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GENETIC VARIATION IN SEED AND FRUIT CHARACTERS IN SUGAR MAPLE

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Abstract

A study of the seeds and fruits of sugar maples from 32 provenances has shown that: (1) dry weight of seed and percentage of filled fruit varied genetically among and within provenances; (2) dry weight of seed and latitude of provenance are positively correlated; provenances from higher latitudes and colder temperatures exhibited higher weights; (3) the percentage of filled fruit was not significantly related to dry weight of seed and was negatively correlated with latitude; (4) dry weight of seed exhibited a complex pattern of genetic variation; in the northeast the variation was ecotypic with a strong suggestion of a cline within ecotype; in the remainder of the species' range the variation appeared clinal in nature.

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INTRODUCTION

SUGAR MAPLE (*Acer saccharum* Marsh.) grows from Minnesota through eastern Canada and south into Tennessee and Missouri. The different environments within this wide range exert selection pressures which the species must adapt to if it is to survive. Consequently, the potential for genetic variability in sugar maple is high.

In support of our program to improve sugar maple, samples of seed from throughout the species range were collected for a study of the nature and pattern of genetic variability. Currently, the study is in its early stage of development with outplantings established in Vermont, New York, West Virginia, and Michigan.

Before the outplantings were established, the differences in the dry weight of seed and the percent of filled fruit of the samples were examined. This paper reports on the variations observed within and among provenances.

MATERIALS AND METHODS

Seeds and fruits were collected from eight trees within each of 32 provenances (Table 1). Freedom from damage caused by insects and disease was the criterion for the selection of mother trees. All collections were kept separate, by tree within provenance, during the experiment.

The average values derived from the percentage of filled fruit and dry weight of seed were based on

Table 1.—Location and elevation of provenances of *Acer saccharum*

Seed lot	Town	District or county	State or province	Latitude north	Longitude west	Elevation
						Ft
3	Hinton	Caddo	OK	35°30′	97°45′	1,100
7	Cumberland	Harlan	KY	36°55′	82°57′	3,600
8	Carbondale	Jackson	IL	37°40′	89°10′	425
9	Parsons	Tucker	WV	39°02′	79°40′	2,400
10	Hoosier Natl. For.	Monroe and	IN	38°56′	86°31′	600
		Lawrence	IN	38°56′	86°31′	600
11	Greendale	Hocking	OH	39°34′	82°17′	700
	Maxville	Perry	OH	39°34′	82°17′	840
12	Ligonier	Dist. #4	PA	40°10′	79°10′	1,500
13	Alliance	Columbiana	OH	40°57′	81°10′	1,120
14	Irvine and		PA	41°50′	79°16′	1,200
	Warren	Warren	PA	41°50′	79°07′	1,300
15	East Lansing	Ingham	MI	42°45′	84°30′	600
16	Stamford	Delaware	NY	42°27′	74°38′	2,200
17	Lanesboro	Berkshire	MA	42°32′	73°15′	1,500
18	Plainfield	Sullivan	NH	43°27′	72°23′	400
	Newport	Sullivan	NH	42°37′	72°23′	400
19	Hancock	Addison	VT	43°55′	72°50′	950
20	Indian River	Lewis	NY	44°00′	75°23′	900
21	Maple	York	ON	43°50′	79°30′	500
22	Grayling	Crawford	MI	44°35′	84°45′	1,300
23	Farmington	Franklin	ME	44°40′	70°07′	560
24	Bradley	Penobscot	ME	44°52′	68°39′	200
25	Argonne Exp. For.	Forest	WI	45°42′	89°02′	
26	Ste. Anne de Bellevue		PQ	45°15′	74°00′	150
27	Killarney	Manitoulin	ON	45°58′	81°31′	600
28	Amasa	Iron	MI	46°15′	88°33′	1,550
29	Quebec City		PQ	46°44′	71°18′	330
30	St. Quentin	Victoria	NB	47°20′	67°38′	1,000
31-A	Pike Bay Exp. For.	Cass	MN	47°15′	94°30′	1,300
33	North Branford	New Haven	CT	41°20′	72°45′	200
34	Mille Lacs	Mille Lacs	MN	46°03′	93°40′	1,300
35	Fairfield	Franklin	VT	44°48′	72°57′	600
36	Underhill Center	Chittenden	VT	44°28′	72°56′	750
37	Wallingford	Rutland	VT	43°27′	72°54′	1,575
38	Bennington	Bennington	VT	42°57′	73°10′	1,000

