ANATOMY AND MORPHOLOGY OF SELECT RED MAPLE CULTIVARS

by Jeff L. Sibley, D. Joseph Eakes, Charles H. Gilliam, Gary J. Keever, William A. Dozier, Jr., and Curt M. Peterson

Abstract. This study was conducted to compare and define foliage features of select red maple and red maple hybrid cultivars under similar environmental conditions. Nine red maple (*Acer rubrum*) cultivars, three Freeman maple (*Acer x freemanii*) cultivars, and a red maple seedling selection were evaluated in a field study for differences in average leaf area, petiole length, stomatal density, foliar nitrogen (N) content, and chlorophyll content. Leaves of the three *A.* x *freemanii* cultivars were the largest. Leaves of *A. rubrum* 'Autumn Flame' were the smallest. 'Autumn Blaze' had the highest stomatal density. Leaf photographs of each cultivar are included.

In recent years, arborists, horticulturists, and nurserymen, prompted by an increased emphasis on tree plantings in cities and residential districts, have accelerated the selection and introduction of species and cultivars new to the landscape industry. Red maple (*Acer rubrum*), a commonly used landscape tree, is among the most frequently occurring tree in municipalities across the United States (9). *A. rubrum* has a native range extending from southern Canada to southern Florida, and from Maine in the east to Minnesota and Texas in the west (2). In the past, seedling red maples have been planted with expectations of rapid growth, attractive canopy form, and excellent red fall color. However, great variability in these characteristics exists among red maples from seedling sources.

The most notable red maple seedling study to date began in 1972 with the objective to determine the degree of genetic variation within the species (13). In this study seedlings were collected from over 70 locations across their native range and grown to maturity in Delaware, OH to examine seedling variation and to identify superior seedlings. Variability among seedlings has been the major source for development of marketable selections of red maple (12), resulting in more than 48 distinct red maple cultivars. The popularity of cultivars is due to their uniformity in a particular form, unique foliage, summer or fall leaf color, or some other landscape feature selected from seedling variants.

A trend in production and use of cultivars necessitates developing means of distinguishing characteristics by which cultivars can be readily separated from one another. Few of these characteristics have been catalogued to any degree in the literature. A number of studies have reported differences in red maple cultivars in terms of growth and fall color (5), wound response (6), shade density (7), and cold hardiness (4,15). Wandell (14) gave general descriptions of ten *A. rubrum* and four *A.* x *freemanii* cultivars but these were largely individual and not comparative. He further stated that 'Franksred' (Red Sunset™) is considered the standard for red maple cultivars. As pointed out by Dirr and Lindstrom (4) the opportunity to evaluate related trees in a single location is a seldom available luxury. Often the only observational data available have been collected under different growing conditions. Such observations are difficult or impossible to compare and interpret.

The purpose of this study was to complete a comparative evaluation of selected red maples grown under the same environmental conditions in order to characterize the trees based on their leaf anatomy, morphology and appearance. A unique feature of this study was to compare red maples previously reported to perform well in the Southeastern United States (5,16) with selections from the Freeman maple group. Maples in this category are generally considered as red maple cultivars, but are classified botanically as *A.* x *freemanii* indicating their hybrid origin. These maples are interspecific crosses between *A. rubrum* and *A. saccharinum*.

Materials and Methods

Cultivars of red maple were obtained in March 1988 from a single nursery source (Microplant Inc., Fairview, OR) as tissue culture microplantlets. Trees were containerized to 2.8 liter pots in an amended 6:1 (v:v) pinebark/sand medium and grown in a double layer polyhouse for three months, then outdoors under overhead irrigation for the remainder of the growing season. In 1989, trees were transplanted to 9.5 liter containers for another 12 months. Trees ranged in height from 1.2 to 1.5 m 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). Selections were planted in a randomized complete block design with 5 blocks of 2 plants each for a total of 10 trees. Drip irrigation was supplied to each tree based on 100% replacement of net evaporation from a class A pan, thereby eliminating moisture-stress concerns. Trees were planted on a 9.1 x 10.7 m spacing and were fertilized at planting and annually in March prior to bud break with 59 g of N, 25 g of phosphorus (P), and 49 g of potassium (K), as 13N - 5.6 P - 10.8 K (13-13-13), per 2.5 cm of diameter (caliper) at 30 cm above ground level.

