Root and Shoot Growth Periodicity of Pot-in-Pot Red and Sugar Maple[1]

J. Roger Harris and Jody Fanelli[2]
Department of Horticulture
Virginia Polytechnic and State University
Blacksburg, VA 24061

Abstract

Red maple (*Acer rubrum* L. 'Franksred') and sugar maple (*Acer saccharum* Marsh. 'Green Mountain') trees were grown in a 56 liter (15 gal) pot-in-pot system for two years. During the second year of production, root growth was observed through observation plates fitted into the container sidewalls, and shoot extension was periodically measured. Root growth began in early March, approximately one month before budbreak for both species. Root growth dramatically slowed down at the onset of budbreak, but quickly resumed and was concurrent with shoot elongation. Root growth slowed dramatically in the fall when substrate temperatures dropped to 5–7C (40–45F). Root growth stopped during the winter for red maple, but some nominal root growth continued throughout the winter for sugar maple. Red maples had over 5 times more total root length against observation plates at the end of the experiment than sugar maples.

Index words: nursery production, transplanting, rhizotron.

Species used in this study: red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.).

Significance to the Nursery Industry

Extensive root growth occurs two to four weeks before budbreak for 15 gal pot-in-pot red and sugar maples in regions with climate similar to Blacksburg, VA (USDA Climate Zone 6a), although timing between the two events can vary from year to year. Trees must be planted no later than very early in the spring (e.g., February) to take full advantage of establishment before spring budbreak. Root growth sharply slows at the beginning of spring shoot growth. This is not an optimum time to transplant. Root growth begins in the spring as substrate temperatures near 10C (50F) and dramatically slows in the fall when substrate temperatures drop to 5–7C (40–45F) for both species. Some nominal root extension occurs throughout the winter for sugar maple, but red maple has almost no root growth at this time.

Introduction

Investigations into the root and shoot growth periodicity of trees have produced mathematical descriptions of growth patterns that are based on resource limitation feedback between roots and shoots that results in a favorable root:shoot relationship (19, 20). Future innovations in molecular biology will likely reveal some of the actual mechanisms involved (18). Interspecific differences in root growth (2) perhaps explain why some authors report alternating cycles of root and shoot growth (11), but others report no such alternating cycles (17). The partitioning of growth between roots and shoots has been experimentally shown to be affected by mineral nutrition (16) and soil water availability (3), two factors under control of nursery operators.

Transplant timing decisions can be made more accurately with root and shoot periodicity knowledge. In addition, a description of root and shoot growth periodicity will help nursery operators plan more effective production strategies. For example, Gilliam and Wright (4) found that timing fertilizer application to just after cessation of shoot elongation, during a period of active root growth, increased top growth of young Japanese holly (*Ilex crenata*). Therefore, the objective of this study was to describe the root and shoot growth periodicity of red maple (*Acer rubrum* L. 'Franksred') and sugar maple (*Acer saccharum* Marsh. 'Green Mountain') grown in a pot-in-pot (PIP) production system.

Materials and Methods

Bare-root, 6 ft (2 m) tall red and sugar maple trees were obtained from J. Frank Schmidt and Sons, Inc. Nursery (Boring, OR) and planted into 56 liter (15 gal) containers in a PIP production system in Blacksburg, VA, in the spring of 1994. The PIP system consisted of 56 liter (15 gal) socket containers, spaced 1.2 m (4 ft) on center in rows 1.5 m (5 ft) apart. The area between containers was covered with black landscape fabric, and an underground drainage system assured that growing containers were not in standing water. Each production container was fitted with a 28 cm (11 in) wide × 28 cm long × 6.4 mm (0.25 in) thick, clear polycarbonate sheet (GE Worldwide Manufacturing Sites, Mount Vernon, IN) as a window through which root growth could be observed (i.e. rhizotron). Substrate was unamended pine bark (pH = 6.2). Four trees of each species were planted in a completely random arrangement and grown until February 1995, at which time root growth measurements began. All trees were fertilized with 161 grams (5.7 oz) of encapsulated slow-release fertilizer (18N–2.6P–9.9K, Osmocote, The Scotts Co., Maryville, OH) and irrigated with a micro-irrigation system so as to maintain substrate moisture near field capacity throughout the experiment. Substrate temperatures were monitored for each species with thermocouples, one placed in the container of a randomly chosen tree of each species, just inside the polycarbonate window and 20 cm (8 in) deep. Temperatures were recorded in early afternoon, approximately twice weekly for the duration of the experiment. Since substrate temperatures did not vary between species, data were averaged for the two species at each measurement. Shoot

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[2]Associate Professor and Research Technician, respectively.

