ONE-PARENT PROGENY TEST OF SUGAR MAPLES SELECTED FOR SUPERIOR SAP-SUGAR PRODUCTION -- EARLY RESULTS

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INTRODUCTION

It is common knowledge among those who make maple syrup that within the same sugarbush the sap from some trees is sweeter than that from others; and syrup producers often pause in the course of collecting sap to take a drink from these sweet trees.

Independent surveys conducted in Vermont and New York have shown that the average sap-sugar content of trees in these two major syrup producing states was 2.5 percent. At this level of concentration, 34 gallons of sap must be collected and boiled down to make 1 gallon of syrup. However, trees have been found that exceed this average by a considerable margin. To the best of my knowledge, the highest sugar content observed and documented for any healthy tree, during a steady sap flow, was 10.6 percent. At this level, only 8 gallons of sap would be required to make a gallon of syrup.

Several studies have been carried out in the past by other researchers in an effort to correlate variation in sap sugar with environmental factors. Average sugar percents of open-grown roadside and forest-grown trees on similar sites were compared by Stevenson and Bartoo (1940). The results of the study led the authors to conclude that crown length contributed more to the sap-sugar content than crown width.

Morrow (1955) found that live crown ratio and crown diameter accounted for only a small part of the variability in sugar percentages in three different sugarbushes that he studied. Similarly, the variation in sugar content of trees observed by Moore, Anderson, and Baker (1951) could not be correlated by the authors with site or other environmental factors.

Taylor (1956) reported variations in sap sugar as high as 100 percent between trees within the same stand. Performance records that were kept on these trees showed that the degree of variation changed, but that the same trees maintained their superior ranking from year to year.

This paper is a report on the results of a one-parent progeny test of sugar maples selected for sap-sugar production, 10 years after outplanting, in a cooperative effort between the Northeastern Forest Experiment Station and the Vermont Agricultural Experiment Station. It should not be confused with a more extensive program for the selection of sugar maples for superior sap sugar that was recently completed by our genetics project at Burlington.

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Table 1.--Performance records of parent trees represented in the sugar maple one-parent progeny test.

Parent tree number	Sap-sugar content--annual average percent													Average
	'44	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	
545	-	-	-	-	-	-	-	-	4.2	4.5	4.3	-	4.8	4.5
572	-	-	-	-	-	-	-	-	4.3	4.4	6.8	-	6.7	5.6
573	-	-	-	-	-	-	-	-	4.4	4.4	4.7	-	4.5	4.5
574	-	-	-	-	-	-	-	-	3.1	4.0	3.5	-	4.1	3.7
575	-	-	-	-	-	-	-	-	4.7	3.2	4.0	-	4.4	4.1
576	-	-	-	-	-	-	-	-	3.5	3.0	4.0	-	3.9	3.6
577	-	-	-	-	-	-	-	-	5.1	4.6	4.2	-	5.5	4.9
583	-	-	-	-	-	-	-	-	4.8	3.9	4.6	-	4.5	4.5
585	-	-	-	-	-	-	-	-	4.3	4.1	3.4	-	3.9	3.9
624	-	-	-	-	-	-	-	-	4.1	4.4	4.0	-	4.1	4.2
632	-	-	-	-	-	-	3.9	-	3.2	3.7	3.8	-	4.5	3.8
640	-	-	-	-	-	-	3.5	-	3.4	3.5	3.6	-	4.7	3.7
645	-	-	-	-	-	-	3.9	-	3.5	4.2	4.4	-	4.0	4.0
664	-	-	-	-	-	-	-	-	4.0	4.5	4.4	-	4.3	4.3
397	-	-	-	2.4	2.2	2.2	2.6	2.6	2.4	2.2	2.3	2.2	2.1	2.3
457	-	-	-	-	1.9	2.3	2.3	2.5	2.6	2.6	2.3	2.0	2.1	2.3
463	-	-	-	3.5	3.0	3.2	2.6	3.1	3.7	3.0	3.0	2.7	2.9	3.1
491	-	-	-	3.2	-	3.6	2.9	3.4	3.5	3.2	3.0	2.8	2.9	3.2
226	6.6	5.9	-	5.6	4.6	4.2	5.2	6.0	6.9	4.9	4.5	3.5	-	5.3
227	7.0	5.0	4.8	4.8	4.4	4.5	4.6	5.6	6.2	4.9	4.0	-	-	5.1
232	4.9	5.1	4.5	3.7	4.0	4.1	4.5	4.9	4.9	3.7	4.5	3.9	-	4.5
234	4.2	4.2	3.3	4.2	4.0	4.4	4.0	4.6	4.2	3.4	3.1	4.5	-	4.0
263	3.9	3.8	3.6	3.5	3.5	3.7	3.7	4.0	3.5	2.3	3.0	2.4	-	3.4
269	3.8	3.8	3.1	3.2	3.2	3.1	3.0	3.6	3.4	3.0	2.5	2.8	-	3.2
303	4.3	4.1	4.5	-	4.8	3.7	4.4	5.4	3.4	3.2	4.3	-	-	4.2

