



1836 State Street

Canary Island Date Palm Removal

- Legend**
- 1836 State St
 - Feature 1
 - NeuroField Neurotherapy, Inc

Approximate Planting Location
of new 15 gallon *Dracaena draco* tree

City Of Santa Barbara
Attn: Planning and Zoning Counter
630 Garden Street
Santa Barbara, CA 93101

Date: June 28, 2022

Re: 1836 State Street Date Palm Removal Tree Replacement

To Whom It May Concern,

It is my recommendation that the Canary Island Date Palm (*Phoenix canariensis*) located at the south side of 1836 State Street be replaced with one 15-gallon size *Dracaena draco* (Dragon tree). Dragon trees are on the list of approved trees for El Pueblo Viejo district and will make a striking tree long into the future. The tree will be planted in approximately the middle of the front planter along State Street at approximately the same location as the existing Canary Island Date Palm (to be removed).



Approximate planting location of new 15-gallon size *Dracaena draco*.

It is my recommendation to plant a 15-gallon size tree rather than a larger box size tree in order to improve the establishment speed and long-term growth and success of the new tree. Arborists have long known, and studies have shown that smaller trees establish more quickly, have quicker overall growth, and eventually outgrow larger transplants. Please see *Tree Size Affects Root Regeneration and Top Growth after Transplanting* (Gary Watson, 1985) and *Influence of Tree Size on Transplant Establishment and Growth* (Todd Watson, 2005). Transplanting a larger tree will not result in a larger tree over time.

Thank you for your consideration.

Sincerely,

Richard Mason
Board Certified Master Arborist WE-7081-B

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TREE SIZE AFFECTS ROOT REGENERATION AND TOP GROWTH AFTER TRANSPLANTING¹

by Gary Watson

Slow growth of trees over 4 inches dbh, following transplanting, is often a source of concern for arborists and landscape contractors. Growth of these trees is often stagnant for several years. Smaller 1- to 3-inch trees, transplanted at the same time, will often equal in size or surpass them before larger trees regain their pretransplanting vigor. In spite of these difficulties, larger trees continue to be transplanted for the immediate advantages they can provide in landscape design.

All newly transplanted trees are subject to an initial period of reduced vigor, but the duration of this period varies. This period is often referred to as transplanting shock. Neither researchers nor practitioners have been able to identify any single, specific cause for the prolonged period of transplanting shock experienced with large transplanted trees. Various physiological stresses are often implicated. All transplanted trees are subject to varying degrees of water stress because the root system is drastically reduced (Watson and Himelick, 1982a). Water stress can reduce photosynthetic activity (Kozlowski and Keller, 1966), potentially diminishing carbohydrate reserves and reducing growth. Recent work has shown that levels of carbohydrate reserves are not reduced in transplanted trees when they are watered adequately following transplanting (Watson and Himelick, 1982b), and may only play a role in cases of severe or prolonged water stress. Stressed trees are often susceptible to a wide variety of insect and disease problems which can result in reduced vigor, distortion of shape, and death (Schoeneweiss, 1981). The

causes of transplanting shock are complex and relate to the reduced size of the root system of the transplanted tree. The root-shoot imbalance created by transplanting appears to be the primary cause of transplanting shock with other physiological and pathological problems acting as secondary agents. Until the natural root-shoot balance of the tree is restored, some degree of transplanting stress will exist.

It is the intention here to show the relationship between the duration of stress from transplanting and the length of time necessary to replace that portion of the root system lost during transplanting. When standard nursery practices are used to determine the size, the root ball is proportionate to the crown for both large and small trees (Himelick, 1981). It is important to remember that as the size of the tree increases, the lateral spread of the original root system increases. Although a consistent percentage of the root system is left behind, a greater mass and length of roots is lost from the large tree and these must be replaced at the new site. If the roots of both the large and small trees grow at the same rate, the root system of the larger tree will take much longer to regenerate. This point is illustrated in the following model.

Figure 1 illustrates a model of a small (4 inches dbh) and a large (10 inches dbh) transplanted tree of the same species transplanted at the same time. It shows the reduction in the root system at the time of transplanting and the regeneration of the root system during the succeeding years. The model incorporates several aspects of root development which should be thoroughly