Cultivars included in these trials represent a broad cross section of the classified red maple cultivars. The nine *Acer rubrum* and three *Acer* x *freemanii* selections evaluated followed by site and date of introduction were: *A.* x *freemanii* 'Autumn Blaze', also known as 'Jeffersred', Fostoria, OH, 1980 (Plate 1); *A. rubrum* 'Autumn Flame', Fairview, OR, 1964 (Plate 1); *A. rubrum* 'Fairview Flame', the most recent cultivar introduced, Fairview, OR, 1992 (Plate 1); *A. rubrum* 'Franksred' or Red Sunset™, Troutdale, OR, 1966 (Plate 2); *A. rubrum* 'Karpick', Buffalo, NY, 1985 (Plate 2); *A.* x *freemanii* 'Morgan', also known as 'Indian Summer' or 'Embers', Morgan Arboretum, MacDonald College, Quebec, Canada, 1971 (Plate 2); *A. rubrum* 'Northwood', Minn. Agri. Expt. Sta., 1980 (Plate 2); *A. rubrum* 'October Glory', Princeton, NJ, 1961 (Plate 3); *A. rubrum* 'Redskin',

Table 1. Leaf characteristics of select red maple cultivars and a seedling group.[z,y]

Cultivar/seedling	Average leaf area (cm^2)	Petiole length (cm)	Stomata per cm^2	Foliar[x] N(%)	Chlorophyll content (SPAD)
Autumn Blaze	83.9 c[w]	11.8 cde	91,350 a	2.3 cde	42.5 e
Autumn Flame	40.0 f	12.3 cd	68,270 f	2.6 a	46.2 b
Fairview Flame	58.3 de	15.4 b	63,460 i	2.4 abc	45.8 bc
Franksred	53.4 e	9.3 g	76,410 b	2.2 de	52.0 a
Karpick	66.2 d	9.6 fg	70,190 e	2.1 de	45.3 bcd
Morgan	93.6 b	11.5 cde	65,710 g	2.2 de	42.9 de
Northwood	54.7 e	10.6 ef	66,350 g	2.4 abcd	51.1 a
October Glory	61.9 de	17.1 a	64,420 h	2.5 ab	43.2 de
Redskin	65.6 d	11.4 de	67,630 f	2.0 e	41.8 e
Scarsen	131.5 a	12.7 c	53,420 j	2.5 abc	43.1 de
Schlesingeri	66.6 d	12.5 cd	72,440 c	2.3 bcd	49.6 a
Seedling	53.2 e	6.2 h	71,450 d	2.1 e	43.5 cde
Tilford	60.5 de	9.3 g	67,310 g	2.2 de	42.9 de
Original Auburn collection					
Armstrong	84.4 a[y]	15.8 a	68,270 a	2.2 a	44.2 a
Bowhall	89.6 a	12.3 b	55,130 c	2.2 a	41.8 a
Gerling	54.6 b	11.4 c	60,580 b	2.0 a	44.2 a

[z]Means by column derived from: 520 leaves, 520 leaves, 260 leaf peels, 7800 samples, and 7800 samples, respectively.
[y]Means Original Collectionn from: 120 leaves, 120 leaves, 60 leaf peels, 1800 samples, and 1800 samples, respectively.
[x]Nitrogen levels determined with LECO CHN-600 analyzer (LECO Corp., St. Joseph, MI).
[w]Mean separation within columns by Duncan's Multiple Range Test, $P = 0.05$.

Orchard Park, NY, 1982 (Plate 3); *A.* x *freemanii* 'Scarsen' also known as Scarlet Sentinel™, Ashtabula, OH, 1972 (Plate 3); *A. rubrum* 'Schlesingeri', considered the oldest red maple cultivar, NY, 1888 (Plate 3); and *A. rubrum* 'Tilford', Wooster, OH, 1951 (Plate 3). A group of seedling red maples from seed collected in 1987 at the same Oregon nursery was also included.

