Seasonal Effects of Transplanting on Northern Red Oak and Willow Oak[1]

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Abstract

Seasonal effects on transplant establishment of balled-and-burlapped (B&B) shade trees are not well documented. Early post-transplant root growth and aboveground growth over a 3-year period were therefore determined for November- and March-transplanted northern red oak (*Quercus rubra* L.) and willow oak (*Q. phellos* L.). Survival of red oak was 100% for both treatments. Survival of November- and March-transplanted willow oak was 67% and 83%, respectively. No new root growth was observed outside or within the root balls of either species upon excavation in January. New root growth was evident when trees of both species were excavated in April, indicating that root system regeneration of November-transplanted trees occurs in late winter and/or early spring, not late fall and/or early winter. November-transplanted red oak, but not willow oak, grew more roots by spring bud break than March-transplanted trees. However, little difference in height growth and trunk expansion was evident between the November- and March-transplanted red oaks throughout the 3 years following transplant. While height growth of willow oak was nearly identical between treatments after 3 years, November transplants exhibited greater trunk diameter increase for all 3 years. Overall, season of transplant had little effect on height and trunk diameter increase of red oak, even though November-transplanted trees grew more roots prior to the first bud break following transplant. Among the willow oaks that survived, season of transplant had little effect on new root growth and height growth, but November transplanting resulted in greater trunk expansion. However, when the mortality rate of November-transplanted willow oak is taken into consideration, March may be a better time to transplant willow oak in climates similar to southwest Virginia.

Index words: establishment, tree, root growth, balled-and-burlapped, *Quercus rubra* L., *Q. phellos* L.

Significance to the Nursery Industry

Season of transplant potentially affects plant establishment through poorly understood changes in early root system regeneration. This study sought to determine the effects of fall vs. spring (November vs. March) transplanting on height and trunk growth of northern red and willow oak and determine when roots resume growth following transplanting. Root growth was not observed within or outside of root balls of fall-transplanted trees of either species until early spring, indicating that while it may be advantageous to transplant these species in fall, it is not due to late fall and/or early winter root growth. Thus, first-season irrigation practices should focus on the root ball and nearby adjacent soil. November transplanting did not result in increased height and trunk diameter growth of red oak. However, November-transplanted willow oaks exhibited greater trunk expansion than the March transplants. Survival of red oak was 100%, however, survival of November- and March-transplanted willow oak was 67% and 83%, respectively. Thus, March may actually be a better time of year to transplant willow oak in climates similar to that in this study.

Introduction

Root systems of most trees extend well beyond the maximum spread of the branches (30). As a result, less than 10% of the total root length of the original root system may be moved with a tree when it is harvested for transplanting (9, 29). Gilman and Beeson (11) reported that while more than 90% of coarse [>10 mm (0.4 in) diameter] root weight was within the confines of the root balls of field-grown trees, less than 15% of the fine, absorbing root weight [<2 mm (0.1 in) diameter] was within the confines of the root balls. The significant loss of roots that occurs as a consequence of transplanting results in a root system that is disproportionately small compared to the aboveground portion of the tree (30, 31) and until the transplant regenerates a sufficient root system, water absorption will be limited by the absorptive capability of the much reduced, transplanted root system. The limited size of the transplanted root system relative to the aboveground portion of the tree can result in the tree absorbing moisture from the root zone more rapidly than water can move in from the surrounding soil (30). Consequently, moisture stress, a common cause of transplant failure, may occur despite the presence of ample moisture in the surrounding soil. Limited available soil moisture may result in reduced root as well as shoot growth (2). Therefore, the more rapidly a root system is regenerated, the less moisture stress will be imposed upon the tree and the greater the chance of survival (26).

Season of transplant is important with respect to plant growth because season often corresponds to specific stages of growth and maturity (e.g., dormancy, leaf drop, bud set, flowering), as well as specific weather patterns and light characteristics (e.g., temperature, moisture, daylength, and light intensity and quality) that influence plant growth (18). While fall transplanting may be superior to spring transplanting for many species (5, 12, 16, 18, 20, 29, 32), spring transplanting may be superior (5, 12, 22) or similar (17, 28, 29, 31) to fall transplanting for other species. However, initial differences in growth of fall- and spring-transplanted trees may disappear after a few years (5, 31).

Season can also influence root regeneration potential and length of time until root growth commences (16, 17, 22, 23).