1. This work supported in part by the Theodore Brickman Company, Long Grove, Illinois.

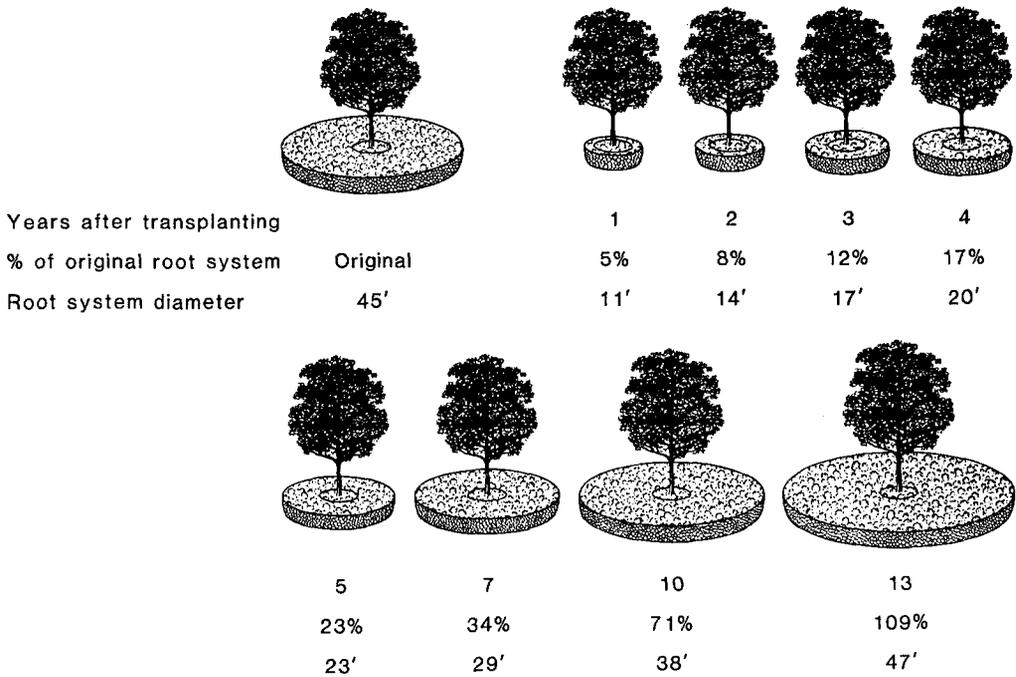
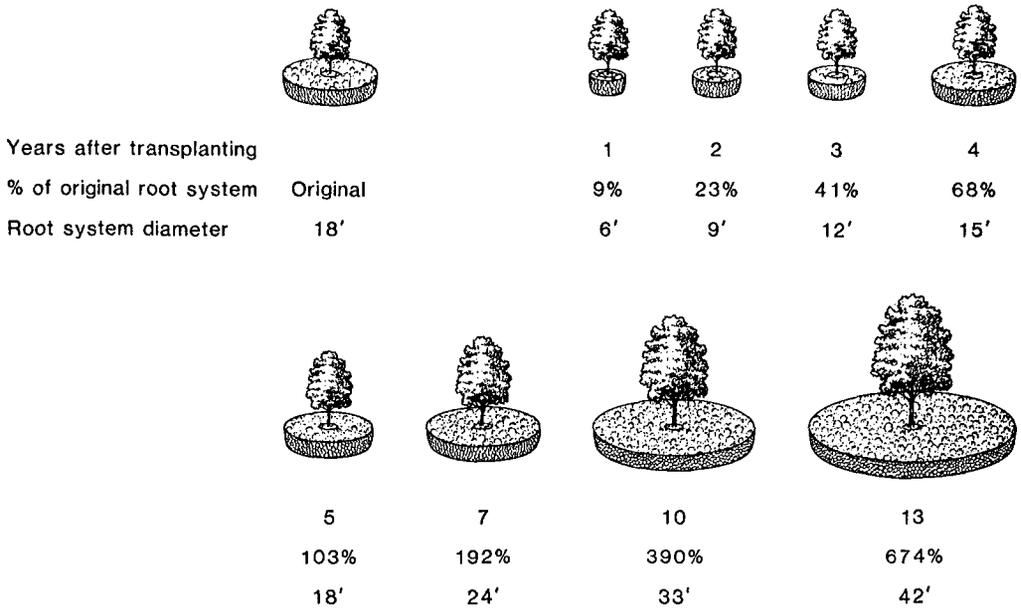


Figure 1. The relationship between root growth and top growth of transplanted trees of 4- and 10-inch dbh at the time of transplanting. The larger tree grows very slowly for many years, while the smaller tree resumes a normal rate after only a few years. Eventually, the two trees are nearly equal in size.

understood in order to fully comprehend the model:

1. The natural root distribution of shade trees is very shallow and widespread. Little, if any, root growth occurs below 48 inches in most soils. Fine roots are heavily concentrated in the top 4-12 inches of soil. Structural or sinker roots penetrate deeper, but seldom below 48 inches. Tree taproots are rare or absent for most tree species. Actual depth of the roots is highly influenced by soil type at the site.

2. Root regeneration occurs laterally from the perimeter of the root ball. The rate of growth of regenerated roots is essentially the same for both large and small trees of transplantable size, if unstressed. Lateral growth out from the soil ball of 18 inches per year is average for a well-maintained tree transplanted in friable, well drained soil. In previous studies, lateral root growth ranged from 12-27 inches per year (Watson and Himelick, 1982b).

3. As roots grow, exploitation of the soil by the fine roots is uniform throughout the lateral spread of the root system. Seldom are there large areas of soil in which roots do not grow unless the soil conditions are unfavorable.