Leaf samples from 3 additional red maple selections from the original shade tree trials conducted by Auburn University (5) were taken (Table 1). These trees have not been maintained in the same manner as the current study, are from budded origins, and are 10 years older. These selections were: *A.* x *freemanii* 'Armstrong' introduced as an *A. rubrum* cultivar in 1947, Windsor, OH, (Plate 1); *A. rubrum* 'Bowhall', Circleville, OH, 1951 (Plate 1); and *A. rubrum* 'Gerling', Olmsted Falls, OH, 1950 (Plate 2). With consideration for the parentage of *A.* x *freemanii* trees and for comparisons of stomatal density, stomatal shape, and presence or absence of trichomes, leaves from silver maple (*A. saccharinum*) in the original Shade Tree Trials were collected and handled in the same manner as the red maple leaves in this study. Materials and methods for these original shade tree trials were previously reported (5,16).

The parameters of the study included leaf area, petiole length, stomatal density and location, N content, leaf greenness, and leaf appearance. All data were subjected to analysis of variance. Mean separations among cultivars were determined by Duncan's Multiple Range Test at $P = 0.05$.

Ten leaves were harvested arbitrarily from the midpoint of actively growing shoots from each tree in May, July, August, and September 1993. Leaves were transported in a cooler to Auburn University where total leaf area and petiole length measurements were determined. Leaf area was determined with a Transparent Belt Conveyer Accessory Leaf Area Meter, LI-COR Model LI-3050A (LI-COR Inc., Lincoln, NE).

Leaves for stomatal and trichome density determinations were collected arbitrarily from the midpoint of actively growing shoots of each sample within one replication of the study in August and September 1993. Stomatal and trichome densities were calculated using an eyepiece reticle with an area of 0.0156 mm^2 at 40x magnification. Means were derived from 5 leaves per cultivar, with 4 fields (subsamples) per leaf, for a total of 20 observations per cultivar.

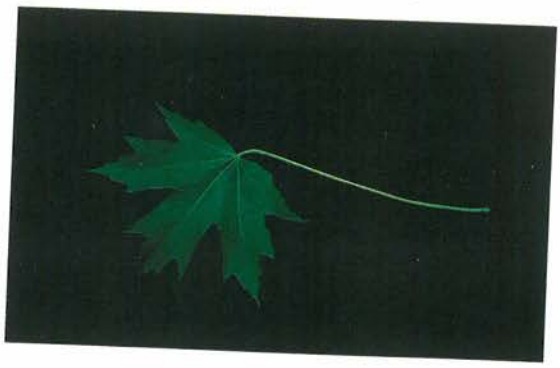
Foliar N levels were determined with a LECO CHN-600 Analyzer (LECO Corp., St. Joseph, MI). by removing 25 discs (0.31 cm^2 per disc) with a paper hole punch from each of 6 leaves of each red maple selection (150 total discs per tree) collected in August 1993. N determinations were repeated in September using three leaves. Discs were dried at 80°C and ground in a cyclone mill to pass a 0.5 mm sieve. Total dry weight of each sample was taken and analyzed by combustion.

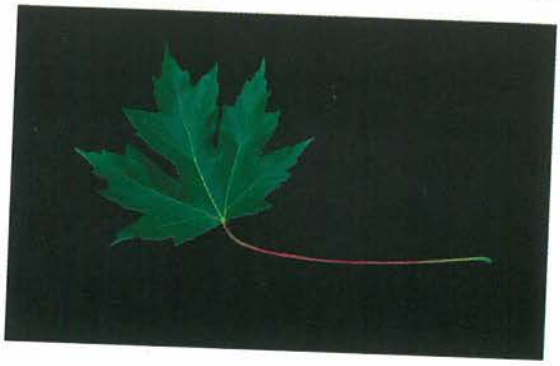
Chlorophyll content measurements were taken with the same SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ltd., Japan) in August and September on each of the 600 discs to be used for N determinations immediately after they were excised with the hole punch.

