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Differences in Growth of Container-Grown Red Maple Cultivars in Different Hardiness Zones[1]

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Abstract

Growth of eight container-grown red maple cultivars was evaluated at four locations under dissimilar environmental conditions/hardiness zones in Georgia and Alabama for two years. Rooted cuttings and tissue cultured plantlets were planted in #3 (9.1 liter) containers in one location in the same substrate in April 1995. Trees were transported the second week of June to Blairsville, GA; Muscle Shoals, AL; Auburn, AL; and Tifton, GA in USDA hardiness zones 6b, 7a, 8a, and 8a, respectively. Dormant trees were transplanted to #10 (38 liter) containers the second week of December 1995. At the conclusion of the study, December 1996, growth differed by location and cultivar. Height and stem diameter increase, and root and stem dry weights were greatest at the two Alabama locations for most cultivars and were least at the two Georgia locations. Root:shoot ratios were greatest at the two Georgia locations, an indication of increased carbon partitioning of photoassimilates to roots over stems under dryer growing conditions. Irrigation rates and different environmental conditions among locations have a significant impact on growth response of container-grown red maple cultivars.

Index words: container production, climate, cultivars, ornamental tree production, environmental conditions.

Species used in this study: red maple (*Acer rubrum* L.); Freeman red maple (*Acer* x *freemanii* E. Murray).

Significance to the Nursery Industry

Several field studies have been conducted in the Southeastern United States to determine performance of *Acer rubrum* and *A.* x *freemanii* cultivars. However, limited information regarding container production of red maple cultivars is available. The cultivars included in this study originated in USDA Hardiness Zones 3 through 6 within the native range, and also included selections from growers fields in Oregon, representing a broad cross-section of those in production nationwide. This study demonstrates that differences in temperature and substrate moisture levels (irrigation and rainfall) consequently impact total growth of red maple cultivars over a 2-year period in containers using typical production practices. Greater overall growth across cultivars at the Alabama locations, compared to the Georgia locations, is attributed to non-limiting irrigation at the Alabama locations during the greatest period of growth. Of the eight cultivars tested, 'Franksred' demonstrated the greatest adaptability to environmental conditions across all four locations. The new cultivars 'Celzam' and 'Olson' appear to be well adapted to container production in the southeastern United States, whereas 'Landsburg' was deemed not suitable.

Introduction

Red maple has a native range from Maine in the east, west to Texas, from southern Canada to Florida (5). National and regional surveys have shown red maple to be one of the most frequently planted trees (9, 25). Witte et al. (26) reported height and stem diameter increases for the first two years for a large number of field-grown red maple selections in McMinnville, TN. In Tifton, GA, Ruter (16) reported average height increase for several red maple selections over the first four years following transplanting to the field. Similar information can be deduced in reports from field growth data in central Alabama (20). Red maple selections evaluated under field conditions in Athens, GA (M.A. Dirr, personal communication) had growth similar to red maple selections evaluated at other Southeastern locations following transplant to the field (16, 20, 26).

Container production of shade and ornamental trees is increasingly important to the horticulture industry. Aboveground and pot-in-pot production methods are less expensive and more profitable than traditional field-grown methods (12). Container production of trees offers numerous advantages over traditional field production methods including year-around availability of plant material (3). Literature about container production of red maple cultivars is limited (2, 7, 23), with no reports of multiple cultivar by location studies. About 55 distinct cultivars of red maple are available in the nursery industry, many which have developed popularity under field production but have not been evaluated in container production. Climatological data give an indication of differences in rainfall, length of growing season, and maximum/minimum temperatures with USDA hardiness zones ranging from 8b to 6a across Georgia and Alabama (Table 1). Other studies have demonstrated effects of different climates on growth of field (18) and container-grown plants (11, 17, 22). Therefore the objective of this study was to evaluate the growth of eight container-grown red maple selections at four locations in Georgia and Alabama with different growing environmental conditions and irrigation practices.

Materials and Methods

Rooted cuttings and tissue cultured plantlets 5–25 cm (2–10 in) tall of *Acer rubrum* and *A.* x *freemanii*, were obtained from A. McGill & Son Nurseries, Fairview, OR; Bailey Nurseries, St. Paul, MN; Grassland Nursery, Muscle Shoals, AL;

[1]Received for publication on November 15, 1997; in revised form March 27, 1998.