The model is based on the concept that as long as the roots and aerial portions of the tree are out of balance, the vigor of the tree will be reduced. The roots cannot supply sufficient quantities of water and mineral nutrients to the upper portions of the tree for vigorous growth until the natural balance has been restored. The greater the imbalance, the slower the resultant growth. In the model, the root system of the 4-inch tree had a diameter of approximately 45 feet before transplanting. The above- and below-ground portions of the tree were in natural balance. During transplanting this balance is grossly distorted and the root system may be reduced by as much as 98 percent (Watson and Himelick, 1982a). New roots are initiated from callus formed near the cut end of the roots at the edge of the root ball. This occurs soon after transplanting. By using 18 inches per year as an average annual root growth, the smaller tree will replace its original root system in less than 5 years. Since the top of the tree has continued to grow slowly during this period, it may take slightly longer to restore the original root-

shoot balance. After 5 years, the regenerated root system of the 10-inch tree will be only about 25 percent of its original size, and the tree remains stressed. As Figure 1 illustrates, a period of 13 years or more is required to restore the original balance of the 10-inch tree. At this time, the root system of the smaller tree is nearly as large as that of the larger tree. Since the root systems are nearly equal in size, it follows that the above-ground portions are also nearly equal. Since the small tree has been growing vigorously for several of the 13 years while the larger tree has been under at least some degree of stress, it is possible for the original 4-inch tree to be larger than the 10-inch tree by this time.

The model can be used to understand the concepts involved in root regeneration and transplanting shock, and to predict the timing of events. It is difficult to model all of the factors that influence root regeneration. Roots of different tree species grow at varying rates. Soil conditions have a profound effect on root growth rates. Promoting vigorous root growth is the best way to minimize the severity and duration of transplanting shock for trees of any size.

The soil environment must be favorable for optimum root growth. Most importantly, moisture, aeration, and nutrient levels must be favorable. When used as backfill, heavy, compacted soils should be modified to improve drainage and aeration. Soil conditions are usually most favorable for the fine root development in the top 4-6 inches of soil, especially in the disturbed clay soils often encountered in urban areas. The deeper soil layers are often waterlogged and oxygen deficient. Modification of this surface soil around the root ball would promote more rapid root regeneration in the early years following transplanting. A large planting hole with the sides sloping at a shallow angle would accomplish this and also provide a large interface between the backfill and the native soil. Only in unusual circumstances should there be difficulties as the roots grow through the interface between the ball and the native soil (Whitcomb, 1979). Mulching the surface would further improve the rooting environment and increase root growth. Litzow and Pellett (1983) have published a review on this subject. Rooting hormone treatments may also be useful in increasing

root regeneration during the initial period of establishment (Prager and Lumis, 1983; Lumis, 1982).

Summary

The model shows why large transplanted trees are likely to have reduced growth for many years following transplanting due to the length of time required to regenerate the roots lost during the transplanting process. The above-ground portion of the tree must be in balance with the root system for proper growth. The size of the above-ground portion of the tree is controlled by the size of the root system. When the root system is reduced or restricted, the growth of the trunk and branches will also be reduced. Since the spread of the regenerated root systems of the large and small transplanted trees differs only by the relatively small difference in size of the original root balls, it follows that the growth of the above-ground portions of the trees must eventually be similar if the root-shoot balance is to be maintained. Trees transplanted into poor sites may never regain proper root-shoot balance and nor-

mal vigor.

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DISTRIBUTION TREE CLEARANCE PROGRAM AT BALTIMORE GAS AND ELECTRIC¹

by Thomas D. Mayer

Abstract. The Baltimore Gas and Electric Company's tree clearance policy is to provide for the safe and reliable supply of electric energy in an economic manner which is compatible with the environment. To that end, the Distribution Tree Clearance Program utilizes many methods and techniques to trim trees and shrubs and to maintain line integrity. Natural trimming is preferred, as is selective clearing with appropriate treatment with an EPA-approved herbicide. Following the introduction of an aggressive "Think Cut Down" program, more trees are being removed from the system, thus reducing future maintenance time. Often, where undesirable tree species are cut down, an aesthetically pleasing grass-herb-shrub-desirable tree species community becomes established.

The Baltimore Gas and Electric Company (BG&E) is an investor-owned utility serving an area of approximately 2,300 square miles in Northern and Central Maryland. The service area is bordered on the north by the State of Pennsylvania, on the east by the Chesapeake Bay and the Susquehanna River, on the south by parts of Calvert and Prince George's Counties, and on the west by portions of Montgomery and Carroll Counties. The BG&E service area experiences about 43 inches of rainfall annually. The climate of

1. Presented at the annual conference of the International Society of Arboriculture in Quebec City, Canada in August 1984.

Influence of Tree Size on Transplant Establishment and Growth

W. Todd Watson¹

ADDITIONAL INDEX WORDS. urban trees, urban forestry, arboriculture, tree planting, tree growth, root ball

SUMMARY. Studies have demonstrated that the size of transplanted trees has a measurable impact on establishment rates in the landscape. Larger trees require a longer period of time than smaller trees to produce a root system comparable in spatial distribution to similar sized non-transplanted trees. This lag in redevelopment of root system architecture results in reduced growth that increases with transplant size. Research has demonstrated that smaller transplanted trees become established more quickly and ultimately result in larger trees in the landscape in a few years. Additional studies dispute these findings. This paper provides a review of current research on the effect of tree size on transplant establishment.

