SEASONAL EFFECTS ON TRANSPLANTABILITY OF SCARLET OAK, GREEN ASH, TURKISH HAZELNUT AND TREE LILAC

by J. Roger Harris and Nina L. Bassuk

Abstract. *Quercus coccinea* (scarlet oak), *Fraxinus pennsylvanica* (green ash), *Corylus colurna* (Turkish hazelnut) and *Syringa reticulata* 'Ivory Silk' (tree lilac) trees were transplanted bare-root throughout the spring and fall planting season. Post-transplant response was compared with the root growth activity of established trees at the time of transplanting. Root growth rate of established trees at transplanting was not related to transplantability. Green ash and tree lilac transplanted well at all dates. Scarlet oak and Turkish hazelnut transplanted poorly during the late spring and early fall, but survival was good in early spring and mid fall.

Street trees probably experience more physiological stress and mortality in the establishment phase than any other time during their life span. Gilbertson and Bradshaw (5) concluded that 39% of newly planted trees in London died within five years after planting and that the even a higher percentage of replacements died. This was primarily a result of unfavorable water balance due to poorly established root systems. The half-life of street trees in London was concluded to be only 10 - 15 years. High temperatures and low relative humidities in inner cities impose high evaporative demands (17), and this undoubtedly exacerbates establishment problems. Rapid transplant establishment is essential in order to facilitate transplant survival and the longevity of our urban forests. A better understanding of the effect that time of year has on transplanting will aid the city forester in managing tree installations to achieve quick plant establishment.

Evaporative demands are greatest on transplanted trees in late spring and summer as temperatures increase, leaves develop, and transpiration increases. However, warmer temperatures and photosynthesizing leaves promote root growth, and the capacity for plant establishment, if favorable water balance is maintained, may be greater than when the plant is dormant (12).

Since shoot growth is readily observed, the relationship between shoot activity of the tree at transplanting and eventual transplant success may be easily observed. However, determination of root growth rate at the time of transplanting is considerably more difficult, particularly for large trees. For this reason, comparisons between transplantability and root growth rate at transplanting have not been made for landscape-sized trees. The purpose of this research was to test the hypothesis that periods of active root growth in established trees will be periods of quick transplant establishment. An additional objective of this research was to determine if observations of shoot growth could be used to predict active periods of root growth during which transplanting would be most successful.

Materials and Methods

Root and shoot growth periodicity. Four each of *Quercus coccinea* (scarlet oak), *Fraxinus pennsylvanica* (green ash), *Corylus colurna* (Turkish hazelnut) and *Syringa reticulata* 'Ivory Silk' (tree lilac) trees were established on a rhizotron (9) in spring, 1991. Height and caliper of all trees were taken one year after transplanting to the rhizotron, just prior to spring, 1992 bud break, and shoot and root growth data were taken throughout the 1992 growing season. Five shoots with the greatest diameter were marked on each tree for periodic measurement of shoot extension. The mean of the five shoots at each measurement date was the shoot extension for that tree. At the end of the growing season, the rate of increase in shoot extension for each measurement day (SE) was calculated for each replicate by:

$\mathbf{SE} = (\Delta_{SE} / \mathbf{T}_{SE}) / \mathbf{t} \times \mathbf{100}$; where Δ_{SE} = increase in extension between measurements, $\mathbf{T}_{SE}$ = total shoot extension for the season and **t** = time (days) between measurements. Units for **SE** are %/day.

Root extension was measured on the rhizotron by marking with colored marking pens several individual roots which were growing most vigorously. Root extension at each measurement for each replicate was the maximum extension measured on a single root. At the end of the growing season, the rate of increase in root extension for each measurement day (RE) was calculated for each replicate by: $\mathbf{RE} = (\Delta_{RE} / \mathbf{T}_{RE})/\mathbf{t} \times 100$; where Δ_{RE} = increase in maximum root extension between measurements, $\mathbf{T}_{RE}$ = total increase in maximum root extension for the season and **t** = time (days) between measurements. Units for **RE** are %/day. Means of all replicates for each species and the standard error of the means were then calculated for RE and SE and graphed for depiction of seasonal shoot and root growth patterns.