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Table 1. Mean monthly maximum (T_{max}) and minimum (T_{min}) temperatures[z], monthly rainfall totals[y], and length of growing season by location June, 1995–December, 1996.

	Blairsville			Auburn			Muscle Shoals			Tifton		
1995												
Growing season	5/4–10/22			3/10–11/12			3/11–11/14			3/10–11/12		
Frostfree days	171			247			238			247		
Rainfall events	65			80			70			69		
1996												
Growing season	5/2–10/13			3/12–11/11			4/11–11/13			3/13–12/20		
Frostfree days	164			244			206			282		
Rainfall events	57			63			70			65		
Month	T_{max}[z]	T_{min}	Rain[y]	T_{max}	T_{min}	Rain	T_{max}	T_{min}	Rain	T_{max}	T_{min}	Rain
1995												
June	25.7	13.0	18.3	30.2	18.9	8.7	30.1	18.4	7.3	30.1	19.2	9.4
July	30.2	16.7	12.0	35.2	22.0	7.9	33.4	21.6	14.7	33.2	21.7	9.4
August	29.7	18.8	18.5	33.3	23.3	12.3	33.5	23.1	12.5	32.6	22.0	5.6
September	25.2	14.1	6.5	30.1	18.9	5.8	28.9	16.8	5.8	30.2	18.1	1.6
October	21.2	6.6	22.4	25.2	13.9	27.4	23.1	10.8	13.1	27.2	14.1	4.0
November	13.1	0.4	13.4	17.6	5.1	7.9	14.6	3.3	12.4	18.7	5.0	6.3
December	9.2	–2.4	6.9	13.6	2.6	11.8	10.7	1.7	12.1	15.1	2.7	3.8
Mean[z] & total[y]	22.1	9.6	98.0	26.4	14.9	81.8	24.9	13.7	77.9	26.7	14.7	40.1
1996												
January	5.5	–5.4	25.9	13.2	3.6	15.8	9.2	0.6	16.3	15.9	2.2	7.9
February	8.7	–4.6	10.5	16.0	5.3	8.7	10.9	1.5	8.8	17.8	3.9	7.3
March	11.7	–1.9	18.0	17.7	6.7	22.9	14.2	3.6	13.9	17.9	6.0	19.4
April	18.9	2.7	12.4	24.0	10.5	5.5	21.5	9.2	16.6	23.6	10.1	9.7
May	25.1	11.1	12.9	28.7	17.1	3.0	28.8	17.1	3.7	30.0	17.4	2.9
June	27.1	14.8	14.6	29.4	19.7	5.8	30.8	19.6	8.4	31.2	19.7	5.2
July	28.4	16.7	9.2	31.3	21.7	13.2	32.1	21.2	16.4	33.3	21.9	2.5
August	28.1	16.3	9.8	29.9	20.7	4.7	31.1	19.8	14.9	31.6	20.6	15.5
September	24.4	12.7	15.4	27.3	17.9	12.1	27.6	15.7	17.0	29.6	18.3	10.1
October	20.4	6.1	2.8	22.2	12.2	1.6	22.7	10.8	10.1	24.7	11.9	7.1
November	12.1	0.6	14.4	16.6	7.5	8.1	14.5	6.1	14.5	19.4	6.7	3.3
December	11.4	–1.0	16.0	15.2	6.2	12.0	13.1	4.7	26.7	17.4	4.8	9.5
Mean[z] & total[y]	18.5	5.7	161.8	22.5	12.4	113.4	21.4	10.8	167.3	24.4	12.0	100.4

[z]Temperature in C.

[y]Rainfall in cm.

and J. Frank Schmidt and Sons, Troutdale, OR, in April 1995. The trees were all transplanted on the same day in Auburn, AL to #3 (9.1 liter) containers in a pinebark:sand (6:1 by vol) substrate amended with 8.3 kg/m^{-3} of 17N–3P–10K (17–7–12) Osmocote (O.M. Scotts Co., Maryville, OH), 0.9 kg/m^{-3} Micromax (O.M. Scotts Co.), and 3.0 kg/m^{-3} dolomitic lime in May 1995. Trees were grown in full sun under standard nursery practices for one month in Auburn.

