A Window Into Below-ground Growth of Landscape Trees: Implications for Transplant Success

Roger Harris[1], Nina L. Bassuk[2], and Thomas H. Whitlow[3]

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Summary. **Root and shoot phenology were observed, and root length within rootballs were calculated for *Fraxinus pennsylvanica* Marsh. (green ash), *Quecus coccinea* Muenchh. (scarlet oak), *Corylus colurna* L. (Turkish hazelnut), and *Syringa reticulata* (Blume) Hara 'Ivory Silk' (tree lilac) trees established in a rhizotron. Easy-to-transplant species (green ash and tree lilac) had more root length within rootballs than difficult-to-transplant species (Turkish hazelnut and scarlet oak). Shoot growth began before root growth on all species except scarlet oak, which began root and shoot growth simultaneously. Fall root growth ceased for all species just after leaf drop. Implications for tree transplanting are discussed.**

The below-ground growth of landscape trees is of interest to nursery operators and landscape contractors because knowledge of root activity enhances evaluation of transplant methodology. Inaccessibility of roots of large trees hinders the

Urban Horticulture Institute, Cornell University, Ithaca, NY 14853.

[1]*Former Graduate Research Assistant. Present address: Department of Horticulture, Virginia Polytechnic Institute & State University, Blacksburg, VA 24060.*

[2]*Professor.*

[3]*Assistant Professor.*

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study of root growth dynamics. Destructive harvest methods, such as coring, subsample excavations, and complete excavations (Böhm, 1979), result in a single-point estimate of root growth. Rhizotrons (Huck and Taylor, 1982) provide a nondestructive alternative for studying roots. Using a rhizotron, one can observe root growth activity and estimate root length density (root length per unit of volume). Root length density within the harvest zone of trees may be a factor in transplant success because rootballs that contain more root length would have more absorptive surface exposed to the soil. The purpose of this research was to describe the major seasonal root and shoot growth events and to calculate the relative root length within the harvest zones of landscape-sized green ash, scarlet oak, Turkish hazelnut, and tree lilac trees.

Rhizotron construction

Two trenches, 1 m wide × 1 m deep × 8 m long, were excavated in early Spring 1991 near the Cornell Univ. campus, Ithaca, N.Y. Clear polycarbonate (Lexan) plates, 6.35 mm thick × 61 cm wide, were fastened to wooden frames and placed so that the smooth Lexan side was against the entire length of the two long earthen walls of each trench and held in place by a series of posts and beams. The floor was covered with 10 cm of gravel, and each trench was fitted with drains. A three-part, removable, 1-cm-thick plywood cover was constructed to cover the trench. Soil type was Williamson silty clay loam (pH 6.2). The effect of the rhizotron on soil temperature was monitored with copper–constantan thermocouples attached to a datalogger (model CR21X, Campbell Scientific, Logan, Utah) and placed through the Lexan plate of one rhizotron just into the soil profile adjacent to the Lexan plate and 25 cm into the soil profile at depths of 30 and 45 cm. Due to instrument failure, temperatures were measured with the datalogger periodically only. Soil temperature at a 20-cm depth was monitored continuously by a weather station ≈500 m from the test site. Styrofoam insulation (5 cm thick) was placed against the Lexan plates beginning in early November and removed in early April to insulate against winter temperatures.

Green ash, scarlet oak, Turkish hazelnut, and tree lilac were chosen because they differ in response to transplanting. Green ash and tree lilac are considered easy to transplant, while scarlet oak and Turkish hazelnut are considered difficult to transplant (Flemmer, 1990). Four bare-root trees of each species (one per side) were planted immediately adjacent to the sides of the rhizotrons in May 1991. The statistical design was a randomized complete block with one side of each rhizotron serving as a block and each species a treatment. Distances between trees were 2 m. Root observation began in Spring 1992. Average height (m) and trunk diameter (cm) taken 10 cm above the soil line were 2.1 and 3.5 for scarlet oak, 3.7 and 6.5 for green ash, 2.4 and 4.3 for Turkish hazelnut, and 2.5 and 3.5 for tree lilac, respectively.

