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Evaluation of Various Traits of 40 Selections and Cultivars of Red Maple and Freeman Maple Growing in Maryland[1]

A. M. Townsend[2] and L. W. Douglass[3]
U. S. National Arboretum, USDA-ARS,
3501 New York Avenue, NE
Washington, DC 20002

Abstract

Thirty-seven red maple (*Acer rubrum* L.) and three Freeman maple (*A.* x *freemanii* E. Murray) selections and commercial cultivars were evaluated for six years in a replicated field plot at Glenn Dale, MD. Significant differences among clones occurred for growth rate; for time, intensity, and duration of autumn color; for time of growth initiation in the spring; and for injury sustained from potato leafhopper (PLH) [*Empoasca fabae* (Harris)] feeding. The red maple cultivars showing the best red color over three years time were 'Autumn Flame,' 'Brandywine,' 'Cumberland,' 'Red Rocket,' 'Somerset,' 'Sun Valley,' and 'Van.' The cultivar 'Bowhall' was the least reddish. Of the three Freeman maples evaluated, 'Jeffersred' and 'Indian Summer' manifested the best red color and also low PLH injury; whereas 'Armstrong' consistently showed the least reddish color of all 40 clones tested, and intermediate PLH injury. Those cultivars and selections from northern seed sources reached their peak color the earliest, but often dropped their leaves more quickly after showing their best color, compared to clones originating in more southerly locations. The clones showing the least PLH injury over several years included the Freeman maples 'Jeffersred' and 'Indian Summer,' and red maple clones and cultivars selected by the U.S. National Arboretum either from full-sib progenies (e.g., 'Brandywine,' 'Somerset,' 'Sun Valley') or from an Ohio provenance-progeny test (e.g., 'Cumberland,' 'Red Rocket'). Those clones initiating growth (or "flushing") earliest in the spring generally showed the least PLH injury; correlations between lateness of flushing and degree of PLH injury were highly significant.

Index words: foliage color, insect tolerance, potato leafhopper tolerance, growth rate, growth initiation, defoliation time, *Acer rubrum*.

Significance to the Nursery Industry

Red maple and Freeman maple (red x silver maple hybrids) cultivars are among the most popular landscape trees grown by the nursery industry in the United States. This article reports wide variation in the relative quality, timing, and duration of autumn leaf color; tolerance to the potato leafhopper (PLH); and growth rate among 37 selections and cultivars of red maple and three cultivars of Freeman maple growing in a replicated evaluation plot in Maryland. Data were collected over several years. Results showed the most reddish color by five recently released U.S. National Arboretum cultivars and two cultivars of red maple in the trade. Freeman maples generally had less PLH injury than did the red maples. However, several cultivars of red maple showed excellent PLH tolerance combined with exceptional autumn foliage color. Nurserymen and arborists can use the information provided in this article to select the best clones and cultivars of red and Freeman maples for nursery production or landscape use.

[1]Received for publication March 13, 1998; in revised form July 23, 1998. Supported in part by the Maryland Agricultural Experiment Station. We gratefully acknowledge the assistance of Susan E. Bentz and Thomas E. Abell in propagation of clones and in establishment and maintenance of this evaluation plot.

[2]Research Geneticist.

[3]Professor of Biostatistics, Department of Animal Science, University of Maryland, College Park, MD 20740.

The *Journal of Environmental Horticulture* (ISSN 0738-2898) is published quarterly in March, June, September, and December by the Horticultural Research Institute. Subscription rate is $65.00 per year for educators and scientists; $85.00 per year for others; add $25.00 for international orders. Periodical postage paid at Washington, D.C. and at additional mailing office. POSTMASTER: Send address changes to HRI, 1250 I Street, N.W., Suite 500, Washington, D.C. 20005.

