SURVIVAL AND GROWTH OF TRANSPLANTED LARGE- AND SMALL-CALIPER RED OAKS

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Abstract. Red oak (Quercus rubra L.) of 2 caliper sizes, 8.4 and 3.6 cm (3.3 and 1.4 in.), and 2 vigor classes (high and low) within the small-caliper trees, were transplanted to compare growth and establishment over a 4-year period. Possible confounding factors such as pre-transplant vigor, genetics, relative root-ball to backfill volume, and relative canopy to root-ball volume were controlled to determine whether small-caliper trees establish more rapidly than large-caliper trees. Large-caliper trees had high mortality, 58%, while no small-caliper trees died. Based on trunk caliper and height growth after transplanting, surviving large-caliper trees established faster than small-caliper trees—demonstrating that transplanted large-caliper red oaks can establish as rapidly as small-caliper red oaks.

Key Words. Transplant establishment; trunk-caliper increase.

Transplanting stress is a temporary condition of distress resulting from injuries, depletion, and impaired function. It is a process of recovery and a period of adjustment to a new environment (Rieveld 1989). It is generally accepted that large trees experience greater transplant stress than smaller trees. This perception is based more on observation than on experimental evidence. Nursery production practices associated with large (greater than 10-cm [4-in.] caliper) tree production may be more responsible than innate large tree biology for increased transplant stress, reduced survival, and extended establishment periods. Under typical production practices, large trees are the last ones harvested from a nursery block; the vigorous trees (the first to reach harvestable size) are dug at smaller caliper sizes. The more vigorous (genetically superior) trees are harvested first; slower-growing (genetically inferior) trees are harvested later as large-caliper trees. Thus, trees harvested as large trees may be genetically inferior to those trees dug at smaller sizes.

Another uncontrolled genetic consideration is seed source. Significant provenance (Kriebel et al. 1977; Kriebel et al. 1988) and mother tree (Struve and McKeand 1993, 1994) differences in survival and growth have been found. Transplanting studies typically do not account for intraspecific genetic differences among planting stock types. The mother tree (the tree from which the open-pollinated seed was collected) significantly affects transplant survival and regrowth (Kormanik et al. 1989).

Large trees may also be physiologically inferior to smaller trees. Root pruning and soil compaction associated with harvesting trees can reduce the vigor of the remaining trees in the nursery block. Increment bores of transplanted willow oaks (Quercus phellos) showed that 2 to 5 years before transplanting, the rate of trunk caliper growth began to decrease (Neal and Whitlow 1997). The data suggest that the declining trunk caliper increment occurred concomitant with the first harvests within the nursery block.

Watson (1985) developed a hypothesis to explain the longer establishment periods for large trees. It was based on the time to re-establish the pre-transplant shoot to root ratio. Watson (1985) assumed, and Gilman demonstrated (Gilman 1989, 1990; Gilman and Kane 1991), that large and small trees had similar crown spread to root spread ratios, and by deduction, similar root elongation rates. Although harvesting removes proportionally similar amounts of the root system (Gilman 1988a, 1988b), larger trees take longer to establish than small trees because more time is need to re-establish the original shoot to root ratio (Watson 1985). To date, only one study has tested this hypothesis (Gilman et al. 1998). Small (6.8-cm [2.7-in.] caliper) trees had faster height and trunk caliper growth after transplanting than large (9.3-cm [3.7-in.] caliper) trees, but several possible confounding factors were not accounted for.

Another possible confounding factor in transplanting studies is the amount of soil amended when trees of different sizes are transplanted. Typical landscape practice is to make the planting hole 15 to 30 cm [6 to 12 in.] larger than the root ball. Thus, relatively more soil is amended when small-caliper trees are transplanted than when large trees are. Soil amendment, even if only loosening the compacted soil, has been proposed as a method to reduce transplant shock and speed establishment (Barnett et al. 1983; Watson 1986; Watson and Kupkowski 1991; Watson 1992).

A final possible confounding factor considered in this study is the relative canopy to root-ball volume. Small (10-cm [4-in.] caliper) trees have a smaller canopy to root-ball volume ratio than large (greater than 10-cm caliper) trees because small tree root-ball depth is 75% of root-ball diameter, whereas large tree root-ball depth is 66% of root-ball diameter (AAN 1996).

