Variation Among Full-Sib Progenies of Red Maple in Growth, Autumn Leaf Color, and Leafhopper Injury[1]

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Abstract

Controlled pollinations made between selected parents of red maple (*Acer rubrum* L.), and seedling progenies were planted in a randomized block design along with trees of the cultivars 'October Glory,' 'Autumn Flame,' and 'Red Sunset'. Tree height, autumn color, and leafhopper (*Empoasca fabae* (Harris)) injury were evaluated over an eight-year period. Differences among progenies and cultivars in leafhopper injury and in the time and quality of peak autumn leaf color were statistically significant for all years. These traits were significantly influenced by the female and/or male parent used to create the progeny. The timing of peak color was also influenced by a significant interaction between male and female parents. Growth rate and color intensity of the same progenies were generally consistent across years, whereas correlation for leafhopper damage was weak between years. Clonal selections from the best progenies have been made and are being evaluated for possible release to the nursery industry.

Index Words: red maple, leaf color, height growth, *Empoasca fabae*, full-sib crosses.

Significance to the Nursery Industry

Red maple (*Acer rubrum* L.) has widespread genetic variation in many desirable traits. Results of this study demonstrated that time and quality of autumn leaf color and tolerance to potato leafhopper can be changed and improved by making controlled pollinations between selected parents. Improvement for these traits can be made using crosses between specifically selected male and female parents or by choosing female (or male) parent trees that have an ability to generally transmit high quality traits to progenies. Superior clones have already been selected from some of these progenies and are under evaluation for possible release in the future to the nursery industry.

Introduction

Red maple (*Acer rubrum* L.) has become a very popular shade, landscape, and street tree. It is used for its environmental adaptability, attractive form, colorful flowers and fruits, and red autumn foliage color. A range-wide provenance test of this species revealed a wide degree of genetic variation in many important characteristics, including growth rate, quality of autumn leaf color, cold hardiness, phenology, precocity and frequency of flowering, and injury from potato leafhopper (*Empoasca fabae* (Harris)) feeding (4, 7, 8, 9, 10). In these studies, significant variation was found among stands and among trees within stands in their ability to transmit differences to their progenies.

Among the most important traits of a desirable red maple cultivar are rapid growth, good autumn color, and lowered susceptibility to leafhopper injury. To develop new, improved cultivars, it would be useful to assess the genetic mechanisms and levels of inheritance for these traits. The breeding study reported here will provide this information and will allow us to design the most efficient breeding and selection programs to make rapid genetic gain in these important characteristics.

This paper reports on a limited controlled-pollination study using several clones of red maple, and presents information on genetic variation among full-sib progenies and the importance of parent selection for red autumn leaf color, time of peak autumn color, height growth, and potato leafhopper susceptibility.

Materials and Methods

Crosses were made near Delaware, Ohio, in all combinations using the cultivars 'October Glory' and 'Red Sunset', and 118 TN (a tree chosen for its green autumn color, from a provenance near Harriman, Tennessee) as females and 'Autumn Glory', 'Autumn Flame', and R.S. 100 (a tree randomly selected in the Secrest Arboretum, Wooster Ohio) as males. Unfortunately, many of the crosses produced little or no seed. Progenies from successful crosses are listed in Table 1.

In order to make the crosses, mature branches were brought inside about a month before normal anthesis and placed in water in separate greenhouse sections. Pollen was collected on glass, sieved, and stored in a refrigerated desiccator until used. Non-woven cloth bags were placed over unopened flower buds on the female parent trees in late March, 1982. For each cross attempted, three bags were placed on each female tree. Controlled pollinations were made from April 1 to April 5, 1982, by using artist's brushes laden with pollen and inserted through small holes cut in each of the bags. After there was no longer a possibility of foreign pollen interference, all bags were ventilated in mid-April by reopening the original small holes made for pollination. Fruit was collected in mid-May, 1982. Fruit was collected also from two single trees, one tree grown from a seedlot from South Kingstown, Rhode Island (144C), another tree from an Alfred, Maine (152A) seedlot. Fruit was planted in flats (in a mixture of 2:2:1 peat:perlite:soil) immediately after collection and resulting seedlings were transplanted to one gallon pots in June, 1982.