Spring and fall transplanting. Eighty trees of both green ash and scarlet oak trees were obtained from Schichtel's Nursery, Springville, New York and established on a research field near the campus of Cornell University in Ithaca, New York, in the spring of 1991. Beginning in April of 1992, four replicates of each species were chosen at random and harvested bare-root according to American Association of Nurserymen standards (1). Plants were stored in an enclosed barn on site for two days before planting. Root-balls were covered with burlap and watered at the time of storage. No additional water was applied before planting. Within three days of harvesting the green ash and scarlet oak, four replicates of Turkish hazelnut and tree lilac were picked at random and harvested in the manner described above from Schichtel's Nursery, Springville, New York. Trees were then immediately transported in an enclosed van to Ithaca and stored in the manner as described for green ash and scarlet oak. At the end of the respective two-day storage period, trees were planted in a randomized complete block design and irrigated. Irrigation was applied thereafter when weekly precipitation totals were negligible.

Mean total tree height and caliper of all replicates were taken at the time of transplanting. Beginning transplant dates were April 4, April 24, May 16, June 8, September 6, September 28, October 17, November 6 and December 8, 1992. This effectively bracketed the spring and fall transplanting seasons.

At the conclusion of the first shoot flush (bud set) after transplanting, the longest post-transplant shoot extension was measured for each tree on three separate shoots which originated in the upper 1/3 of the canopy. Shoot extension for each tree was the mean extension of these three shoots. Shoot extension of the transplanted trees was indexed against the concurrent shoot extension of the trees established on the rhizotron. At the conclusion of all initial post-transplant shoot extension (July, 1993), trees were scored for survival (alive or dead), and the survival percentage at each planting date was calculated for each species. Trees were considered alive if new shoot growth was evident within the upper 50% of the above ground height of the tree.

Results and Discussion

Relationship between transplant dates and seasonal growth patterns of established trees. Height and caliper of established trees and transplanted trees are shown in Table 1. Spring transplanting began before shoot or root growth of established trees, and continued into the periods of peak shoot growth for each species (Fig. 1A-D). Fall transplanting began after cessation of shoot growth, but during active root growth, and continued until all root growth had stopped. At the April 4 planting date there was no visible bud activity, and slight bud swell was evident at the April 24 transplanting date (data not shown). Shoots had begun extension on all species at the May 16 transplanting date.

Spring and fall transplanting of scarlet oak. No plants survived late spring (June 8) or early fall (Sept. 6) transplanting (Fig. 2A). Early spring (April 4, April 24) and late fall (November 6) survival, however, was 100%. Survival of trees transplanted on May 16 was only 25%. This planting date coincided with the period of maximum shoot extension (Fig. 1A). Scarlet oak had the quickest shoot extension of any species observed. Young expanding shoots are underdeveloped

Table 1. Mean height and caliper of scarlet oak, green ash, Turkish hazelnut and tree lilac trees established on a rhizotron and at transplanting.[Z]

Species	Height (m)	Caliper (cm)[Y]
Scarlett oak		
established	2.08(0.44)[X]	3.1(0.2)
transplanted	2.27(0.77)	3.8(0.2)
Green ash		
established	3.32(0.18)	5.1(0.1)
transplanted	3.70(0.08)	6.1(0.2)
Turkish hazelnut		
established	2.25(0.03)	3.1(0.2)
transplanted	2.00(0.04)	3.4(0.1)
Tree lilac		
established	2.48(0.09)	2.8(0.1)
transplanted	2.22(0.04)	3.5(0.1)

Z n=4.
Y Caliper = trunk diameter 10 cm above soil line.
X Standard error of the mean.

structurally and have little resistance to water loss (4). Water loss through these shoots probably contributed to whole tree water loss and poor post-transplant survival. Root growth rate on established trees was increasing on the May 16 and June 8 planting dates, but was decreasing on the September 6 and September 28 planting dates, and survival was 100% on trees transplanted on November 6 when root growth was ending on the established trees. It appears, therefore, that transplantability of scarlet oak has little to do with root growth rate of the tree just prior to transplanting.