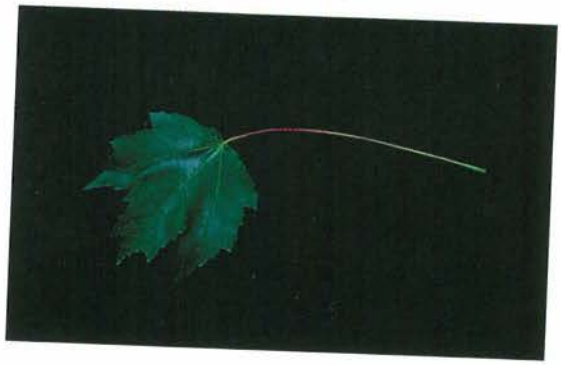
Results and Discussion

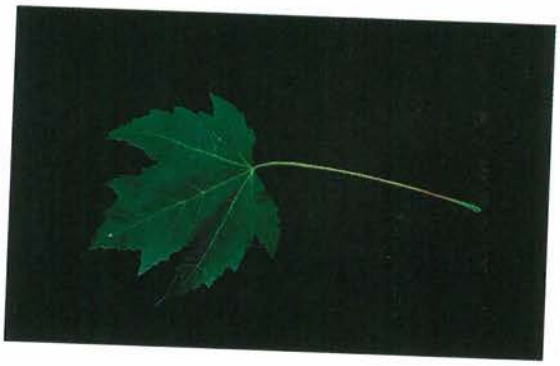
Acer x *freemanii* 'Scarsen' had the largest leaves, (131.5 cm^2) followed by *A.* x *freemanii* 'Morgan' (93.6 cm^2) and 'Autumn Blaze' (83.9 cm^2) (Table 1; Plate 4). 'Autumn Flame' had the smallest leaves (40 cm^2), a trait noted in a previous study comparing other cultivars not used in this study (5). 'October Glory' had the longest petioles of the cultivars evaluated (17.1 cm), followed by 'Fairview Flame' (15.4 cm). Both of these cultivars have striking red petioles throughout the growing season.

An extensive review on stomata by Salisbury and Ross (11) indicates that stomata are often found on both surfaces of leaves, but generally are more prevalent on the abaxial surface. In the current study all stomata were found on the abaxial surface for the *Acer* spp. evaluated. 'Autumn Blaze' had the highest stomatal density with 91,350 stomata per cm^2, while 'Fairview Flame' had the least with 63,460 (Table 1). There were fewer stomata on the sampled silver maple than on any of the red maples evaluated. Mean stomatal density for the silver maple was 48,766 per cm^2. Wide ranges in stomatal density within a genus can be expected. Kozolowski et al. (10) noted stomatal densities ranging from 68,000 per cm^2 in northern