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Table 1. Height, leafhopper injury, and autumn color of red maple progenies.

Progeny or Cultivar	No. of trees	November Height (cm)			Leafhopper injury (%)			Peak autumn color (0-100)				No. of days from 9-30-83 to peak color
		1983	1987	1990	6/87	6/91	7/91	1983	1985	1986	1987	1983
'October Glory' × 'Autumn Flame'	45	65	269	403	58	19	25	89	86	78	78	26
'October Glory' × 'Autumn Glory'	2	69	269	—[w]	60	5	10	90	100	40	45	36
'October Glory' × R.S. 100	3	60	272	429	60	13	17	87	77	73	77	21
118 TN × 'Autumn Flame'	19	70	269	409	58	53	51	63	41	34	34	17
118 TN × 'Autumn Glory'	2	64	245	405	70	40	50	50	30	30	15	17
118 TN × R.S. 100	7	65	292	407	58	41	45	48	22	36	27	23
'Red Sunset' × 'Autumn Flame'	2	72	286	410	55	20	25	95	70	95	85	34
'Red Sunset' × R.S. 100	4	70	323	403	37	25	33	73	53	55	40	28
144 RI Open-pollinated	12	49	266	392	55	43	52	57	37	42	33	24
152 ME Open-pollinated	12	59	254	374	47	24	27	56	29	32	15	17
'October Glory'	18	(119)[z]	(299)	(451)	47	9	8	89	72	77	82	33
'Red Sunset'	18	(125)	(337)	(451)	42	21	24	85	89	78	59	34
'Autumn Flame'	18	(−)	(240)	(358)	48	27	35	100	84	81	87	11
Significance level between groups[y]		NS	NS	NS	*	**	**	**	**	**	**	**
LSD (0.005)[x] =		—	—	—	18	21	19	18	18	23	23	8

[z]Trees representing cultivars were larger when planted and therefore height data were not included in the analyses. Cultivar means are presented in parentheses.

[y]Significance level between groups was 0.05(*) or 0.01(**) levels of probability, or not significant (NS).

[x]LSD was calculated using the harmonic mean of the number of trees per group.

[w]Trees were broken by a storm which made height measurement invalid.

Seedlings were transplanted in April, 1983, to a cultivated field site (Morely silt loam) near Delaware, Ohio, in a randomized block design with six blocks. The number of trees per plot from each controlled cross varied from one to eight, depending on the number of seedlings germinated. Own-rooted cultivars of 'Red Sunset,' 'October Glory,' and 'Autumn Flame' purchased from commercial sources were transplanted along with the controlled- and open-pollinated seedlings. Various data on height, autumn leaf color (visually indexed from 0 = no red color to 100 = most reddish), time of peak autumn leaf color, and leafhopper injury were recorded in different years from 1983 through 1991.

Significant differences among entry means (progenies and cultivars) for the evaluated traits were determined by analysis of variance (ANOVA) using the general linear model procedure (SAS) (6). When differences among entries were significant ($P = 0.05$) by ANOVA, an LSD at the 0.05 probability level was used to separate means. Factorial analyses were conducted for traits of the progenies from crosses between 'Autumn Flame', R.S. 100, and 'Autumn Glory' (male parents) and 'October Glory' and 118 TN (maternal parents). Phenotypic correlations between the various traits also were estimated and tested for signficance.

Results and Discussion

Heights of the red maple progenies did not differ significantly during the seven-year period in which measurements (Table 1). Leafhopper feeding during 1987 generally was high and resulted in more injury thanin 1991 (Table 1). The greater leafhopper injury of trees in 1987 compared to 1991 could be attributed to a higher density of leafhoppers that year, or to younger maples being more susceptible, or to some other environmental factor.

In 1987, the progeny of 'Red Sunset' X R.S. 100 had significantly less leafhopper injury than any of the other progenies. However, in 1991, the leafhopper damage of the progeny of this cross was only intermediate compared to the other progenies. In 1991, leafhopper injury differed significantly among progenies of female but not male parents (Table 2). Progenies of 'October Glory' had the least damage while progenies of 118 TN had the most damage. These results indicated that 'October Glory' possesses good general combining ability for leafhopper resistance and would be a good parent for improving leafhopper resistance in red maple. Also, based on the limited number of crosses, general combining ability appears to be more important than specific combining ability for leafhopper resistance. The importance of general combining ability has also been found in studies of other traits of full sib families of other woody species, including pear (1), peach (2), loblolly pine (3), and hybrid poplar (5).