Survival of scarlet oak increased steadily in the fall, which coincided with the lower evaporative conditions of cooler soil and air temperatures. Desiccation tolerance has been demonstrated to increase when trees are in a dormant condition, such as on the November 6 planting date (3). Survival was only 25% on trees transplanted on December 8, however. Root permeability to water can be very low for some species when soil temperatures are cold (7), and plants may not have been able to take up sufficient water to

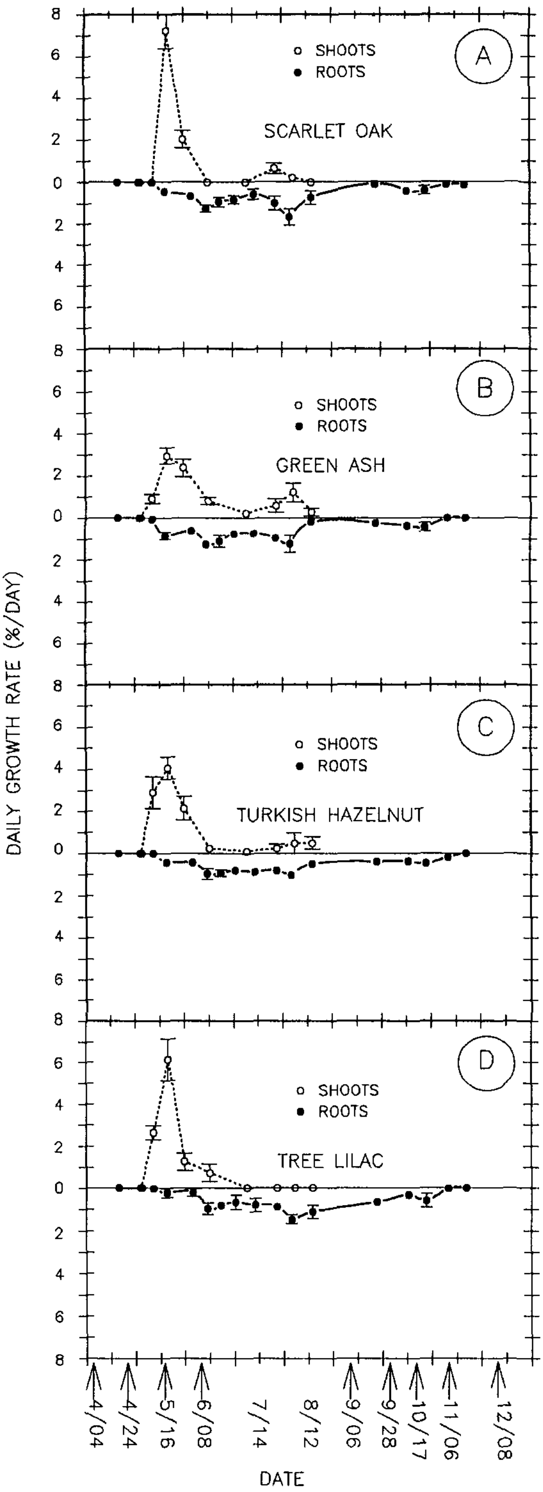

Figure 1. (right column) Daily shoot and root growth rates (SE and RE) of established scarlet oak (A), green ash (B), Turkish hazelnut (C) and tree lilac (D) for 1992. Transplant dates are indicated by arrows. n = 4.