Trees have been transplanted since ancient times. Egyptians transplanted trees as early as 2000 B.C., and early temple pictographs depict workers transporting frankincense trees (*Boswellia* sp.) in containers. Records reveal that the Egyptians transported large trees by ships from faraway lands to be transplanted in Egypt (Campana, 1999). As mechanization and knowledge of arboriculture have increased, so have the sizes of trees that have been planted. Tree transplanting technology has now reached a level where any size tree can be excavated and successfully transplanted to a new location (Harris et al., 2004; Watson and Himelick, 1997).

Transplanting procedures and success rates have been largely based on anecdotal evidence (Gilman, 1990; Struve et al., 2000; Watson, 1985). Experimental techniques have recently

begun to be applied to identify and measure stresses associated with transplanting trees. Recent studies have suggested that transplanting large trees may not necessarily result in a larger tree over time. Some research reveals that smaller sized transplants become established more quickly and may eventually outgrow larger transplants due to a shortened establishment period (Lauderdale et al., 1995; Watson, 1985). Other studies do not support these findings and propose that several factors should be considered when comparing establishment and growth rates of small and large transplanted trees (Gilman et al., 1998; Struve et al., 2000).

The goal of this paper is to review recently published research on transplanted trees in relation to the size of nursery stock used. The findings from these studies will be compared to provide a better understanding of how various factors affect establishment and post-transplant growth rates of small and large trees.

Post-transplant stresses

According to Struve et al. (2000), "transplanting stress is a temporary condition of distress resulting from injuries, depletion, and impaired function." It is generally assumed that "transplant shock" is largely due to stresses resulting from removal of a substantial portion of the transplanted trees' root systems, which creates a root-shoot imbalance (Watson, 1985). However, several additional stress factors can affect post-transplant survivability and recovery rates of trees from transplant shock. Gilman (1990) and others (Bevington and Castle, 1985; Fare et al., 1985) proposed that establishment rates are dependent on such factors as tree species, environmental conditions, physiological status of tree transplants, time of year, cultural practices, and type of root system. Struve et al. (2000) further proposed that in addition to these factors, provenance, root ball:canopy volume ratio, and relative root ball to backfill volume may also have confounding effects on establishment and growth rates of various sizes of transplanted trees.

When using ANSI Z60.1 standards (American Association of Nurseryman, 1996), the size of the root ball is always proportional to the size of the tree (Himelick, 1981). Only 2% to 5% of the soil rooting volume is harvested

when assuming that the root system is in the upper 45.7 cm (18 inches) of soil and extends out from the trunk up to three times the diameter of the dripline of the tree (Gilman, 1988a; Watson and Himelick, 1982a). When measuring root length harvested with some species of field-grown trees, the amount of roots harvested within the root ball range from 5% to 8% (Gilman, 1988b; Watson and Sydnor, 1987). If the weights of roots are considered, up to 84% of root weight is harvested in the root ball of field-dug trees due to the concentration of larger roots near the trunk (Gilman and Beeson, 1996). At least one study demonstrated that 55% of the total surface area of roots is retained within the excavated root ball (Harris and Gilman, 1993).

Post-transplant establishment rates

Due to this loss of root system, transplanted trees experience a phase after planting in which growth is significantly reduced (Fig. 1). This lag in growth is due in large part to a reduction in the acquisition and assimilation of water and essential minerals and an expenditure of stored carbohydrates to regenerate new roots (Gilman et al., 1998; Lauderdale et al., 1995; Watson, 1985). Consequently, this lag phase is more pronounced during the early stages of the establishment period, but growth rate increases as the root system approaches its original size (Gilman and Beeson, 1996; Watson, 1987). In order to become fully established in the landscape, transplanted trees must generate a new root system so that shoot growth is comparable to a non-transplanted tree (Watson and Himelick, 1997). To achieve a pre-transplant root system, roots typically have to grow to a distance equal to three times the diameter of the canopy width (Gilman, 1988b; Watson and Himelick, 1982a).

The length of time for trees to become fully established depends on the rate of root elongation and the extent of original root spread (Watson, 1992). Depending on species and growing conditions, when roots are cut, it takes 6 to 49 d for adventitious roots to form (Arnold and Struve, 1989; Shoemaker et al., 2004; Struve and Rhodus, 1988). Root elongation rates are similar for small and large trees (Watson, 1985; Watson and Himelick, 1982b). Elongation rates

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can vary from 30 to 60 cm (11.8–23.6 inches) per year in northern climates (Coutts, 1983; Gilman, 1988b; Watson et al., 1986) to 60–110 cm (23.6–43.3 inches) per year or more in subtropical climates (Beeson and Gilman, 1992; Gilman, 1989, 1990; Gilman and Beeson, 1996). Depending on the tree and site characteristics, for each 1 inch (2.5 cm) of trunk diameter, it takes approximately 1 year for the root system to regenerate to an extent where the tree's shoot:root ratios and pre-transplant growth rates will be restored in USDA zone 5 (Chicago) (Watson, 1987); in USDA zone 8b (Gainesville, Fla.), it takes as little as 3 months (Gilman, 1996).

