Tree Transplant Size Influences Post-Transplant Growth, Gas Exchange, and Leaf Water Potential Of 'October Glory' Red Maple[1]

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Abstract

Effects of red maple transplant size [3.8 cm (1.5 in, small) and 7.6 cm (3.0 in, large) trunk diameter] on growth were evaluated at park and residential planting sites in Mobile, AL, during 1993 and 1994. Gas exchange and leaf water potential of transplants were monitored. Small trees had greater shoot elongation than large trees during both growing seasons. In 1994, small trees had greater height increases than large trees. Trunk diameter increases of small transplants were twice those of large transplants in 1994. Photosynthesis, leaf conductance, transpiration, and water use efficiency were higher for small transplants than large transplants on every observation date. In August 1993, pre-dawn and daily leaf water potentials were higher (less negative) for small trees than for large trees.

Index words: photosynthesis, leaf conductance, transpiration, leaf water potential, urban trees, urban forestry.

Species used in this study: Red maple (*Acer rubrum* L. 'October Glory').

Significance to the Nursery Industry

Results from this study demonstrate that transplant size is an important variable to consider when planting maple trees in urban environments. Compared to large trees, small trees grew more during the first two years after transplanting and had higher gas exchange and leaf water potentials (daily and pre-dawn), all indications of their ability to overcome transplant stress more quickly. In addition to more rapid establishment smaller transplants have lower planting and replacement costs, and require less maintenance.

Introduction

Conditions in urban plantings are often very different from natural forest environments. Water stress has been reported to be a limiting factor in the productivity of urban trees (4, 7, 8, 13, 14, 15, 19). Water stress is particularly a problem with transplanted balled and burlaped (B&B) trees, since severed roots do not begin regeneration for one to two weeks (2). Since adequate photosynthetic rates are required to provide carbohydrates for growing tissues and storage for later use (6, 10), water stress and/or root removal (11), which may reduce photosynthesis rates, can result in limited shoot growth. High root-to-shoot ratios, which are typical of trees planted when small, encourage shoot growth compared to low ratios typical of larger transplants (5). Using a computer model based on tree growth in the northern United States, Watson (16) showed that five years after transplanting, the regenerated root system of a tree with a 25.4 cm (10.0 in) trunk diameter will be only about 25% of the original size. A tree with a 10 cm (4.0 in) trunk diameter transplanted at the same time will replace its root system after about five years. Rapid regeneration of root systems for smaller trees may result in more shoot growth than larger trees transplanted at the same time; however, limited data are available concerning the influence of transplant size on subsequent growth. This study was initiated to evaluate the effects of tree transplant size on performance after transplanting.

Materials and Methods

Balled and burlapped *Acer rubrum* 'October Glory transplants in two sizes, 3.8 and 7.6 cm (1.5 and 3 in) trunk diameter, were planted either in a city park or a residential site in Mobile, AL (32 trees total). Eight single plant replicates of two sizes were planted in a completely randomized design at each location. The 3.8 cm (1.5 in) trunk diameter transplants had root balls 45.7 cm (18.0 in) in diameter, while 7.6 cm (3.0 in) trunk diameter transplants had root balls 81.3 cm (32.0 in) in diameter. All tree specifications conformed to American Association of Nurserymen Standards (1).

Trees were planted in May 1993, by city personnel. Particle size for soil at the park site (Municipal Park) was 78% sand, 19% silt, and 3% clay. Particle size for soil at the residential site was 80% sand, 18% silt, and 2% clay. Soil pH in the park ranged from 5.4 to 7.1, while residential soil pH ranged from 5.7 to 6.0.

Planting holes were dug two times the width and the same depth as the root ball. Trees were placed in the planting holes, burlap and cord were removed, and two-thirds of the soil was backfilled. Trees were then watered in and the remaining soil was added. Thereafter trees were hand irrigated twice per week during the summer of 1993. No irrigation was applied during 1994. During March 1994, all trees were fertilized with 181.6 g (0.4 lb) 13N–5.3P–10.5K (13–13–13) per cm of trunk diameter (1 lb per caliper in) measured at 15 cm (6.0 in) above the soil surface.