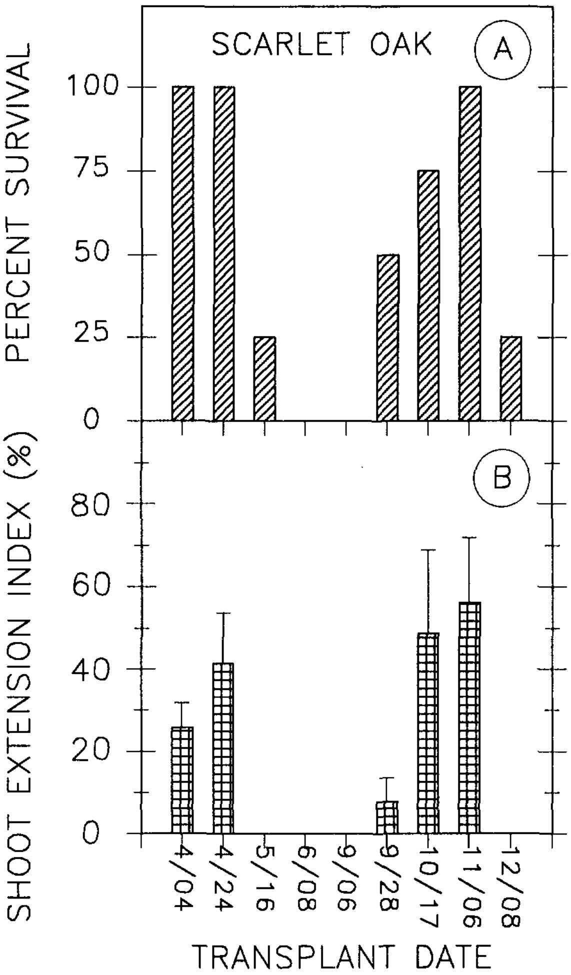

Figure 2. Percent survival (A) and initial post-transplant shoot extension index (B) of scarlet oak trees transplanted throughout spring and fall of 1992. Bars represent standard errors of the means. Shoot extension for transplant dates with 25% survival are not shown. n = 4.

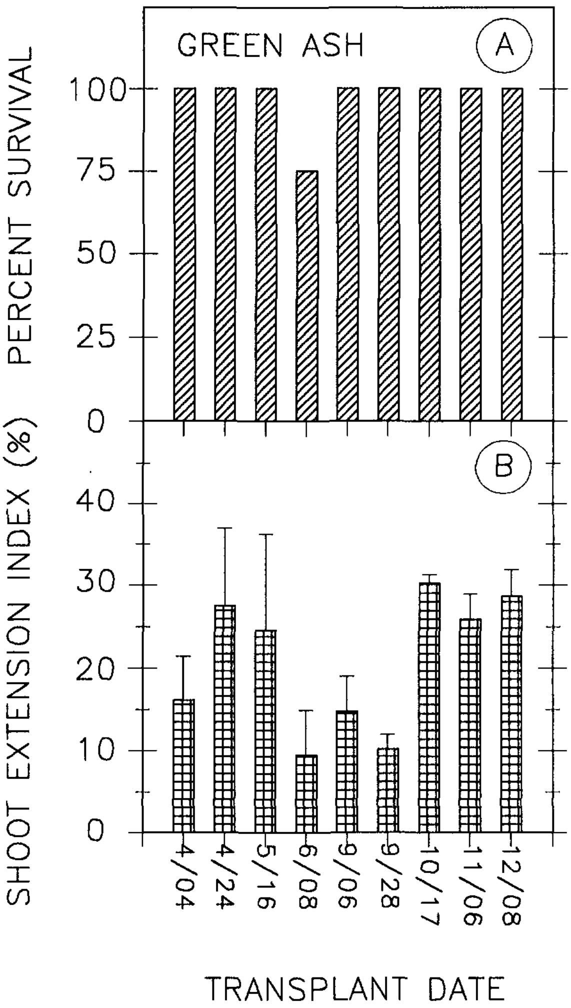

Figure 3. Percent survival (A) and initial post-transplant shoot extension index (B) of green ash trees transplanted throughout spring and fall of 1992. Bars represent standard errors of the means. n = 4.

prevent desiccation. Soil temperature on December 8 was less than 3°C, but the soil temperature on the November 6 planting date was around 8°C (data not shown). A dramatic increase in water flow resistance through some tree species has been demonstrated to occur when root zone temperatures drop below 7°C (10,13). Scarlet oak trees planted on November 6 may have been able to take up sufficient water to ensure survival before colder soil temperatures caused a decreased root permeability to water, whereas those transplanted on December 8 may not have.