This study was conducted to determine the survival and establishment of large (8.4-cm [3.3-in.] caliper) and small (3.8-cm [1.5-in.] caliper) red oak (Quercus rubra) trees while accounting for the possible confounding effects of seed source, cultural practices, pre-transplant physiological vigor, relative root-ball to canopy volume ratio, and relative root-ball to backfill volume.

MATERIALS AND METHODS

Two sizes of red oak trees were transplanted large caliper (8.4 cm [3.3 in.]) and small (3.6 cm [1.4 in.]) in spring 1996. Large trees were selected from forty 1- to 1.3-m (3- to 4-ft) tall, 1-year old, container-grown whips lined out in spring 1988. They were planted on a 2 m within-row and 4 m between-row (approximately 1.8 by 3.6 m [6 by 12 ft]) spacing. The block was clean cultivated the first growing season; sod was established between rows after the second season. A 1.3-m (4-ft) wide clean cultivated strip was maintained within the rows. Annual applications of 2.9 kg ∞ 100 m^{-2} N (6 lb per 1,000 ft^2) from urea, 45-0-0, were broadcast over the clean-cultivated strip. Plants were trained to a central leader and crowns raised to 2 m (6 ft) height.

Small trees were raised from 1- to 2-m (3- to 6-ft) tall container-grown whips lined out in spring 1993 at a similar spacing in an adjacent field. They were maintained under similar cultural conditions as the large trees. Trees of both sizes were raised from open-pollinated acorns collected from the same mother tree in either fall 1986 (large trees) or 1991 (small trees). Thus, the trees in both size classes were half-sibs.

In spring 1996, large trees were harvested by first removing every other tree within a row by sawing them off at 15 cm (6 in.) above the ground. Seven of these trunks were randomly selected and the growth rings measured to document pre-transplant vigor. Twelve trees were dug from the block with a Vermeer 44 (Pella, IA) tree spade. The root-ball diameter averaged 112 cm (44 in.).

Twenty-four small-sized trees were dug from the adjacent block within 5 days of digging the large trees. A Care Tree 32 (Columbus, OH) tree spade was used to dig trees with a 50-cm (20-in.) root ball. There were two vigor classes, low and high, for the small-caliper trees. Low-vigor trees were approximately 1 m (3 ft) tall when lined out; high-vigor trees were 2 m (6 ft) tall when lined out. Thus, survival and growth of large and small-caliper trees grown from low-vigor whips could be compared to each other and survival and growth of small-caliper, high-vigor whips. The high-vigor, small trees were included as representative of those fast-growing trees that would be first dug from a block at smaller caliper sizes. The low-vigor trees represent those slower-growing trees remaining in a block after the rapidly growing trees had been harvested. These putative low-vigor whips would typically be harvested as large-caliper trees.

The planting site was a sod-covered fallow field of Crosby Silt loam soil. Small-caliper trees were planted in holes dug as deep as the soil ball, 41 cm (16 in.), and 30 cm (12 in.) wider than the root ball. Large-caliper trees were planted in holes dug as deep as the soil ball, 74 cm (29 in.), and 269 cm (106 in.) wide. Thus, the backfill to root-ball volume ratio, 4.25:1, for both trees sizes was similar. Native soil was used as backfill. A 5-cm (2-in.) deep wood-chip mulch, the diameter of the planting hole, was placed under each tree. The mulch ring was maintained weed free by mechanical and chemical means. The trees were planted in a randomized complete block design with 12 one-tree replications.

After planting, the crowns of large trees were raised to about 3 m (8 ft) to give a similar crown to root-ball volume ratio as the small-caliper trees. All trees were irrigated 3 times each in 1996 and 1997. No irrigation was applied in 1998. Rainfall from May to October was above average in 1996 and 1997, average in 1998, and significantly below average in 1999. Rainfall ranged from 20 to 22 cm (4 to 9 in.)

below normal during May to October 1999. No fertilizer was applied after transplanting.

Annually for 4 years after transplanting, 5 shoots in the lower crown were measured for current season's shoot extension. Also, 5 leaves from each tree were collected annually and leaf area determined with a LiCor Model 3100 (LiCor, Inc., Lincoln, NB) leaf area meter. Trunk calipers (30 and 15 cm [12 and 6 in.] above grade for the large- and small-caliper trees, respectively) and tree heights were also measured for 4 years after transplanting. In addition, 5 trees (3 low vigor, 2 high vigor) in the small-caliper tree block, which were not dug, served as nontransplanted controls. Similar growth data were taken on these trees as on the transplanted trees. Average shoot length and leaf area were calculated. The data were subject to analysis of variance using SPSS for the personal computer. Means were separated using the Student-Neuman-Kuels test at 0.05 level of significance.