The trees were transported to four locations in the second week of June 1995. Locations were: Blairsville, GA 34°53'N × 83°58'W, elevation 577 m (1892 ft); Muscle Shoals, AL, 34°43'N × 87°37'W, elev. 157 m (516 ft); Auburn, AL 32°36'N × 85°29'W, elev. 216 m (709 ft); and Tifton, GA 31°27'N × 83°31'W, elev. 109 m (357 ft), in USDA hardiness zones 6b, 7a, 8a, and 8a, respectively (24). Trees were arranged at each location on landscape fabric covered beds in a randomized complete block design consisting of six blocks with three plants per replication of each cultivar placed pot to pot. All trees were pruned to a central leader the last week of July 1995. Trees were overhead irrigated, using standard production practices for each location, at 1.3 cm (0.5 in) per day in Blairsville and Tifton; and 3.8 cm (1.5 in) per day in Muscle Shoals and Auburn as needed in 1995 and 1996. Dormant trees were transplanted to #10 (38 liter) containers the second week of December 1995. Substrate for transplanting was prepared in Auburn for each location one day prior to use, receiving the same amendments as in 1995.

Average daily maximum and minimum air temperatures and rainfall were averaged for each month and location in 1995 and 1996 (Table 1). Trees were transported to a single location for harvest at the end of December 1996. Final stem diameter (15.2 cm (6 in) above the medium) and plant height were measured prior to dry weight measurements for each tree. Root:shoot ratios were determined as described by Harris (8) after roots (washed free of medium) and stems were oven dried at 60C (140F) for three days for dry weight measurements. All data were subjected to analysis of variance using SAS Version 6.03 (19). Mean separations were by Waller-Duncan K ratio *t*-tests. Differences were considered significant at $P = 0.05$.

Results and Discussion

Despite differences in temperature and moisture (irrigation and rainfall) among locations (Table 1), growth response across cultivars in Blairsville and Tifton was similar, with growth response in Muscle Shoals similar to Auburn (Tables 2–6). Number of rainfall events varied little across locations

Table 2. Height increase from Spring 1995 to December 1996 for eight red maple cultivars grown at four locations.[zyx]

Cultivar	Location			
	Blairsville	Auburn	Tifton	Muscle Shoals
October Glory	133.6DE[y]bc[x]	157.8Eb	118.6CDc	203.3BCa
Franksred (Red Sunset™)	166.9Ac	229.8Ab	175.9Ac	261.7Aa
Armstrong	153.4A–Dc	200.4BCb	151.3ABCc	276.8Aa
Fairview Flame	136.4CDEbc	147.1Eb	114.4Dc	201.4BCa
Celzam (Celebration™)	142.7B–Ec	218.7ABb	110.3Dd	256.3Aa
Autumn Flame	156.6ABCc	198.4CDb	138.9BCDc	223.0Ba
Landsburg (Firedance™)	129.8Ebc	146.6Eb	109.9Dc	196.9Ca
Olson (Northfire™)	163.2ABb	180.8Db	160.9ABb	261.4Aa

[z]Height increase (cm) determined by difference in initial height (6/95) and final height (12/96). Mean separations by Waller-Duncan K ratio *t* tests (n = 18) considered significant at the 0.05 level.

[y]Differences by cultivar at each location within columns in uppercase.

[x]Differences by location for each cultivar within rows in lowercase.

during the two growing seasons, however total rainfall was greater in Blairsville, Auburn, and Muscle Shoals, than Tifton in 1995 (22) (Table 1). Total rainfall was highest in Blairsville and Muscle Shoals, than Auburn and Tifton in 1996. In a related container study, we found the greatest growth for container-grown red maple cultivars occurred between May and July (Sibley et al., 1997; unpublished data). Martin et al. (10) found more than 67% of height growth occurred prior to June in the second year for container-grown red maple seedlings. The greater overall growth across cultivars at the Alabama locations, compared to the Georgia locations, is attributed to non-limiting irrigation at the Alabama locations during the greatest period of growth.

Across all cultivars tree height growth was highest for trees grown in Muscle Shoals (Table 2). Auburn trees had greater height growth than Tifton, with the exception of 'Olson' (Northfire™). Four cultivars were similar in height growth in Auburn and Blairsville.

