Half-Sib Family Selection Improves Container Nursery and Landscape Performance of Sycamore[1]

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Abstract

Seven groups of seedlings from each of seven single parent (half-sib) families of sycamore, *Platanus occidentalis* L., were grown to a marketable size in 9.1 liter (#3) containers to test responses to container nursery production in south Texas. Seedlings were then transplanted to a field site (Brazos County, TX) in the fall, spring, and summer to assess seasonal effects on landscape establishment. Regional selections grew larger, both during container production and following subsequent transplant to the field. Growth of non-improved local half-sib families equaled or exceeded that of genetically improved families from a distant region. Differential responses among genetically improved and non-improved sources were less pronounced when genotypes were grown in a region from which they did not originate. Fall and spring transplanted seedlings had substantially greater growth and survival than did summer transplants regardless of genotype. This study demonstrates a potential for regional market segregation of seed-propagated landscape trees.

Index words: seed source, provenance, genotypic selection, *Platanus occidentalis* L., container production, transplant, sycamore, tree, marketing.

Significance to the Nursery Industry

With selection of proper genotypes within a species, shoot growth during container production and post-transplant growth in the field/landscape of seed-propagated trees can be increased. Conversely, a similar sized plant may be produced more rapidly, thus potentially shortening rotation times for a given species and stock size. This study suggests that regional testing is needed to determine which provenances and/or families within provenances will be best adapted to a particular region. However, local native populations or land races of non-native species are likely better choices than more geographically distant selections of a given species. Regional improved selections can be made that have superior growth characteristics compared to non-improved genotypes or improved genotypes from geographically distant regions. Regional selection of seed-propagated nursery stock could lead to regional marketing of improved genotypes.

Introduction

While many species utilized in the eastern United States are grown in southwestern U.S. nurseries, their performance in southwestern landscapes is variable. Production of container-grown trees in the southwestern United States entails a variety of challenges relative to production in more mesic environments. Drought and heat typically limit growth from late spring to late autumn. Rapid fluctuations in winter temperatures from those favorable for plant growth during the day to below freezing at night are common. Irrigation water is frequently of poor quality, high in pH, salts, bicarbonates or combinations.

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Within species variation has been reported for numerous forest trees. This variation has been exploited for such traits as greater biomass accumulation, tolerance to various environmental stresses, improved disease/pest resistance, straighter boles, improved fiber characteristics, increased height, and/or more desirable branching patterns for several forest tree species (15, 16). Genotypically improved seedlings typically originated from phenotypically superior selections that were subsequently progeny tested or from advanced breeding lines developed in public or commercial tree improvement programs. Testing of seedling growth has, with few exceptions, occurred only in systems producing bare-root or small container-grown seedlings for reforestation purposes (3, 13). In recent years, the Texas Forest Service selected superior phenotypes growing in urban sites for use in seed orchards to provide genetically superior seeds for the landscape and nursery industry. Among species included was sycamore, *Platanus occidentalis* L., an important landscape species throughout much of the United States (9, 12). Substantial intraspecific genetic variation has been documented in growth rate and form of sycamore (8, 14). Genetically improved half-sib sycamore families were also available from a geographically distant operational forest tree improvement program (personal communication, R.J. Rousseau, Westvaco Corp.). A previously tested less desirable half-sib family (3), and *P. occidentalis* from local non-improved stands were readily available for comparison to improved families.

Previous studies indicated that increased growth and reduced pruning requirements could be obtained with field-grown *P. occidentalis* and *Liquidambar styraciflua* L. by utilizing seedlings from forest tree improvement programs compared to conventional seed sources (3). Such genetic material is commercially utilized in production of small bare-root seedlings for reforestation purposes (15, 16). Struve and McKeand (13) reported improved nursery productivity with use of mother tree selection in northern red oaks (*Quercus rubra* L.). Applicability of their findings to container production at geographically distant sites is unknown. Most seed-propagated species of landscape trees are sold without regard to geographic or ecological origin of the seed (1). Little has been done to facilitate the transfer of forest tree improvement program technology to the nursery/landscape industry (1).