MATERIALS AND METHODS

The progenies in the study originated from 25 selected phenotypes on which performance records had been kept for periods ranging from 4 to 12 years (Table 1). Fourteen of the selections were made in the vicinity of Williamstown, Massachusetts, by Northeastern Station personnel, and 11 trees were selected in northeastern Chittenden County, Vermont, by personnel from the Vermont Agricultural Experiment Station.

Seeds resulting from open-pollinated flowers were collected from 23 superior and 2 low sugar-producing phenotypes. After 3 years in the nursery, randomly selected seedlings from each progeny were set out in a randomized block design in duplicate outplantings at Williamstown, Massachusetts, and Underhill Center, Vermont. Each plantation was enclosed in a 10-foot-high, deer- and rabbit-proof fence.

A micro-tapping technique described in one of my earlier publications (Gabriel, 1969) was used in making sap-sugar tests. Essentially, it made use of a No. 20 hypodermic needle inserted into the seedling's stem to act as a spile, and a refractometer that required only one drop of sap to obtain a measurement of the sap-sugar content. The data collected were subjected to a statistical analysis to partition the variance according to progenies, plantation location, block, progeny-location interaction, and experimental error.

RESULTS AND DISCUSSION

The results of the experiment, to date, indicate that there are significant differences between progenies in sap-sugar content (Table 2). In the Massachusetts outplanting, sap sweetness ranged from 1.7 percent to 3.1 percent. In the Vermont outplanting, the range was from 1.5 percent to 3.2 percent. I would like to point out that the seemingly small difference of 0.3 percent in sap-sugar content between the ranges in variation at the two outplantings amounts to 11 gallons of sap for each gallon of syrup that would be manufactured.

Table 2.--Analysis of variance of sugar maple one-parent progeny data.

Source of variation	Degrees of freedom	Mean square	F
Progeny	24	0.3197	2.184**
Location	1	1.9429	13.271**
Blocks (in location)	6	0.8253	4.972**
Progeny x Location	24	0.1464	0.882
Error	144	0.1660	

** Significant at 0.01

A comparison of the relationship of the performances of parent trees with corresponding progenies showed that, of 8 trees ranked as the top third of

Table 3.--Ranking of parent trees and corresponding progenies at the Massachusetts and Vermont locations according to average sap-sugar content.

Progeny number	Parent tree		Massachusetts location		Vermont location	
	Sap sugar ave. percent	Rank	Sap sugar ave. percent	Rank	Sap sugar ave. percent	Rank
572	5.6	1	2.2	20-1	2.2	10-2
226	5.3	2	2.4	7-6	2.6	1-1
227	5.1	3	2.3	15-3	2.6	1-2
577	4.9	4	2.2	20-2	1.9	23-2
573	4.5	5-1	2.4	7-1	2.1	17-1
583	4.5	5-2	2.6	1-1	2.5	3-1
545	4.5	5-3	2.5	5-1	2.2	10-1
232	4.5	5-4	2.2	20-4	2.2	10-6
664	4.3	9	2.2	20-3	2.2	10-4
303	4.2	10-1	2.4	7-8	2.1	17-4
624	4.2	10-2	2.3	15-1	2.0	21-1
575	4.1	12	2.1	24-2	2.1	17-2
234	4.0	13-1	2.4	7-7	2.0	21-2
645	4.0	13-2	2.3	7-2	2.3	6-3
585	3.9	15	2.4	7-3	2.3	6-2
632	3.8	16	2.4	7-4	2.2	10-3
640	3.7	17-1	2.6	1-2	2.5	3-2
574	3.7	17-2	2.1	24-1	2.3	6-1
576	3.6	19	2.4	7-2	1.9	23-1
263	3.4	20	2.3	15-4	2.2	10-7
491	3.2	21-1	2.6	1-4	2.2	10-5
269	3.2	21-2	2.3	15-5	1.9	23-3
463	3.1	23	2.5	5-2	2.4	3
397	2.3	24-1	2.6	1-3	2.1	17-3
457	2.3	24-2	2.4	7-5	2.3	6-4