Stem diameter increase was generally greater for the Alabama locations compared with the Georgia locations (Table 3). Stem diameter increase was the same for Blairsville and Tifton for all cultivars with the exception of 'Celzam' (Celebration™) and 'Landsburg' (Firedance™). Stem diameter increase was the same for Auburn and Muscle Shoals for all cultivars with the exception of 'Landsburg' and 'Franksred' (Red Sunset™). Based on the similarities from Blairsville to Tifton, and Muscle Shoals to Auburn, the overall differences in stem diameter increase are attributed to differences in irrigation and rainfall across locations more than differences in temperature. Others have found stem diameter growth increased as irrigation increased in container-grown *A. rubrum* seedlings (10). For most cultivars, differences in diameter growth in this study would be considered a marketable difference from a container production standpoint. Based on common practice in the nursery industry and the *American Standard for Nursery Stock* (1), for trees of a similar height, diameter increases are generally considered marketable in 0.6 cm (0.25 in) increments up to 5.1 cm (2 in).

'Celzam' exhibited the most root dry weight at each location (Table 4). Root dry weights ranged from 28.7 g (0.06 lb) for 'Landsburg' at Tifton to 450.0 g (0.99 lb) for 'Celzam' in Muscle Shoals. Irrigation rates as high as 400% replacement of net evaporation from a class A pan increased total root dry weight of red maple (10). However, one study showed high irrigation rates to reduce fibrous roots for red maple (15), while in another silver maple (*Acer saccharinum* L.) root growth was greatly reduced under flooded conditions (14). Therefore, greater irrigation and rainfall could explain increased root growth, yet reduced root:shoot ratios due to greater shoot growth at the Alabama locations compared to the Georgia locations (Table 6). Martin et al. (10) showed that seedling red maples grown in similar media and con-

Table 3. Stem diameter increase from Spring 95 to December 1996 for eight red maple cultivars grown at four locations.[zyx]

Cultivar	Location			
	Blairsville	Auburn	Tifton	Muscle Shoals
October Glory	16.0Bb	21.6BCa	14.0Bb	21.1Ba
Franksred (Red Sunset™)	20.5Ac	26.7Aa	20.6Ac	23.2ABb
Armstrong	17.3Bb	21.8BCa	15.5Bb	23.3ABa
Fairview Flame	16.8Bab	17.7Dab	14.5Bb	20.1Ba
Celzam (Celebration™)	16.7Bb	24.0ABa	14.0Bc	25.1Aa
Autumn Flame	19.3Ab	25.8Aa	19.1Ab	23.5ABa
Landsburg (Firedance™)	10.9Cb	11.0Eb	7.7Cc	13.9Ca
Olson (Northfire™)	16.3Bb	19.1CDab	16.3Bb	23.0ABa

[z]Stem Diameter increase (mm) determined by difference in initial diameter (6/95) and final diameter (12/96). Mean separations by Waller-Duncan K ratio *t* tests (n = 18) considered significant at the 0.05 level.

[y]Differences by cultivar at each location within columns in uppercase.

[x]Differences by location for each cultivar within rows in lowercase.

Table 4. Red maple cultivar root dry weight December 1996 at four locations.[zyx]

Cultivar	Location			
	Blairsville	Auburn	Tifton	Muscle Shoals
October Glory	138.0BCb	267.9Ba	171.8BCb	323.9Ba
Franksred (Red Sunset™)	145.3BCb	268.6Ba	211.3ABab	236.9BCa
Armstrong	139.1BCbc	228.9BCab	96.7Ec	255.0BCa
Fairview Flame	152.1Bab	121.9CDb	114.0CDEb	221.4BCa
Celzam (Celebration™)	233.9Ab	417.0Aa	241.1Ab	450.0Aa
Autumn Flame	134.4BCa	251.4Ba	163.9BCDa	208.7CDa
Landsburg (Firedance™)	69.6Dab	88.9Da	28.7Fb	104.1Da
Olson (Northfire™)	114.7Cab	200.6BCDab	99.2DEb	256.3BCa

[z]Root dry weight (g). Mean separations by Waller-Duncan K ratio *t* tests (n=18) considered significant at the 0.05 level.

[y]Differences by cultivar at each location within columns in uppercase.

[x]Differences by location for each cultivar within rows in lowercase.

Table 5. Red maple cultivar shoot dry weight for December 1996 at four locations.[zyx]

Cultivar	Location			
	Blairsville	Auburn	Tifton	Muscle Shoals
October Glory	246.4ABCb	503.5Aa	228.5ABb	411.6Aa
Franksred (Red Sunset™)	269.1Ac	582.0Aa	308.8Ac	478.4Ab
Armstrong	204.1BCb	434.4ABa	139.9Cb	477.7Aa
Fairview Flame	233.6ABCab	274.7BCab	149.5BCb	357.4ABa
Celzam (Celebration™)	226.6ABCb	545.2Aa	152.6BCb	525.6Aa
Autumn Flame	256.0ABb	571.5Aa	268.1Ab	364.4ABb
Landsburg (Firedance™)	108.9Db	188.8Ca	48.3Db	204.2Ba
Olson (Northfire™)	191.3Cb	417.8ABa	184.6BCb	396.0Aa

[z]Top dry weight (g). Mean separations by Waller-Duncan K ratio *t* tests (n=18) considered significant at the 0.05 level.

