# PHENOTYPIC SELECTION OF SUGAR MAPLES FOR SUPERIOR SAP VOLUME PRODUCTION

William J. Gabriel[1]

## INTRODUCTION

A complex of problems in the maple syrup industry has been gathering force during the past 50 years, led by increased costs, reduced production, and a dwindling labor supply. Within the last two decades, research has done much to alleviate these problems. For example, recent studies on the technical and mechanical aspects of sap collection have resulted in an increase of nearly 300 percent in sap production. Although this improvement requires a sizable investment in new equipment, it can be made with a sharply reduced labor force.

Improvements in the biological aspects of sugar-making, although of a long-term nature, are also progressing. The selection and clonal propagation of superior phenotypes for the development of improved strains of sugar maple for sap-sugar production have been completed. The next step, clonal and progeny testing, is being taken.

A program for the improvement of sugar maples for sap volume has been initiated recently at our project in Burlington, Vermont, and is being conducted in parallel with the experiment in sap-sugar improvement.

The importance of sap production in the manufacture of maple syrup is pointed out by the fact that an average of 34-1/2 gallons of sap are required to make 1 gallon of standard weight syrup (11 pounds). This figure is based on an average sap sugar content of 2.5 percent.

Also, sap flow is depending upon favorable weather conditions. Whenever a cold night is followed by a warm day, the sap usually runs well. Knowing the large volume of sap required to make syrup, and the uncertainty of spring weather in southeastern Canada and northeastern United States, one can see that the sugarmaker must obtain as much sap as possible when the conditions are optimum.

The program for the selection of high sap yielding trees was conducted in Maine, New Hampshire, Vermont, Massachusetts, New York, Pennsylvania, Ohio, Michigan, and Wisconsin. This broad coverage was made possible through the cooperation of state forestry organizations who provided the fieldmen for making the initial selections. This paper gives the results of the first year of operation of the program.

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## BACKGROUND

A search of the literature has shown that there is a general agreement among researchers that certain tree characteristics are correlated with high sap-volume yield., However, no single character or combination of characters were found that satisfactorily explained the observed phenotypic variation in sap production.

Toma (1961) reported that sap yield increased significantly with dbh, and he noted that live crown ratio (tree height to live crown length) was positively correlated with sap yield. But crown length alone showed no correlation. The author further stated that the combined effects of dbh, tree height, crown diameter, and live crown ratio accounted for only 19 percent of the phenotypic variation observed. Morrow (1955) and Blum (1971), in separate similar studies, obtained results that were in general agreement with those mentioned above.

Marvin et al. (1967) found large differences between trees in both sap volume and sap sugar. The authors also reported a highly significant relation between sap-volume yield and sap-sugar content, based on 18 years of data, Our own observations and those of Morrow (1952) do not indicate a relationship between the characters of sap sugar and sap volume, but it should be pointed out that the latter findings were based on shorter study periods of 3 to 5 years.

Summarizing the pertinent literature, I find an apparent relation between sap yield and live-crown ratio and dbh. But a large part of the phenotypic variation in sap yield cannot be explained satisfactorily by differences in these characters. This leads me to believe that much of the unaccounted for variation could be inherited. However, I would like to point out the possibility that some of the unaccounted-for variation may be associated with the inherited tendencies of the factors that were found to be related to sap production.

## METHODS AND CRITERIA

The methods and criteria that were used in making selections were based on our past experience in selecting for superior sugar production, and on the results of exploratory studies that were carried out during the last 2 years.

The selection of superior sap-producing phenotypes was based on sap-flow rate measurements. In an exploratory study, we found that sap-flow rate was satisfactorily correlated ($r_p$ = 0.55 - 0.93) with the total sap volume produced during the sugaring season (Gabriel et al. 1972). This favorable relationship helped to make this program possible.

An average sap-flow rate was determined for each sugarbush, based on a sample of 100 trees taken along a transect. On a few occasions the number of trees in the sample dropped below 100. The measurements were recorded (Fig. 1); and when a tree with an unusually high sap-flow rate was found, it received further attention.

Figure 1.--Completed Form 1 showing sap volume test data and other information pertinent to the sugarbush.