The objectives of this study were: 1) to compare growth responses in container production of selected genetically improved or non-improved half-sib families of *P. occidentalis* from the Texas region to those from a geographically distant region; 2) to determine if the selected genotypes retained their relative growth differences when out-planted on a common site; and 3) to determine the consistency of post-transplant growth responses among families across seasons of transplant.

Materials and Methods

Container production. Seed from genetically improved half-sib families were obtained from the Texas Forest Service tree improvement program (from regional parental selections TFS-09 and TFS-24) and the Westvaco Corp. hardwood tree improvement program based in Kentucky (from geographically distant parental selections WV-10 and WV-14). Seedlings were also derived from non-improved selections in Tennessee (geographically distant selection Putnam from Putnam County, TN) and Texas (regional selections Brazos-C and Brazos-D from Brazos County, TX). Each half-sib family was derived from seeds obtained from a single mother tree.

On June 1, 1994, stratified [4C (40F) for 90 days] seeds of seven half-sib families of sycamore (*Platanus occidentalis* L.) were planted in flats containing Metromix 360 media (Scotts Corp., Marysville, OH), irrigated as needed with distilled water, and treated with a preventative fungicidal drench, 17.2 g/liter (2.3 oz/gal) each of Banrot® (Scotts Corp.) and Chipco® (Rhône-Poulenc, Research Triangle Park, NC). On June 13, 1994, when seedlings averaged two to three true leaves, 90 seedlings of each of the seven families were planted in 2.8 liter (#1) black plastic containers (Lerio Corp., El Campo, TX) filled with a pine bark:sand (3:1 by vol) media amended with 3.4 kg/m^3 (6 lb/yd^3) of dolomite (Vulcan Materials Co., Tarrant, AL), 1.7 kg/m^3 (3 lb/yd^3) each of gypsum (Standard Gypsum Corp., Fredericksburg, TX) and treblesuperphosphate (Scotts Corp.), and 0.68 kg/m^3 (1.5 lb/yd^3) micromax micronutrients (Scotts Corp.). Controlled release fertilizer, 18N–3P–8.3K (18–7–10, Sierrablen, Scotts Corp.), was applied to the media surface after planting at a rate of 19.6 g (0.69 oz)/container. All plants were fertigated weekly with 350 mg/liter (350 ppm) of N from a 24N–3.5P–13.3K (24–8–16) water soluble fertilizer (Scotts Corp.). On July 15, 1994, plants were transplanted to 9.1 liter (#3) black plastic containers (Lerio Corp.) in the same media as above. Fifteen seedlings from each of seven families were randomly placed into each of six blocks (630 total plants) in a randomized complete block design. All plants were grown under 55% light exclusion, drip irrigated (#9 spot spitters, Roberts Irrigation, San Marcos, CA) to run-off twice daily during the summer, and hand watered as needed in winter.

On September 18, 1994, the number of pruning cuts per plant required to maintain a central leader was recorded. On June 7, 1995, the number of pruning cuts required to remove limbs from the main trunk below 1 m (3 ft) for all plants were recorded.

