Variation in Sugar Content of Maple Sap

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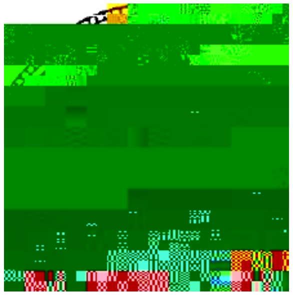

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best available planting stock should be used, and a knowledge of variation in sugar content is a necessary preliminary to the production or selection of this stock. For example, individual trees of known performance are absolutely essential to the genetical studies of a maple improvement project. Then, too, the first step in propagation by vegetative means is the careful selection of plants whose characteristics are those desired in the clonal material. Certainly high sugar content is one of these characteristics.

Furthermore, the understanding of variation in sugar content is likely to have bearing on certain aspects of research in processing. Flavor development and evaluation, as well as other features of quality control, are concerned with the solids fraction of maple sap of which sugar is a major constituent. The fact of variation in sugar content points up the possibility of tree-to-tree variation in other important constituents as well.

Fig. 1. Boiling down maple sap to syrup means increasing the proportion of sugar

by eliminating great quantities of water.

Maple sap is a dilute solution of water and sugar, along with traces of other compounds. The proportions are variable but usually fall within the following limits: 95 to 99 percent water and 1 to 5 percent sugar. In addition sap contains minute quantities of organic acids, nitrogen-containing compounds, inorganic salts, and other substances, as yet undetermined.

The manufacture of syrup from maple sap is essentially a boiling process whereby water is removed and the solids fraction of the sap is increased (Figure 1). The boiling is continued until the resu

2. The relation of sap flow and total yield of sap to sugar content.
3. The relation of the leaf-bearing capacity and the storage capacity of the tree to the sugar content of the sap.
4. The long-term and short-term relations of environmental conditions, such as light, altitude, exposure, range of temperature, nature and fertility of the soil, and availability of water, to the sugar content of the sap.

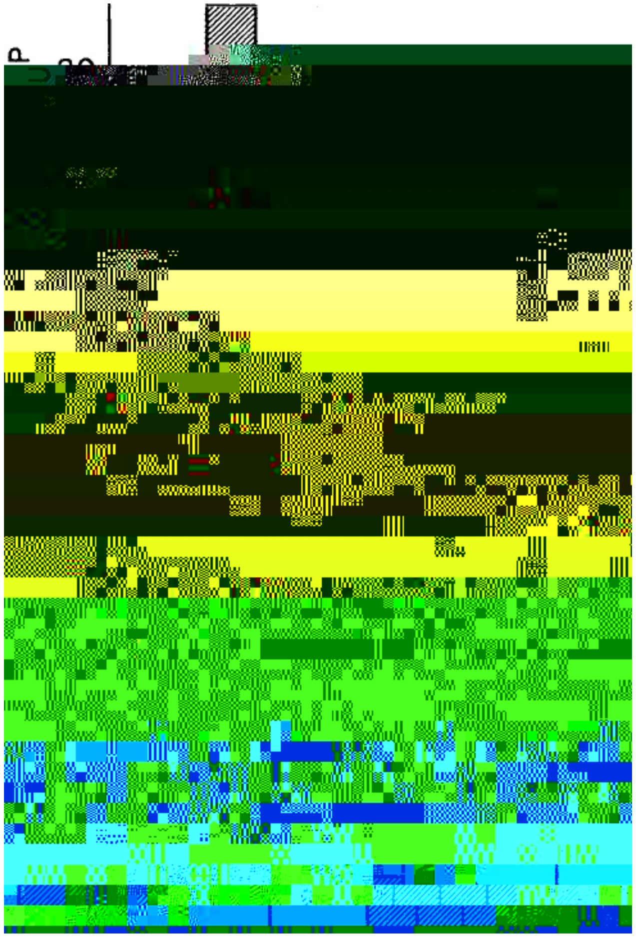

Fig. 2. An increase in sugar content reduces markedly the amount of sap needed to produce a gallon of syrup.

Yet, the investigator who would measure the sugar content of maple sap cannot go out into the sugarbush, make tests on a few trees, and immediately utilize these data with confidence. In our first experience at testing we nical ones had been disposed of. And it seemed equally evident that neither the fundamental nor the technical problems could be solved without a thorough understanding of how much variation actually exists.

Nowhere in the literature is there reported a survey which could be used as a broad base for studies on variation in maple sap. In fact by 1943, when this project was begun, only Jones *et at*. (3, 4) and McIntyre (7) had published any extensive data on sugar content of sap, and even these data had been presented in support of or in combination with other findings. In their studi tree he says that there is considerable variation. On the basis of differences in sugar content he concludes, ".... the sugar maple is twice as valuable as the red or silver maple."

A year later, in 1933, Jones and Bradlee (3) published a table in which the total solids and sucrose, hexose, and ash contents of 50 sap samples are included. Since these samples were selected at random from many hundreds, the authors conclude that the average sucrose content of 2.93 percent "should be reasonably typical."