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Early fall-transplanted sugar maple (*Acer saccharum* Marsh.) and northern red oak began root growth earlier and grew more roots in the first season after transplanting than the mid fall- and spring-transplanted treatments (15). Differences in survival rates of fall- and spring-transplanted trees were suggested to be related to poor root system regeneration and excessive water deficit (5, 22). In addition to season and species-specific responses, other factors, such as habit (conifer vs. broad-leafed evergreen vs. deciduous) (18), pre-planting preparation, soil preparation, planting technique (1), post-transplant practices, soil type, site conditions, environmental conditions (e.g., weather, moisture), and production, harvest and handling methods (5) may also influence transplant success.

Fall and spring are often considered the best times for transplanting most landscape plants in climates characterized by wet springs and falls, particularly if post-transplant care is expected to be minimal, due to favorable conditions such as increased soil moisture, cooler air temperatures, the absence of active shoot growth, and the associated reduced potential for desiccation (14, 19, 31). Proposed advantages of fall transplanting include an increased opportunity for trees to regenerate a root system prior to shoot growth in spring, more time to develop contact between the roots and soil (5), more time to acclimate to the physiological stresses of transplanting before shoots resume growth in spring (14), and more time for physiological processes involved in the resumption of root growth to occur (16). As a consequence, fall-transplanting may result in increased pre-bud break root growth and the development of a larger root system, which can access a greater soil water reservoir to support shoot growth the following spring (14, 16). Additionally, spring transplanting might interfere with production of root-produced hormones involved in shoot extension (20). While fall transplanting is recommended in many regions, late fall transplanting is not advised in climates with severe winters (12). For some species, spring conditions in temperate climates (e.g., ample soil moisture, warming soils) provide optimal conditions for root growth and tree establishment (1). Advantages of spring transplanting (prior to bud break) include the avoidance of damaging cold weather, cool temperatures and minimal transpirational losses, and the potential for pre-bud break root growth. However, transplanting at or just prior to bud break in spring is usually ill advised (7, 8) and can result in poor root system regeneration and growth (28) unless trees can be supplied adequate moisture.

Root system regeneration is essential for transplant survival. A basic knowledge of rooting behavior of transplanted trees is still needed to better understand the establishment of transplanted trees. With an increased understanding of factors relating to the dynamics of post-transplant root system regeneration, better decisions regarding plant management can be made, resulting in better transplant establishment of these and other species. The objectives of this project were to determine which season is best for transplanting northern red and willow oak, and to determine when post-transplant root system regeneration commences.

Materials and Methods

Plant material. Unbranched seed-grown northern red oak whips [1.2 to 1.5 m (4 to 5 ft)] were obtained from J. Frank Schmidt and Sons Co. (Boring, OR) and grown for 2 years in a nursery bed of field soil at the Urban Horticulture Center, Blacksburg, VA [zone 6a on 1990 USDA plant hardiness zone map (27), zone 4 on AHS plant heat zone map (3)]. Lightly branched seed-grown willow oak whips [0.5 to 0.6 m (1.5 to 2 ft)] were obtained from Heritage Seedlings (Salem, OR) and grown for 3 years, also in a nursery bed of field soil at the Urban Horticulture Center. All trees were spaced 1.2 m (4 ft) apart in rows 1 m (3.5 ft) apart. Soil type was a Groseclose silt loam (clayey, mixed, mesic Typic Hapludults) with pH 6.2. Thirty willow oaks and 30 red oaks of uniform size were selected for use in this project. Mean initial heights (SE mean in parentheses) of the red and willow oaks were 2.66 (0.08) m and 2.38 (0.05) m [8.73 (0.26) ft and 7.81 (0.16) ft], respectively. Mean initial trunk diameters of the red and willow oaks 15 cm (6 in) above the soil line were 40.92 (1.01) mm and 37.17 (0.68) mm [1.61 (0.04) in and 1.46 (0.03) in], respectively.

Treatments. Eighteen trees of each species were randomly assigned to the November transplant treatment (November 5, 1999) and 12 trees of each species were randomly assigned to the March transplant treatment (March 10, 2000). Trees were planted in a nursery bed at the Urban Horticulture Center in a completely randomized design, keeping species in separate beds. To assess late fall and early winter root system regeneration of the November-transplanted trees, six trees of each species were randomly selected to be excavated in January (N–J). To assess late winter and early spring root system regeneration in the November-transplanted trees, six trees of each species were randomly selected to be excavated in April, just prior to spring bud break (N–A). To assess late winter and early spring root system regeneration in March-transplanted trees, six trees of each species were also randomly selected to be excavated in April, just prior to spring bud break (M–A). Early winter and spring excavation dates were January 15 and April 21, 2000, respectively. Height and trunk diameter growth of the six remaining trees of each species and planting date were measured for three growing seasons following transplant.