1 — Sugarbush Number

#1

Do not write in this space

100-TREE SAMPLING FORM

☒ SUGARBUSH ☐ ROADSIDE OR FENCELINE TREES

Name of Owner: Patterson (Last Name) J (Middle Initial) Orville (First Name)

Address: Voice Rd. Kingsley, Michigan 49649

Location of Bush if different from owner's address: T26N, R10W, Sec 36, SW 1/4 of NE 1/4 Grand Traverse County

TREE NUMBER AND SAP FLOW RATE (ml./30 sec.)

| Tree No. | Flow Rate | Tree No. | Flow Rate | Tree No. | Flow Rate | Tree No. | Flow Rate | Tree No. | Flow Rate |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 20 | 21. | 32 | 41. | 28 | 61. | 36 | 81. | 48 |
| 2. | 20 | 22. | 38 | 42. | 38 | 62. | 38 | 82. | 48 |
| 3. | 16 | 23. | 34 | 43. | 38 | 63. | 44 | 83. | 46 |
| 4. | 18 | 24. | 28 | 44. | 28 | 64. | 48 | 84. | 46 |
| 5. | 22 | 25. | 28 | 45. | 34 | 65. | 54 | 85. | 44 |
| 6. | 18 | 26. | 30 | 46. | 30 | 66. | 56 | 86. | 40 |
| 7. | 28 | 27. | 24 | 47. | 40 | 67. | 56 | 87. | 34 |
| 8. | 22 | 28. | 34 | 48. | 36 | 68. | 54 | 88. | 30 |
| 9. | 36 | 29. | 38 | 49. | 36 | 69. | 48 | 89. | 34 |
| 10. | 32 | 30. | 38 | 50. | 36 | 70. | 48 | 90. | 38 |
| 11. | 20 | 31. | 46 | 51. | 36 | 71. | 52 | 91. | 32 |
| 12. | 28 | 32. | 42 | 52. | 42 | 72. | 48 | 92. | 40 |
| 13. | 30 | 33. | 40 | 53. | 40 | 73. | 42 | 93. | 42 |
| 14. | 34 | 34. | 42 | 54. | 32 | 74. | 50 | 94. | 42 |
| 15. | 38 | 35. | 40 | 55. | 40 | 75. | 56 | 95. | 44 |
| 16. | 36 | 36. | 32 | 56. | 40 | 76. | 48 | 96. | 48 |
| 17. | 38 | 37. | 32 | 57. | 34 | 77. | 44 | 97. | 42 |
| 18. | 36 | 38. | 38 | 58. | 30 | 78. | 40 | 98. | 40 |
| 19. | 40 | 39. | 38 | 59. | 34 | 79. | 44 | 99. | 52 |
| 20. | 30 | 40. | 38 | 60. | 44 | 80. | 46 | 100. | 46 |

Date: March 21, 1973 Time Started: 11:00 A.M. Time Completed: 1:30 P.M

By: Ramon D. Westbrook Title: Forest Technician

Remarks:

11-72

To qualify as a selection candidate, a tree had to exceed the average performance of several surrounding standards by a minimum of 70 percent, and be at least 30 percent above the best performing standard. All trees that were selected by the fieldmen will be closely screened according to the criteria listed in table 1. In the screening process the selected tree will be penalized for departing in appearance and proximity from its standards. Trees with the lowest number of penalties and highest differentials will be placed in our select tree catalogue. Since our selection program is in its first year of operation, screening will not begin until the 1974 sugaring season.

## RESULTS AND DISCUSSION

The results of the selection program after one sugaring season are summarized, according to states, in table 2.

At first glance, it may seem that the selections made this year are rather small in number. However, this figure compares favorably with the first year's results of the now successfully completed sap-sugar program when 58 trees were selected. Correspondence from the field has indicated that such factors as heavy workloads, uncooperative sap-flow weather, and some faulty field work contributed to the relatively small number of sugarbushes and trees that were tested and selected.

It is too early yet to begin looking for possible patterns in variation between states or between areas within states. But the present indications are that selection differentials will be large, as seen in this example (fig. 2).

A limited number of field selections will receive a final screening during the 1974 sap season. Characters that will be scored are listed in the lower part of figure 1. The screening criteria (table 1) will oe applied to reduce the number of selections that may owe their superior performance to environmental rather than genetic factors.