Introduction

As a very popular landscape tree species, red maple (*Acer rubrum* L.) has received much attention by nurserymen, arborists, and landscape architects. The nursery industry has selected many new cultivars, with emphasis on crown shape, autumn color, and other aesthetic characteristics (5). The U.S. National Arboretum has been actively involved in the development of genetically improved, horticulturally desirable, insect- and stress-tolerant red maple cultivars (1, 9, 10, 11, 12, 13, 14, 15). 'Cumberland,' 'Red Rocket,' 'Somerset,' 'Sun Valley,' and 'Brandywine' were recently named and released. All of these were selected for their tolerance to the potato leafhopper (PLH) [*Empoasca fabae* (Harris)], superior autumn leaf color and horticultural desirability. Freeman maple (*A.* x *freemanii* E. Murray), hybrids of red maple and silver maple (*Acer saccharinum* L.), also are grown frequently in the trade (5). Trees designated as Freeman maples are not products of controlled hybridization and their identification has been based solely on opinions expressed by nurserymen and horticulturists (4).

Other research projects on red and/or Freeman maple have shown variation among cultivars in response to wounds (3) and root-zone heat (15), and in an Alabama location, in autumn foliage color (2, 7, 8). In this study, rooted cuttings of 40 clones or cultivars of either red maple or Freeman maple were planted in a field plot near Glenn Dale, MD. Trees were evaluated over a six-year period for several traits related to insect tolerance, autumn leaf color, and phenology. The purpose of this study was to compare the relative performance and attributes of many U.S. National Arboretum red maple selections and cultivars with other commercial cultivars of red and Freeman maples; and to identify those clones or cultivars showing the most promise.

Materials and Methods

Ramets of the 40 clonal selections or named cultivars listed in Table 1 were planted in a randomized block design with two blocks and three trees per clone per block in a field plot at the USDA-ARS, U.S. National Arboretum station near Glenn Dale, MD. Trees were planted 305 cm (10 ft) within rows and 366 (12 ft) between rows in a sandy loam soil. Trees were irrigated, but only during very hot and dry periods, generally once or twice a year. No fertilizer was applied during the course of the study. Twenty-nine clones were planted in 1989, three were planted in 1990 (USNA red maples 123 QU and 5095; also 'Jeffersred'), and eight in 1992 (USNA red maples 19 MI; 71 WI; 121 RI; 122 CT; 124 CT; 202 MN; 5104; and 5184). Twenty-seven of the 40 trees were USDA selections from the red maple provenance test (9, 14) or full-sib progeny test (12) that the U.S. National Arboretum maintains near Delaware, OH. Most of these USDA clones were selected for PLH tolerance, but a few (such as 27 RI and 5012) were selected only for autumn color and form (without regard to PLH tolerance) and therefore served as control trees with respect to PLH tolerance.

Five of these 27 USDA clones have been officially released as new cultivars, named 'Cumberland,' 'Red Rocket,' 'Somerset,' 'Sun Valley,' and 'Brandywine.' Commercial red maple cultivars included were 'Autumn Flame,' 'Bowhall,' 'October Glory,' 'Franksred' (trademark Red Sunset), and 'Van.' Freeman maple cultivars were represented by 'Armstrong,' 'Jeffersred' (trademark Autumn Blaze), and 'Indian Summer' (also known as 'Embers' or 'Morgan').

Height was measured in November of 1990, 1994, and 1996; diameter of the main trunk [137 cm (4.5 ft) above ground level] of each tree was measured in November of 1994 and 1996. Data on the color of autumn foliage was recorded at least once weekly during 1992, and twice weekly during 1994 and 1995. Leaf color was estimated (by eye) on each tree, using a visual index from 0 = no red color to 100 = most reddish color. A color chart was not used because we wanted to 'capture' the degree of red color shown by each tree on each date, to simulate how a homeowner, landscape contractor, or other consumer would compare different red maple cultivars in degree of reddishness before purchase at a landscape/garden center. The buyer would not use a color chart, but might compare by eye the overall visual impact of all the cultivars available at the time. Additional data on the time when peak fall color commenced, and later, when 70% of a tree's leaves had dropped, also were recorded at the same time color ratings were made in the autumn of 1994 and 1995.