Tree harvest and planting. All trees were harvested with a mechanical tree digger (tree spade). Root balls were 45-cm (18-in) diameter. All root balls were wrapped with industry-standard copper sulfate-treated burlap (A.M. Leonard, Piqua, OH), enclosed in wire baskets, and laced with sisal twine (balled-and-burlapped). Trees were planted in a nursery bed in 0.75 m (2.5 ft) diameter augered holes 2.3 m (7.5 ft) apart and staggered in rows 1.05 m (3.5 ft) apart. After positioning the trees in holes, native soil was used to fill the space around the trees. All twine was loosened from around the tree trunks. Burlap and wire baskets were left in place to facilitate excavation of the root balls. However, baskets tops were pulled away from the tops of the root balls. After planting, all trees were flood irrigated and any crevices that opened were filled with native soil.

Tree care: fertilization, irrigation, etc. In spring 2000, 200 grams (7 oz) of encapsulated slow release fertilizer (15N–3.9P–10K, Osmocote Plus 15N–9P_2O_5–12K_2O 8–9 Month Northern Formula, The Scotts Company, Marysville, OH) was broadcast over the planting hole of each tree. The same fertilizer and rate was broadcast beneath the canopy of each tree prior to spring bud break in 2001. In spring 2002, 9.8 g N/m^2 (2 lb N/1000 ft^2) of 27N–1.3P–10K fertilizer (Statesman Supreme Methex 40 Controlled Release N, 27N–3P_2O_5–12K_2O, Southern States Cooperative, Inc., Richmond, VA) were broadcast over both nursery beds. Soil was maintained near field capacity for two growing seasons with a micro-irrigation system. During the growing seasons of 2000 and 2001, trees were irrigated once a week. Trees were not irrigated in 2002, except for occasional irrigation due to drought. Weeds were eliminated by hand pulling and applications of RoundUp Pro® (41% glyphosate, Monsanto Company, St. Louis, MO) and pre-emergent herbicides Snapshot 2.5TG (0.5% isoxaben and 2.0% trifluralin, Dow AgroSciences LLC, Indianapolis, IN), Pendulum® WDG (60% pendimethalin, BASF Corp., Research Triangle Park, NC), and Surflan A.S. (40.4% oryzalin, Dow AgroSciences LLC, Indianapolis, IN). Herbicides were applied according to manufacturer's recommendations.

Measurements and analysis. Height and trunk diameter were measured at the time of transplant and at the end of each subsequent growing season. Height of the tallest branch tips was measured with a telescoping meter pole. Trunk diameter 15 cm (6 in) above the soil line was determined by averaging two measurements, one made parallel to the nursery bed and the other made perpendicular to the nursery bed. Upon excavation, all new root growth outside the original root balls was removed. Root balls were rinsed free of soil and all new roots inside the root balls were removed. White, unsuberized roots were considered to be new roots. Root length was measured with a ruler. Roots were then dried to a constant weight at 65C (149F) and weighed. Soil and substrate temperatures were monitored with a thermocouple (Model HH21 Microprocessor Thermometer, Type J-K-T Thermocouple, Omega Engineering, Inc., Stamford, CT) placed 30 cm (12 in) deep in the nursery bed. Afternoon temperatures were recorded twice weekly. All data were subjected to analysis of variance with the GLM procedure of SAS (SAS for Windows Version 8.02, SAS Institute, Cary, NC). Species were analyzed separately.

Results and Discussion

No new root growth occurred within or outside the root balls of either red or willow oak during the 71 days between transplanting on November 5, 1999 (just after fall leaf abscission), and excavation on January 15, 2000 (Table 1), indicating that any advantage there may be to transplanting red and willow oak in the fall is not due to late fall and/or early winter root growth. Due to the lack of late fall and early winter root growth, November transplants had to rely on the transplanted root system until root growth commenced in late winter and/or early spring. Larson (21) reported that under greenhouse conditions, minimal root regeneration occurred in northern red oak seedlings at temperatures below 13C (55F). Afternoon soil temperatures in our study dropped below 13C (55F) by mid October. Thus, the lack of new root growth between November transplanting and January excavation may have been a result of low soil temperatures. However, other studies suggested that root growth was limited at lower temperatures (13, 14, 17, 24). By the end of November, afternoon soil temperatures dropped below 5C (41F). Thus, late fall and/or early winter root growth may have initially been restricted by the physiological stresses of being transplanted (5, 16) and later restricted by soil temperature.