three samples taken from each seed lot. For the filled fruit determinations, the number of fruits that were opened to obtain 15 seeds was recorded for each sample. Dry weights were based on 10-seed samples that were oven-dried at 40°C and weighed on an electronic balance.

Since a portion of the seed is sacrificed when dry weights are determined, the quantities of seed collected in provenances 3 and 22 (Oklahoma and Michigan) were judged to be too small to be included in the study. Similarly, the mean values for provenances 9, 11, 14, and 28 were based on seed collections from 7, 6, 5, and 7 mother trees. These provenances were not included in the computations because the number of seeds in one or more seed lots was inadequate.

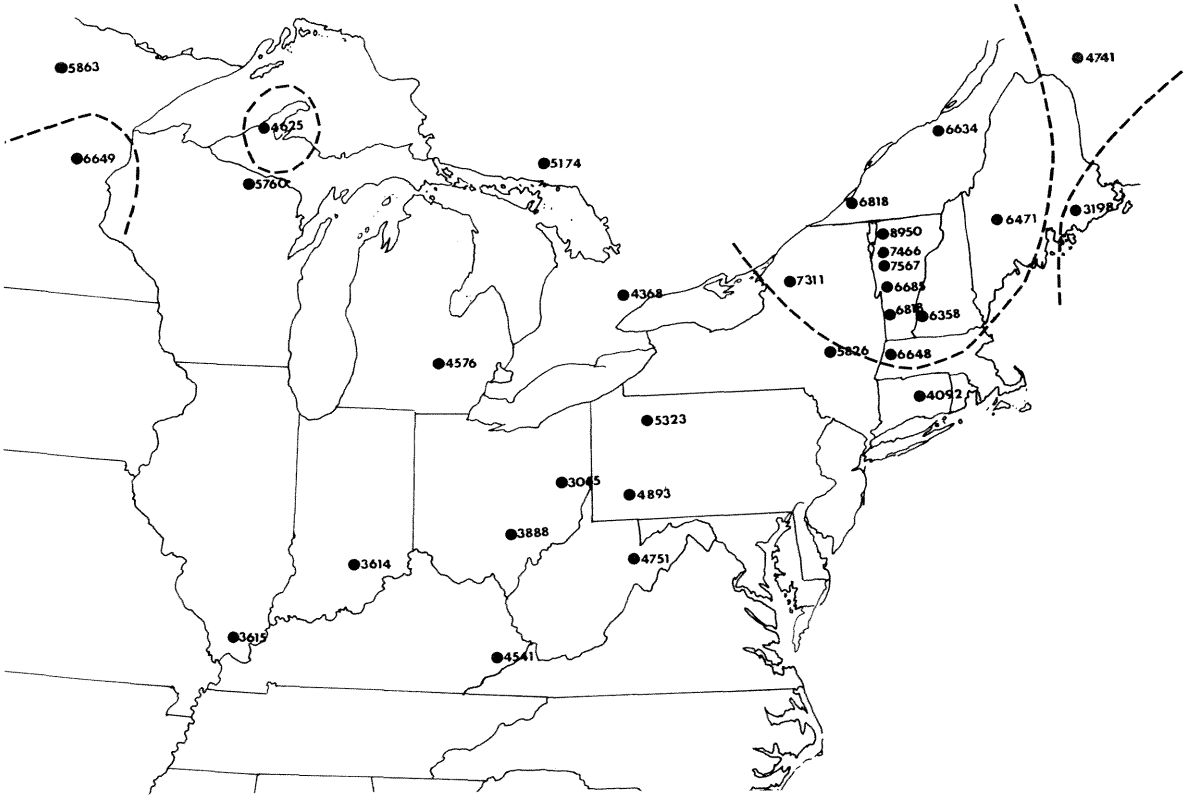
Analysis of variance was used to evaluate the significance of differences among and within provenances. Before the analysis, an angular transformation of the percentage of filled fruit was made, scatter diagrams and maps were drawn, and correlation analyses were run to illustrate the relations of attributes to each other and to the latitude of seed origin.