Roots of larger trees occupy a larger soil volume and are spread out farther from the trunk than root systems of smaller trees (Watson, 1992). Because smaller trees return to more vigorous growth more quickly after transplanting than larger trees do, it has been hypothesized that the smaller trees will surpass the larger trees in size (Watson, 1985). Figure 2 illustrates how larger trees require a longer establishment period due to the additional annual root growth increments required to develop a root system equal to the original root spread (Watson, 1985, 1992). Watson (1985) devised a model to demonstrate the time required to reestablish root systems for small and large trees (Fig. 3). Watson estimated that it will take a 10.2-cm-diameter (4 inches) tree approximately 5 years to regenerate a new root system in USDA zone 5, whereas a 25.4-cm-diameter (10 inches) tree would require approximately 13 years to regain its original root volume (Watson, 1985; Watson and Himelick, 1997).

Post-transplant responses of small and large trees

Several criteria have been developed to determine when trees have fully recovered from transplant shock. As discussed previously, reestablishment of shoot:root ratios (Gilman, 1988a, 1988b, 1989; Gilman and Beeson, 1996; Gilman and Kane, 1991; Watson, 1985) and pre-transplant growth rates (Gilman and Beeson, 1996; Struve, 1992) are commonly utilized to determine when trees have become established. In addition to growth, xylem water potentials (Beeson and Gilman, 1992; Gilman et al., 1998; Lauderdale et al., 1995), photosyn-

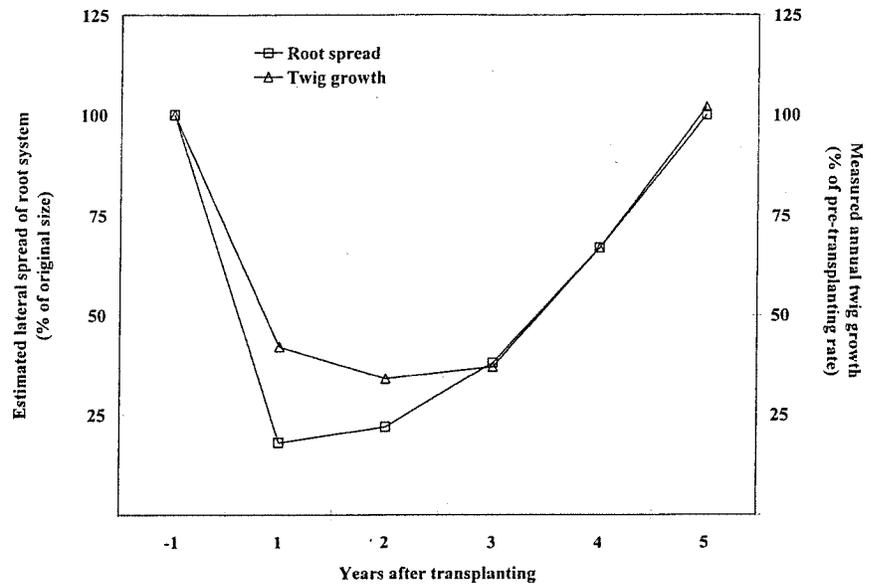


Fig. 1. Root loss as a result of transplanting causes a corresponding decrease in twig growth. Recovery of twig growth rate is closely related to regeneration of the root system; adapted from Watson (1987).

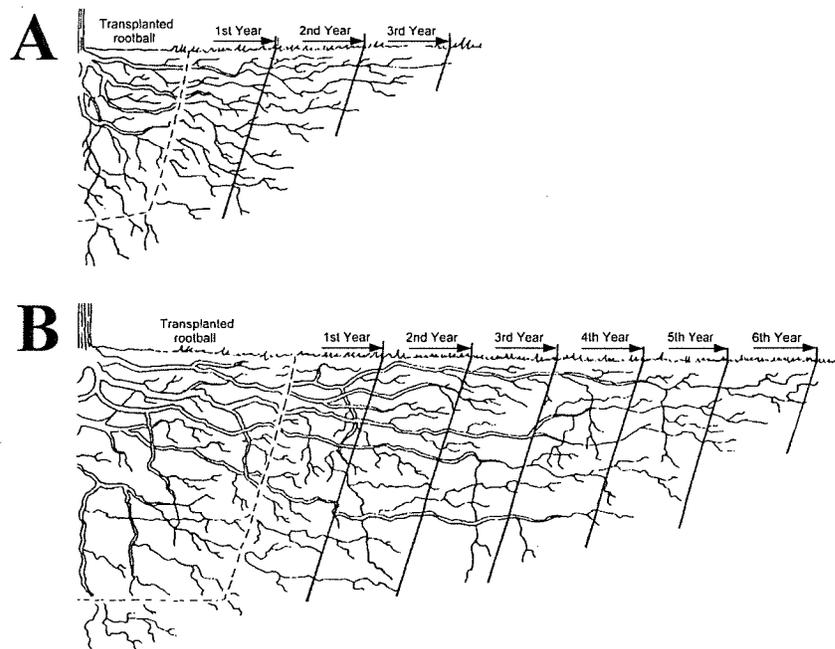


Fig. 2. Roots grow at a similar rate regardless of tree size. In comparison to a smaller tree (A), roots of a larger tree (B) must grow over a longer distance to redevelop a normal root spread after transplanting. This requires more years of growth and results in a longer establishment period for a large tree; adapted from Watson and Himelick (1997).

thetic rates (Lauderdale et al., 1995; Struve, 1992), and leaf area (Struve et al., 2000) have also been successfully utilized to determine recovery of transplants as compared to non-transplanted control trees.