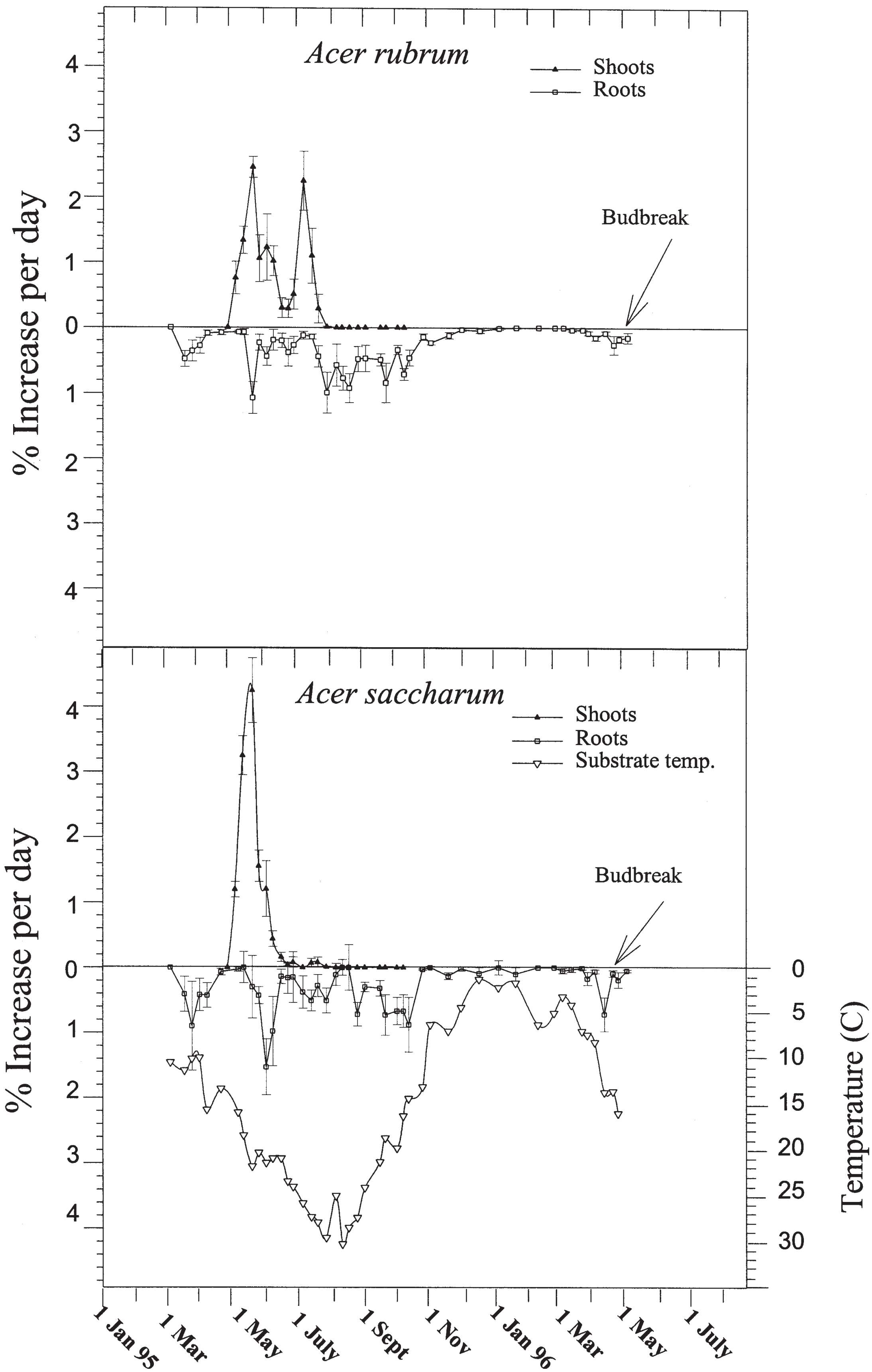

Fig. 1. **Rate of increase in shoot extension and root length against rhizotron windows for red maple and sugar maple trees over a 14-month period. Data were taken weekly. Bars = s.e. mean. n = 4. Substrate temperatures for the same period are shown in the lower quadrant, with units on the right axis.**

extension was measured weekly on each of five lateral shoots which had been randomly selected before budbreak for each tree. The mean shoot extension of these five shoots was the shoot extension for that tree for that measurement period. Root growth was monitored weekly for 14 months by digitizing 35 mm photographic slides and employing a combination of image-processing computer software (Adobe Photoshop, ver. 3.0; Adobe Systems, Mountain View, CA, and SigmaScan/Image, ver. 1.2; Jandel Scientific, San Rafael, CA). Total root length against rhizotron windows was estimated with the line intersect method (13, 15) by counting root:line intersections on an electronic grid (SigmaScan). Increase in root length and shoot length at each measurement was divided by the total seasonal increase and the days between measurements to calculate the percentage increase per day for each measurement day (8). These data, along with substrate temperatures, were plotted over time to reveal the root and shoot growth periodicity for each species. The difference between total seasonal root length increase of red and sugar maple was analyzed by analysis of variance (Minitab vers. 12, Minitab, Inc., State College, PA).