Despite the lack of early post-transplant root regeneration in late fall and/or early winter, new root growth was evident in both red and willow oak prior to bud break in spring. November-transplanted red oaks had greater new root length and dry weight outside the root ball (P = 0.032 and 0.069, respectively) and greater total new root length and dry weight (P = 0.019 and 0.021, respectively) at spring bud break than March-transplanted trees (Table 1). Thus, November-transplanted red oaks in this study entered the period of spring shoot elongation with more new roots than March-transplanted trees. In contrast, November-transplanted willow oaks had no root growth outside of the root balls prior to spring bud break. Modest root growth occurred within the willow oak root balls by spring bud break in both the November- and March-transplanted treatments; however, there was no

Table 1. Analysis of variance of new root length and dry weight of northern red oak (*Quercus rubra* L.) and willow oak (*Q. phellos* L.) transplanted on November 5, 1999, or March 10, 2000, and excavated on either January 15, 2000, or April 21, 2000. n = 6.

Transplant/excavation date	Inside root ball		Outside root ball		Total	
	Length (mm)	Dry wt (g)	Length (mm)	Dry wt (g)	Length (mm)	Dry wt (g)
Northern red oak						
November/January (N/J)	0.0	0.00	0.0	0.00	0.0	0.00
November/April (N/A)	306.0	0.07	170.8	0.03	476.8	0.10
March/April (M/A)	127.3	0.03	0.0	0.00	127.3	0.03
Willow oak						
November/January	0.0	0.00	0.0	0.00	0.0	0.00
November/April	541.7	0.10	0.0	0.00	541.7	0.10
March/April	390.2	0.07	0.0	0.00	390.2	0.07
			P > F			
Northern red oak						
N/J vs. N/A	0.017	0.012	0.032	0.069	0.003	0.003
N/J vs. M/A	0.283	0.276	1.000	1.000	0.351	0.313
N/A vs. M/A	0.139	0.105	0.032	0.069	0.019	0.021
Willow oak						
N/J vs. N/A	0.117	0.129	—	—	0.117	0.129
N/J vs. M/A	0.249	0.290	—	—	0.249	0.290
N/A vs. M/A	0.648	0.620	—	—	0.648	0.620

Table 2. Analysis of variance of end-of-season height growth and trunk expansion of northern red oak (*Quercus rubra* L.) and willow oak (*Q. phellos* L.) transplanted on November 5, 1999, or March 10, 2000. n = 6.

Transplant date	Height growth (m)			Trunk diameter growth (mm)		
	2000	2001	2002	2000	2001	2002
Northern red oak						
November	0.32	0.66	1.58	4.3	20.4	40.0
March	0.23	0.60	1.34	6.8	23.4	40.9
P > F	0.275	0.708	0.357	0.306	0.345	0.891
Willow oak						
November	0.58	1.54	2.06	18.9	43.3	79.1
March	0.33	1.06	1.94	12.6	33.3	63.3
P > F	0.192	0.118	0.790	0.039	0.029	0.027

transplant time effect (*P* = 0.648 and 0.620 for length and dry weight, respectively). Blacksburg is near the extent of the climate range in which willow oaks can be successfully grown (6, 10), and early spring soil temperatures may have been more limiting to the extension of new roots of willow oak than to the more cold tolerant red oak.

As mentioned previously, late fall and/or early winter root growth of fall-transplanted trees was probably restricted by physiological stresses and wound responses associated with transplanting. By the time the transplants had overcome these stresses, winter soil temperatures had dropped sufficiently to limit root growth. Therefore, as spring soil temperatures increased and became more favorable for root growth, roots of the November transplants were likely better able to quickly resume growth compared to the March transplants. March transplants may have still been adjusting to the considerable injury and loss of roots that occurred as a result of transplanting, thereby delaying the resumption of root growth. Subsequently, November transplants likely resumed root growth earlier, resulting in more roots prior to bud break than the March transplants. Other authors (5, 14) also suggested that fall transplanting provides more time for transplants to acclimate to the physiological stresses of transplanting. Late fall and early winter root growth may also have been restricted due to the roots being in a dormant state.