Growth data collected in October of the first and second growing seasons included: height increase (determined each year as the increase in height from planting or the previous year on trees with less than 25% crown dieback), trunk diameter increase (determined each year as the increase in trunk diameter from the previous year at 15 cm (6 in) above

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the soil surface), and shoot elongation (based on growth from bud scales to the terminal bud and taken as an average of three randomly selected shoots per tree).

Maples in both locations were selected for gas exchange and water potential measurements. Gas exchange on clear to partly cloudy days was monitored on a single, randomly selected, fully expanded leaf from the side of the canopy with LI-COR 6250 Portable Photosynthesis Systems (LI-COR, Inc., Lincoln, NE) on August 25–26, 1993; June 13–14, 1994; and August 11–12, 1994. Ranges for environmental conditions over the three observation periods were: photosynthetically active radiation (1000–2036 $\mu E \cdot m^{-2} \cdot sec^{-1}$), leaf temperature [30–41C (86–106F)], chamber temperature [29–41C (84–106F)], carbon dioxide (334–392 ppm), and relative humidity (25–55%). Environmental conditions were similar for small and large transplants at all observation dates and times. Trees at both sites (park and residential) were monitored over the same period of time by utilizing two LI-COR Portable Photosynthesis Systems. Each tree was evaluated using a different leaf starting at 9 A.M., 11 A.M., 1 P.M., and 3 P.M. for a total of four observations per tree per day (eight observations per sampling period). Gas exchange variables included net photosynthesis (Pn), leaf conductance (Cs), and transpiration (Ts). Water use efficiency (WUE) was calculated by dividing simultaneous Pn by Ts measurements. Leaf water potential was determined on the same leaf immediately following each gas exchange observation, and pre-dawn (4 A.M.) on single leaves using a pressure chamber (Soil Moisture Equipment Corp., Santa Barbara, CA).

Trees were visually evaluated August 1993 and September 1994 for crown dieback, and general health using evaluation criteria designed in assessing elm trees on the Capitol Mall in Washington, DC (Effects of the 25th Annual Festival of American Folklife on Soil Physical Characteristics of the Capitol Mall and on the Vegetation Resources of this Area, USDA, ARS, National Soil Dynamics Laboratory, P.O. Box 3439, Auburn, AL 36831). Criteria of these data sheets include the general tree health as well as specifics concerning the trunk, branches, and foliage. Using these forms, trees were visually evaluated for percent crown dieback, death, mechanical injury, and presence or absence of disease or insects (data not shown).

Means were separated by LSD, $\alpha = 0.05$. Growth, gas exchange, and leaf water potential were pooled by sample date regardless of planting site due to lack of planting site replication (park vs residential). Based on ANOVA for gas exchange and leaf water potential no interactions occurred between time and size, and data collected at different sample times were pooled.

Table 1. Effects of tree size at transplanting on growth (Mobile, AL).

	Acer rubrum 'October Glory'			
	1993		1994	
Variable	Small[z]	Large[y]	Small	Large
Height increase (cm)	7.3a[x]	5.3a	34.3a	5.7b
Shoot elongation (cm)	11.4a	6.1b	22.4a	5.5b
Trunk diameter increase (mm)	4.1a	2.7a	14.1a	7.1b
Trees measured	15[w]	10	14	15

[z]3.8 cm (1.5 in) trunk diameter at transplant (Small).

[y]7.6 cm (3.0 in) trunk diameter at transplant (Large).

[x]Mean separation by date within rows by LSD, P = 0.05.

[w]Number of trees measured out of 16 having less than 25% crown dieback.

Results and Discussion

Growth. In 1993, only shoot elongation was affected by transplant size (greater shoot elongation with small maples); however, by 1994 values for all three growth variables measured were higher with small transplants (Table 1). During 1994, small trees had a height increase six times greater than that of large trees. Trunk diameter increase in 1994 for small trees was about twice as great compared to large trees, while the increase in shoot elongation was four times greater than those of large trees. These data concur with findings of Watson and Himelick (17, 18). Greater shoot elongation for small transplants may indicate less stress than large transplants.

Greater height increase, trunk diameter increase, and shoot elongation for small transplants support Watson's findings (16) that 13 years after transplanting, a 10 cm (4.0 in) trunk diameter tree transplanted at the same time as a 25.4 cm (10.0 in) diameter tree may have a shoot system of similar size. These data also are in agreement with work by Brouwer (5), who reported that small transplants with a higher root to shoot ratio than large transplants have enhanced shoot growth.