Root length within rootballs

Root length against the Lexan plate was measured using the line intersect method of Newman (1966), as modified by Tennant (1975) on 50 × 50-cm grids with 5 × 5-cm increments drawn directly on the Lexan plates. The grids were centered directly under the trunk of each tree, and all visible roots on the grid were measured. Root length density ($cm \cdot cm^{-3}$) was calculated by dividing root length present against the Lexan plate by the volume of the viewing area (50 × 50 × 0.2 cm); assuming that roots could be viewed 0.2 cm behind the Lexan plate (Glenn and Welker, 1993). Total root length contained within the harvest zone for each tree was calculated by using root length density measurements when root growth ceased in late Oct. 1992. The harvest zone was the rootball volume($\pi r^2 h/2$; r = radius and h = height of the rootball) for each tree if that tree were moved balled and burlapped (B&B) (American Assn. Nurserymen, 1990). Trunk diameters (cm) used in the rootball determinations were 3.3, 6.5, 4.3, and 3.5 for scarlet oak, green ash, Turkish hazelnut, and tree lilac, respectively. Data were subjected to analysis of variance and differences among treatments were determined by LSD.

The easy-to-transplant species, green ash and tree lilac, had much more root length (m) per centimeter of trunk diameter within the rootball than the difficult-to-transplant species, scarlet oak and Turkish hazelnut (LSD = 216.7, $P \leq 0.05$). Root length values (SE of the mean in parentheses) were 142 (24.4), 426 (33.8) 159 (50), and 454 (198.2) for scarlet oak, green ash, Turkish hazelnut, and tree lilac, respectively. Because the viewing plate is an artificial interface, root length density measurements are best used for comparative purposes among species, not as an absolute determination. These data are similar to those of Fare et al. 1985), who found that the easy-to-transplant 'Nellie R. Stevens' holly had more root length within the rootball than the difficult-to-transplant 'Burfordi' holly. Struve and Moser (1984) also reported that the difficult-to-transplant scarlet oak had less root length in the rootball than the relatively easy-to-transplant pin oak. Green ash and tree lilac roots remained relatively white, not darkening with age, whereas Turkish hazelnut and scarlet oak darkened. Although only visual observations were made (no chemical analyses), this suggests that Turkish hazelnut and scarlet oak roots became increasingly suberized with age, whereas green ash and tree lilac remained relatively unsuberized (Kramer and Kozlowski, 1979). Water influx into an older, heavily suberized root may be 10- to 100-times less than that of a young unsuberized root (Nobel, 1991). The fact that green ash and tree lilac had much more calculated root length within rootballs (more fibrous) and that they appeared to have less suberization on older roots may help explain why green ash and tree lilac are easier to transplant than scarlet oak and Turkish hazelnut. Rootball fibrosity, however, is not the only explanation for species variation in transplanting success. Some species with fibrous root systems [i.e., *Betula papyrifera* Marsh. (paperbirch)] are considered by the nursery industry to be difficult to transplant, particularly during the fall (Flemmer, 1990). The roots within the harvested rootball apparently are not able to sustain the tree until new root growth begins in the spring. Future research should address the physiology behind this phenomenon.

Root and shoot phenology

Root and shoot phenology were observed throughout 1992 and 1993. Because data from both years revealed similar trends, only results from 1992 are presented. Root extension began on all species at soil temperatures between 12 and 15C in the spring and ended at ≈6 to 8C in the fall (Fig. 1). These temperatures were measured at a 20-cm soil depth. Because roots on each replicate extended below the field of view and point of temperature measurement, the cooler spring and warmer fall temperatures from deeper in the soil profile may have affected general spring root growth commencement and fall cessation. Headley and Bassuk (1991), however, reported that root growth of Norway maple (*Acer platanoides* L.) and red maple (*Acer rubrum* L.) seedlings began at 8 to 10C in the spring and ended at 4 to 5C in the fall. That study measured the soil temperature within enclosed below-ground root observation boxes and therefore had no roots deeper in the soil profile. The soil temperatures in this report were measured at the nearby weather station undersod, but the ground around the rhizotron was kept clear of vegetation. These temperatures should therefore be used only as a general guide for the beginning of spring and the end of fall root growth. Low temperatures that limit root growth have been shown to range from 2 to 11C for many tree species (Lyr and Hoffmann, 1967). Soil temperatures adjacent to the Lexan wall were the same as temperatures 25 cm into the soil profile at either 30 or 45 cm of depth throughout the year. Shoot growth began (bud scales parted and leaves emerging on three of four replicates) for all species before root extension, except for scarlet oak, in which case shoot and root extension began simultaneously. Shoot growth was determined to begin on 22 Apr. for Turkish hazelnut and tree lilac, 2 May for green ash, and 10 May for scarlet oak. Shoot extension ceased on 13 June for tree lilac, 7 Aug. for scarlet oak, and 20 Aug. for green ash and Turkish hazelnut. All visible root tips against the Lexan plates were marked with marking pens for beginning and ending root growth determination. Root extension began (root tips were white and began visible extension) on 10 May for all species. Variability was therefore great among species for beginning shoot growth, but not for beginning root growth. Root growth was determined to cease when extension did not occur beyond a mark on the observation plate. Root growth was determined to cease on 5 Nov. for green ash and tree lilac and on 16 Nov. for Turkish hazelnut and scarlet oak.

