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Gas Exchange Rates for Selected Red Maple Cultivars Grown in Alabama[1]

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Abstract

The objective of this study was to develop a rapid screening technique to characterize selected red maple (*Acer rubrum* L.) cultivars based on their gas exchange capacities. Evaluations were conducted in Alabama under ambient conditions on an established,irrigated field trial. In preliminary evaluations 9 red maple cultivars ('Autumn Flame', 'Fairview Flame', 'Franksred', 'Karpick', 'Northwood', 'October Glory', 'Redskin', 'Schlesingeri', and 'Tilford') and 3 Freeman maple (*Acer* x *freemanii* E. Murray) selections ('Autumn Blaze', 'Morgan', and 'Scarsen') were observed for differences in net photosynthesis (Pn), transpiration (E), and stomatal conductance (Cs). Based on these results, 4 cultivars of *A. rubrum* were selected and evaluated intensively over 2 years. Throughout the study, growth rates for the 4 selections failed to correspond with gas exchange observations.

Index words: tissue culture, growth, photosynthesis, CO_2 assimilation, transpiration, stomatal conductance, respiration, water use efficiency.

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

Significance to the Nursery Industry

The gas exchange capacities of 12 red maple (*Acer rubrum* L.) cultivars were measured. Evaluations were conducted under ambient conditions on an established field trial equipped with drip irrigation. Preliminary evaluations indicated that 9 red maple cultivars and 3 Freeman maple (*Acer* x *freemanii* E. Murray) selections differed in net photosynthesis (Pn), transpiration (E), and stomatal conductance (Cs). Based on these results, 4 cultivars of *A. rubrum* were selected for further evaluation. Throughout the study, growth rates for these 4 selections failed to correspond with gas exchange rates.

Our work determined that differences in performance of the red maple cultivars in this study could not be determined by their gas exchange capacities. Continuing studies in various components of gas exchange and environmental conditions affecting these components may reveal factors limiting growth for individual cultivars. However, cultivar evaluations by field performance with conventional methods remain essential.

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Introduction

Several studies have been conducted in an effort to link gas exchange and growth in *Acer* species (2, 5, 7). Studies have shown great variability among red maple seedlings collected from 49 locations across their native range, extending throughout the eastern United States and Canada (10). However, limited work has been reported on the relationship of growth and gas exchange capacities of red maple cultivars grown in a similar environment in the Southeastern United States. Differences in performance (1, 9) and gas exchange capacities (8) of red maple cultivars in the Southeastern United States have been reported. Correlation of gas exchange capacities to field performance might identify climatic zones or microclimates in which a new selection would perform best without lengthy field evaluations. Our objective was to develop a rapid screening technique to characterize selected red maple cultivars based on their gas exchange capacities.

Materials and Methods

Microplantlets of 9 red maples (*Acer rubrum*) and 3 Freeman red maples (*A.* x *freemanii*) along with a group of seedling red maples (cultivars listed in Table 1) were obtained from a commercial nursery (Microplant, Fairview, OR) in March 1988. Trees were transplanted into 2.8 liter (#1) pots in an amended 6:1 (by vol) pinebark:sand medium and grown in a double layered polyhouse for 3 months, then outdoors under overhead irrigation for the remainder of the growing season. In 1989, trees were transplanted to 9.5 liter (#3) containers for another 12 months. Trees ranged in height from 1.2 to 1.5 m (4 to 5 ft) when transplanted in March 1990 into a Cecil gravelly sandy loam soil at the Piedmont Substation, Camp Hill, AL (lat. 32° 83' N, long. 85° 65' W). Trees were planted on a 9.1 × 10.7 m (30 × 35 ft) spacing in a randomized complete block design with 2 plants of each cultivar in 5 replications. Drip irrigation was supplied to each tree based on 100% replacement of net evaporation from a class A pan. Trees were fertilized with 0.21 kg/cm of diameter (caliper) of nitrogen (N), phosphorus (P), and potassium (K) as 13N–5.6P–10.8K (13–13–13) at 30.5 cm above ground level (1 lb/1 in at 1 ft), at planting and annually in March prior to bud break.

