Growth Periodicity for Container-Grown Red and Freeman Maple Cultivars in AHS Heat-Zone 8[1]

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Abstract

Growth patterns of seven red maple (*Acer rubrum* L.) and three Freeman maple (*Acer* x *freemanii* E. Murray) cultivars grown in containers in Alabama were evaluated using monthly destructive harvests. The effectiveness of a growth modeling technique not previously described is demonstrated using the data presented for both the Freeman maple (red maple x silver maple interspecific cross) and red maple categories. Freeman maple cultivars 'Armstrong', 'Celzam' (Celebration™), and 'Jeffersred' (Autumn Blaze™); and red maple cultivars 'Autumn Flame', 'Fairview Flame', 'Landsburg' (Firedance™), 'Franksred' (Red Sunset™), 'Olson' (Northfire™), 'Northwood', and 'October Glory®' were studied. Uniform liners of each cultivar were planted in 9.1-liter (#3) containers in March 1996. More than 75% of seasonal height and diameter growth was complete for most cultivars before mid-August, while only 25% of root growth had occurred by the end of August. The remaining 75% of root growth occurred from August through November. The greatest overall growth (based on height, diameter, and root growth increase) was for 'Autumn Flame' and 'October Glory®', both red maple cultivars; and Freeman maple cultivars 'Celzam' and 'Jeffersred'. The least overall growth (based on height, diameter, and root growth increase), was for red maple cultivars 'Northwood' and 'Landsburg'.

Index words: predicted growth curves, modeling, Gauss-Newton, dry mass, growth, leaf area, container tree production, cultivars.

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

Significance to the Nursery Industry

The differences seen in growth patterns and performance of red and Freeman maple cultivars in this short-duration study are similar to those observed in longer studies with similar cultivars, indicating that future growth in larger containers may be predicted based on intense and careful observation in one season of juvenile growth. Growth began for five cultivars in April, but not until May for the other five cultivars. Greater than 50% of the seasonal increase in height occurred in June for all cultivars, with more than 75% of height increase accounted for by the end of July for all cultivars. More than 75% of root growth occurred from the end of July through the end of October. Much can be gained from this study regarding cultivar performance under similar environmental conditions. 'Celzam', 'Landsburg', and 'Olson' are new introductions and have not been included in container or field studies focused on production prior to this report. 'Olson' and 'Celzam' appear to be well adapted to container production. Based on the results of this study, we can not recommend 'Landsburg' as a suitable choice for container production in AHS Heat-Zone 8.

Introduction

National and regional surveys have shown red maple to be one of the most frequently planted trees (13, 31). Red maple is often considered a good candidate for regional selection. New red maple cultivars appear almost annually, and there are about 55 distinct cultivars currently available in the nursery industry. Many of these cultivars have developed popularity under field production, but have not been evaluated in container production. Several field studies conducted in the southeastern United States have shown considerable variation in performance (i.e., growth, fall color, regional adaptability) among red maple cultivars (21, 23, 32); however, there is a lack of adequate information on growth rates during container production (5, 8, 17, 26). Container production of shade and landscape trees is increasingly important to the horticulture industry. Few studies have specifically investigated the growth periodicity of trees in container production systems (8, 9, 10, 18, 28).

The classic measures of yield for ornamental crops are total plant height, stem diameter, and canopy width (11, 28). Often tissue dry masses of various components are considered. Using single variables such as height or shoot length alone can lead to different conclusions than if dry masses alone are used. Moreover, time of harvest or measurement can have a pronounced effect upon the parameters selected to estimate growth. Consequently statistical differences may be transitory, depending on the time of observation.

Most phenotypic traits change throughout growth and development of individual plants, and rates of growth and development are highly variable. When growth comparisons are a function of plant size or developmental stage, as well as age, we broaden our understanding of phenotypic variation between plants (4).

Root elongation is usually possible over a wide range of temperatures. In woody plants native to the temperate zone, the minimal limiting temperature for root growth is rather low, at between 2 and 5C (35 and 40F) (14). Headley and Bassuk (10) reported root growth of red maple seedlings began about the time of bud break in upper New York, USA. Harris reported seedling red maple root growth began before shoot growth in a pot-in-pot study in Virginia (8). Others

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have shown shoot and root growth of red maple (6) was highly dependent on the temperature at which roots were grown. In general, root and shoot growth of red maple was similar in plants grown from 18 to 30C (64 to 86F), but 36C (97F) strongly inhibited stem growth, shoot and root dry masses, and leaf area development.