The post-budbreak timing of new root growth has profound implications for transplanting. Spring transplanting of bare-root and B&B landscape trees normally is completed before budbreak to ensure favorable internal water relations, especially for bare-root stock. If spring root growth begins after the onset of shoot growth, as reported for recently transplanted seedlings of green ash (Arnold and Struve, 1989) and red oak (*Quercus rubra* L.) (Struve and Joly, 1992) in Indiana and for the much larger established trees in our report, trees transplanted late in the fall or early in the spring must rely on old roots for water uptake to support the first flush of growth. The maintenance of a favorable water balance during this period is vital for survival because photosynthates from the first shoot flush are important for early root growth (Thompson, 1992), and hence establishment. If new root growth does not precede spring shoot growth, then the harvested root system containing the old roots must be the initial source of root-supplied water, minerals, and carbohydrates for initial shoot extension. The physiological and morphological characteristics of the harvested roots are therefore very important. Differences in the post-transplant capability of the remaining older roots to absorb and transport water and minerals, produce hormones, reduce nitrogen, etc., may help explain why species vary in their transplant response. Furthermore, this may serve to alter transplant research emphasis from the production of new roots to the efficacy of old roots.

Windows of opportunity for post-transplant root regeneration in the the eastern United States temperate zone are limited because little time exists after leaf drop and before cool soil temperatures in the fall limit root growth. Fall-transplanted trees must therefore be transplanted in leaf to take advantage of warm soil temperatures if root regeneration is to take place before spring budbreak. Methods that help prevent water loss through these leaves or that speed root regeneration will be required.

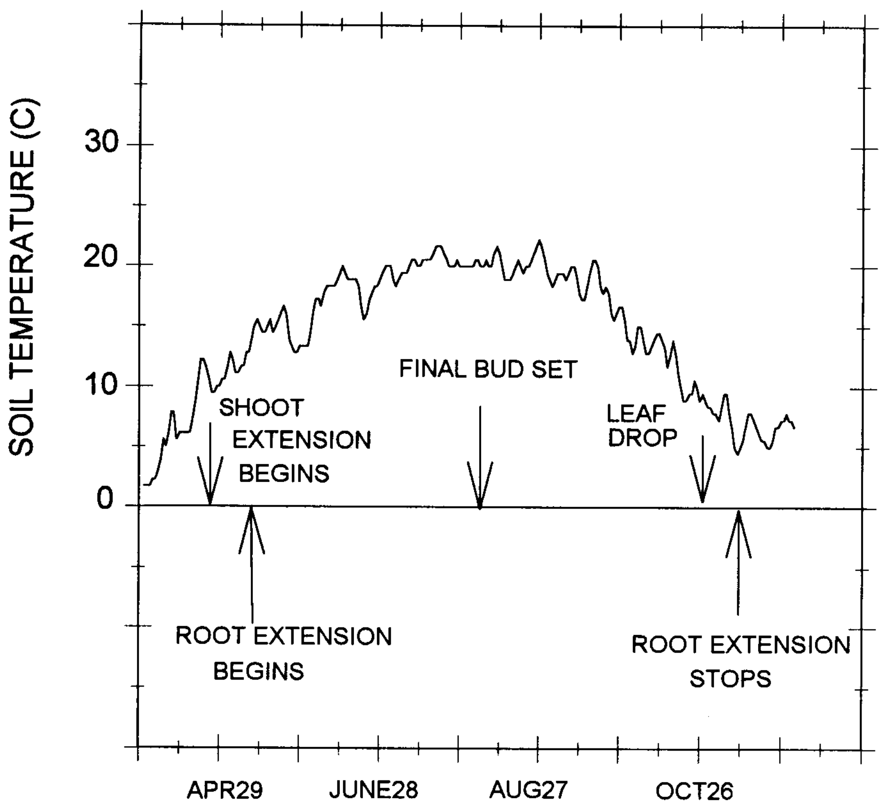

Fig. 1. ***Mean dates of 1992 shoot and root phenological events for scarlet oak, green ash, Turkish hazelnut, and tree lilac trees and seasonal soil temperature measured at a 20-cm depth. n = 4.***

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