RESULTS

There was no reduction in trunk caliper growth rate for the large-caliper trees before harvest (Figure 1). The whips had an average of 1.1-cm (7/16-in.) caliper increase per year since lining out.

All small-caliper trees survived transplanting for the 3 years of this study. All large-caliper trees survived the first growing season. During the second growing season, 7 trees (58%) died. There was no additional mortality during the third growing season.

Shoot-length increment in 1996 was significantly greater for the large-caliper trees than for the small-caliper trees, whether transplanted or not (Table 1). In the second growing season, shoot extension for the untransplanted trees was greatest; averaging more than 5 times the shoot extension of small-caliper transplanted trees and more than 13 times that of large-caliper trees. In the third growing season, shoot extension for the low-vigor, small-caliper trees was similar to that of the untransplanted trees. Shoot-extension increment for the high-vigor, small-caliper and large-caliper trees was statistically similar.

Average leaf area during the 3-year study for untransplanted trees was significantly greater than large-caliper transplanted trees (Table 1). In the first year, all transplanted trees had similar average leaf area. In the second year, untransplanted and transplanted low-vigor trees had greater leaf area than large-caliper trees. By the third year, average leaf area for the small-caliper trees, whether transplanted or not, was greater than that of transplanted trees of either caliper.

Small trees averaged 2.4 m (94 in.) in height when dug; large trees averaged 5.4 m (211 in.). There was no statistical difference in tree height among the small tree types (P = 0.59). Height at the end of 1996 ranged from 2.9 to 3.4 m (9.4 to 11 ft) for the small-caliper trees; large-caliper trees averaged 5.5 m (17.9 ft, Table 1). Increase in tree height during the first growing season

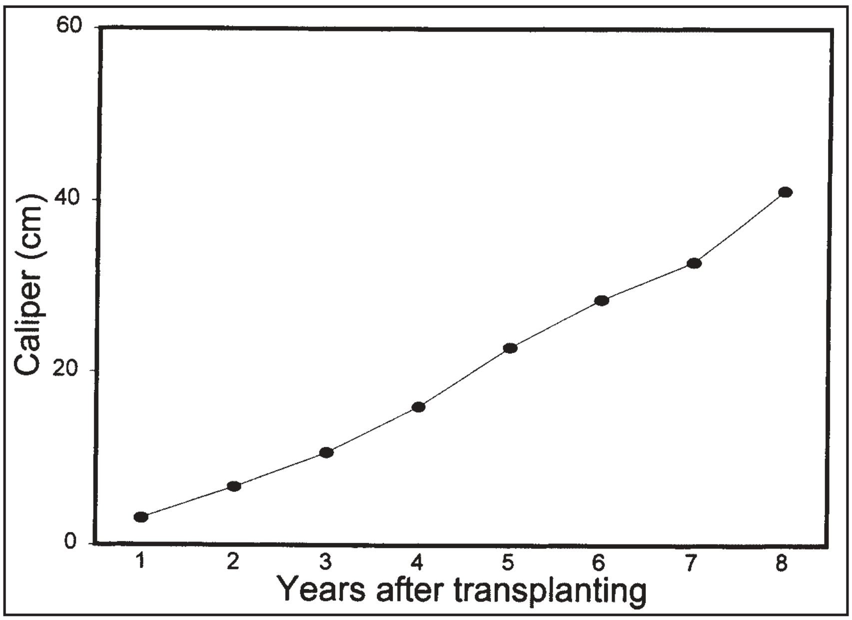

Figure 1. Red oak trunk-caliper growth during 8 years after lining out at 1-m-tall whips. Trunk caliper was measured 15 cm above the ground. These trees were randomly selected from those trees thinned prior to digging the experimental trees. Each point is the mean of 7 trees. Pre-harvest trunk-caliper growth is predicted by the equation: $C = 0.17 + 1.11T$, ($R^2 = 0.99$) where C is trunk caliper, in cm, and T is time, in years, from lining out.

Table 1. Growth of large (8.4-cm caliper) and 2 vigor classes of small (3.6-cm caliper) red oak trees following transplanting. Untransplanted small trees were included as a control.