Intimate root:soil contact is critical for the survival of bare-root transplants (14). Scarlet oak is a coarse rooted tree (15) and therefore would have less total contact with the backfill soil than more fibrous rooted species. The much reduced coarse root system of scarlet oak would therefore probably have more difficulty supplying sufficient water under high evaporative conditions or when cold soils reduced root permeability. This may partially explain the poor survival rates of scarlet oak trees transplanted in late spring, summer and early fall when air temperatures were high and on December 8, when soil temperatures were very cold. Shoot extension the following spring, as well as survival, was poor on trees transplanted on September 28 (Fig. 2b). This was probably a result of water loss through leaves of the transplants since survival was always less than 100% when trees were in leaf.

Spring and fall transplanting of green ash. In contrast to scarlet oak, green ash survival was good for trees transplanted on all dates (Fig. 3A). Trees were apparently somewhat more stressed, however, when transplanted in the late spring and early fall, since initial post-transplant shoot growth on trees transplanted at these dates was generally less than those transplanted on other dates (Fig. 3B). These were the warmer transplant dates, and trees were in full leaf. Unlike scarlet oak, survival was excellent for green ash trees transplanted in December. Green ash has a more fibrous root system than scarlet oak and would therefore have more absorptive surface exposed to the backfill soil. In addition, roots of green ash appeared much less darkened than scarlet oak. This suggests a higher concentration of suberin deposits for scarlet oak (11), which could hinder water uptake on scarlet oak as compared to green ash. There is also evidence that green ash has a higher root initiation rate than scarlet oak (2,16). Green ash would probably therefore regenerate new roots faster under unfavorable environmental conditions, increasing survival. These data indicate that landscape contractors can transplant green ash bare-root successfully at all fall and spring dates. This is in spite of the fact that shoots may be in active growth or that the capacity for root growth is low (Fig. 1B).

Spring and fall transplanting of Turkish hazelnut. Turkish hazelnut transplanted poorly when in full leaf or in December (Fig.4A), similar to results for scarlet oak. However, contrary to scarlet oak, survival was 75% when transplanted during active shoot extension (May 16). Survival was 0% when most buds had begun to set and root growth was well underway (June 8) (Fig. 1C). This is contrary to popular thought which says that trees should not be planted during shoot extension, but only after buds are set. The low survival on June 8 was perhaps due to the higher evaporative conditions created by warm temperatures after the June 8 transplant date. Alternatively, shoot extension or leaf size may have been reduced on the expanding shoots of Turkish hazelnut at transplanting because of reduced turgor, and subsequent post-transplant water loss may have been reduced because of the lowered plant evaporative surface area. The much more rapid shoot extension of scarlet oak (Fig.1A) was probably less able