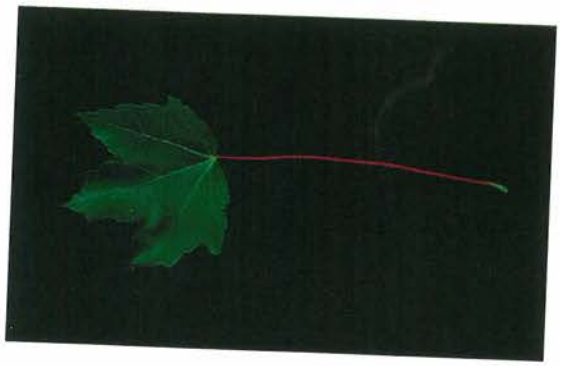
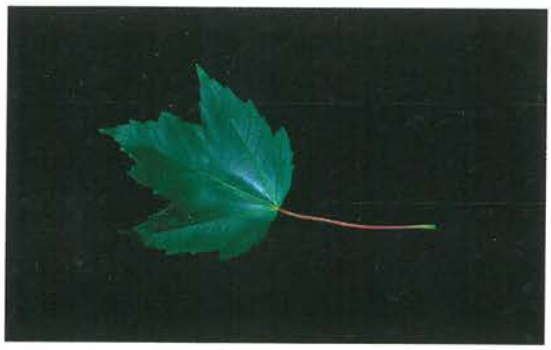
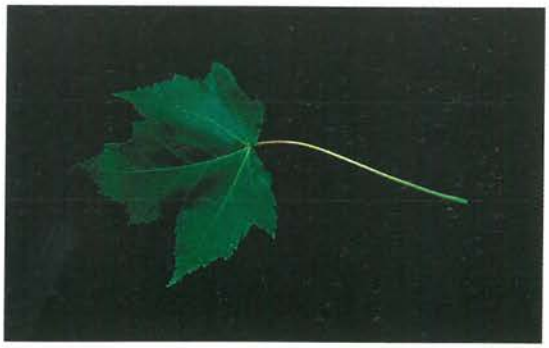
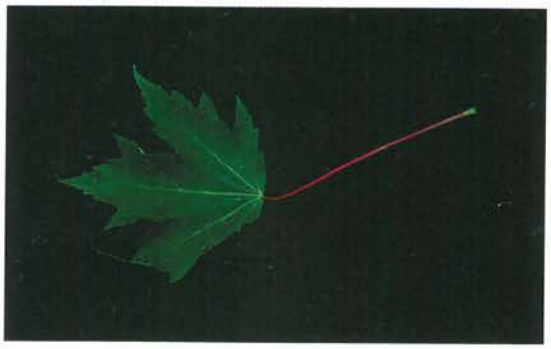
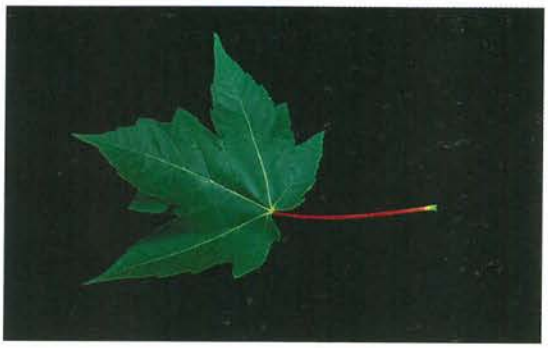


Plate 1. Foliage (top, l to r) of *Acer* x *freemanii* 'Armstrong' and *A.* x *freemanii* 'Autumn Blaze' (also known as 'Jeffersred'), (center, l to r) *A. rubrum* 'Autumn Flame' and *A. rubrum* 'Bowhall' (bottom) *A. rubrum* 'Fairview Flame'.