A visual estimate of the percentage of each tree's total foliage showing PLH injury was made on June 28, 1990; June, 30, 1991; June 22, 1992; August 8, 1994; June 29, 1995, and August 8, 1995. This assessment of leaf injury reflected the degree to which leaves were curled, deformed, chlorotic, or necrotic, as a response to feeding by the PLH. Time of growth initiation, or 'flushing,' was recorded on April 5 and April 20, 1995, and was based on an index of leaf development and growth from 0 = very late to 100 = very early.

Data were analyzed using linear mixed models procedures in SAS (6). For individual tree data within a year or for tree data averaged across years, the fixed portion of the model included clone effects, while block, block × clone interaction, and residual tree variances were defined as random. Analyses of the same variable across years using individual tree data included clone, year, and year × clone interaction as fixed sources of variation, while block, block × clone, tree within block and clone, block × year, block × clone × year, and the residual variances were defined as random. Trees were included in the analysis only if they had data recorded for every year, and clones were included only if there were tree data available in both blocks. There were two clones with two trees, one clone with four trees, and four clones with five trees; the remaining clones had data on all six trees. Least square means are reported and the least significant difference (LSD) is based on the mixed model variance components and the harmonic mean number of trees per clone. Two correlation matrices were computed, one using individual tree data and the second using the clone means for the two to six available trees for each clone.

Results and Discussion

Analyses of variance showed significant differences among clones for all traits measured (Tables 1, 2, and 3). For clones planted in 1989 (29 of the 40 planted), there were highly significant differences in height growth between 1990 and 1994 and also between 1990 and 1996 (Table 1). Those clones producing the most height growth between 1990 and 1996 were 'Indian Summer,' 56 NH, 'Armstrong,' 205 WI, 'Brandywine,' 'Franksred,' 78 MI, and 11 ME (Table 1). Most of these also showed the largest diameter in November 1996. The slowest-growing clones in height during this six-year (1990-1996) period were 'Autumn Flame,' 96 WI, 93 WI, 91 ME, 'Jeffersred,' 17 MN, 1 QU, and 123 QU (Table 1). It

Table 1. Origin and mean growth characteristics of red and Freeman maple clones and cultivars growing in Maryland.

Clone			Height			Diameter[z]	Height		Diameter
USNA accession no.	Selection no. and state or province of origin or cultivar name	Year planted	11/90 (cm)	11/94 (cm)	Growth 11/90 to 11/94 (cm)	11/94 (mm)	11/96 (cm)	Growth 11/90 to 11/96 (cm)	11/96 (mm)
56020	1 QU	1989	127	370	243	46	498	371	68
56022	4 AR	1989	114	431	317	49	599	485	82
55899	7 PA	1989	118	415	297	49	556	438	80
56023	11 ME	1989	162	442	280	57	653	491	89
56024	17 MN	1989	166	388	222	51	533	367	70
63504	19 MI	1992	—	52	—	—	101	—	—
56025	20 ME	1989	184	480	296	59	639	455	87
56026	27 RI	1989	119	393	274	39	529	410	60
55406	42 NB	1989	67	296	229	21	474	407	45
56028	56 NH	1989	125	477	352	55	672	547	87
63505	71 WI	1992	—	71	—	—	114	—	—
57776	78 MI	1989	104	400	296	42	597	493	70
56029	91 ME	1989	105	296	191	26	464	359	53
55900	93 WI	1989	80	245	165	21	404	324	45
56030	95 NH	1989	151	411	260	47	578	427	75
55410	96 WI	1989	93	284	191	26	407	314	48
62074	121 RI	1992	—	123	—	7	249	—	26
62075	122 CT	1992	—	232	—	13	448	—	45
60066	123 QU	1990	45	258	213	17	417	372	42
60067	124 CT	1992	—	243	—	19	410	—	47
63506	202 MN	1992	—	135	—	—	223	—	18
57775	205 WI	1989	113	437	324	45	625	512	72
60068	5012	1989	102	386	284	40	532	430	69
59904	5013	1989	42	275	233	24	426	384	57
61016	5095	1990	69	410	341	41	540	471	74
62076	5104	1992	—	220	—	12	371	—	42
62898	5184	1992	—	200	—	7	315	—	30
55890	Armstrong	1989	181	507	326	56	712	531	91
55889	Autumn Flame	1989	204	375	171	42	501	297	71
55891	Bowhall	1989	104	409	305	30	560	456	54
59907	Brandywine	1989	121	445	324	48	627	506	81
56021	Cumberland	1989	130	471	341	43	606	476	71
55895	Franksred	1989	120	448	328	52	614	494	84
55892	Indian Summer	1989	103	493	390	52	729	626	90
67256	Jeffersred	1990	234	426	192	42	599	365	76
55894	October Glory	1989	128	369	241	41	548	420	74
57772	Red Rocket	1989	82	310	228	25	493	411	48
59905	Somerset	1989	129	403	274	49	600	471	76
59906	Sun Valley	1989	108	365	257	47	514	406	75
55896	Van	1989	124	406	282	41	588	464	68
Overall mean			120	345	271	37	501	437	64
LSD (0.05 level)			25	88	98	14	134	140	18
Sig. clone (p <)			0.001	0.001	0.003	0.001	0.001	0.015	0.001

