal and rudimentary corrective pruning. Our program of preventative tree maintenance seeks to maintain a high level of vigor and avoid unnecessary injuries and wounding. Reinforcing weak tree crotches with steel cables and preventing or limiting construction damage to trunks and root systems are examples of protecting trees from physical damage. However, the major emphasis of our tree care program is the maintenance of tree health. It has been demonstrated many times that a healthy tree is better able to withstand the attack of insects and disease. Watering during drought, planting in good soil, mulching, fertilizing, and avoidance of trunk injuries are all tree health maintenance practices that encourage good health and avoid attack by pests.