The three standard cultivars generally had good peak colors in all years, except for 'Red Sunset' in 1991 (Table 1). The cultivars had significantly better autumn colors than the two open-pollinated seedling groups. Progenies varied significantly for autumn color. These differences are due mainly to the female parent (Table 2). Progeny of 'October Glory' and 'Red Sunset' generally had good quality color. Progeny

Table 2. Summary of factorial analyses of variance for selected crosses of red maple.

Source of variation	df	Height 1983	Height 1987	Height 1990	Leafhopper injury 6/87	Leafhopper injury 6/91	Leafhopper injury 7/91	Peak autumn color 1983	Peak autumn color 1985	Peak autumn color 1987	Peak autumn color 1987	Day to peak color from 9-30-83 1983
						Mean Squares for each trait						
Block	5	82.8	214.0	1070.1	5.4*[x]	2.9	1.3	2.6*	0.3	1.4	4.5	18.8
Female parent (F)[z]	1	1.3	259.4	259.4	0.1	52.2**	49.6**	51.6**	150.2**	42.4**	74.8**	374.1**
Male parent (M)[y]	2	53.6	1172.1	2729.5	1.3	5.1	2.4	4.2*	5.1	9.4	14.0*	41.0
M × F	2	35.2	285.4	285.4	1.1	0.1	0.7	0.8	2.4	4.3	0.8	167.0*
Error	14	2189.5	2414.7	2414.7	1.8	2.3	1.8	0.8	1.9	4.1	3.4	36.6

[z]Female parents were 'October Glory' and 118 TN.

[y]Male parents were 'Autumn Flame', 'Autumn Glory', and R.S. 100.

[x]Significant at the 0.05(*) or 0.01 levels (**), resp.

of 118 TN did not have good color even when highly colored males were used to pollinate it (Table 1). The interaction between male and female parents for color intensity was not significant in any of the years (Table 2), indicating the lack of dominant gene action. Based on the highly significant differences among females and to a lesser extent males, additive gene effects are important in determining autumn leaf color. With additive gene action, parents such as 'October Glory', selected for good autumn color, should produce progeny with good autumn color.

Time of peak autumn color varied significantly among cultivars, with 'Autumn Flame' coloring three weeks earlier than 'October Glory' and 'Red Sunset' (Table 1). Progenies also were markedly different in the timing of their peak color, with a span of almost three weeks between the earliest and the latest group (Table 1). The female parent and interaction between male and female parents significantly influenced time of autumn color (Table 2); both specific and general combining abilities therefore were important in controlling this trait in these full-sib progenies.

The correlation between leafhopper injury in 1987 and 1991 was significant, but weak (Table 3). The feeding damage of a tree in 1987 was not a good indicator of feeding damage for the same tree in 1991. The weak correlation suggests that selection of genotypes tolerant to leafhopper should be based on more than one year's data and that early, reliable prediction of tolerance may not be possible.

Consistency of color intensity across years resulted in highly significant and strong correlations for color ratings between years (Table 3). Selection for color intensity therefore could be accomplished by early evaluation in a limited number of years.

Leafhopper susceptibility in 1991 was negatively correlated with intensity of autumn color and with height. This association perhaps can be explained partly by the fact that those trees with the least susceptibility to leafhoppers are from northern or northcentral areas (10), and seedlings from these provenances frequently have shown rapid height growth and superior autumn color in Ohio (7, 9). On an individual tree basis, however, growth rate was not consistently and significantly correlated with intensity of autumn color. Determining whether or not leafhopper injury and autumn color are causally or coincidentally related to each other will require further investigation.

This study shows that controlled pollinations between selected parents of red maple can be used to increase or vary the timing of red autumn color, and to increase tolerance to leafhopper injury. Scientists at the U.S. National Arboretum are capitalizing on this information by selecting the best clones from the best progenies reported in this study.