Field/landscape establishment. On November 17, 1994, April 10, 1995, and June 12, 1995, five plants of each half-sib family from each of the six blocks were randomly selected and transplanted to a field site (College Station, TX) on 1 m (3 ft) within row and 3 m (10 ft) between row spacings. Soils were Boonville Series, Boonville fine sandy loam, fine, montmorillic thermic ruptic-vertic albaqualfs (pH 9.1, bulk density 1.51 g/cm^3, 61% sand, 11% clay, 28% silt). Heights and trunk diameters of seedlings were measured at transplant. Mid-day (prior to planting) and pre-dawn (after planting) xylem water potentials of lateral shoots (Ψ_{xylem}) were measured from five plants per family randomly selected across blocks (Model 610 Pressure Chamber, PMS Instruments, Corvallis, OR). Subsequent Ψ_{xylem} measures were determined at 7, 14, 21 and 28 days after each transplant date. Plants were irrigated from drip emitters (3.8 liters/hr (1 gal/hr)) daily for two hours during the first week of establishment, for four hours weekly for the next three weeks, and afterwards when soil water potential reached –1.5 kPa as determined using tensiometers (Jetfill Tensiometers, Model 2725, Soil Moisture Equipment Corp., Santa Barbara, CA) placed adjacent to one plant in each of the six blocks. Clean cultivation was maintained between rows with mechanical tillage. Glyphosate (Monsanto, St. Louis, MO), oryzalin (Dow Elanco, Indianapolis, IN), and hand weeding were used to control weeds within the rows.

On August 30, 1995, foliar drought stress ratings were recorded for each plant. Ratings ranged from one to five (one = plant with 100% of existing foliage appearing wilted, with marginal necrosis or having an abnormal shape, to five = plant with 100% of the existing foliage with no signs of drought stress). On November 20, 1995, and December 10, 1996, heights, trunk diameters [15 cm (6 in) from soil surface], and survival (plants with green leaves or green cambial tissue when leaves were absent) were assessed for the first and second post-transplant growing seasons, respectively.

Statistical analysis was performed using the general linear models procedures in SAS for Windows (11). The experiment was analyzed as a randomized complete block design consisting of three transplant times × seven half-sib families with six blocks containing five randomly distributed replicates per family and transplant time. Family, block, experimental error, and sampling error were considered random effects, while transplant time was considered a fixed effect. Main effects are presented only for those characteristics not involved in significant ($P \leq 0.05$) interactions. Percent data were transformed for analysis, but are presented in the text as non-transformed data. Dead plants were treated as missing data points for analysis of measures taken on subsequent dates.

Results And Discussion

Container production. During nursery production, families did not differ significantly ($P \leq 0.05$) in the number of pruning cuts required to maintain a central leader (data not presented). Putnam, WV-14, and TFS-09 seedlings required more cuts per plant to remove limbs below 1 m (3 ft) on the main trunk than did Brazos-C, Brazos-D and TFS-24 (Table 1). Generally local regional selections required fewer pruning cuts during initial production than did the more geographically distant genotypes. TFS-09 and WV-10 were the exceptions as both were intermediate in pruning cuts required.

In general, Texas regional half-sib families (TFS-09, TFS-24, Brazos-C, and Brazos-D), regardless of selection for genetic improvement or not, grew larger more quickly during

Table 1. **Main effects of half-sib families, pooled across transplant season, on required pruning, growth responses, and stress symptoms in the nursery or field.**

Half-sib family	Limbs removed to 1 m height	Nursery height	Field: Two yr. survival	Field: Height: Initial	Field: Height: Year 1	Field: Height: Year 2	Field: Height: Change in height: Year 1	Field: Height: Change in height: Year 2	Field: Trunk diameter: Initial	Field: Trunk diameter: Final	Field: Visual rating
	(number)	(cm)	(%)	(cm)	(cm)	(cm)	(cm)	(cm)	(mm)	(mm)	(1–5)[z]
TFS-09	12.4[y]bc	155ab	84a	157a	170a	200a	13a	30ab	18.5a	28.3a	3.3a
TFS-24	10.5f	148bc	74b	149b	155ab	175b	6ab	20abc	17.1b	27.0b	3.0b
Brazos-C	11.5de	158a	86a	150b	165a	203a	15a	37a	18.1a	29.3a	3.3a
Brazos-D	10.7ef	150ab	72b	150b	146bc	157bc	–4bc	11bcd	17.0bc	26.6b	3.1ab
WV-10	11.8cd	140cd	69b	142c	131cd	143c	–11c	12bcd	16.4c	25.2c	2.8c
WV-14	13.3ab	137de	73b	140c	131cd	137cd	–9bc	5cd	16.7bc	24.4c	2.7c
Putnam	13.4a	130e	66b	131d	121d	119d	–10bc	–2d	15.4d	22.5d	2.7c

[z]Visual rating scale; from 1 (100% of foliage with drought stress symptoms) to 5 (none of foliage exhibiting drought stress symptoms).