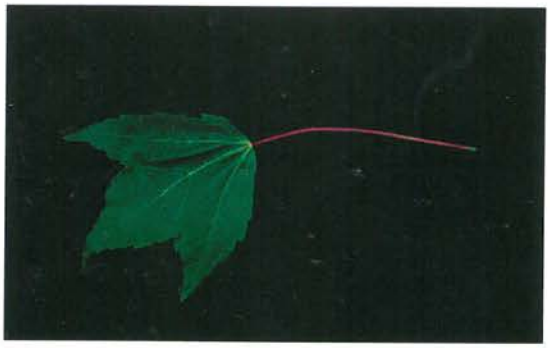
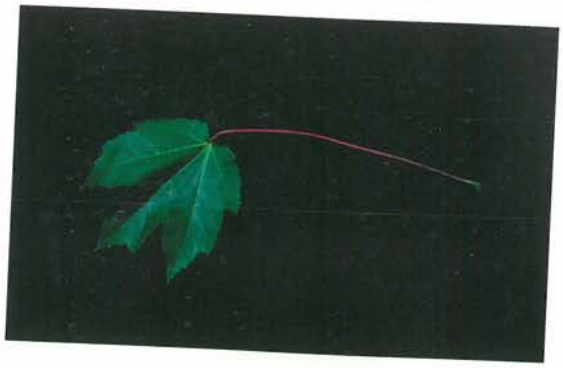
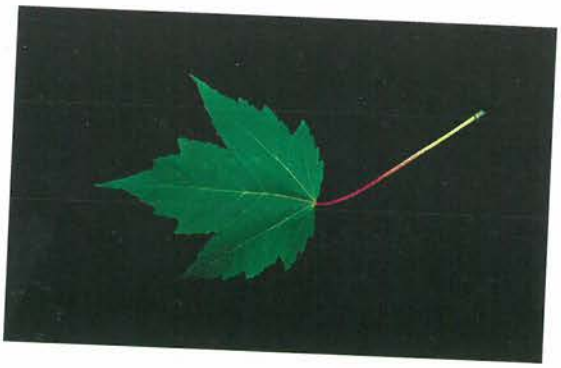
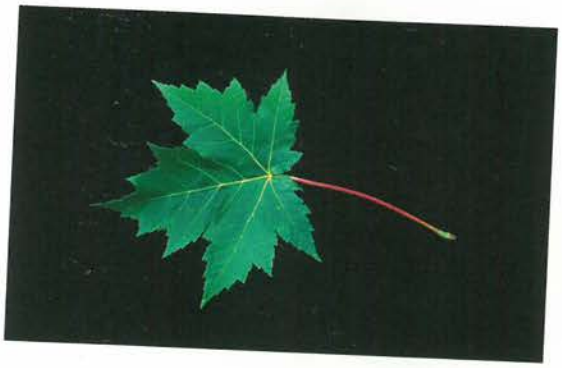
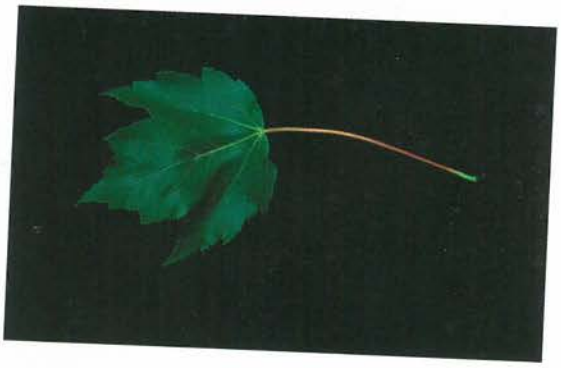


Plate 2. Foliage (top, l to r) of *Acer rubrum* 'Franksred' (also known as Red Sunset™)and *A. rubrum* 'Gerling'.
(center, l to r) *A. rubrum* 'Karpick' and *A.* x *freemanii* 'Morgan' (also known as 'Embers' or 'Indian Summer')
(bottom) *A. rubrum* 'Northwood'.









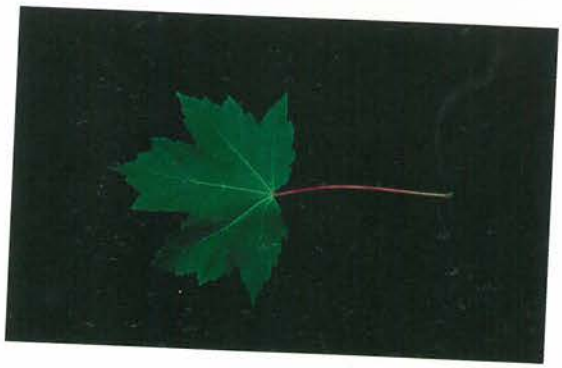


Plate 3. Foliage (top, l to r) of *Acer rubrum* 'October Glory' and *A. rubrum* 'Redskin' (center, l to r) *A. x freemanii* 'Scarsen' (also known as Scarlet Sentinel™)and *A. rubrum* 'Schlesingeri' (bottom) *A. rubrum* 'Tilford'.