The objective of this study was to evaluate the growth of container-grown red and Freeman maple selections with monthly destructive harvests in AHS Heat-Zone 8, USDA Hardiness Zone 8a (1, 30). The cultivars included in this study represent a broad cross-section of those in production nationwide (25, 32).

Materials and Methods

Uniform liners (rooted cuttings or tissue cultured plantlets of similar age) obtained from commercial nurseries (A. McGill & Son Nurseries, Fairview, OR; Bailey Nurseries, Yamhill, OR; and J. Frank Schmidt and Sons, Troutdale, OR), were planted in March 1996 prior to budbreak in 9.1 liter (#3) containers in a pinebark:sand (6:1 by vol) substrate in Auburn, AL (32°36'N × 85°29'W, elev. 216 m, AHS Heat-Zone 8). Substrate was amended with 7.7 kg/cu m (13.0 lb/cu yd) of 23N–2P–7K (23–4–8 Scotts, Southern Formula, O.M. Scotts Co., Marysville, OH), 0.9 kg/cu m (1.5 lb/cu yd) Micromax (O.M. Scotts Co.), and 3.0 kg/cu m (5.0 lb/cu yd) dolomitic lime. Trees were grown in full sun with overhead irrigation supplied twice daily. Trees were arranged in a randomized complete block design consisting of 9 blocks with 5 plants of each cultivar placed 61 cm on center (450 total plants).

Growth parameters. Height and diameter were measured every 30 days, beginning March 28 through November 28, 1996. Height was measured from the substrate surface to the tip of the uppermost growing point; stem diameter at 5 cm (2 in) above the substrate. To determine total biomass gain over time, data were collected at the end of each month beginning March 28. Five replicates of each cultivar were harvested monthly. Each leaf was harvested and its projected leaf area (LA) determined by optical planimetry (leaves counted if >0.5 cm (0.2 in)) (Li-3000 leaf area meter, LiCor Inc., Lincoln, NE) for each tree prior to dry mass measurements. Stems, leaves, and roots (washed free of substrate) were bagged separately and oven dried at 60C (140F) for 3 days before dry mass and root:shoot ratio determinations (7, 11).

Data were subjected to analysis of variance, and when appropriate, regression analyses (22). Mean separations were by Waller-Duncan K ratio *T* tests. Differences were considered significant at $P = 0.05$.

Due to the exponential nature of height, diameter, and root dry mass, a least squares approach was used to analyze these data by estimating parameters of growth with the Gauss-Newton method of non-linear regression, fitting a sigmoidal response curve to data across time. A useful model and detailed procedures as outlined by Ingram (12) has been beneficial in analysis of data found to be sigmoidal. A sigmoidal equation:

$$\mathbf{G = [(x - z) / (l + \exp[- K(T - G_m)])] + z}$$

was used to fit the data, where G was the particular growth function under consideration, x = maximum observed level of the particular growth variable, z = baseline, or initial value of the growth variable, G_m = predicted midpoint of the season's growth (i.e., inflection point of the response curve), k = slope of the predicted response curve at G_m, and T = time, in days. From the calculated G_m, times corresponding to a 25%, 50%, and 75% growth increase (GT_{25}, GT_{50}, GT_{75},) of each parameter were estimated with the inverse function of the Gauss-Newton method of non-linear regression set to 0.25, 0.50, and 0.75 of maximum values for each cultivar independently.

Results and Discussion

Greater than 50% of the seasonal increase in height occurred in June for all cultivars, with more than 75% of height increase accounted for by the end of July for all cultivars (Table 1). The cultivars with the greatest height increase for the season were 'Autumn Flame', 'Fairview Flame', 'Franksred', 'October Glory®', 'Olson', 'Armstrong', 'Celzam', and 'Jeffersred'. The cultivar 'Northwood' had the least seasonal height increase but was not different from 'Fairview Flame', 'Landsburg', 'Olson', or 'Armstrong' (Table 1).

Stem diameter continued to increase after cessation of height growth. Greater than 50% of increase in diameter occurred during the eight weeks from mid-June to mid-August, with more than 75% of diameter increase accounted for by the middle of August for all cultivars (Table 2). Greatest diameter increases for the season were for red maple cultivars 'Autumn Flame', 'Fairview Flame', and 'October Glory®' and Freeman maple 'Jeffersred'. The cultivars 'Landsburg', 'Northwood', 'Olson', and 'Armstrong' had the smallest diameter increases during the season (Table 2).

