GENETIC VARIATION IN RED MAPLE ROOTSTOCKS

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Red maple (Acer rubrum L.) is one of the most widely planted species in metropolitan regions of the Northeast. The genus Acer accounts for nearly one third of the trees planted by municipalities and highway departments (Gerhold et al. 1975) - it is clearly in the lead of the top 50 genera. The only street tree species planted in greater numbers are Acer platanoides L. and Gleditsia triacanthos L. (Long et al. 1973). Over 15,000 red maples have been planted annually by public agencies in recent years, representing annual investments in excess of $600,000. Large numbers are also planted by private property owners. Commercial nursery sales are estimated to exceed 150,000 trees per year.

A large proportion of red maples produced by commercial nurseries consists of selected clones budded on unselected seedling rootstocks. Possible effects of different provenances on scion characteristics have never been tested systematically. Nurserymen know of at least one root-stock effect, a graft incompatibility that may affect five or ten percent of the ramets. These have weak graft unions subject to breakage and their leaves show autumn coloration prematurely. Perhaps this problem could be alleviated through genetic control of rootstocks, for example by using selected provenances or families   Any rootstock effects on other characteristics such as growth rate, autumn coloration, or resistance to environmental stresses are still unknown,

The purposes of this report are twofold: (1) to describe the initial phase of an experiment that will explore effects of genetically variable rootstocks on four red maple cultivars, and (2) to discuss potential applications of the results.

METHODS

The seedlings to be used as rootstocks were grown from seeds planted at Delaware, Ohio, in May 1972. They are a portion of a range-wide seed source study organized by A, M. Townsend. In March 1974, twenty open-pollinated families from fifteen provenances were lifted and transported to Princeton, New Jersey, and planted in four-inch-deep clay pots. Some root pruning, occasionally rather drastic, was required on most seedlings. They remained in an irrigated cold frame until July 23, when they were transplanted into a portion of Princeton Nurseries. Though the root pruning, potting, and late transplanting were abnormal, the seedlings came

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through in excellent condition with only 2.2% mortality. The planting design consisted of four long rows (5.5 feet apart, with trees spaced 2.0 feet apart within rows) broken transversely into four complete replicates, each containing randomized 12-tree plots positioned across the four rows.

Total height and foliage color were measured October 12, 1974, when autumn colors were at a peak. The color scale ranged from 0 to 10, and 0 to 10 scale units were allocated to green, yellow, or red according to proportion of leaf surface occupied by each color. The sum of the three color scores on each tree equalled 10. Measurements were subjected to analyses of variance. Similar data from Ohio, consisting of means from seedlings of the same families and provenances, were used in correlation analyses.

In July or August 1975 four commercial cultivars are to be budded on the rootstocks. The clones will be randomly assigned to rows within replicates, so that three trees of each family plot will serve as rootstocks per clone.

RESULTS

The potting and root pruning operations provided a good opportunity to observe considerable variation in rooting habit among and within families, Some seedlings had many fibrous roots within three inches of the root collar, while others had deep tap roots with few side roots, Some had a wide spereading system. Most notable among those was family 166 L from Quebec; many of its seedlings had a right angle bend an inch or two below the root collar.

Large differences in height were apparent at the end of the third growing season (Table 1). The tallest families, from South Carolina and Ontario, were more than twice the height of the shortest, from Wisconsin and Quebec. The differences between two Quebec families ,(14.1 versus 8.9 inches) and two Ohio families (14,5 versus 10.4) from the same populations indicate that at least some of the variations observed is attributable to families within provenances. Heights of three-year-old (2-1)transplants in New Jersey were closely correlated with those of two-year-old seedlings in Ohio. The r2 values (9 d.f., significant at 5% level) were 0.52 when family means were used, and 0.68 when family means in New Jersey were compared with population means in the more extensive Ohio experiment.

The data on color required careful interpretation because proportions of the three colors were not independent and measurements were not taken at the time of maximum coloration for all families. Proportion of green foliage was probably a measure of time of autumn coloration. In general the greener, or later, families were native to warmer regions (Table 2). The family from South Carolina was especially noticeable because it was much greener at the time of measurement. Many of these southern trees also showed signs of recent shoot growth,

Table 1.--Mean heights of red maple families.

Family[1]	Source	Height, Inches	Significant Differences[2]
170A	South Carolina	21.3	A
164D	Ontario	18.0	AB
141B	Michigan	16.7	BC
152C	Maine	16.2	BCD
137B	Michigan	15.3	BCDE
128C	Ohio	14.5	CDEF
166L	Quebec	14.1	CDEFG
162C	Michigan	14.1	CDEFGH
137A	Michigan	13.8	CDEFGHI
139BD	Minnesota	13.8	CDEFGHIJ
141C	Michigan	13.4	CDEFGHIJK
142B	Pennsylvania	13.2	CDEFGHIJKL
163C	Maine	12.7	EFGHIJKLM
162E	Michigan	12.4	EFGHIJKLMN
167F	New Brunswick	11.0	FGHIJKLMNO
153J	Ontario	10.7	GHIJKLMNO
129C	Ohio	10.4	IJKLMNO
155E	Wisconsin	9.8	LMNO
166H	Quebec	8.9	NO
155D	Wisconsin	8.2	O

[1] Families from the same locality share the same numerical designation; also, 128C and 129C are from the same locality. Two families are combined in 139BD.

[2] Families not sharing the same letter were signific different.

Table 2.--Percent of green foliage in red maple families.