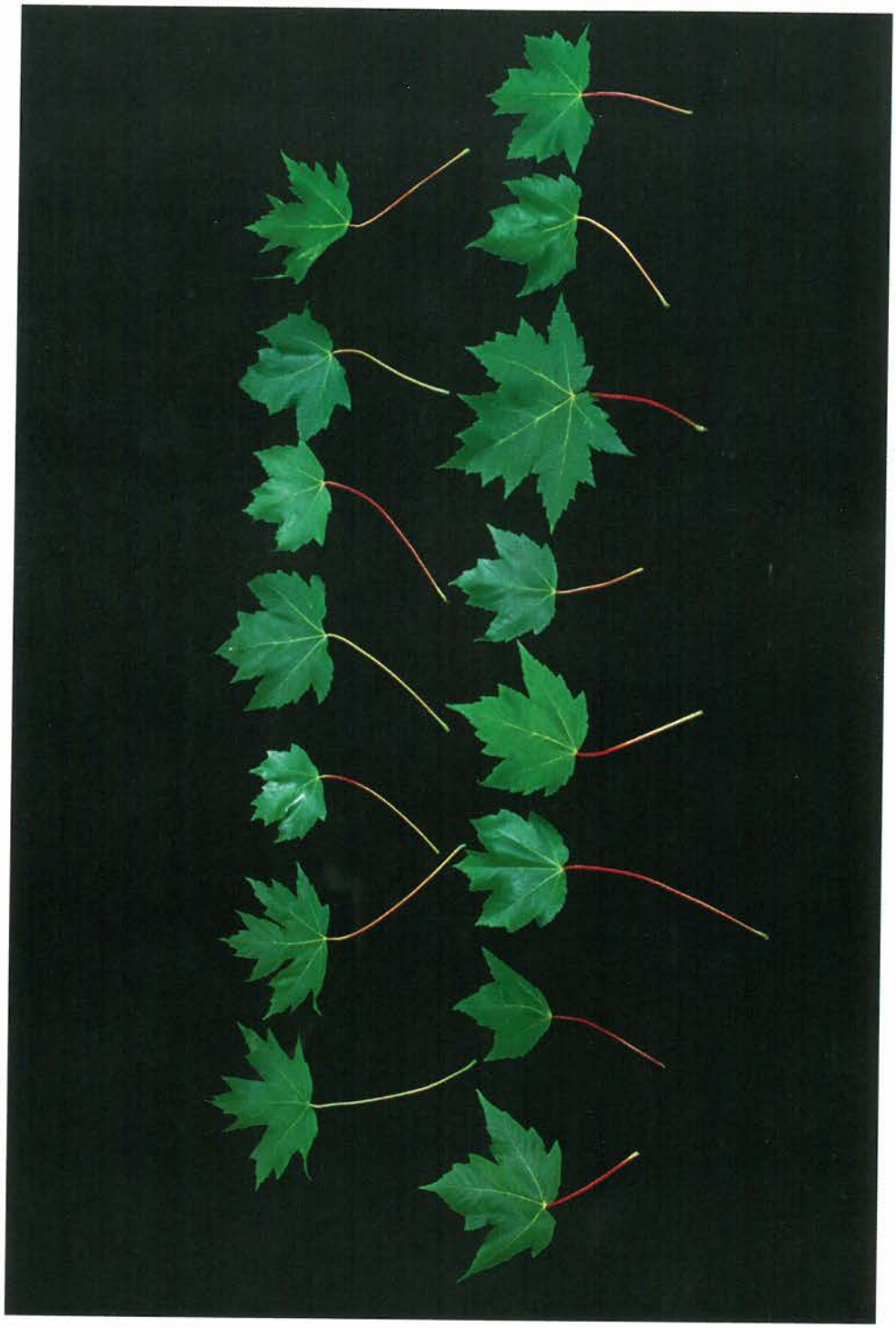


Plate 4. Foliage of red maple cultivars (top row, l to r) Armstrong, Autumn Blaze, Autumn Flame, Bowhall, Fairview Flame, Gerling, Karpick, (bottom row, l to r) Morgan, Northwood, October Glory, Redskin, Red Sunset, Scarsen, Schlesingeri, and Tilford.

red oak to over 100,000 per cm^2 in scarlet oak. There was no apparent correlation between stomatal density and other leaf characteristics including leaf size. There were 54,487 abaxial trichomes per cm^2 on the silver maple evaluated but no trichomes were evident on the *Acer rubrum* or *A.* x *freemanii* selections in this study (data not shown).