The greatest overall growth (seasonal height increase + seasonal diameter increase, data not shown), was for 'Autumn Flame' and 'October Glory®', both red maple cultivars, followed by Freeman maple cultivars 'Celzam' and 'Jeffersred'. The least overall growth (when both height and diameter increase were considered), was for red maple cultivars 'Northwood' and 'Landsburg'.

Root growth differences were minimal through the first five harvests. Approximately 25% of the total season root growth had occurred by the end of August (Table 3). Once underway, root growth was steady through the end of the study, with approximately 25% of final root growth occurring in August, 25% in September, 25% in October, and 25% in November (Table 3). Greatest seasonal root dry mass increases were found for Freeman maple cultivars 'Jeffersred' and 'Celzam'; and red maple cultivars 'Autumn Flame', and 'October Glory®' (Table 3).

'Autumn Flame' had the greatest total number of leaves per tree on a monthly basis throughout the study, although other cultivars were similar in early April through May, and late September through October (data not shown). Total leaf area (LA) for 'Autumn Flame' was also greatest in most months, although the Freeman maple selections and 'October Glory®' were similar in many months (Table 4). Mean leaf areas (MLA) (Table 5) were similar to previous studies when fully expanded, mature leaves, typical for each species were considered (24). MLA's for mature leaves were greater for the Freeman maple selections than for the red maples, which would appear to contradict data presented in Table 5. However, MLA's (Table 5) were compiled from all expanding leaves >0.5 cm (>0.2 in). For example, 'Northwood', had very little new growth beyond the initial flush of growth, such that smaller, expanding leaves common to those culti-

Table 1. Seasonal height progression for container-grown red maple cultivars.

Genotype	Day of 25%[z] increase	Day of 50% increase	Day of 75% increase	Final[y] height	Season[y] increase
Red maples					
Autumn Flame	65	86	106	111.3ab	103.1ab
Fairview Flame	54	79	104	107.8ab	88.3abc
Franksred	80	100	120	101.7ab	97.1ab
Landsburg	75	93	111	85.2b	76.5bc
Northwood	52	74	96	83.7b	60.7c
October Glory®	75	94	111	118.6ab	112.3a
Olson	66	86	106	104.3ab	89.6abc
Freeman maples					
Armstrong	62	84	105	98.6ab	86.3abc
Celzam	67	90	113	117.5ab	111.6a
Jeffersred	70	89	109	123.8a	109.3a

[z]A predicted growth midpoint (G_m) equation was determined by least squares approach Gauss-Newton method of non-linear regression from which predicted days corresponding to 25%, 50%, and 75% of maximum growth attained was estimated with an inverse function of the Gauss-Newton method of non-linear regression set to 0.25, 0.50, 0.75 of maximum values for each cultivar independently.

[y]Height (in cm, substrate surface to uppermost bud) data compiled from growth studies in 1996, initiated 3/28/96. Mean separations by Waller-Duncan K ratio *T* tests (n = 5), considered significant at $P \leq 0.05$.

Table 2. Seasonal stem diameter progression for container-grown red maple cultivars.

Genotype	Day of 25%[z] increase	Day of 50% increase	Day of 75% increase	Final[y] height	Season[y] increase
Red maples					
Autumn Flame	87	112	137	23.4a	21.5a
Fairview Flame	76	104	133	20.5ab	18.1abc
Franksred	93	115	138	15.6c	14.4cde
Landsburg	85	109	132	10.4d	7.4g
Northwood	77	97	117	14.8cd	9.6fg
October Glory®	89	114	139	20.7ab	19.4ab
Olson	87	113	140	16.9bc	13.7def
Freeman maples					
Armstrong	83	117	133	17.2bc	12.5ef
Celzam	82	108	135	19.2abc	16.2b–e
Jeffersred	84	107	132	19.1abc	17.1a–d

[z]A predicted growth midpoint (G_m) equation was determined by least squares approach Gauss-Newton method of non-linear regression from which predicted days corresponding to 25%, 50%, and 75% of maximum growth attained was estimated with an inverse function of the Gauss-Newton method of non-linear regression set to 0.25, 0.50, 0.75 of maximum values for each cultivar independently.

[y]Diameter (in mm, taken 5 cm above substrate) data compiled from growth studies in 1996, initiated 3/28/96. Mean separations by Waller-Duncan K ratio *T* tests (n = 5), considered significant at $P \leq 0.05$.