In June 1992, gas exchange evaluations consisting of net photosynthesis (Pn), transpiration (E), and stomatal conductance (Cs) were determined using a portable photosynthesis system (Model LI-6250, LI-COR Inc., Lincoln, NE) in a closed mode (6), allowing 12.3 cm^2 of a leaf to decrease the CO_2 concentration in a 1-liter chamber over a 20-second period. Photosynthetically active radiation (PAR) levels were monitored with a quantum sensor (Model LI-190, LI-COR, Lincoln, NE) attached to the plexiglass chamber. Gas exchange measurements were made on 3 leaves on each of 10 trees for each cultivar. Measurements were made non-destructively on attached, mature leaves growing in full sun at the mid-point of current seasons' growth and tree canopy. Assimilation rates were observed over a 45-minute period within each replication with CO_2 concentrations ranging from 320 to 390 mg $liter^{-1}$ at leaf temperatures of approximately 32C. Measurements were taken from 8:00 AM until 2:00 PM CST at an average PAR level of 1474 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$. Water use efficiency (WUE) was calculated as Pn/E derived from simultaneous measurements. Methods for measurement of CO_2 exchange rate followed Jurik (3).

Following the June 1992 evaluations, selections were made to narrow the pool of cultivars allowing more data to be collected. In making selections, the *A.* x *freemanii* cultivars ('Autumn Blaze', 'Morgan', and 'Scarsen') were omitted. *A. rubrum* cultivars 'Northwood', 'Schlesingeri', 'Franksred', and 'October Glory' were selected for closer evaluation. This restricted list was based on high rates of Pn for 'Northwood' and 'Schlesingeri' and low rates of Pn for 'Franksred' and 'October Glory' among the *A. rubrum* cultivars in the June 1992 evaluations. This more intensive testing involved making additional observations in September 1992, June 1993, and August 1993. Materials and methods for these evaluations followed those established in the initial evaluations.

Dark respiration rates (R_d) were determined on three consecutive nights between 10:00 PM and 2:00 AM CST in July and August 1993. These evaluations were made as described for Pn rates, data being transformed from negative to positive numbers. Measurements were made under full moon light with the only supplemental light from the diode on the LI-COR monitor.

Data were subjected to analyses of variance. Mean separations were determined by Duncan's Multiple Range Test, $P = 0.05$.

Table 1. Initial gas exchange rates[z] for select red maple cultivars in the Southeastern United States.[y]

Cultivar	Pn ($\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$)	Cs ($cm{\cdot}s^{-1}$)	E ($mol{\cdot}m^{-2}{\cdot}s^{-1}$)	WUE (Pn/E)
Autumn Blaze[w]	11.6abcd[x]	0.410c	3.52b	3.75ab
Autumn Flame	11.3abcd	0.454bc	3.79b	3.39ab
Fairview Flame	11.2abcd	0.358c	3.35b	4.09a
Franksred	10.4bcd	0.464bc	3.50b	3.16ab
Karpick	11.9abc	0.471bc	3.95b	3.34ab
Morgan[w]	13.3ab	0.646a	5.55a	2.84b
Northwood	14.4a	0.602ab	5.29a	3.27ab
October Glory	9.6c	0.401c	3.07b	2.73b
Redskin	8.5d	0.424c	3.56b	2.71b
Scarsen[w]	11.9abc	0.444bc	3.84b	3.47ab
Schlesingeri	12.0abc	0.504abc	4.31ab	2.85b
Tilford	9.0cd	0.358c	3.22b	3.22ab

[z]Pn = net photosynthesis, Cs = stomatal conductance, E = transpiration, and WUE = water use efficiency (calculated as Pn/E).

[y]Evaluations made in June 1992.

[x]Mean separation within columns by Duncan's Multiple Range Test, $P = 0.05$.

[w]Freeman maple (*Acer* x *freemanii*).

Results and Discussion

Jurik (3) demonstrated that the CO_2 exchange rate of sugar maple (*A. saccharum*) leaves measured at light saturation increased to a maximum near the completion of leaf expansion in early June, was constant until mid-September, and then declined rapidly until leaf death. In June 1992, 'Northwood' and 'Morgan' showed a significantly higher Pn rate than 'October Glory', 'Redskin', and 'Tilford' (Table 1). The stomatal conductance (Cs) for June 1992 evaluations of 'Morgan' and 'Northwood' was significantly greater than that for 'Redskin', 'Autumn Blaze', 'October Glory', 'Fairview Flame' and 'Tilford'. Leaf transpiration (E) followed a similar trend to Cs for most cultivars, with 'Morgan' and 'Northwood' again showing the highest rates (Table 1).

In 1992, the highest Pn rates for *A. rubrum* selections were observed on trees reported to have the slowest growth rates (8). The overall growth for these cultivars was good at this location. Final mean heights through December 1993 were 404 cm (13.3 ft), 340 cm (11.2 ft), 436 cm (14.4 ft), and 366 cm (12.0 ft) for 'Franksred', 'Northwood', 'October Glory', and 'Schlesingeri', respectively (9). In this test no clear relationship appeared between Pn and growth for these red maple selections. Others (2, 4, 8) have failed to link aboveground growth rates and CO_2 assimilation rates. In the initial study, 'Fairview Flame' showed significantly greater WUE than 'Morgan', 'October Glory', 'Redskin', and 'Schlesingeri' (Table 1). There were no differences in WUE among the cultivars evaluated in 1993.