Lowest N concentrations occurred with seedlings (2.08% N) and 'Redskin' (2.01% N) (Table 1). 'Karpick', 'Morgan', 'Tilford', 'Franksred', and 'Autumn Blaze' were similar. The highest N levels occurred with 'Autumn Flame' (2.62 % N), with 'October Glory', 'Scarsen', 'Fairview Flame', and 'Northwood' being similar (Table 1). A container study with 'Franksred'(8) reported similar results. N concentration in leaves is an important determinant of the feeding and oviposition behavior of a wide variety of insects (17). A cultivar typically having low N levels or a decreasing N concentration across the growing season, may have an important effect on the activity of the potato leaf hopper (*Empoasca fabae* Harris), the primary insect pest of red maple (3). Bachtell (1) indicated differences in susceptibility of maple species to the potato leafhopper. It is possible that susceptibility may be cultivar specific within a species as well. Work to evaluate incidence of insect damage among the cultivars in this study has been initiated.

Our results indicate that for red maple grown under the same conditions, the SPAD-502 Chlorophyll Meter can be a useful tool in ranking cultivars in leaf greenness. Often leaf greenness is considered to be highly correlated with foliar N levels. However, in this study 'Franksred', generally accepted among growers as having the deepest green color of red maple cultivars, had one of the lowest concentrations of N while having one of the highest SPAD-502 values (Table 1). 'Redskin' had the lowest SPAD value, but was similar to other cultivars noted for light green foliage. In general, correlations between actual foliar N concentrations and SPAD-502 Meter values were poor in this study (data not shown).

Results from evaluations of the three additional selections found the greatest leaf area on 'Bowhall' (89.6 cm^2) and 'Armstrong' (84.4 cm^2). 'Armstrong', an *A.* x *freemanii* also had the longest petioles (15.8 cm) and greatest stomatal density (68,269 cm^2) (Table 1). No differences were found among the three cultivars in foliar N or chlorophyll content.

Results from these evaluations define distinctions that characterize foliage features among several red maple cultivars. These results show morphological differences in a nonsubjective way, and may be used for identification purposes.

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Received for publication on November 9, 1994.

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Department of Horticulture and
Department of Botany and Microbiology
Auburn University
Auburn University, AL 36849

Résumé. Cette étude a été menée afin de comparer et de définir les caractéristiques du feuillage de sélections d'érables rouges et de cultivars hybrides d'érables rouges sous des conditions environnementales similaires. Neuf cultivars d'érables rouges et une sélection de semis d'érables rouges ont été évalués lors d'une étude sur le terrain en regard de leurs différences de surface foliaire, de longueur du pétiole, de densité en stomates, du contenu d'azote foliaire et du contenu en chlorophylle. Les feuilles de trois cultivars d'*A. x freemanii* étaient les plus larges. Les feuilles d'*A. rubrum* 'Autumn Flame' étaient les plus petites. 'October Glory' comportait les pétioles les plus longs. Des photos des feuilles de chacun des cultivars sont incluses.

Zusammenfassung. Diese Studie wurde in Auftrag gegeben, um die Blattmerkmale von ausgewählten Rotahornen und Hybrid-Rotahornen unter ähnlichen Umweltbedingungen zu vergleichen und zu bestimmen. Neun Rotahorn-Kultivare und eine Auswahl von Rotahornsämlingen wurden in einer differenzierden Feldstudie auf folgende Markmale verglichen: durchschnittliche Blattfläche, Länge der Petiolen, Dichte der Stomata, Stickstoffgehalt der Blätter und Chlorophyllanteil. Die Blätter von drei *A. x freemanii*-Kultivaren waren am größten, die von A. rubrum 'October Glory' waren am kleinsten. 'October Glory' hatte die kürzesten Blattstiele. Die Photographien der Blätter von allen Bäumen sind beigefügt.