	Shoot length (cm)			Leaf area (cm^2)			Height (m)				Trunk caliper (m)			
Treatment	1996	1997	1998	1996	1997	1998	1996	1997	1998	1999	1996	1997	1998	1999
Large caliper	15.6 a	2.6 c	6.3 b	41.8 b	41.2b	65.1 b	5.5 a	5.3 a	6.7 a	6.9 a	8.4 a	9.4 a	11.2 a	12.3 a
Small caliper low vigor	6.3 b	7.4 b	25.7 a	50.0 b	67.4 a	107.6 a	2.9 b	3.0 b	4.5 b	5.0 b	3.6 c	5.1 b	6.0 c	6.7 b
Small caliper high vigor	7.3 b	7.7 b	13.1 b	47.6 b	60.4 ab	108.9 a	3.2 b	3.2 b	4.4 b	4.9 b	3.6 c	4.5 b	5.6 c	7.0 b
Small-caliper untransplanted control trees	6.6 b	39.1 a	31.3 a	83.9 a	85.2 a	101.4 a	3.4 b	3.5 b	4.3 b	4.7 b	4.3 b	6.0 b	7.8 b	9.8 ab

Large trees averaged 8.4 cm in trunk caliper where transplanted; small-caliper trees averaged 3.6 cm in trunk caliper. Low-vigor trees averaged 1 m in height when lined out in 1992, whereas high-vigor trees averaged 2 m in height.

Each value is the mean of 5 lateral shoots per plant. Means within a column followed by different letters are significantly different from each other at a = 0.05 level using the Student-Newman-Kuels test.

Each value is the mean of 5 leaves per plant.

Height and caliper values are the average of 12 plants per treatment in 1996, except for small-caliper untransplanted trees, where there were 5 trees. In 1997 and 1998, the values for the large trees are the average of the 5 surviving trees.

averaged 0.8 m (31 in.) for the small-caliper trees; it ranged from 0.5 (19 in.) to 1 m (39 in.) for small-caliper, low-vigor trees and untransplanted trees, respectively, and only 0.1 m (4 in.) for the large trees. Height increase during the second growing season, regardless of tree size, was greatly reduced compared to the first growing season. The reduction in height for the large-caliper trees between 1996 and 1997 reflects both mortality (taller large-caliper trees tended to die in greater numbers than shorter large-caliper trees) and crown dieback in some of the surviving large-caliper trees. During the third growing season, height increased more than 1 m (39 in.) for the large-caliper trees. In the third growing season (1998), small-caliper, transplanted trees of both vigor classes averaged 1.3 m (51 in.) height increases, while untransplanted trees averaged 0.8 m (31 in.). Large-tree height increased 1.4 m (55 in.) in 1998. In the fourth year, large-caliper trees grew an average of 20 cm (8 in.), while the small-caliper trees increased 50, 50, and 40 cm (20, 20, and 16 in.) for the high-vigor, low-vigor, and control trees, respectively. During the study period, there were no significant differences in tree height between transplanted and untransplanted small-caliper trees.

Initial trunk caliper averaged 3.6 and 8.4 cm for small and large trees, respectively. There was no statistical difference ($P = 0.48$) in initial trunk caliper among the small-caliper tree types. Caliper after the first growing season ranged from 3.6 to 4.3 cm for transplanted and untransplanted small-caliper trees, respectively (Table 1). There was no measurable increase in trunk caliper during 1996 for transplanted trees. Untransplanted tree caliper increased 1.7 cm (0.7 in.) annually between 1996 and 1999. Trunk caliper increased 1.5 and 0.9 cm (5/8 and 3/8 in.) for the small-caliper, high- and low-vigor trees, respectively, during 1997. There was no statistical difference in trunk caliper between transplanted and untransplanted small-caliper trees in 1997, but in 1998, untransplanted trees had significantly greater trunk caliper than transplanted trees. For the transplanted small-caliper trees, caliper increased 0.9 and 1.1 cm (3/8 and 7/16 in.), respectively, for the high- and low-vigor trees. In the fourth year, large-tree caliper increased 1.1 cm (0.4 in.), and small-tree caliper increased 0.7, 1.4, and 2 cm (1/4, 9/16, and 3/4 in.), respectively, for the high-vigor, low-vigor and control trees. Small-caliper transplanted trees had significantly smaller caliper than large trees throughout the study period. However, the untransplanted small-caliper trees had statistically similar calipers as the large trees 4 years after transplanting.