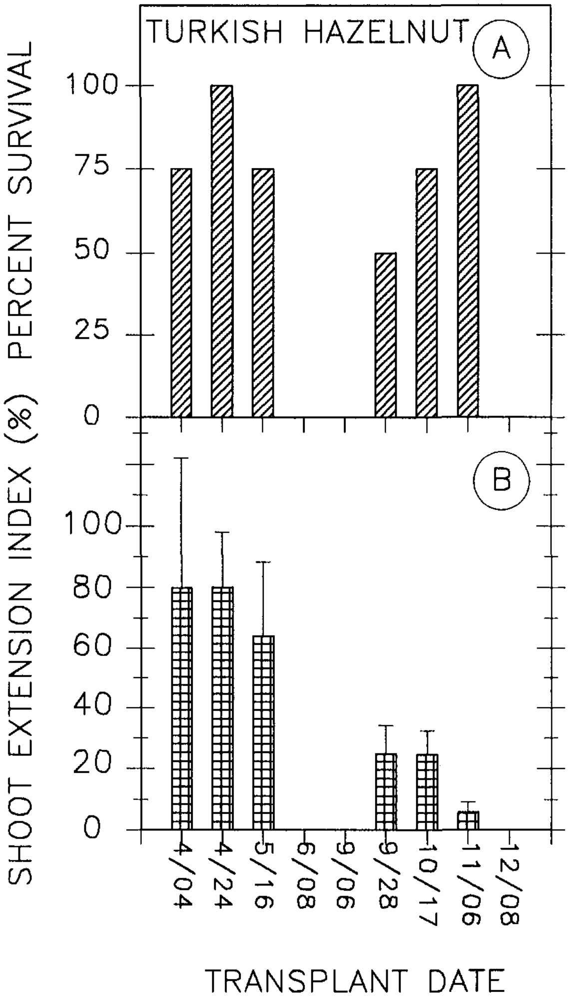

Figure 4. Percent survival (A) and initial post-transplant shoot extension index (B) of Turkish hazelnut trees transplanted throughout spring and fall of 1992. Bars represent standard errors of the means. n = 4.

to adapt to the moisture stress created by the massive root removal at transplanting than the more sustained shoot extension of Turkish hazelnut (Fig. 1C).

Turkish hazelnut, similar to scarlet oak, has a coarse root system and would probably encounter the same limitations supplying water to the shoots on the warmer transplant dates, as discussed above for scarlet oak. Post-transplant shoot extension of surviving trees was lower for all fall transplanting dates (Fig. 4C). Turkish hazelnut expressed the same 100% survival pattern as scarlet oak on November 6, but very low survival on trees planted one month later on December 8. Early November may be the latest that many tree species can be successfully transplanted in the northeastern United States. Turkish hazelnut, similar to scarlet oak, did not transplant with more success when root growth rates were high on established trees. Instead, environmental conditions such as high air or low soil temperatures were a better indicator of transplant success.

Spring and fall transplanting of tree lilac. In contrast scarlet oak and Turkish hazelnut, tree lilac had 100% survival on all transplanting dates (Fig. 5A). Surprisingly, as evident by the post-transplant shoot extension (Fig. 5B), trees seemed to transplant very well in the late spring (6/08). Tree lilac trees are apparently able to exploit the potential for active root growth which exists in the warmer months (Fig. 1D).

Overall relationship to periodic growth rate of established trees. Established trees broke bud prior to new root growth (Fig. 1A-D). The scarlet oak, green ash, Turkish hazelnut and tree lilac trees transplanted in the spring therefore likely began spring shoot growth with only the resource gathering capabilities of the transplanted root ball, without the aid of new roots. Others have also reported that spring bud break preceded root growth. Arnold and Struve (2) reported spring bud break before root growth for green ash seedlings in Indiana, and Struve and Joly (15) reported similar results for red oak (Q*uercus rubra*) seedlings, also in Indiana. Headley and Bassuk (8) reported that root growth did not precede bud break for Norway maple (*Acer platanoides*), red maple (*Acer rubrum*), pin oak (*Quercus palustris*)