[z]Diameter was measured 137 cm (4.5 ft) above ground level.

should be noted that most (e.g., 96 WI, 93 WI, 91 ME, 17 MN, 1 QU, and 123 QU) of these slow-growing clones were from more northerly origins. If these northern clones had been planted in a location closer to their native origin, they perhaps would have been more likely to maximize their growth, as has been shown in previous studies with seedling progenies (11, 13). However, not all clones from northern areas grew slowly in Maryland. For example, selections 56 NH, 205 WI, 78 MI, and 11 ME had shown good height growth by 1996 (Table 1). Studies in Alabama (2, 7, 8) also have demonstrated the superior growth rate of 'Armstrong' maple.

Based on a mean of the 1992, 1994, and 1995 data, the clones or cultivars showing the most reddish color were 5095, 5184, 5104, 'Red Rocket,' 'Brandywine,' Somerset,' 'Sun Valley,' 'Van,' 96 WI, 5012, 'Cumberland,' 17 MN, 'Autumn Flame,' 7 PA, and 93 WI (Table 2). The cultivars 'Franksred' and 'October Glory' were not quite as red as the best of the most reddish clones, and 'Bowhall' and 'Armstrong' showed below average color. 'Jeffersred' showed the best red color of the three Freeman maples tested. Mean colors between 1994 and 1995 reflected the same pattern as the mean of 1992, 1994, and 1995, with 'October Glory,' 'Indian Summer,' Bowhall,' and 'Armstrong' showing the least reddishness among the cultivars tested. A comprehensive analysis of variance across years showed that mean peak red color varied significantly among clones but not among years; but the year × clone interaction was sig-

Table 2. Characteristics related to autumn leaf color of red and Freeman maple clones and cultivars growing in Maryland.