[y]Differences by cultivar at each location within columns in uppercase.

[x]Differences by location for each cultivar within rows in lowercase.

Table 6. Red maple cultivar root:shoot ratio December 1996 at four locations.[zyx]

Cultivar	Location			
	Blairsville	Auburn	Tifton	Muscle Shoals
October Glory	0.56CDEb	0.54Bb	0.75BCab	0.83Aa
Franksred (Red Sunset™)	0.54DEb	0.46Bb	0.69BCa	0.50Bb
Armstrong	0.68Ba	0.52Bb	0.68BCa	0.53Bb
Fairview Flame	0.65BCab	0.46Bb	0.89Ba	0.59Bab
Celzam (Celebration™)	1.05Ab	0.77Ac	1.53Aa	0.88Abc
Autumn Flame	0.53Eab	0.40Bb	0.60Ca	0.56Bab
Landsburg (Firedance™)	0.66BCa	0.46Ba	0.76BCa	0.50Ba
Olson (Northfire™)	0.63BCDab	0.44Bb	0.53Cab	0.64Ba

[z]Mean separations by Waller-Duncan K ratio *t* tests (n = 18) considered significant at the 0.05 level.

[y]Differences by cultivar at each location within columns in uppercase.

[x]Differences by location for each cultivar within rows in lowercase.

tainers under irrigation replacing net evaporation at 50%, 100%, 200%, and 400% had root dry weights of 193.4g, 258.7g, 321.2g, and 361.9g (0.43, 0.57, 0.71, and 0.80 lb), resp. Dry weights in this study indicate that root growth at the Georgia sites may have been limited by irrigation and rainfall during the second year of production (Table 4).

No differences were found in tissue dry weights by location for each cultivar collected from the late July 1995 pruning (data not shown). However, stem dry weights by cultivar differed considerably by the end of the study (Table 5). The highest stem dry weight was for 'Franksred' and 'Autumn Flame' grown in Auburn. Generally, trees at the Alabama locations had the highest stem dry weights across all cultivars (Table 5).

Much can be gained from this study regarding cultivar performance under dissimilar environmental conditions. Three cultivars: 'Celzam', 'Landsburg', and 'Olson' are new introductions and have not been included in container or field studies prior to this report. 'Franksred' demonstrated the greatest adaptability to the varied environmental conditions

across locations. For each location 'Franksred' had the greatest height and caliper growth, with the exception of caliper at one location (Table 3), pointing out why this selection is often included in container studies (6, 7, 21). 'Olson' and 'Celzam' appear to be well adapted to container production in growing conditions of the Southeast. Based on the results of this study, we can not recommend 'Landsburg' as a suitable choice for container producers in the Southeast. This Zone 3 selection (see Sibley et al. (21) for complete listing of origins of introduction for cultivars used in these and other studies) had the least height, caliper, and root growth for each of the four locations.

This study shows that differences in temperature and irrigation have a greater impact on growth of container-grown red maple cultivars by the end of the second year. In an earlier report no differences in first year tree height were found for 'October Glory' at three locations with dissimilar climates in Georgia and Alabama (22). Martin et al. (10) found height growth was unaffected by irrigation rate in the first growing season in container grown *A. rubrum* seedlings, but height and caliper growth increased as irrigation increased in the second year.

This study provides good information regarding the impact of a long growing season on the growth of container-grown trees. For example, although Tifton had 118 more frost free days (almost 4 months) than Blairsville, these days apparently did not contribute to a growth advantage for Tifton over Blairsville as might be expected with container-grown ornamental shrubs. With primary shoot extension occurring early in the growing season in Tifton, the extended growing season may have caused a depletion in reserves through extended maintenance respiration (4, 13). However, greater growth might have been realized from the longer growing season in Tifton, compared with Blairsville, if irrigation rates had replaced 100% of evapotranspiration, as opposed to 1.3 cm (0.5 in) per day.

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