[y]Means within a column followed by the same letter are not significantly different ($P \leq 0.05$) using expected least squares means procedure, values are means of 90 observations.

container nursery production in south central Texas than did genetically improved (WV-10, WV-14) or non-improved (Putnam) selections from the upper south (Table 1). Brazos-C, TFS-09, and Brazos-D were taller than WV-10, WV-14, and Putnam (Table 1). Putnam remained the shortest family across all planting dates (Table 1), while across families height growth continued with increased time in the nursery (Table 2). There were no significant interactions among transplant season and half-sib families for any measured characteristics except trunk diameter (caliper) in the nursery and change in trunk diameter in the field during the first growing season after transplant (Fig. 1A). At all measurement times, Brazos-C and TFS-09 had the greatest trunk diameter in the nursery, while Putnam seedlings were the smallest (Fig. 1A). The interaction involved shifting of rank orders among families with intermediate trunk diameters across transplant seasons (Fig. 1A).

In previous trials in Central Tennessee, bare-root transplants of WV-14 produced 11% greater height and required 62% fewer pruning cuts during field production than Putnam seedlings (3). Following transplanting from the field in Tennessee WV-14 seedlings had greater shoot growth than Putnam seedlings (3). Moving WV-14 and Putnam seedlings southwest of their genetic origin to Texas, reduced the adaptive advantages of WV-14 seedlings over Putnam seedlings. While WV-10 seedlings represent an elite selection from Westvaco's Kentucky based forest tree improvement program (personal communication, R.J. Rousseau, Research Geneticist, Westvaco Corp., Wickliffe, KY), WV-10 fared poorly compared to both Texas Forest Service Selections 09 and 24 and local non-improved genotypes, Brazos C and D (Tables 1, Fig. 1A). Increased shoot growth due to regional half-sib family selection have been reported for *P. occidentalis* (3, 5) and *Quercus rubra* L. (13).

Field establishment. At transplant to the field, Texas regional selections (TFS-09, Brazos-C, Brazos-D, and TFS-24) were typically larger in height and trunk diameter (Table 1) than the selections originating more geographically distant from the test site (WV-10, WV-14, and Putnam). Texas

Table 2. **Main effects of transplant season, pooled across half-sib families, on xylem water potentials (Y_{xylem}), post transplant growth responses, and foliar stress symptoms.**

Season of transplant	Nursery height[z]	Mid-day Ψ_{xylem}[y]	Pre-dawn Ψ_{xylem}[y]	Field: Height: Year 1[x]	Field: Height: Year 2[x]	Field: Height: Change in height: Year 1[x]	Field: Height: Change in height: Year 2[x]	Field: Final caliper[x]	Field: Visual ratings[x]
	(cm)	(MPa)	(MPa)	(cm)	(cm)	(cm)	(cm)	(mm)	(1–5)[w]
Fall	119c[v]	–0.48c	–0.27b	180a	223a	61a	43a	32.4a	3.5a
Spring	128b	–0.88b	–0.22c	155b	182b	28b	27b	25.7b	3.3b
Summer	190a	–1.05a	–0.34a	102c	81c	–88c	–21c	20.4c	2.0c

[z]Values are means of 630 (fall), 420 (spring), or 210 (summer) observations.

[y]Values are means of 175 observations.

[x]Values are means of 210 observations.

[w]Visual rating scale of one (100% of foliage with stress symptoms) to five (none of foliage exhibiting stress symptoms).