Gas exchange. Small transplants had higher net photosynthesis (Pn) rates than large transplants during August 1993, June 1994, and August 1994, observations (Table 2). Higher Pn for small tranplants suggests they were under less stress than large trees during the first two growing seasons. Higher Pn for small transplants than large transplants may partially explain greater shoot elongation. Higher Pn during the first growing season likely contributed to the capacity of smaller trees to store carbohydrates, which aided growth the second year.

Table 2. Effects of *Acer rubrum* 'October Glory' tree size at transplanting on gas exchange.

	August 1993		June 1994		August 1994	
Variable	Small[z]	Large[y]	Small	Large	Small	Large
Net photosynthesis ($\mu mole \cdot m^{-2} \cdot sec^{-1}$)	9.0a[x]	5.1b	12.4a	9.6b	12.8a	8.7b
Transpiration ($mole \cdot m^{-2} \cdot sec^{-1}$)	0.0042a	0.0027b	0.0222a	0.0181b	0.0204a	0.0175b
Leaf conductance ($cm \cdot sec^{-1}$)	0.555a	0.302b	2.18a	1.59b	2.306a	1.667b
Water use efficiency ($\mu mole\ CO_2 \cdot mole\ H_2O \cdot sec^{-1}$)	4094.5a	4017.0b	636.41a	549.37b	748.5a	638.6b

[z]3.8 cm (1.5 in) trunk diameter at transplant (Small).

[y]7.6 cm (3.0 in) trunk diameter at transplant (Large).

[x]Mean separation by date within rows by LSD, P = 0.05.

Table 3. **Effects of *Acer rubrum* 'October Glory' tree size at transplanting on leaf water potential.**

Variable	August 1993		June 1994		August 1994	
	Small[z]	Large[y]	Small	Large	Small	Large
Average daily leaf water potential (-MPa)	5.2b	6.6a	5.0a	4.7a	2.3a	2.4a
Pre-dawn leaf water potential (-MPa)	2.0b[x]	3.2a	1.6a	1.8a	1.2b	1.7a

[z]3.8 cm (1.5 in) trunk diameter at transplant (Small).
[y]7.6 cm (3.0 in) trunk diameter at transplant (Large).
[x]Mean separation by date within rows by LSD, P = 0.05.

Transpiration (Ts) rates of small maples were higher than those of large maples on all sampling dates (Table 2). More transpirational water loss by small trees indicates a greater potential for water and nutrient uptake by the root system. Storage of carbohydrates and nutrients one year should aid growth the following year. Although not compared statistically Ts and Pn, regardless of transplant size, appeared greater during 1994 than in 1993, possibly due to greater rainfall in 1994. Monthly precipitation was 5.16, 3.07, and 8.94 cm (2.03, 1.21, and 3.52 in) below normal in June, July, and August 1993, respectively (National Weather Service). However, during the summer of 1994, precipitation was above normal in June and July [1.09 and 8.99 cm (0.43 and 3.54 in)] compared to 12.54 cm (4.94 in) below normal in August 1994.

Stomatal conductance (Cs) rates for small trees were greater than Cs for large maples at all observation dates (Table 2). Greater small tree Cs indicates that those trees were under less moisture stress than large trees. Higher Cs rates also are consistent with the higher rates of Pn for small trees compared to large trees. These data concur with those of other studies (3, 9) that have reported as Cs decreased, Pn decreased.

Water use efficiency (WUE) observations calculated for August 1993 were similar among transplant sizes (Table 2). However, 1994 WUE observations indicate that small trees used water more efficiently than large trees during June and August observations.

Leaf water potential. Mean daily leaf water potentials taken predawn and during gas exchange observations in 1993, and pre-dawn leaf water potentials in August 1993 were greater for small than large transplants (Table 3). These data indicate small trees were under less moisture stress during the first growing season than large trees. Also, these data indicate that small transplants rehydrated to a greater extent over-night from moisture deficits that occurred during the previous day than large trees.

Data collected in 1993 support the theory that one of the first and most important plant processes adversely affected by moisture stress is gas exchange (12). Higher leaf water potentials (less negative) or lower levels of moisture stress for small transplants during gas exchange observations may have resulted in the higher gas exchange observations when compared to large transplants.