Gilman et al. (1998) and Lauderdale et al. (1995) provided evidence to

support earlier claims (Watson, 1985; Watson and Himelick, 1982a, 1982b) that smaller transplanted trees recover more quickly and thereby grow faster than larger transplants. Gilman found that 27 months after transplanting live oaks (*Quercus virginiana*) (USDA zone 8b), trunk diameters and tree

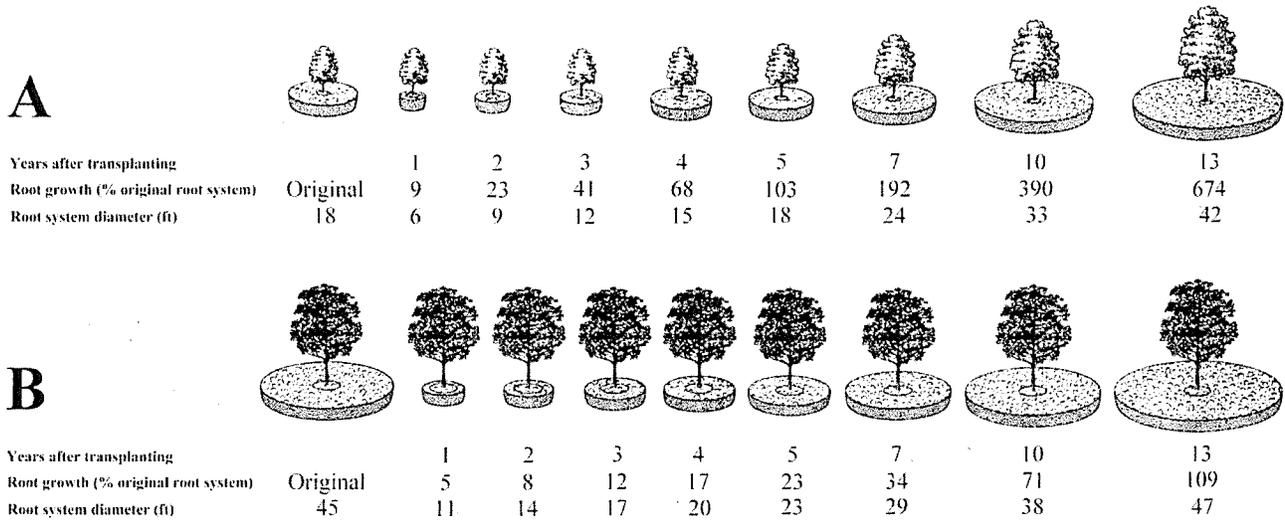


Fig. 3. The relationship between root growth and top growth of transplanted trees of 10.2 cm (A) and 25.4 cm (B) (4 and 10 inches) diameter at breast height (dbh) at the time of transplanting. Larger tree grows very slowly for many years, while smaller tree resumes a normal rate after only a few years. Eventually, the two trees are nearly equal in size; adapted from Watson (1985); 1 ft = 0.3 m.