Table 3. Seasonal root growth progression for container-grown red maple cultivars.

Genotype	Day of 25%[z] increase	Day of 50% increase	Day of 75% increase	Final[y] height	Season[y] increase
Red maples					
Autumn Flame	142	181	211	125.9ab	125.3ab
Fairview Flame	124	161	196	90.3c	89.8c
Franksred	124	155	185	51.4d	51.2d
Landsburg	132	161	184	14.5e	14.2e
Northwood	115	159	197	75.1cd	70.2cd
October Glory®	137	169	202	100.3bc	100.0bc
Olson	137	169	202	67.6cd	67.3cd
Freeman maples					
Armstrong	144	182	210	45.1de	43.5de
Celzam	125	160	192	138.4a	138.0a
Jeffersred	135	171	203	141.6a	141.5a

[z]A predicted growth midpoint (G_m) equation was determined by least squares approach Gauss-Newton method of non-linear regression from which predicted days corresponding to 25%, 50%, and 75% of maximum growth attained was estimated with an inverse function of the Gauss-Newton method of non-linear regression set to 0.25, 0.50, 0.75 of maximum values for each cultivar independently.

[y]Root dry mass (in g) data compiled from growth studies initiated 3/28/96. Mean separations by Waller-Duncan K ratio *T* tests (n = 5), considered significant at $P \leq 0.05$.

Table 4. **Total leaf area (cm^2) for container-grown red maple cultivars.**

Genotype	April[z]	May	June	July	August	September	October
Red maples							
Autumn Flame	95.6b	505.5b–e	3838.5a	6107.0abc	7431.5ab	6469.9ab	6965.9a
Fairview Flame	152.7a	958.0abc	3269.9ab	5774.8a–d	5847.1bc	4410.9c	4156.4bc
Franksred	41.0bc	218.0e	1489.2cd	4726.0cde	5105.9cd	4767.6c	4000.4bcd
Landsburg	0.0c	207.1e	717.3d	903.2f	1412.8e	612.5e	440.9e
Northwood	0.0c	793.9a–d	2052.8bc	3120.3e	4612.2cd	1749.1de	1030.2e
October Glory®	84.3b	399.1cde	3758.6a	7370.5a	7790.2a	6767.4a	5488.8ab
Olson	0.0c	1016.2ab	1722.9cd	4120.1de	4622.7cd	5597.0abc	2235.0de
Freeman maples							
Armstrong	67.9b	354.7de	2250.9bc	4133.6de	3398.8d	2505.0d	2305.3cde
Celzam	0.0c	1254.2a	4273.4a	5288.6bcd	6405.1abc	4944.9bc	3364.1cd
Jeffersred	88.9b	704.5a–e	3878.8a	6859.1ab	7392.2ab	7055.8a	5371.0ab

[z]Data compiled from growth studies initiated 3/28/96. Projected leaf area (LA) determined for harvested leaves >0.5 cm on a monthly basis with a leaf area meter (Li-3000, LiCor Inc.). Mean separations by Waller-Duncan K ratio *T* tests (n = 5), considered significant at $P \leq 0.05$. Means for months with no difference not shown.

vars showing recurrent or episodic growth were not often available for consideration in the MLA for 'Northwood' (Tables 1 and 5).

As has been reported by others (20), root:shoot (stem) ratios in this study generally decreased from the initial harvest to mid-summer (Table 6), and then began to increase again. Lowest root:shoot ratios occurred in June for seven cultivars, and in July for three cultivars, during the period of greatest top growth. As root growth increased (Table 3), root:shoot ratios increased (Table 6), reflecting the allocation of carbon assimilation to roots over shoots later in the season. Top dry masses (dry mass of all above-ground biomass) increased from March through September for most cultivars (Table 7), the primary exceptions were those cultivars with early leaf senescence; 'Landsburg', 'Northwood' and 'Armstrong'. Top dry masses were generally greatest for 'Autumn Flame', 'October Glory®' and 'Jeffersred', although some cultivars were similar in various months.

The differences seen in growth patterns and performance in this short-duration study are similar to those observed in longer studies with similar cultivars (5, 20), indicating that future growth in larger containers may be predicted based on intense and careful observation in one season of juvenile growth (29). The performance of 'Autumn Flame' and 'October Glory®' in this study could be attributed to the greater amount of photosynthetic potential as revealed in total leaf area, and low MLA's (Table 4; Table 5). Plant LA is directly related to light interception, transpiration, and photosynthesis, and is considered the most important single determinant of plant productivity (16).