DISCUSSION

This study accounted for possible confounding effects of seed source, pre-transplant vigor, initial whip vigor, relative canopy to root-ball volume ratio, and relative root-ball to backfill volume ratio when large-and small-caliper trees were transplanted. Red oak is a genetically diverse species, not unexpected for an out-crossing, wind-pollinated species (Schwarzmann and Gerhold 1991). Genetic background was partially controlled by transplanting individuals from the same half-sib family. Significant variation in survival and height growth exists among red oak provenances (Kriebel et al. 1977, 1988) and open-pollinated families (Struve and McKeand 1993, 1994). Height growth is under strong genetic control (Struve and McKeand 1993). An unexpected finding in this study was the good performance of the low-vigor, small-caliper trees that were included for their putative genetic inferiority. It is not known why these trees performed better than the high-vigor, small-caliper trees.

Small-caliper trees survived transplanting better than large-caliper trees, 0 versus 58% mortality, respectively. Large-caliper tree death was attributed to planting too deeply and lack of root pruning during production. The planting holes for the large-caliper trees were dug with a backhoe. For the holes that were dug too deeply, subsurface drain tiles were broken. Soil was added to the planting holes, but the soil couldn't be packed firm and plants settled, sometimes as much as 15 cm (6 in.).

Another contributing factor to large-tree mortality was the production history. The trees were never root pruned after lining out, an 8-year period. Large-diameter roots developed during this period. At harvest, these roots were severed. Large-diameter roots do not regenerate roots as rapidly as do small-diameter roots (Johnson et al. 1984; Arnold and Struve 1989). Root pruning prior to harvest increases the percentage of roots within the root ball (Kozlowski and Davies 1975; Watson and Sydnor 1987; Harris and Gilman 1991; Gilman et al. 1992). Gilman and Kane (1991) found that regrowth may be promoted by a high proportion of small-diameter roots within the soil ball. For instance, root pruning prior to harvest stimulated first-year growth of transplanted southern magnolia (Gilman 1992a). Rapid root regeneration is key to transplant survival (Watson and Himelick 1982). Thus, mortality of the large-caliper trees may be partly attributed to root morphology; root regeneration for the large trees would have to come from large-diameter pruned roots.

Many criteria have been used to determine when a tree is established including re-establishment of the static branch:root spread ratio (Watson 1985; Gilman 1988a, 1988b, 1989; Gilman and Kane 1991; Gilman and Beeson 1996), resumption of pre-transplant growth rate (Struve 1992; Gilman and Beeson 1996), shoot xylem water potential relative to untransplanted controls (Beeson 1994; Beeson and Gilman 1992, 1996; Gilman et al. 1992), and unit photosynthetic rate (Struve 1992). These criteria were developed so that landscape managers would know when to stop post-transplanting practices designed to reduce transplant stress, especially when irrigation can safely reduced or eliminated (Gilman 1992b). None of the trees received irrigation during the third growing season, despite a mild drought, and none showed drought symptoms such as foliar discoloration, leaf margin burn, early fall color development or defoliation. Because the trees needed no supplemental irrigation during the drought, they were considered established. A 3-year establishment period for 1.5-in.-caliper trees in USDA Hardiness Zone 5 is consistent with the 1-year-per-inch trunk caliper proposed by Watson (1985) and confirmed by Gilman (1992b), but a year less than that required for the large-caliper trees. Resumption of pre-transplant growth rates also indicates that the plants are established. Prior to transplanting, the trunk caliper of the large-caliper trees increased at 1.1 cm (7/16 in.) annually; the 3-year average after transplanting was 0.9 cm (3/8 in.). The 3-year post-transplant average trunk caliper increase for the small-caliper trees was 0.8, 0.67, and 1.17 cm (5/16, 1/4, and 1/2 in.) for the low-vigor, high-vigor, and untransplanted trees, respectively. However, using this criterion, none of the transplanted trees are established. Post-transplanting annual height increase for the large-caliper trees averaged 0.6 m (23 in.); for the small-caliper trees it was 0.8, 0.55, and 0.45 (31, 21, and 18 in.), respectively, for the low-vigor, high-vigor, and untransplanted trees, respectively. Pre-transplant growth rates averaged 0.7 m (26 in.) for the large and 0.6 m (23 in.) for the small-caliper trees. All trees exceeded their pre-transplant height growth rates in 1998.