RESULTS AND DISCUSSION

Dry weight of seed

The dry weight of seed is highly variable in sugar maple. Differences between and within provenances were highly significant. Provenance means (in grams) ranged from 0.8950 g (northern Vermont) to 0.3065 g (southeastern Ohio). The variation within provenance was greatest along the north shore of Georgian Bay, Ontario, where averages varied from 0.8699 g to 0.5258 g. The least variation was found in Quebec, where averages ranged from 0.7582 g to 0.57705 g. Among all 233 seed lots in the study, the highest dry weight average was 1.1152 g (Vermont); the lowest was 0.1995 g (Maine).

Figure 1.—Dry weight of seed plotted according to origin (Grayling, Michigan, and Hinton, Oklahoma not shown), with approximate boundary of northeastern ecotype. (Means in grams x 10^{-4}.)



A simple north-south gradient was found in the western and central parts of the study area (Fig. 1). In general, the northern sources had higher dry weights than the southern. Correlation between weight and latitude was significant at the 1 percent level (r = 0.486). The higher weights among the Kentucky and West Virginia origins are irregularities that may be related to the higher elevations of the seed collection sites (Table 1).

Variation in the northeast was characterized by a moderately distinct ecotype (Fig. 1). The average dry weight of seed of provenances in this ecotype exceeded that of the other origins in the study by 42 percent. Boundaries of this ecotype generally followed the Adirondack Mountains on the west, and the Berkshire Mountains on the south. The relatively heavy seed and the insect pollen vectors typical of sugar maple suggest that the mountains could offer an effective barrier to gene exchange between most of the New England region and the remaining part of the species' range.

A more intensive sampling was made within a relatively small area of the ecotype. Seed collections were made in five locations along a north-south transect in Vermont. The average dry weights of seed for each origin and the corresponding average annual minimum temperature for the general area of each seed collection are:

Origin north to south	*Average annual minimum temperature (degrees C)*	*Average dry weight (grams)*
Fairfield	−47.8	0.8950
Underhill	−39.1[1]	.7466
Hancock	−43.2	.7567
Wallingford	−36.0	.6685
Bennington	−35.6	.6618

The apparent north-south trend in seed weights strongly suggests a cline within the ecotype. The gradient in minimum temperature is in general agreement with the dry weight gradient. From this, the inference is drawn that higher dry weights of seed associated with higher latitudes are an adaptive response of the species to colder climates. Factors relating heavier seed to survival are beyond the scope of this study. However, in other species, rapid initial growth of seedlings was correlated with seed weight (Adams and Thielges 1976, Gall and Taft 1973); this has not yet been demonstrated in sugar maple.

[1] Based on weather data taken at Burlington Airport. Temperatures at Underhill are 5 to 6 degrees colder, according to personal communications with personnel at the Proctor Maple Research Farm at Underhill.

Percentage of filled fruit

The percentage of filled fruit was relatively uniform over a large part of the area, although differences among and within provenances were statistically significant. But most provenance means were closely grouped about the overall mean of 49.5 percent. The significant difference found in the analysis was attributed to the large variation among a smaller number of provenances in the extreme north and south part of the area.

The percentage of filled fruit was highest among southern origins (Fig. 2), particularly Illinois (63 percent), Kentucky (61 percent), and southeastern Pennsylvania (60 percent). The lowest values were found in the north: two origins from Ontario (33 and 40 percent), Minnesota (42 percent), and Wisconsin (42 percent). No clear indications of ecotypes were found, but the expression of clinal variation seemed stronger in the central and western parts of the study area.