[v]Means within a column followed by the same letter are not significantly different ($P \leq 0.05$) using expected least squares means procedures.

regional selections were 14% to 22% taller than Putnam, the non-improved geographically distant seedlings, at the end of nursery production; and 32% to 71% taller two years after transplanting. TFS-09 and Brazos-C had the greatest height and trunk diameters among the tested half-sib families (Table 1). Brazos-D was frequently equivalent in growth to the geographically distant genetically improved selections, WV-10 and WV-14 (Table 1). The geographically distant genetically non-improved selection, Putnam, was always smallest among the half-sib families tested (Table 1).

Survival among families was not significantly ($P \leq 0.05$) different during the first year in the field (data not presented), but survival was greater after two years in the field for TFS-09 and Brazos-C than for other half-sib families tested at the site (Table 1). During the first year in the field, only TFS-09 and Brazos-C had significant shoot extension (Table 1). Mean height of geographically distant families was not statistically different from that at transplanting to the field two years prior. Negative shoot extension represented a net dieback of the main stem during the measurement interval. Regional selections were less prone to dieback. Less dieback in field transplants of bare-root *Liquidambar styraciflua* L. seedlings was associated with greater root grades (7).

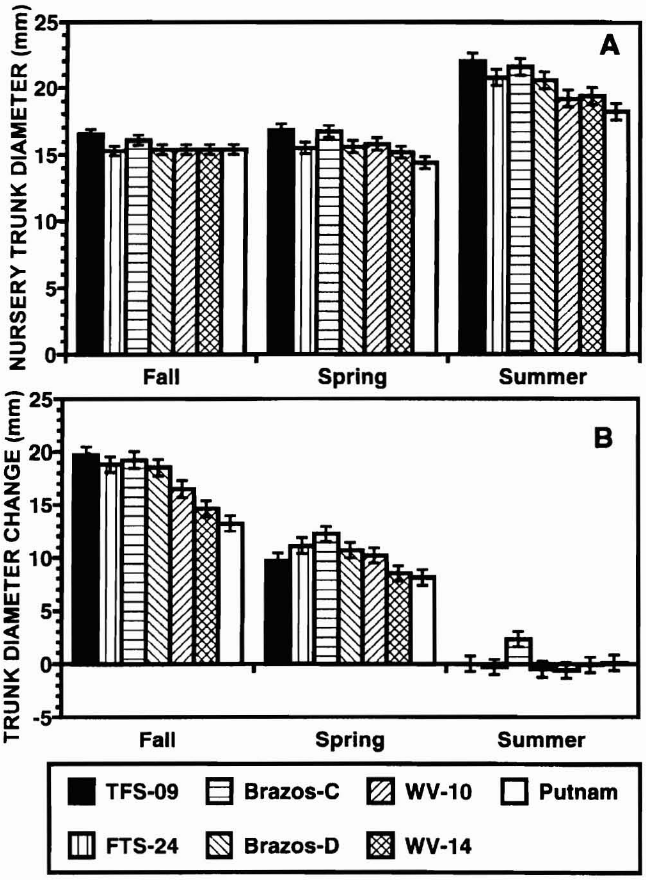

Fig. 1. Half-sib family by transplant season interactions for effects on trunk diameter during nursery production in 9.1 liter (#3) black plastic containers (A) and change in trunk diameter one year after transplanting to a field site (B). Values in A are means (± standard error) of 90, 60, and 30 observations for fall, spring, and summer, respectively. Values in B are means (± standard error) of 30 observations.

Foliar drought stress ratings (Table 1) mostly paralleled field performance for other shoot growth characteristics suggesting that differential water deficits may be involved in family responses. However, no significant differences in mid-day or pre-dawn Ψ_{xylem} (data not presented) among families occurred at weekly intervals for the first 28 days after planting. Weekly water potential measurements following transplanting may have missed differential water deficits occurring among families, or water deficits may have occurred later in the first or second growing seasons. The greater initial size of the Texas regional transplants may have improved the chances of successful establishment of these genotypes. Johnson et al. (6) reported a positive correlation between initial shoot size and post-transplant root elongation with *Q. rubra* seedlings.