Family[1]	Source	Percent Green	Significant Differences[2]
170A	South Carolina	51	A
142B	Pennsylvania	34	B
128C	Ohio	34	BC
129C	Ohio	30	BCD
162E	Michigan	30	BCDE
141C	Michigan	28	BCDEF
164D	Ontario	28	BCDEF
167F	New Brunswick	28	BCDEF
137B	Michigan	26	BCDEF
137A	Michigan	25	BCDEF
152C	Maine	25	BCDEF
163C	Maine	23	BCDEF
162C	Michigan	23	BCDEF
141B	Michigan	22	CDEF
153J	Ontario	19	DEF
155E	Wisconsin	19	DEF
166H	Quebec	18	EF
139BD	Minnesota	18	EF
155D	Wisconsin	18	EF
166L	Quebec	18	F

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[2] Families not sharing the same letter were significantly different,

As an estimate of eventual color development in the families, we calculated the ratio of percent red foliage to percent red plus yellow foliage as it existed on the day of measurement. This trait is mathematically independent of the proportion of green foliage, but it remains to be determined whether the ratio changes as more of the green leaves turn color. As Table 3 shows, several families differed in their proportions of red foliage, There was no discernible geographic trend to the variation.

None of the correlations attempted between autumn foliage color in New Jersey and autumn or spring foliage color or percent leaf fall in Ohio were significant, However, data from only eleven families were available at both locations, and these did not include the more southerly ones from South Carolina and Pennsylvania.

DISCUSSION

The families in the experiment probably include a large proportion of the variation that exists in the northern half of the natural distribution of red maple. The fifteen provenances are rather widely separated, but the one or two families representing each provenance are not necessarily typical of their populations. The results are in general agreement with an earlier report by Townsend (1974), which included additional northern slow-growing populations and southern fast-growing populations. The proportion of variation that has been sampled, and the components attributable to populations or families, can be defined better after subsequent results of the more extensive provenance experiments of A. M. Townsend become available. The fairly strong correlation of seedling height at New Jersey and Ohio will make interpretation of the rootstock experiment results easier and more reliable.

The effects that rootstock genotype may have on scions remain to be seen. The rather wide variation that exists among the families in root development, growth rate, and foliage color suggests that prospects for rootstock effects are good. Any of several characteristics could be influenced. The results that Copes (1974) obtained with Douglas-fir indicate that the graft incompatibility mentioned earlier could be reduced. Growth rate could be increased or decreased, as suggested by the well-known dwarfing effect in fruit trees. Even foliage color might be affected -- we have elsewhere observed variation in autumn coloration within several red maple clones, though it was not possible to determine whether variation in rootstocks or site conditions was the cause. Genetic differences in tolerance to Verticillium wilt have been reported by Townsend and Hock (1973). Wilt resistance would be a useful characteristic in rootstocks, as the roots are a common entry point for the pathogen. Red maple provenances also differ in reaction to water stress (Townsend and Roberts 1973), which suggests that resistance to drought or recovery from transplanting might be improved. These improvements or others are of course speculative at this time.

Table 3.--Percent of red foliage in red maple families, expressed in proportion of total autumn color.

Family[1]	Source	Percent Red	Significant Differences[2]
141B	Michigan	42	A
155E	Wisconsin	31	AB
139BD	Minnesota	30	B
153J	Ontario	30	B
128C	Ohio	30	B
166L	Quebec	29	B
152C	Maine	28	B
162C	Michigan	26	B
141C	Michigan	26	B
137B	Michigan	26	B
155D	Wisconsin	26	B
170A	South Carolina	26	B
167F	New Brunswick	26	B
164D	Ontario	25	B
129C	Ohio	25	B
162E	Michigan	25	B
137A	Michigan	24	B
142B	Pennsylvania	24	B
163C	Maine	24	B
166H	Quebec	20	B

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POTENTIAL APPLICATIONS

Rootstock Cultivars. Any beneficial effects of rootstocks on scions that may be discovered will require the growing of specialized cultivars if their advantages are to be exploited. Rootstock cultivars could be grown from seed of selected provenances, seed orchards, or single families; or they could be cloned through stem or root cuttings. The costs and benefits associated with each type of rootstock will need to be compared carefully, Not the least of the considerations is the degree of adaptability and stability that can be derived from genetically uniform or variable rootstock - scion combinations. Root properties are of special concern when exposed to urban stresses caused by soil compaction, restricted space for roots, chemical contaminants in the soil and air, and other unnatural conditions.

If, on the other hand, rootstock effects are found to be inconsequential under nursery and street-side conditions, the experimental results need not be considered a waste. In that case nurserymen and arborists would not have to be concerned about genetic qualities of the rootstock portion of the tree. Any seed that is cheap and available would suffice

Underground Genetic Tests,--Genetic variation in rootstocks offers interesting possibilities for genetic tests and perhaps partial solutions to some of the problems of urban tree improvement. One of the most serious difficulties faced by urban tree breeders is the constraint on numbers of trees that can be tested in urban spaces. Seldom is there room to plant hundreds or even dozens of trees together in a suitable statistical design. Hence, complete tests may have to be spread over large areas with the consequence of increased environmental variation and large experimental error terms. This difficulty may not be so great in genetic tests of rootstocks, since at least above-ground environmental variation will have less effect on the characteristics in question than would be true in conventional experiments.

Another drawback with urban tree tests is that the amount of variation (in height, branching habit, leaf shape, etc.) in a typical provenance test would not be acceptable to most municipal arborists, By going underground with provenance or progeny tests, it might be possible to alleviate this problem. Since genetic variation would be confined to root systems, the aerial portions of the trees (consisting of commercial cultivars) would probably have sufficient uniformity to satisfy arborists and the public. Data would come from the effects of genetically different rootstocks on the scions -- effects probably more related to survival and vigor than to the more aesthetic qualities of appearance. We must admit that few such effects are known, but the subject seems important enough to justify more thorough investigation.

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