There were no consistently well-defined trends in the Pn rates (Table 2) between early summer and late summer of 1992 and 1993. Net photosynthesis increased from early summer to late summer for 'October Glory' and 'Franksred' in 1992, but the increase from early summer to late summer was not significant in 1993. Differences were not significant from early summer to late summer in 1992 or 1993 for 'Northwood' and 'Schlesingeri'. The rate of Pn often varies over time and from leaf to leaf, even within clones of a species, as previously noticed by Kozlowski et al. (4). Net photosynthesis rates for individual leaves will increase if adjacent leaves are removed or the root system is reduced in size (4). A container study comparing root regeneration and root dry weight of 'Northwood' and 'October Glory' reported

Table 2. **Net photosynthesis rates for four selections of *Acer rubrum* in a field study with trickle irrigation.**[z]

Cultivar	Net photosynthesis (μmol·m^{-2}·s^{-1}) 1992 June		1992 September		1993 June		1993 August	
Franksred	10.4bc	B	17.0ab	A	17.0b	A	15.9a	A
Northwood	14.4a	AB	12.9c	B	18.2ab	A	15.6a	AB
October Glory	8.5c	B	17.4a	A	14.7c	A	17.3a	A
Schlesingeri	12.0ab	B	15.7b	AB	19.9a	A	20.6a	A

[z]Mean separation within columns (lowercase) and rows by year (uppercase) by Duncan's Multiple Range Test, $P = 0.05$.

Table 3. **Leaf transpiration rates for four selections of *Acer rubrum* in a field study with trickle irrigation.**[z]

Cultivar	Transpiration (mol·m^{-2}·s^{-1}) 1992 June		1992 September		1993 June		1993 August	
Franksred	3.50b	C	4.65a	B	6.35b	A	7.21a	A
Northwood	5.29a	B	4.42a	B	7.52a	A	7.46a	A
October Glory	3.07b	C	4.85a	BC	5.57b	B	8.59a	A
Schlesingeri	4.31ab	B	4.79a	B	7.94a	A	10.18a	A

[z]Mean separation within columns (lowercase) and rows by year (uppercase) by Duncan's Multiple Range Test, $P = 0.05$.

Table 4. **Stomatal conductance for four selections of *Acer rubrum* in a field study with trickle irrigation.**[z]

Cultivar	Stomatal conductance cm·s^{-1} 1992 June		1992 September		1993 June		1993 August	
Franksred	0.46ab	B	0.70ab	AB	0.57ab	AB	0.96a	A
Northwood	0.60a	B	0.59c	B	0.69a	AB	1.04a	A
October Glory	0.40b	B	0.76a	AB	0.50b	B	1.13a	A
Schlesingeri	0.50ab	B	0.65bc	B	0.72a	B	1.68a	A

[z]Mean separation within columns (lowercase) and rows by year (uppercase) by Duncan's Multiple Range Test, $P = 0.05$.

differences in root performance between the 2 cultivars (1). 'October Glory' had 5 times greater root regeneration and 3 times greater root dry weights than 'Northwood'. In our field study the root system of 'Northwood' appeared to be weak; this weakness may partially explain its high Pn rate. Pressure applied to the trunks of 'Northwood' trees indicated a flexibility not evident in the other cultivars.

Leaf transpiration (E) rates increased from early summer 1992 to early summer 1993, and from late summer 1992 to late summer 1993 for all cultivars (Table 3). Stomatal conductance was greater for all cultivars in late summer 1993 than early summer 1992 (Table 4).

There were no differences in dark respiration rates (R_d) within a cultivar from night to night during July and August 1993, therefore data were pooled for each cultivar over time. Differences in mean R_d between cultivars in μmol·m^{-2}·s^{-1}, followed by Duncan's Multiple Range Test placement were: 1.478 a, 0.919 b, 1.454 a, and 1.166 ab, for 'Franksred', 'Northwood', 'October Glory', and 'Schlesingeri', respectively. Although dark respiration can be considered expensive to growth (4), R_d for 'Franksred' and 'October Glory', had a tendency to exceed the R_d found on 'Northwood', but have had greater growth than 'Northwood' in this study (9).

For the study presented here there was not a positive relationship between previously reported growth rates and gas exchange on the red maple selections evaluated. Our work determined that gas exchange measurements could identify differences among cultivars, but such differences are not reliable predictors of growth performance. The results of this study provide an indication of the gas exchange rates that could be expected in future work in this area for these cultivars. However, cultivar evaluations by field performance with conventional methods remain essential.

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