Clone		Peak autumn red color (0–100)					No. of days from Sept. 30 to beginning of peak color			No. of days from peak color initiation to 70% defoliation		
USNA accession no.	Selection no. and state or province of origin, or cultivar name	1992	1994	1995	Mean of 1994 & 1995	Mean of 1992, 1994, & 1995	1994	1995	Mean both years	1994	1995	Mean both years
56020	1 QU	67	90	78	84	78	16	21	19	7	12	9
56022	4 AR	75	77	63	70	72	21	24	23	20	11	15
55899	7 PA	100	88	92	90	93	11	20	15	15	11	13
56023	11 ME	62	95	77	86	78	16	16	16	10	17	13
56024	17 MN	97	100	88	94	95	15	20	17	13	13	13
63504	19 MI	86	90	80	85	85	25	35	30	9	4	7
56025	20 ME	83	82	90	86	85	12	22	17	12	10	11
56026	27 RI	90	92	85	81	89	15	22	19	11	11	11
55406	42 NB	77	83	82	83	81	16	16	16	7	11	9
56028	56 NH	65	63	68	66	66	16	21	19	10	11	11
63505	71 WI	—	57	56	57	—	20	24	22	7	8	7
57776	78 MI	65	53	42	48	53	22	25	24	10	10	10
56029	91 ME	82	80	73	77	78	10	13	12	11	7	9
55900	93 WI	93	92	87	89	91	9	11	10	9	12	11
56030	95 NH	57	77	65	71	66	22	27	24	3	7	5
55410	96 WI	95	100	97	98	98	12	21	16	10	8	9
62074	121 RI	77	82	85	83	81	19	23	21	10	13	12
62075	122 CT	85	80	78	79	81	18	19	18	7	7	7
60066	123 QU	70	95	97	96	87	15	22	19	12	9	11
60067	124 CT	77	85	88	87	83	22	20	21	13	16	15
63506	202 MN	77	70	50	60	66	13	15	14	6	5	5
57775	205 WI	90	85	90	88	88	12	16	14	10	13	12
60068	5012	98	97	95	96	97	18	28	23	13	10	12
59904	5013	87	92	85	88	88	26	28	27	12	10	11
61016	5095	100	100	100	100	100	17	32	25	25	12	19
62076	5104	100	100	100	100	100	19	25	22	21	17	19
62898	5184	100	100	100	100	100	15	24	20	21	12	17
55890	Armstrong	60	36	47	42	48	23	22	27	15	14	15
55889	Autumn Flame	95	88	97	93	93	10	19	15	11	11	11
55891	Bowhall	60	65	70	68	65	19	27	23	9	7	8
59907	Brandywine	100	100	98	99	99	15	29	22	24	13	18
56021	Cumberland	93	100	93	97	96	15	23	19	23	10	17
55895	Franksred	85	97	88	93	90	22	30	26	19	13	16
55892	Indian Summer	82	87	80	83	83	17	27	22	15	7	11
67256	Jeffersred	80	95	90	93	88	19	29	24	13	5	9
55894	October Glory	97	88	80	84	88	29	31	30	15	17	16
57772	Red Rocket	100	100	97	98	99	11	17	14	9	10	9
59905	Somerset	100	100	95	98	98	18	26	22	17	12	15
59906	Sun Valley	100	97	97	97	98	20	26	23	18	11	15
55896	Van	97	95	97	96	96	16	27	21	11	9	10
Overall mean		85	86	83	85	85	17	23	20	13	11	12
LSD (0.05 level)		10	17	18	14	10	7	8	6	7	6	5
Sig. clone (p<)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.011	0.001

nificant ($p < 0.001$). The ranking among cultivars shown here was somewhat in line with the color shown by some of these cultivars growing in Alabama (2, 7, 8). In both Alabama and Maryland, for example, 'Jeffersred' showed the best red leaf color of the Freeman maples and 'Bowhall' displayed the poorest red color of the red maples. In contrast, 'October Glory' was one of the best for reddish fall color in Alabama, but not in Maryland.

The variation in peak color is important from both a horticultural and biological viewpoint. Horticulturally, significant differences were shown among clones in the degree of red color, as perceived on a scale useful to the consumer. The biological significance of the color data is that red and Freeman maple clones differ in their inherent genetic capability to express attractive red autumn leaf color. It is important that we identify those clones which have the greatest genetic potential to manifest this trait so as to attract the consumer in the marketplace.

As measured by the number of days from September 30 to the beginning of peak color, those clones and cultivars from northern seed sources reached peak color earliest, for example selections (given here with their state or province of origin) or cultivars 93 WI, 91 ME, 202 MN, 205 WI, 'Red Rocket,' 7 PA, 'Autumn Flame,' 11 ME, 42 NB, and 96 WI (Table 2), reflecting the inherent tendency of most northern clones to color early (9). Among those latest to show their best color were 'October Glory,' 'Armstrong,' 5013, 'Franksred,' and 5095 (Table 2).