the selected phenotypes, 4 had progenies in the top third of the Massachusetts outplanting and 3 were in the top third of the Vermont outplanting (Table 3). Differences observed between outplanting locations were found to be highly significant.

No apparent relationship was noted between the performances of progenies and parent trees. In all but two cases, the average sap-sugar content of progenies was lower than those of parent trees (Table 3). In a number of instances, the parent-tree values were nearly double those of their progenies. In the two exceptions noted, both progenies were from phenotypes considered low in sugar content. These results differ from those of Kriebel (1957), who found that sugar contents of young trees were comparable to mature trees and concluded that early correlations between parent and progeny trees were feasible.

The results of the one-parent progeny test would indicate that there are genetic differences between progenies, but the unusually large number of progenies with the same average sugar content points out that full genetic expression has not yet been reached and that still greater variations between progenies should be expected as the experiment progresses. Further development may also reduce the discrepancy noted between Kriebel's observations and those made in this study, regarding the effects of tree age on sap sugar.

The lack of interaction between location and progenies indicated that the performance of the latter was consistent in both outplantings. Highly significant differences were found between blocks. However, as the experiment progresses and a more complete expression of the trees occurs, I feel that block effects will be greatly reduced.

Sap sugar measurements will be continued, and another report on this study will be made in the near future.

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LEDIG- Bill, did you calculate any statistics from that value, such as parent-progeny regressions or heritability based on variance components?

GABRIEL - I don't want to go too deeply into this because this is the first year that we got readings from all of our individuals. In view of the large numbers of progenies that have the same average sugar content, I felt that we weren't justified in doing this.

VALENTINE - You used more than one progeny from a given parent tree. Did you use a number of the open-pollinated seeds from a given source? The point I am trying to make is that these would be maternal half-sibs. One could estimate the heritability, as there should be less variation within that group than between sources.

GABRIEL - There are so many factors that influence the variability, such as the time of the year, the time of the day, etc. I think you have to be careful that you get the right situation when you take your readings, so that you don't try to read too much into it too early. Everyone seems to think I should be calculating heritability, but I don't think so, yet.

GERHOLD - Do your remarks imply that the heritability may not be high?

GABRIEL - It's hard for me to believe that all those progenies are equal in their performance and that they will maintain their equal status. As the plantation grows older, I feel that this will break up and we'll begin to get differences such as we saw between the phenotypes; some of those readings are based on 14 years of observations of the same phenotypes, and they are very consistent in their performance. This is another reason why I feel that these progenies still have a little way to go before they are going to measure up to their parent trees' expressions.

DORN - You've probably noticed individual tree variation in date of leaf flush in sugar maple. Have you made any observations as to the relationship between this and sugar content in the original phenotypic selections?

GABRIEL - We didn't consider bud break. We do have a provenance study where we plan to measure this and also sugar content plus several other characters. This is something I haven't done with the one-parent progeny test at this point, but it is something that we could do very easily.

GERHOLD - Are you doing any artificial pollination now with your selected trees?

GABRIEL - We tried to get around the 27,000 square miles. We did do some crossing; we drove 5,000 miles to cross 6 trees in the New York area, and this is just too much. Now we are hoping our trees will flower in 7 to 12 years, as Kriebel predicted, and we can make our crosses at that time and carry our clonal tests along. We hope to do this in Burlington, rather than go to the parent trees.

BEY - John Genys, did you combine data for the two plantations and then test to see whether the interaction was significant?

GENYS - The two research units included different numbers of strains, different numbers of blocks, and different plot sizes. The relationships between the data from these two plantations were expressed through correlation coefficients. If the correlation coefficient (r) for a particular characteristic was insignificant and the determination coefficient (r) was low, it was assumed that there was some type of interaction.