Results of this study emphasize the impact of a long growing season on the growth of container-grown trees. Considerable gains in dry matter production may be obtained by selecting for early budburst and by encouraging rapid spring development. Early budburst is associated with a small chilling requirement, a small thermal time to budburst or both; the two are genetically variable within a species (15). However, early budburst involves an increased risk of early frost damage; for each region, an optimum date of budburst must be estimated (3). In our study, means for height, parameters related to leaf production, and relative growth rates (11) indicated growth began for five cultivars in April, but not until May for the other five cultivars (Table 1; Tables 4–5). Martin et al. (17) found more than 67% of height growth occurred before June in the second year for container-grown red maple seedlings. Height growth was complete for all

Table 5. **Seasonal mean leaf area for container-grown red maple cultivars.**

Genotype	April[z]	May	June	July	August	September	October
Red maples							
Autumn Flame	6.0b	8.6d	10.1c	10.9e	8.3e	9.9c	14.8d
Fairview Flame	16.7a	19.2bc	13.3bc	12.4de	8.9de	11.5c	11.8de
Franksred	7.7b	7.4d	11.1c	16.2cde	10.6cde	8.1c	10.3de
Landsburg	0.0c	7.9d	17.8b	21.1bc	12.8cd	23.4b	7.8e
Northwood	0.0c	25.7ab	25.3a	28.5a	35.2a	33.9a	45.3a
October Glory®	7.3b	8.2d	16.8b	18.7bcd	12.9c	11.3c	15.5d
Olson	0.0c	15.9cd	10.9c	13.4de	6.9e	10.2c	14.8d
Freeman maples							
Armstrong	5.8b	7.6d	10.4c	9.7e	7.1e	10.0c	16.8d
Celzam	0.0c	29.8a	27.5a	24.7ab	24.6b	31.6a	36.6b
Jeffersred	10.9ab	30.5a	24.3a	23.8ab	14.1c	20.0b	27.0c

[z]Data compiled from growth studies initiated 3/28/96. MLA determined from total projected leaf area (LA) / total harvested leaves >0.5 cm, on a monthly basis for each cultivar on an independent basis. Mean separations by Waller-Duncan K ratio *T* tests (n = 5), considered significant at $P \leq 0.05$. Means for months with no difference not shown.

Table 6. **Root:shoot ratio for container-grown red maple cultivars.**

Genotype	March[z]	April	May	June	July	August	September	October	November
Red maples									
Autumn Flame	2.0a	2.0ab	1.1bc	0.4a	0.5de	0.6de	0.7b	0.7de	0.9b
Fairview Flame	0.9b	1.3cd	0.8bcd	0.5a	0.5cde	0.7d	0.7b	0.8cd	0.8bc
Franksred	2.4b	2.5a	1.9a	0.5a	0.5cde	0.6de	0.6bc	0.8cde	0.8bc
Landsburg	0.6b	0.9d	0.9bcd	1.2a	0.3f	0.6de	0.4c	0.7de	0.7cd
Northwood	1.1b	1.4bcd	0.9bcd	1.1a	0.7b	0.9bc	0.9a	1.5a	1.5a
October Glory®	7.7a	2.6a	1.2b	0.5a	0.6bcd	0.7cd	0.7b	0.7de	0.9b
Olson	1.1b	0.8d	0.9bcd	0.4a	0.4ef	0.5ef	0.5c	0.6de	0.6d
Freeman maples									
Armstrong	0.5b	1.0cd	0.5d	0.3a	0.4ef	0.4f	0.5c	0.5e	0.6d
Celzam	1.4b	1.1cd	0.8cd	0.8a	0.9a	1.1a	0.9a	1.0c	1.4a
Jeffersred	1.1b	1.6bc	0.9bcd	0.5a	0.7bc	0.9b	1.1a	1.3b	1.3a

[z]Data compiled from growth studies in 1996, initiated 3/28/96. Mean separations by Waller-Duncan K ratio *T* tests (n = 5), considered significant at $P \leq 0.05$. Means for months with no difference not shown. Root:shoot ratio = root dry mass / shoot dry mass.

cultivars in our study by the end of August, with the exception of 'Northwood', which did not show height increase after the end of July (Table 1).