Table 3. Potato leafhopper injury and time of growth initiation for red and Freeman maple clones growing in Maryland.

Clone		Potato leafhopper injury (%)									
								Mean of		Index of growth initiation (flushing) (0–100)[z]	
USNA accession no.	Selection no. and state or province of origin, or cultivar name	6/90	6/91	6/92	8/94	6/95	8/95	Aug. 94 & 95	June 90, 91, 92, & 95	4/5/95	4/20/95
56020	1 QU	12	7	4	3	2	2	3	6	20	52
56022	4 AR	4	1	2	8	2	4	6	2	22	37
55899	7 PA	5	5	2	11	3	5	8	4	12	30
56023	11 ME	2	1	6	1	2	2	1	3	30	53
56024	17 MN	1	5	4	3	2	2	3	3	40	78
63504	19 MI	—	—	—	0	3	3	1	—	0	20
56025	20 ME	2	3	1	1	2	2	1	2	5	22
56026	27 RI	25	22	21	20	18	22	21	21	0	12
55406	42 NB	2	7	2	2	3	3	3	3	15	28
56028	56 NH	13	13	10	5	3	4	5	10	3	32
63505	71 WI	—	—	—	0	2	2	1	—	10	35
57776	78 MI	0	6	3	1	2	2	1	3	5	18
56029	91 ME	3	3	0	6	3	3	5	2	5	22
55900	93 WI	4	0	0	1	1	1	1	1	30	50
56030	95 NH	9	5	9	5	4	4	5	7	0	22
55410	96 WI	4	4	2	6	3	3	5	3	13	40
62074	121 RI	—	—	—	5	9	16	11	—	0	8
62075	122 CT	—	—	—	2	6	6	4	—	7	22
60066	123 QU	—	1	0	1	4	4	3	—	0	30
60067	124 CT	—	—	—	2	6	6	4	—	10	25
63506	202 MN	—	—	—	0	3	3	1	—	12	35
57775	205 WI	4	3	3	2	3	3	3	3	7	30
60068	5012	8	16	5	6	10	10	8	10	0	20
59904	5013	—	5	2	4	7	10	7	—	7	27
61016	5095	—	5	4	1	3	3	2	—	5	27
62076	5104	—	—	—	1	2	2	1	—	10	30
62898	5184	—	—	—	3	2	3	3	—	7	27
55890	Armstrong	8	5	5	5	4	4	5	5	0	20
55889	Autumn Flame	3	6	2	5	7	7	6	5	10	30
55891	Bowhall	9	15	6	1	5	5	3	8	10	28
59907	Brandywine	7	3	2	3	3	3	3	4	8	32
56021	Cumberland	4	1	1	1	1	1	1	2	20	43
55895	Franksred	3	14	7	9	6	8	9	7	5	23
55892	Indian Summer	3	2	1	1	3	2	1	2	30	70
67256	Jeffersred	—	—	1	0	0	0	0	—	10	30
55894	October Glory	16	10	6	9	7	9	9	10	5	20
57772	Red Rocket	1	5	3	1	2	3	2	3	8	32
59905	Somerset	2	3	3	3	3	3	3	3	0	22
59906	Sun Valley	3	3	2	4	3	3	3	3	12	30
55896	Van	1	5	2	3	3	3	3	3	5	23
Overall mean		6	6	4	4	4	4	4	5	10	31
LSD (0.05 level)		7	7	5	4	3	4	3	4	7	7
Sig. clone (p <)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

[z]Growth initiation was indexed from 0 = very late to 100 = very early.