Table 3. Individual tree correlations between various traits of red maple progenies.

	Leafhopper injury 6/91	Leafhopper injury 7/91	Autumn color 1983	Autumn color 1985	Autumn color 1986	Autumn color 1987	Height 1983	Height 1987	Height 1990	Day to peak color 1983
					Characteristic					
June 1987										
Leafhopper injury	.16*[z]	.23**	−.16*	−.09−	.18*	−.01	−.23**	−.11	−.03	−.16*
June 1991 leafhopper injury		.88**	−.37**	−.37**	−.31**	−.33**	−.18**	−.16*	−.19*	−.29**
July 1991 leafhopper injury			−38**	−.36**	−.31**	−.34**	−.22**	−.25**	−.29**	−.35**
Autumn 1983 color				.70**	.68**	.72**	.31**	−.02	−.05	.24**
Autumn 1985 color					.76**	.73**	.26**	.09	.11	.41**
Autumn 1986 color						.74**	.28**	.14	.19*	.27
Autumn 1987 color							.30**	.01	.10	.26**
November 1983 height								.34**	.33**	.06
November 1987 height									.83**	.06
November 1990 height										.19*

[z]Single (*) and double (**) asterisks indicate 0.05 and 0.01 levels, resp.

Selections have been made from the 'October Glory' × 'Autumn Flame' and the 'Red Sunset' × 'Autumn Flame' progenies; several of these clones have been propagated and distributed for national evaluation. All combine consistent and excellent color with lower leafhopper susceptibility.

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Nitrogen Leaching from Osmocote-Fertilized Pine Bark at Leaching Fractions of 0 to 0.4[1]

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Abstract

Pine bark-filled PVC columns with 1 g Osmocote (14N-6.3P-11.6K)(14-14-14) per column were irrigated five days a week for 12 weeks with a leaching fraction (LF) of 0, 0.2, or 0.4. Every two weeks cumulative N content of collected leachate and medium solution N concentration (pour-through method) were determined. The total amount of N leached from bark at 0.4 LF was 61% greater than at 0.2 LF. Medium solution NO_3-N concentrations of 0 LF were four to eight times greater than at 0.4 LF for all sampling dates. After 84 days, there was no difference in amount of N remaining in Osmocote prills for the LF treatments.

Index words: container-grown, soilless media, fertilization, controlled release fertilizer

Significance to the Nursery Industry

Nutrient loss from soilless substrates of container-grown plants is directly related to irrigation regime. Results of this study show that leaching fraction has no affect on the release rate, and hence duration of Osmocote, but dramatically affects the amount of N available to plants and the amount leached from the container. To increase the amount of N availabe to plants and to decrease the amount of N lost via leaching, growers should irrigate with the lowest leaching fraction possible.

Introduction

Irrigation of container-grown crops has a profound influence on fertilizer concentration in the medium solution and on the amount of fertilizer leached from the medium. Leaching is usually quantified by the term leaching fraction (LF) which is defined as volume of solution leached/volume of solution applied. Much research is reported without reference to LF which is a significant omission due to the current attention and emphasis on fertilizer pollution.

Ku and Hershey (2) applied 300 mg N/liter to container-grown poinsettia and obtained leachate EC of ≈ 14, 8, and 4 at LF of 0.1, 0.2, or 0.4 dS m^{-1}, respectively. There is considerable commercial as well as scientific interest in controlled release fertilizers (CRF) such as Osmocote, since plants fertilized with CRF may lose less nutrients via leaching (5) than liquid fertilizer. Hershey and Paul (1) irrigated container-grown plants at a LF of ≈ 0.27 for 11 weeks and found that liquid fertilizer N leaching losses were greater than CRF. However, CRF N losses depended on application rate and ranged from 0.3 to 0.8 g per pot which, relative to the amount N applied, was a 12% to 23% N loss. Thus, N loss from CRF can be significant. The objective of this work was to determine the affect of a 0, 0.2, and 0.4 LF on N loss from Osmocote prills and N leached from Osmocote-fertilized pine bark.

Materials and Methods

Ninety grams of moist pine bark (*Pinus taeda*) (38 g oven dry weight) amended with 3 kg dolomitic limestone and 1

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