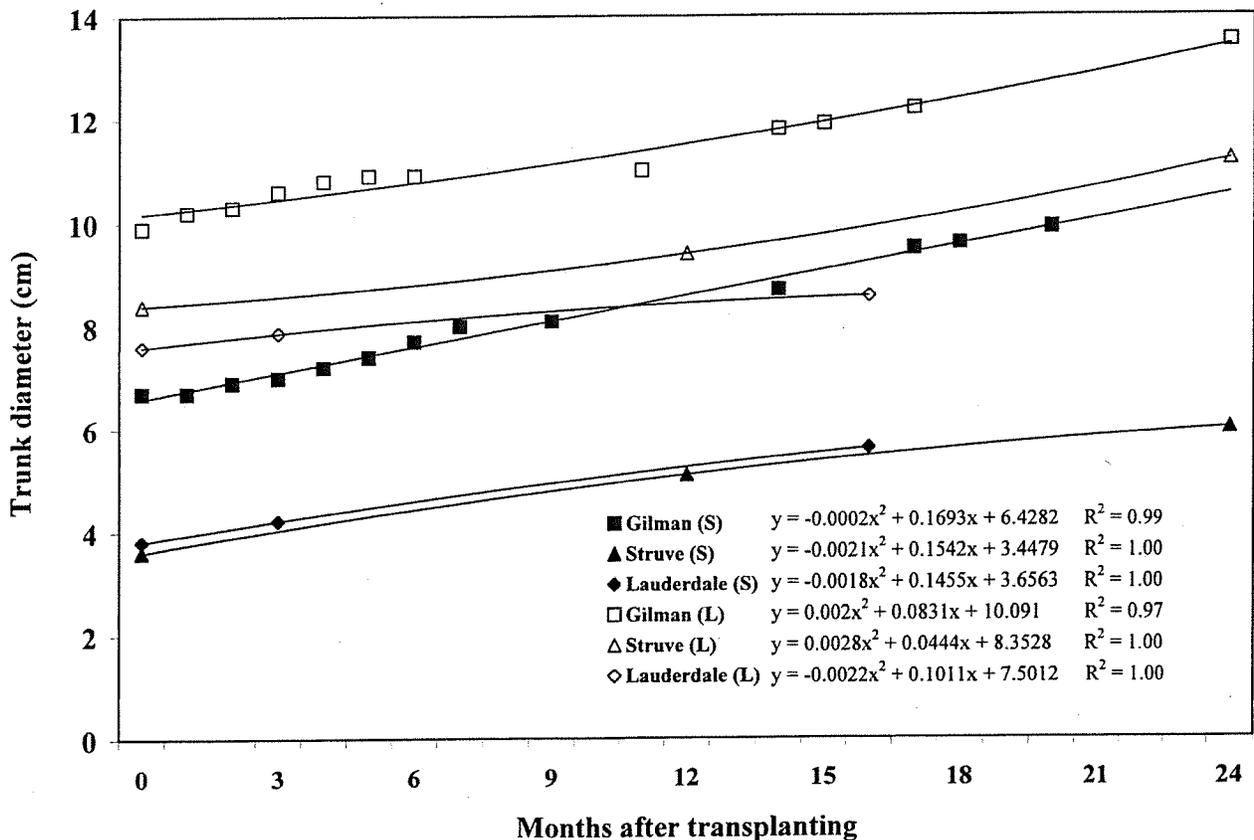


Fig. 4. Effect of tree size at transplanting on tree height increases for small (S) and large (L) transplants; adapted from Gilman et al. (1998), Lauderdale et al. (1995), and Struve et al. (2000). Polynomial regression lines are based on published means of original research; 1 cm = 0.4 inch.

heights increased at a significantly faster rate ($P < 0.01$) on smaller transplants [6.3-cm (2.48 inches) trunk diameter] than on larger transplants [9.4-cm (3.70 inches) trunk diameter].

Lauderdale et al. (1995) also found a significant increase ($P < 0.05$) in trunk diameters and tree heights, as well as shoot growth, on small red maples (*Acer rubrum*) [3.8-cm (1.50 inches)

trunk diameter] vs. large red maples [7.6-cm (2.99 inches) trunk diameter] over a 16-month period (USDA zone 8b). Figures 4 and 5 illustrate some of the trunk diameter and tree height