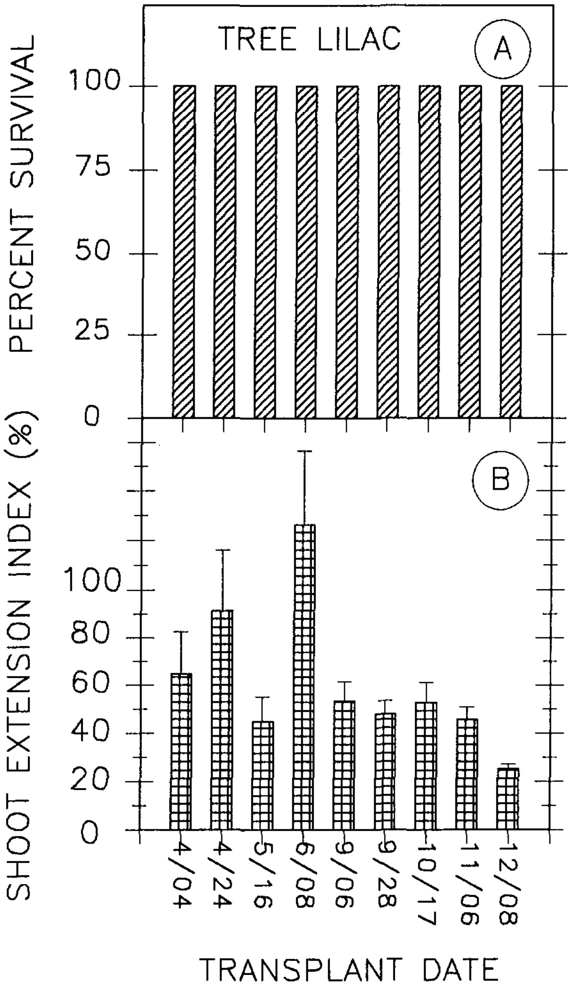

Figure 5. Percent survival (A) and initial post-transplant shoot extension index (B) of Tree Lilac trees transplanted throughout spring and fall of 1992. Bars represent standard errors of the means. n = 4.

or northern red oak (*Quercus rubra*) in upstate New York.

Trees transplanted on November 6 were transplanted at the end of the root growth period, and those transplanted on December 8 were clearly beyond the period when root growth occurs. A longer period was available for root growth for those trees transplanted on September 6 and September 28 compared to those transplanted on October 17. However, temperatures, and thus potential water loss, were higher at this time of year.

Since green ash and scarlet oak were transplanted into nursery rows one year before the beginning of the experiment, stresses imposed at this time could have affected the transplant response the following year. Tree lilac and Turkish hazelnut were grown for several years in the nursery before the final transplanting, and the number of shoot internodes on the new post–transplant shoot flush was dependent upon the pre–transplant growing conditions of the previous season (determinant growth). Although the post–transplant elongation rate would be mostly determined by the limitations imposed by transplant stress, some interaction is possible. Determination of when trees are established is dependent on the criteria used. The root spread:crown spread ratio on trees established on the rhizotron was statistically similar among species and averaged 2.04 in the spring of 1992, which is only slightly less than that thought to be the average for established trees (6).

Summary

The prediction of periods of active root growth was not a reliable tool for the prediction of transplant success. Green ash and tree lilac can be planted with confidence throughout the spring and fall planting seasons. Green ash may respond better to fall transplanting, and tree lilac may respond better to transplanting in late spring and early fall. Turkish hazelnut and scarlet oak transplant best in early spring and mid fall. Survival can be expected to be poor in late spring and early fall for both species. Turkish hazelnut, but not scarlet oak, may be transplanted after buds have broken in the spring.

Tree lilac and Turkish hazelnut had similar root growth patterns, yet they transplanted with very different degrees of success. The same results are evident when comparing green ash and scarlet oak. Seasonal root growth therefore does not appear to be inherently different on easy to transplant species compared to difficult to transplant species.

Trees which cannot normally be successfully transplanted in late spring or early fall, like Turkish hazelnut and scarlet oak, have only a small window of opportunity for fall transplanting.

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Résumé. Des *Quercus coccinea* (chênes écarlates), *Fraxinus pennsylvanica* (frênes de Pennsylvanie), *Corylus colurna* (noisetier de Byzance) et *Syringa reticulata* 'Ivory Silk' (lilas japonais) ont été transplantés à racines nues durant la période de plantation du printemps et de l'été. La réponse posttransplantation était comparée avec des arbres déjà établis en regard de l'activité racinaire durant la période de transplantation. Le taux de croissance des racines des arbres établis durant la période de transplantation n'était pas relié à la transplantabilité. Le frêne de Pennsylvanie et le lilas se transplantaient bien à n'importe laquelle des périodes. Le chêne écarlate et le noisetier de Byzance se transplantaient mal durant les périodes de la fin du printemps et du début de l'été, mais le taux de survie était bon tôt au printemps et au milieu de l'été.