To illustrate a selection unit, figure 3 shows a selected tree and its four standards. Note that we try to use standards that are comparable in appearance to the selected tree. In this example, the selected tree exceeded the average sap-flow rate of the standards by 88 percent, and the sugarbush by 80 percent.

Finally, I feel that if we iron out a few difficulties in the field, and Mother Nature contributes the right kind of weather for good sap flow, we can successfully complete this program by the end of next year.

Table 1.--Criteria assigned for determining index numbers for characters used in screening sugar maples selected for superior sap volume production.

| Character of factor | Index No. | Limits |
|---|---|---|
| Diameter | 0 | ± 0-10% of selected tree diameter |
| | 1 | ± 11-20% of selected tree diameter |
| | 2 | ± 21-30% of selected tree diameter |
| | 3 | ± 31% and over selected tree diameter |
| Height | 0 | ± 0-10% of selected tree height |
| | 1 | ± 11-20% of selected tree height |
| | 2 | ± 21-30% of selected tree height |
| | 3 | ± 31% and over selected tree height |
| Live crown ratio | 0 | ± 0-10% of selected tree live crown ratio |
| | 1 | ± 11-20% of selected tree live crown ratio |
| | 2 | ± 21-30% of selected tree live crown ratio |
| | 3 | ± 31% and over selected tree live crown ratio |
| Distribution | 0 | Within 0-25 feet of selected tree |
| | 1 | Within 26-40 feet of selected tree |
| | 2 | Within 41-60 feet of selected tree |
| | 3 | Beyond 60 feet of selected tree |
| Insect damage, disease damage, and topography | 0[a] | Completely comparable to selected tree |
| | 1 | Some variation but still considered comparable |
| | 2 | Considerable variation, comparability questionable |
| | 3 | Not comparable to selected tree |

[a] Criteria limits 0 through 3 assigned to each character from insect damage through topography.

Figure 2.--Partially completed Form 2 showing individual performances of the selected tree and its standards. Lower part of form will be completed when selected tree is screened.

#2

1-73
Survey Number

SELECTION UNIT PERFORMANCE

AND

FINAL FIELD SCREENING FORM

Catalogue Number

SUGAR MAPLES SELECTED FOR HIGH SAP PRODUCTION

Name of Tree Owner: Patterson (Last Name) J. (Middle Initial) Orville (First Name)

Address: Voice Rd. Kingsley, Michigan 49649

COMPARATIVE PERFORMANCE: SELECTED TREES VS. STANDARDS

1. Sap Flow Rate

| Date of Test | Flow Rate (Ml/30sec) Selected Tree | Standards 1 | 2 | 3 | 4 | 5 | Standard Average | % Gain |
|---|---|---|---|---|---|---|---|---|
| March 21, 1973 | 122 | 52 | 40 | 68 | | | 53 | 130 |
| March 22, 1973 | 144 | 74 | 50 | 80 | | | 68 | 111 |
| March 23, 1973 | 124 | 94 | 58 | 90 | | | 81 | 53 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

2. Environment and Morphology Comparison of Standards and Selected Trees

| | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| (1) DBH | Inches | | | | | | | |
| | Index | | | | | | | |
| (2) Height | Feet | | | | | | | |
| | Index | | | | | | | |
| (3) Crown | Ratio | | | | | | | |
| | Index | | | | | | | |
| (4) Insect Damage | | | | | | | | |
| (5) Disease Damage | | | | | | | | |
| (6) Topography | | | | | | | | |
| (7) Distribution | | | | | | | | |
| | | | | | | | Total Index | |

(4) - (7) Only the index number is entered.

Remarks:



(11-72)

Table 2.--Summary of selection results in 1973, according to states.

| State | Sugarbushes | Trees tested | Field selections |
|---|---|---|---|
| | No. | No. | No. |
| Maine | 1 | 52 | 5 |
| New Hampshire | 3 | 140 | 5 |
| Vermont | 7 | 518 | 7 |
| Massachusetts | 19 | 1,055 | 24 |
| New York | 4 | 210 | 7 |
| Pennsylvania | -- | -- | -- |
| Ohio | -- | -- | -- |
| Michigan | 2 | 200 | 3 |
| Wisconsin | 2 | 200 | 4 |
| Total | 38 | 2,375 | 55 |

Figure 3.--This selected tree (marked "S") exceeded the average of its standards by 98 percent.

## LITERATURE CITED


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