Based on gas exchange and leaf water potential data, small transplants of 'October Glory' red maple underwent less transplant shock than larger transplants. These data indicate that smaller red maple trees established more readily in the landscape than the larger transplants.

Tree health. At the end of the 1993 growing season, a higher number of large transplants at both sites had crown dieback compared to small trees. For example, no crown dieback occurred on small transplants at the residential site, while eight (all) large transplants exhibited some dieback (two with 1–25% dieback and six with 25–50% dieback). At the park, one small and seven large trees exhibited varying levels of crown dieback. After the 1994 growing season, fewer transplants (one small at each site and three large at the park site) exhibited dieback than during the 1993 growing season.

Results of this study indicate transplant size is an important variable to consider when planting red maple trees in urban environments. Small red maples recovered more rapidly from transplanting compared to large red maples.

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Water Conservation Potential and Quality of Non-turf Groundcovers versus Kentucky Bluegrass under Increasing Levels of Drought Stress[1]

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Abstract

In June 1991, a 2-year field study was initiated to examine if three non-turf groundcovers require less irrigation than Kentucky bluegrass (KBG). Irrigation treatments were based on decreasing percentage of evapotranspiration (ET) (100%, 75%, 50%, 25% and 0%). ET was estimated by the modified Penman equation using alfalfa as a reference crop. Plants receiving the 0% irrigation treatment were not irrigated and relied on precipitation for survival. The groundcovers studied were Kentucky bluegrass 'Challenger' (*Poa pratensis* L.), creeping potentilla (*Potentilla tabernaemontani* Asch.), goldmoss (*Sedum acre* L.) and snow-in-summer (*Cerastium tomentosum* L.). Data were collected on visual ratings, growth, soil moisture and canopy temperature. Optimum irrigation for KBG was 50% ET. *Cerastium* required irrigation at 50%–75% of estimated ET during the initial season (1991) for optimum appearance and growth. During 1992, the plants were better established and 25% ET was optimum. *Potentilla* required irrigation at the 75% ET rate for optimum visual quality. *Sedum* maintained a good aesthetic appearance at irrigation rates as low as 25% ET and could be considered as a water-conserving alternative to KBG.

Index words: evapotranspiration, xeriscape, creeping potentilla (*Potentilla tabernaemontani*), goldmoss (*Sedum acre*), snow-in-summer (*Cerastium tomentosum*).

Significance to the Nursery Industry

Limited water supplies in many cities are creating more interest in identifying plants for the landscape that do not require as much water as some that are currently in widespread use. In many areas, large amounts of water are applied to lawns. Lawns are generally composed of turfgrass. This study examined how non-turf groundcovers compare to a commonly used turfgrass (Kentucky bluegrass) in treatments of increasing drought stress. It was found that *Cerastium* and *Sedum* do not require as much irrigation as Kentucky bluegrass. Additional research on these and additional species may someday give the nursery industry an additional product line to grow that would compete well with turfgrass species.

Introduction

The use of non-turf groundcovers as lawns is not a new idea. Ancient Persian and Arabian 'garden lawns' used non-turf groundcovers extensively (1). Interest in non-turf groundcovers for modern lawns has increased recently as the growth of cities has put a strain on water supplies and therefore created a demand for alternative plants with low water requirements. The need for water-saving alternatives is important because in many residential areas 50% of municipal water is applied to landscaping on an annual basis (3). One alternative is greater use of non-turf groundcovers since some possess reputations for having 'low water' requirements. However, much of this information is based on generalization and little scientific data exist to support it. Most of the current literature on groundcovers describes their water use in terms such as 'low,' 'medium,' and 'high.' Virtually none make direct comparisons to Kentucky bluegrass (KBG), which is the predominant lawn grass in many areas of the United States. Therefore, the purpose of this study was to evaluate the landscape quality and establishment of three non-turf groundcovers and KBG at increasing levels of drought stress.

Materials and Methods

In June 1991, a 2-year field study was initiated to examine if three non-turf ground covers with reputations for using low amounts of water actually require less irrigation than Kentucky bluegrass (KBG) when maintained to be aesthetically pleasing. Irrigation treatments were based on decreas-

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