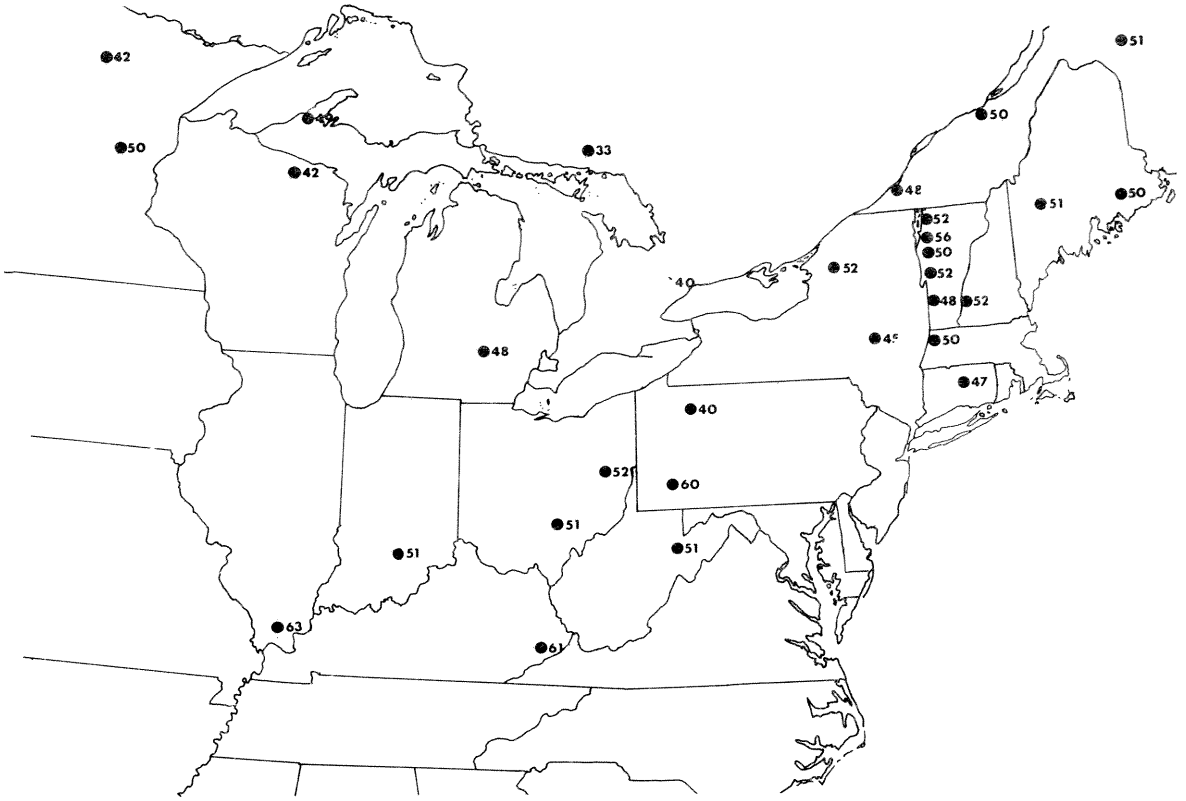
Variation within provenance was highest among seed lots from the northwestern Pennsylvania origin (21 to 83 percent). The least variation was found in the two seed origins from Maine (49 to 51 percent and 50 to 52 percent). Among the 233 seed lots studied, the percentage of filled fruit was highest (90 percent) in northern Vermont and lowest (21 percent) in northwestern Pennsylvania.

A negative relation between the percentage of filled fruit and the latitude of seed origin was found. In the analysis of correlation, the coefficient (r = −0.484) was significant at the 1 percent level. The percentage of filled fruit was comparatively uniform among provenances in the northeastern dry seed ecotype, averaging only 1.5 percent above the overall study mean.

The percentage of filled fruit was not found to be correlated with dry weight of seed. The low correlation coefficient value of +.0145 was not significant.

The number of species competitive with sugar maple increases from the northern hardwood region, through a broad area of transition, into the central hardwood region (Braun 1950). Thus, the pattern of variation in the percentage of filled fruit suggests an adaptation to increased competition for the more mesophytic sites.

Figure 2.—Percentage of filled fruit plotted according to origin (Grayling, Michigan, and Hinton, Oklahoma not shown).



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