One putative benefit from transplanting small-caliper trees is the reduced transplant shock and quicker recovery. Quicker establishment of small-caliper trees suggests that they will soon equal the size of the slower-establishing large trees (Watson 1985). Watson (1985) predicted that a transplanted

10.2-cm (4-in.) caliper tree would equal the size of a transplanted 10-in.-caliper tree after 13 years. Gilman et al. (1998) demonstrated that small-caliper trees (2.5 in. [6.3 cm]) established faster than large-caliper trees (3.5 in. [9.4 cm]). Trunk diameter increase for the small- and large-caliper trees was described by the equations:

$$C_{small} = 6.5 + 0.00567T. \ (r^2 = 0.959)$$
$$C_{large} = 6.5 + 0.00399T. \ (r^2 = 0.849)$$

where C_{small} equals small-caliper tree trunk diameter in cm, C_{large} equals large-caliper tree trunk diameter, and T is time in days. Solving the system of equations simultaneously predicts when small-tree caliper size will equal large-caliper tree size. This occurs 5.7 years after transplanting in USDA Hardiness Zone 9, when the trees are 18.3 cm in caliper. It would take 22.8 years in Hardiness Zone 5 using Gilman's (1992b) estimate of differential rate of establishment according to length of growing season.

Linear and quadratic equations for predicting caliper growth were developed for our 4-year data (Table 2). Based on the 4-year results of this study, height growth of the large- and small-caliper trees would be equal after 14.5, 14.7, and 20.7 years (small-caliper–high-vigor, small-caliper–low vigor, and small-caliper control trees, respectively). The trees will be 10.8, 10.9, or 13.4 m (35.1, 35.4, and 43.6 ft) tall, for small-caliper–high vigor, small-caliper–low vigor, and small-caliper control trees, respectively. Quadratic equations, which result in a higher correlation coefficient for the large-caliper height growth (i.e., are better predictors of height growth), predict that the small-caliper tree height growth will never exceed the height growth of the large-caliper trees. Similar results are obtained with linear and quadratic equations for caliper growth, except that caliper growth of untransplanted trees will equal that of large-caliper trees in 11.3 years, or 16 years when the plants are 18.7 or 59 cm (7.4 or 23.2 in.), based on the linear and quadratic equations, respectively (Table 2). Linear and quadratic equations indicate that transplanted small-caliper tree trunk caliper will not surpass large tree caliper. Linear equations predict that large-tree caliper increased at 1.06 cm (7/16 in.) per year compared to 0.86 and 0.88 cm (5/16 in.) for both the high- and low-vigor small-caliper transplanted trees. The untransplanted small-caliper trees are predicted to equal the caliper of the large-sized transplanted trees after 10.5 years when the trees are 15 cm (6 in.) in caliper. However, caution must be exercised in extrapolating the 4-year data of our study.

Table 2. Linear and cubic regression equations and correlation coefficients for tree height and caliper growth 4 years after transplanting. Large-caliper trees averaged 5.5 m in height and 8.4 cm in caliper at transplanting. Small-caliper trees averaged 2.4 m in height and 3.6 cm in caliper when transplanted. High-vigor small trees averaged 2 m in height when lined out, low-vigor small trees averaged 1 m. Five small trees were not transplanted and served as controls. The regression equations were developed from 5, 12, 12, and 5 trees for large-caliper, small-caliper–high-vigor, small-caliper–low-vigor and control trees, respectively.

Regression equation	R^2
Height, linear	
$H_L = 4.70 + 0.42T$	0.46
$H_{SHV} = 1.52 + 0.68T$	0.92
$H_{SLV} = 1.76 + 0.62T$	0.95
$H_{Control} = 2.01 + 0.55T$	0.95
Height, quadratic	
$H_L = 5.60 – 0.35T + 0.13T^2$	0.83
$H_{SHV} = 2.22 + 0.08T + 0.10T^2$	0.94
$H_{SLV} = 2.06 – 0.36T + 0.04T^2$	0.95
$H_{control} = 1.76 + 0.76T – 0.037T^2$	0.96
Caliper, linear	
$C_L = 6.76 + 1.06T$	0.92
$C_{SHV} = 2.42 + 0.86T$	0.95
$C_{SLV} = 2.22 + 0.88T$	0.92
Caliper, quadratic	
$C_L = 8.26 – 0.23T + 0.21T^2$	0.97
$C_{SHV} = 2.82 + 0.52T + 0.057T^2$	0.95
$C_{SLV} = 3.72 – 0.41T + 0.21T^2$	0.99
$C_{Control} = 2.88 + 0.43T + 0.19T^2$	0.99