The number of days from peak color initiation to time of defoliation varied widely among clones (Table 2). Among the cultivars, 'Brandywine,' 'Cumberland,' 'October Glory,' 'Franksred,' 'Somerset,' 'Sun Valley,' and 'Armstrong' showed a long duration of peak color (15–19 days). In contrast, 'Jeffersred,' 'Red Rocket,' 'Bowhall,' 'Van,' 'Autumn Flame, and 'Indian Summer' dropped their leaves relatively quickly (8–11 days) after showing their best color. This early leaf drop reflects the more northerly origins of these cultivars. Similarly, most of the selections from northern locations (e.g., 202 MN, 95NH, 19 MI, 71 WI, 122 CT, 1 QU, 42 NB, 91 ME, 96 WI) showed a short duration of color (from 5 to 9 days) before significant defoliation (Table 2). These trees defoliated so early that peak color time was naturally shortened. Among the selections, numbers 5104, 5095, 5184, 124 CT, and 4 AR kept their peak color longest, from 15 to 19 days. Analyses of variance across years showed that time of initiation and duration of peak color were significantly influenced by clone and year × clone interaction; but year to year effects were nonsignificant.

Potato leafhopper injury in the present study generally was somewhat less pronounced than in a previous Ohio study of open-pollinated seedling progenies of red maple (10). The clones showing the least PLH mean injury in August of 1994 and 1995 were the Freeman maples 'Jeffersred' and 'Indian Summer' and red maple clones selected for PLH tolerance from northern sources (e.g., 202 MN, 93 WI, 78WI, 71 WI, 20 ME, 19 MI, 11 ME, 'Red Rocket' (origin northern Min-

nesota)), or from full-sib progenies (e.g., 5104, 5095, 'Sun Valley,' 'Somerset,' 'Brandywine,' 5184) (Table 3). 'Cumberland' (native source Tennessee) also showed low injury. Because they had not been planted yet, not all clones were represented in the combined mean of the June readings of 1990, 1991, 1992, and 1995, but many of the aforementioned clones again looked tolerant (e.g., 93 WI, 20 ME, 'Cumberland,' 'Indian Summer,' 'Sun Valley,' 'Somerset,' 205 MN, 'Red Rocket,' 78 MI, 17 MN) (Table 3). The clones showing the most PLH injury were two clones (27 RI and 5012) that had not been selected for PLH tolerance; also somewhat injured were 'October Glory,' 'Franksred,' 56 NH, 95 NH, and 'Autumn Flame.'

Analyses of variance across years showed significant year to year variation in the June injury (1990, 1991, 1992, 1995), but not in the August injury. However, the year × clone interaction was significant ($p < 0.05$) for June and for August injury.

We have reported previously on variation among half-sib (10) and full-sib (12) seedlings of red maple in tolerance to the PLH, but this is the first documented report of significant differences among clones in PLH tolerance. PLH-tolerant red maple clones generally were those that initiated growth earliest in the spring (growth initiation, Table 3) (generally those clones from more northerly seed sources). Correlations between earliness of flushing on April 20, 1995 and PLH injury on June 29 and again on August 8, 1995, were significant ($r = -.47$ and $-.50$ based on clonal means, $n = 40$; $r = -.44$ and $-.46$ based on individual tree values, $n = 227$; all r values significant at 0.002 level). This relationship, with trees flushing earliest showing the least injury, was also found true with seedlings grown from known seed sources in a large provenance test in Ohio (10).

PLH feeding causes stunting of shoots and dwarfing of leaves, and reduces growth rate and vigor. Variation found among the maple clones in PLH tolerance is biologically significant, because those clones showing the least injury (most tolerance) grow more rapidly and are more likely to require less pesticide applications (1). Therefore, these clones can be selected for production, sale, and use in the nursery and landscape industries, with both biological and economic benefits.

This study showed widespread variation among red maple and Freeman maple clones and cultivars in the timing, duration, and intensity of autumn color; in time of growth initiation; and in relative tolerance to the PLH. Several of the U.S. National Arboretum red maple selections and/or cultivars showed promise when compared to several of the commercial cultivars, and therefore offer potential for use by or release to nurserymen. The Freeman maples showed much variability in color, with 'Jeffersred' showing the most reddish autumn color and the best PLH tolerance. The information presented here should provide initial guidelines for use of quality traits of red and Freeman maple cultivars and clones by the nursery and arboricultural industries.

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