The greater pre-bud break root growth of the November transplants relative to the March transplants increased the soil water volume available to support the new developing, non-lignified shoots during shoot elongation in spring (14, 16). However, there was little evidence that differences in height or trunk diameter growth of red oak were due to season of transplant (Table 2). Although November-transplanted red oak produced more root length than the March transplants (*P* = 0.139 and 0.032 inside and outside the root ball, respectively), the amount was actually quite small (Table 1). Thus, the increased pre-bud break new root growth produced by the November-transplanted red oaks relative to the March transplants did not appear to confer any benefit for the November transplants in terms of height and trunk diameter growth in subsequent years (Table 2). Harris et al. (15) determined that October-transplanted red oaks began root growth earlier and produced more roots the first-season following transplant than the November- and March-transplanted treatments. Similar to our findings, earlier and increased root growth in the Harris et al. (15) study did not translate to greater height and trunk diameter growth in the following 3 years. Trees in both projects were kept well irrigated. In circumstances where water is limiting, additional root growth may provide a greater benefit.

November-transplanted willow oaks in the current study also produced more root length by bud break compared to the March transplants, but there was little evidence that these differences are due to treatment (*P* = 0.648). Height growth of the November- and March-transplanted willow oaks was similar all 3 years following transplant (*P* = 0.192, 0.118, and 0.790, respectively). Trunk expansion, however, was greater for the November transplants compared to the March transplants all 3 years (*P* = 0.039, 0.029, and 0.027 for years 1 to 3, respectively).

Survival of November- and March-transplanted willow oak was 67 and 83%, respectively. While November-transplanted willow oaks had greater trunk expansion than the March transplants, these results are based upon the trees that survived. Therefore, November-transplanted willow oaks exhibited greater trunk expansion only if they survived. When taking into account the poor survival rates of November-transplanted willow oak, March may actually be a better time of year to transplant willow oak in climates similar to southwest Virginia (1990 USDA plant hardiness zone 6a, AHS plant heat zone 4). Although additional winter survival studies with more replications would be needed to justify a firm recommendation, anecdotal evidence from growers and landscapers supports spring planting of willow oak in our climate.

Differences in survival rates of fall- and spring-transplanted trees were also reported by Buckstrup and Bassuk (5) [hophornbeam (*Ostrya virginiana* (Mill.) K. Koch.)] and Larson (22) [Austrian pine (*Pinus nigra* Arn.)]. Larson suggested that poor survivability of fall transplants was due to poor root system regeneration and excessive needle water deficit. Due to the lack of late fall and/or early winter root growth in willow oak in this study, the November transplants relied solely on the transplanted root system until root growth commenced in late winter and/or early spring. November-transplanted willow oaks may have been more susceptible to stem desiccation (4) during winter than March-transplanted willow oak, which could have contributed to the poor survival rate. Desiccation and cold injury in very cold temperatures are reported problems in cold climates (18) and may relate to increased hydraulic resistance across roots at temperatures below 45F (25). Late fall and/or early winter root growth was also poor among the November-transplanted red oaks. However, survival of both November- and March-transplanted red oaks was 100%. Therefore, November-transplanted red oak may have been less susceptible to desiccation than November-transplanted willow oak.

Of final note, an air spade (Series 2000, Verona, PA) was used to determine root extension into the surrounding soil after the second growing season (September 2001). Roots were immediately covered and irrigated after inspection. Roots of one willow oak tree were observed approximately 1.8 m (6 ft) from the tree trunk and were 2.54 cm (1 in) diameter near the trunk, indicating the potential post-transplant root extension of willow oak in climates and soils similar to that in our study.

To conclude, root growth of November-transplanted red and willow oak did not occur until late winter and/or early spring under the conditions of this study. Therefore, any advantage to transplanting red and willow oak in fall is not due to late fall and/or early winter root growth. Instead, fall-transplanted trees may be in a better physiological state to resume root growth in the spring. While November-transplanted red oaks began the period of spring shoot growth with more new roots than March-transplanted trees, November- and March-transplanted willow oaks had similar amounts of new roots. In red oak, new root growth was greatest outside the root balls of November-transplanted versus March-transplanted trees. However, the earlier planting date did not confer advantages in terms of increased height and trunk diameter growth. No root growth occurred outside the root balls at spring bud break in any of the willow oak treatments. In contrast to red oak, November-transplanted willow oaks exhibited greater trunk diameter increase than the March transplants, even though each treatment had similar amounts of new roots at bud break. Therefore, in conditions similar to this study, root growth prior to the first spring bud break following transplanting appears not to affect post-transplant height and trunk growth. Due to the lack of early post-transplant root growth and modest pre-bud break root growth of both November- and March- transplanted red and willow oaks, early first-season irrigation practices should be focused on maintaining adequate soil moisture in the root ball and nearby adjacent soil.

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