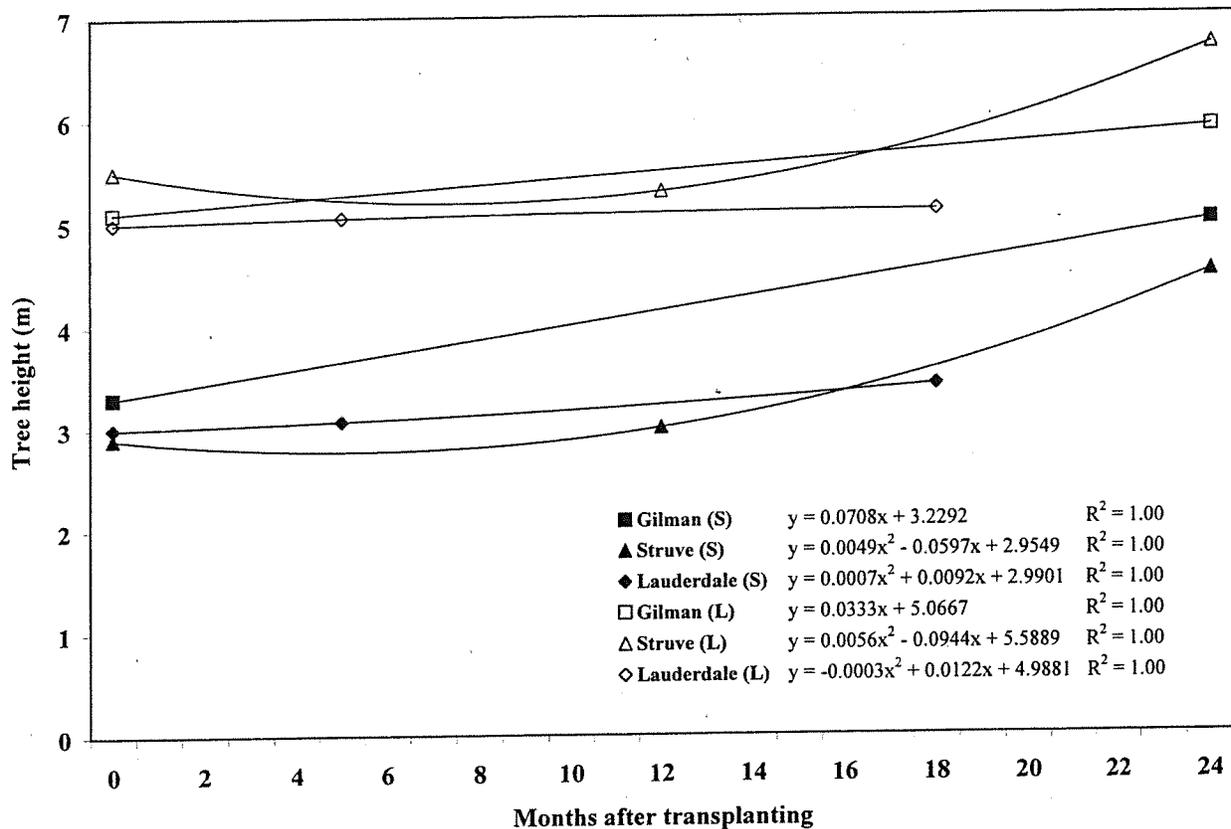


Fig. 5. Effect of tree size at transplanting on tree height increases for small (S) and large (L) transplants; adapted from Gilman et al. (1998), Lauderdale et al. (1995), and Struve et al. (2000). Original research reported only increases in tree height (Lauderdale et. al.) so a 3-m (9.8 ft) initial height was used for small (S) and a 5-m (16.4 ft) initial height was used for large (L) trees at transplanting to facilitate comparisons of growth rates among data from other studies. Polynomial regression lines are based on published means of original research; 1 m = 3.3 ft.

growth rate data from these studies. Second-order polynomial trend lines have been superimposed to accentuate differences among growth rates.

Struve's (USDA zone 5) findings contradict these results and show no significant difference in growth rates of small-caliper [3.6 cm (1.42 inches) trunk diameter] and large-caliper [8.4 cm (3.31 inches) trunk diameter] transplanted red oaks (*Quercus rubra*) over a 4-year period (Struve et al., 2000). These findings should be viewed with caution because 58% of large transplants died within the first year. Struve argued that their results might have differed from prior research trials because their study accounted for genetic variability, production history, planting-hole to backfill volume, and relative mulch ring diameter. However, pre-transplant growth rates did not appear to affect Struve's results. In addition, Gilman et al. (1998) and Lauderdale et al. (1995) provided planting holes and mulch rings that were proportional to the sizes of the

trees planted. The low numbers of surviving large trees (four) in the Struve et al. study were likely the hardiest and fastest growing trees, which possibly skewed the results of the study.

Conclusions

These studies have demonstrated that tree size affects establishment rates. It takes longer for larger transplanted trees to become established due to the longer time required to reestablish a root:shoot ratio comparable to non-transplanted trees. The question that has not been fully answered is whether the difference in recovery times between small and large trees will result in the smaller tree outgrowing the larger tree. Watson (1985), Gilman et al. (1998), and Lauderdale et al. (1995) provided data that when modeled over time provided evidence that smaller transplanted trees would outgrow larger transplanted trees. When other factors were considered, results from Struve et al. (2000) suggested that smaller trees would not

outgrow larger trees. Additional long-term studies need to be conducted to determine how establishment rates of various sized trees affect long-term growth rates of transplanted trees. In addition, prior studies used relatively small trees in comparison to the sizes of large transplanted trees that are commonly planted today by the landscape industry. Studies need to be conducted utilizing larger trees similar to those that Watson (1985) used in his model. When experimenting with larger trees (e.g., 25.4-cm caliper) with a greater size disparity over smaller trees (e.g., 10.2-cm caliper), the influence on establishment rates and ultimate tree size may be more pronounced. However, adequate numbers of plants per replication in studies of this nature are difficult to achieve because of inadequate funding.

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Bareroot and Balled-and-burlapped Red Oak and Green Ash Can Be Summer Transplanted using the Missouri Gravel Bed System

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ADDITIONAL INDEX WORDS. tree establishment, root regeneration, nursery production, transplant shock

SUMMARY. Two experiments were conducted to determine if 5.1-cm-caliper (2 inches) 'Summit' green ash (*Fraxinus pensylvanica*), and 7.6-cm-caliper (3 inches) northern red oak (*Quercus rubra*) could be successfully summer transplanted after being heeled in pea gravel or wood chips prior to planting in the landscape. Spring harvested trees of each species were either balled and burlapped (B&B) or barerooted before heeling in pea gravel or wood chips. Compared to B&B 'Summit' green ash, bareroot stock had similar survival and shoot extension for three growing seasons after summer transplanting. Bareroot and B&B northern red oak trees had similar survival and central leader elongation for 3 years after summer transplanting. In the third year after transplanting, northern red oak bareroot trees heeled in pea had smaller trunk caliper than B&B trees heeled in wood chips. These two taxa can be summer transplanted B&B or bareroot if dormant stock is spring-dug and maintained in a heeling-in bed before transplanting. This method of reducing transplant shock by providing benign conditions for root regeneration can also be used to extended the planting season

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