Water potential measurements suggest that mid-day water stress was greatest and subsequent pre-dawn recovery least during the hot dry summer months when transpiration demands would likely be most intense (Table 2). Reductions in pre-dawn water stress have been correlated with increased small diameter (< 2.0 mm) root regeneration during post-transplant establishment of container-grown *Quercus shumardii* Buckl. (2). Across families, reductions in initial post-transplant mid-day Ψ_{xylem} corresponded well with greater shoot extension, increased trunk diameter, better survival, and reduced visual symptoms of water stress during the first two post-transplant growing seasons (Table 2). Measured mid-day Ψ_{xylem} were considerably less negative than those reported to cause growth reductions in transplanted *Quercus virginiana* Mill. seedlings (4). Rhea (10) found that seasonal response differences in shoot growth of transplanted bare-root seedlings of several species, including *P. occidentalis*, could be explained by seasonal variations in root regeneration potentials. No published information on seasonal within species variation in root regeneration of container-grown *P. occidentalis* is currently available.

While fall transplanted trees were significantly smaller than spring transplants, which were smaller than summer transplants, the effect of transplant times on height was reversed by the end of the first season in the field (Table 2). Fall transplanted seedlings were largest followed by those transplanted in spring, with summer transplanted seedlings being shortest (Table 2). This was a result of a large net increase in shoot extension for fall transplanted seedlings, followed by more moderate increases for spring transplants. In addition, a substantial net dieback of summer transplanted seedlings across half-sib families was observed (Table 2). Similar differences in shoot extension persisted among fall and spring transplanted seedlings during the second growing season in the field. Change in trunk diameter of fall transplanted seedlings in the field tended to be greater for regional than geographically distant selections (Fig. 1B). Changes in trunk diameter in the field among half-sib families were less distinct for spring transplants. With summer transplants, only Brazos-C increased trunk diameter (Fig. 1B). The interaction between season of transplant and family for change in trunk diameter in the field resulted mainly from less pronounced advantages for regional selections when transplanted in the spring, and especially summer, compared to fall.

There was significantly ($P \leq 0.05$) less mortality across families in fall (0%) and spring (2.3%) than in summer (46%) during the first season in the field. By the end of the second growing season in the field, survival was still excellent for fall transplants (97%), somewhat less for spring transplants (88%), and much lower for summer transplants (39%). By far the single best factor for successful transplant and subsequent establishment of plants in this study was to avoid summer transplanting.

With proper seed selection, growth in the nursery could be improved by 22%, pruning cuts reduced by 2 to 3 cuts per plant, and post-transplant performance dramatically improved. A plant that was 70% taller could be achieved in the landscape simply by changing the seed source used at the initiation of production. Additional study may lead to identification of characteristics that can be used to select superior genotypes. While results in this experiment are encouraging, they also suggest caution; they illustrate that genetically superior selections from one region may not be superior performers in another region. Previous forestry research with sycamores (14) indicated the interaction between latitude of origin (on an east/west transect) and planting location was more significantly correlated with height and trunk volume than the half-sib family by planting location interaction, although there were differences among families. Alternatively, Greene and Lowe (5) reported that individual sycamore family selections across provenances were best correlated with height and volume increases of progeny in the field, and that provenance had no significant effect. The present experiment demonstrated that when container-grown half-sib family selections from one region are utilized in another region, the superiority of the genetically improved genotypes can be lost and their performance may be inferior to that of local non-improved genotypes.

For nurseries targeting local markets, the opportunity exists to select genotypes for better growth in the container nursery and for subsequent performance in local landscapes. For nurseries targeting distant markets the answers are less clear. Should the nurseries utilize genotypes that grow most rapidly in their nursery or should they sacrifice some growth in the nursery to market regional selections that will perform well in the landscapes of the target market region? This would be an opportunity to differentiate seed propagated landscape trees for regional target markets, but would likely represent additional inventory costs of an expanded product line. Firms would need to balance the marketing opportunity of a superior product versus added inventory costs.

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