H_L = height (m) of large-caliper trees
H_{SHV} = height (m) of small-caliper high vigor trees
H_{SLV} = height (m) of small-caliper low vigor trees
$H_{Control}$ = height (m) of untransplanted small-caliper trees
C_L = caliper (cm) of large-caliper trees
C_{SHV} = caliper (cm) of small-caliper high vigor trees
C_{SLV} = caliper (cm) of small-caliper low vigor trees
$C_{Control}$ = caliper (cm) of untransplanted small-caliper trees
T = time in years
All equations were significant at the *P* = 0.01 level.

Our results may be different from those of Gilman et al. (1998) because we accounted for factors not considered by them: similar genetics, production history, planting-hole to backfill volume, and relative mulch ring diameter.

Based on these results, surviving large-caliper tree caliper growth was greater than small-caliper transplanted tree caliper growth. However transplant survival of the large-caliper trees was only 42%. Large tree survival probably can be improved if they are root pruned every 3 to 4 years during the production cycle. Higher-quality large-caliper nursery stock can be obtained if the arborist knows the nursery's production practices. In particular, one should purchase large-caliper trees from blocks established specifically for large-tree production, rather than purchase the last plants remaining in a block.

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Résumé. Des chênes rouges (Quercus rubra L.) de deux calibres différents—8,4 et 3,6 cm—et de deux classes de vigueur différentes—bonne et faible—ont été transplantés pour comparer les taux de croissance et de reprise au cours d'une période de trois ans. Des facteurs potentiellement sujets à confusion, tels la vigueur avant la transplantation, la génétique, le volume relatif de la motte versus celui de la fosse ainsi que le volume relatif de la cime versus celui de la motte, ont été contrôlés pour déterminer si les arbres de petit calibre se rétablissaient plus rapidement que ceux de gros calibre. Les arbres de gros calibre avaient un taux de mortalité plus élevé, soit 58%, alors qu'aucun des arbres de petit calibre n'était mort. En se basant sur le calibre du tronc et le taux de croissance en hauteur après la transplantation, les arbres de plus gros calibre qui avaient survécu reprenaient plus rapidement que les arbres de petit calibre.

Zusammenfassung. Roteichen (Quercus. rubra L.) mit den zwei Durchmessergrößen von 8,4 und 3,6 cm und zwei Vitalitätsklassen innerhalb der kleineren Eichengrößen wurden verpflanzt, um das Anwachsen und das weitere Wachstum in einer dreijährigen Periode zu vergleichen. Es wurden begünstigende Faktoren, wie die Vitalität vor dem Verpflanzen, die Genetik, die relative Wurzelballengröße im Vergleich zum Pflanzloch und die Kronengröße in Relation zum Wurzelballvolumen, wurden kontrolliert, um Aussagen darüber zu machen, ob kleinere Bäume sich schneller am Standort etablieren als größere Bäume. Die Größeren Bäume hatten eine höhere Sterberate, nämlich 58 %, während von den kleinen Bäumen keiner starb. Basierend auf dem Stammdurchmesser und Höhenwachstum nach dem Verpflanzen haben sich die überlebenden Bäume mit dem größeren Durchmesser schneller am Standort etabliert als die kleineren Bäume.

Resumen. Se trasplantaron robles rojos de Texas (Quercus rubra L.) de dos calibres, 8.4 y 3.6 cm (3.3 y 1.4 pulg) y dos clases de vigor (alta y baja), con el fin de comparar su establecimiento y crecimiento en un período de tres años. Se controlaron los posibles factores de confusión tales como vigor pre-trasplante, relación cepellón—volumen de relleno y relación copa—volumen del cepellón, con el fin de determinar si los árboles de calibre pequeño se establecían más rápido que los grandes. Los árboles grandes tuvieron la mortalidad más alta, 58%, mientras que ninguno de los árboles pequeños murió. De acuerdo con el calibre del tronco y el crecimiento en altura después del trasplante, los árboles grandes que sobrevivieron se establecieron más rápidamente que los árboles chicos.