Diameter growth, while different across cultivars (Table 2), was not great enough to confer a marketable advantage to any cultivar from a container production standpoint. Based on common practice in the nursery industry and the *American Standard for Nursery Stock* (2), for trees of a similar height, diameter increases are generally considered marketable in 6.4 mm (0.25 in) increments up to 51 mm (2.0 in). Diameter increases were similar to those reported from previous container studies with red maple (17, 26).

While more than 75% of height and diameter growth for the season was complete for most cultivars before mid-August, only 25% of the final root growth had occurred by the end of August (Table 3). The functional balance between roots and shoots is normally perturbed by periodicity in the activity of the shoots during a season (8), and by short-term changes in the environment (3). Current assimilates are usually used preferentially by the shoots during their elongation, and by the roots in the autumn, after shoot elongation has ceased (20). Also during the late summer and autumn carbohydrate reserves are stored in the stems and thick roots and are important for rapid regrowth in the spring (3, 27). Headley and Bassuk (10) reported root growth of *Acer rubrum* seedlings began about the time of bud break in a field study in upper New York, USA. Root growth increased rapidly in late April and early May when soil temperature remained above 8–10C and ceased in the fall when soil temperature fell below 4–5C. Root growth began when temperatures were around 10C and cessation of root growth occurred as substrate temperatures fell to about 7C in the fall in a pot-in-pot study in Virginia (8).

Much can be gained from this study regarding cultivar performance under similar environmental conditions. Three cultivars: 'Celzam', 'Landsburg', and 'Olson' are new introductions and have not been included in container or field studies focused on production prior to this report. 'Olson' and 'Celzam' appear to be well adapted to container production. Based on the results of this study, we cannot recommend 'Landsburg' as a suitable choice for container production in AHS Heat-Zone 8. This AHS Heat-Zone 4, USDA Hardiness Zone 3 selection (Sibley et al., (25) lists origins of introduction for cultivars in these and other studies) had the least height, caliper, and root growth at each observation (Tables 1–3).

Table 7. **Top dry mass (g) for container-grown red maple cultivars.**

Genotype	March[z]	April	May	June	July	August	September	October	November
Red maples									
Autumn Flame	0.25cd	0.64de	4.44cde	36.18a	75.27ab	142.90a	131.81ab	182.75a	140.05a
Fairview Flame	0.66c	1.52c	9.13abc	36.84a	80.36ab	109.12abc	124.19abc	113.34bc	110.14ab
Franksred	0.09d	0.30e	2.00e	12.02b	58.47bc	74.86cd	93.61bcd	91.79bcd	65.50d
Landsburg	0.55cd	0.60de	2.44e	7.49b	9.63d	25.67e	15.02e	31.47d	21.30e
Northwood	4.53a	3.26a	13.79a	34.74a	58.96bc	101.54a–d	66.74d	55.40cd	52.02de
October Glory®	0.07d	0.55de	3.06de	31.19a	95.10a	125.05ab	137.36a	112.00bc	115.10ab
Olson	0.40cd	0.57de	7.77bcd	14.71b	52.16c	89.04bcd	150.39a	96.32bc	110.52ab
Freeman maples									
Armstrong	3.16b	2.67b	6.06cde	30.36a	59.54bc	65.89de	63.29d	88.31bcd	73.77cd
Celzam	0.36cd	0.56de	11.44ab	45.25a	94.63a	93.42bcd	90.64cd	67.94cd	100.61bc
Jeffersred	0.18cd	0.78d	5.86cde	37.07a	89.69a	120.87ab	135.93a	132.25ab	107.22b

[z]Data compiled from growth studies in 1996, initiated 3/28/96. Mean separations by Waller-Duncan K ratio *T* tests (n = 5), considered significant at $P \leq 0.05$. Means for months with no difference not shown. TDW = stem dry mass + leaf dry mass.

When asked to rate projects at public institutions, research, and demonstration stations, growers rank cultivar trials at the top of the list (19). Growers are aware that cultivars have had a profound influence on the horticulture industry, and they want to be first in line when something new appears. This information is beneficial for southern growers selling a finished product to homeowners or shifting up to larger containers. Growth rates for newer introductions 'Landsburg' and 'Northwood' were poor in this study, whereas, growth rates during production for 'Celzam' and 'Olson' look promising. However, longer-term evaluations in field studies or urban landscapes to evaluate fall color, limb and scaffold strength, frost cracking, and pest resistance are necessary to present a complete picture of the desirability of newer introductions.

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