Results and Discussion

Root growth was well underway for both species by the middle of March 1995 (Fig. 1). Substrate temperatures at this time were around 10C (50F). Similar soil temperature has been found to accompany the beginning of spring root growth for field-grown green ash, scarlet oak, Turkish hazelnut, and Japanese tree lilac trees in upstate New York (8). Unlike that study, however, a substantial amount of root growth occurred before budbreak (around May 1) in both species in the current experiment. Early, rapid shoot growth was accompanied by a temporary interruption of root growth in both species (Fig. 1), followed by a dramatic stimulation of root growth. The most rapid root growth for the season in red maple occurred in mid-May and was concomitant with the most rapid shoot extension. Sustained root growth was evident after budset for both species and continued until the fall decline, except for a temporary stop in August for sugar maple. This summer stoppage of root growth occurred when substrate temperatures were at their maximum (25–30C). Since red maple has a much more southern distribution than sugar maple (1), root growth of red maple is probably less sensitive to high substrate temperatures. However, temperatures that were high enough to cause physiological damage to roots (10) were probably not reached. Fall cessation of root growth was accompanied by substrate temperatures near 7C (45F), also similar to that found by Harris et al. (8). In sugar maple, the most rapid root growth of the season occurred approximately two weeks later (around June 1) than in red maple. This was during the period of rapid decline in shoot growth. For both species, root growth began approximately two weeks later in 1996 (around April 1) than in 1995 (around March 15), although this was also before spring budbreak. Budbreak timing was similar for both years (around May 1), resulting in less root growth before budbreak in 1996 than in 1995. Some nominal root growth occurred in sugar maple throughout the winter, but red maple roots were quiescent. This observation agrees with that of Morrow (14), who reported that root growth of sugar maples continues to some degree throughout winter in upstate New York.

Red maples grew an average of 39.2 m (se mean = 2.6) of new roots against the rhizotron windows throughout the measurement period, whereas sugar maples grew only 7.5 m (se = 1.2). These differences were highly significant ($p = 0.0001$). Red maple rootballs could be removed from the growing containers intact before root growth began in 1995, while sugar maples could not. Sugar maples required the flushes of root growth that occurred just before budbreak and again just before budset (Fig. 1) before rootballs could be moved intact. Although plants were not excessively root bound at the end of two growing seasons, consideration can be given to treating 15 red maples as a one-year crop, to be sold in the spring of the second year, but 15 gal sugar maples would not be ready at that time.

Although there was no sustained antagonistic pattern of root vs shoot growth for either species, a transient antagonism was clearly evident since the onset of shoot growth coincided with a sharp temporary reduction in root growth (Fig. 1). This sharp reduction in root growth also occurred at the beginning of the second flush of shoot growth in red maple. Although it is possible to successfully transplant both container and field-grown trees at any time of year, budbreak would not be the ideal time to transplant, since root growth is limited and the potential for water loss through developing, unsuberized shoot tissue is high. One significant advantage to transplanting container-grown trees vs balled-and-burlapped (B&B) or bareroot (BR) trees during the growing season is that the considerable amount of root growth that takes place after budset, while the tree is still in full leaf, can be fully utilized for establishment, whereas B&B or BR trees harvested then would likely undergo transplant shock during this period due to root loss, unless specific measures (e.g., mist nozzles) are implemented. Although the potential for root growth after fall leaf drop is low (Fig. 1), establishment of fall-transplanted trees may be more successful than trees planted in the spring (9). This is probably because the potential for desiccation is much less in cooler weather, and soils are generally wet in the fall. In addition, fall-transplanted trees have much more time to acclimate to physiological transplant stress than spring-transplanted trees before the onset of spring shoot growth. However, transplanting very late in the fall in climates with severe winters is not a good idea for some species (5).

Since low soil temperatures limit root growth and budbreak timing is mostly controlled by air temperatures (12), the timing of these events will likely differ from year to year, as seen in spring 1995 vs spring 1996 in our experiment (Fig. 1). Variations between climate regions would be even more pronounced. For example, root growth does not precede bud growth for established or transplanted trees in cold-soil regions similar to upstate New York (6, 7).

Nursery operators can probably best exploit the pre-budbreak root growth of red and sugar maples by planting liners in the fall instead of the spring. Fall transplanting will assure growers of ample pre-budbreak root growth to support rapid spring shoot growth, whereas transplant stress of spring-transplanted liners may reduce the amount of root growth before budbreak. Landscape establishment may also be faster if root growth into the backfill soil can begin before budbreak, since the increased available soil water reservoir will better support developing shoots. In conclusion, to best exploit the substantial flush of root growth that occurs immediately before budbreak, as we have demonstrated in this experiment, trees should be planted into production containers or landscapes well before the onset of spring shoot growth.

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