Following a study of 19 half-acre plots, Stevenson and Bartoo (14) presented statistical evidence for concluding that open-grown trees are sweeter than forest-grown ones and, further, that roadside trees produce sweeter sap than other open-grown trees.

Consistent performance by maple trees from year to year was reported by Taylor (15), following the testing of over 1,800 trees for two consecutive seasons. From a study of these trees, most of which were tested three times and many of them six times, he states, ". . . . the majority of the `sweet' trees in 1944 were again `sweet' trees in 1945."

In a 1949 report Anderson *et* at. (1) summarized a three-year study of maple yields and costs in Ohio. On 23 fifth-acre plots they found average sugar percentages for the 1948 season to vary from 0.8 to 2.3. Storage tanks of farmer-cooperators ranged from 1.4 to 2.1 percent sugar, with an average of 1.6. The latter figure is 0.2 percent below a comparable figure for 1947.

A progress report in 1950 (Taylor, 16), covering seven years of testing by the Vermont Agricultural Experiment Station, emphasized variation in sugar content of maple sap and presented data to show consistent patterns of variation by individual trees. Trees were found to maintain their positions relative to their neighbors, not only during a single maple season but over a period of years as well. The sugarbushes of nine producers, whose trees were numbered and individually tested on three occasions, showed the same tendency for within-season variation as did single maples.

Ohio Research Bulletin 781 (Moore *et* at., 8), dealing with "some physical and economic factors related to the production of maple syrup," presents the final results (for four years) of the project mentioned above (Anderson *et at.*, 1). Sugar content of sap, usually along with volume of sap, appears in many of the bar graphs presented by the authors. The latter present most of their results graphically and conclude therefrom that high sugar content is related to the following:

1. Species of tree (sugar maples superior to other maples)
2. Position in stand (exposed trees superior)
3. D. B. H. (trees with large trunks productive of more sugar)
4. Foliage density ("good" trees in this respect desirable)
5. Growth rate (trees with wide growth rings sweeter)

Morrow (9) emphasized the same consistency of seasonal variation as did Taylor, with figures for New York State, gathered by the Geneva Experiment Station. Taking this characteristic of maples into account, he suggests testing the sap, in an area to be thinned, twice a season for three seasons. In this way he feels the forester will be better equipped for recommending removal of surplus trees for stand improvement than he would be with visible features of tree and site alone.

"Early Tapping for More Quality Syrup" by Morrow (10) features a recommendation based on the observed decrease in sugar content of sap as the maple season progresses. The author states that in New York over the period 1951-54,

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Trees from the two stands that have been tested regularly from 1944 to 1955 have been under scrutiny in the intensive study. Other trees ob-

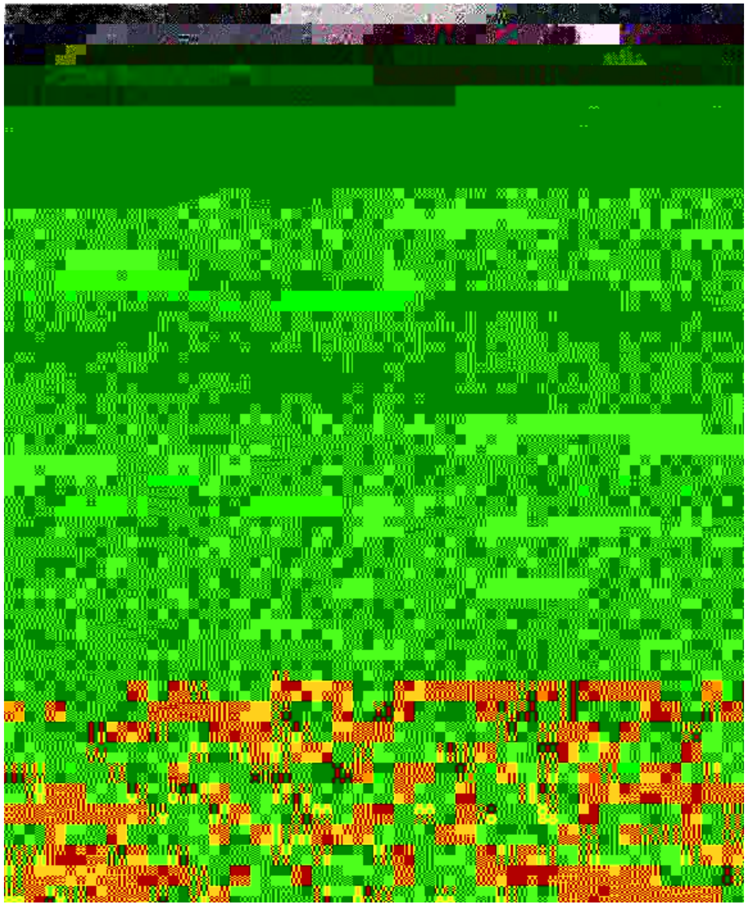

Fig. 3. The author takes a sample of maple sap direct from the spout to test for the sugar content.

served at the Proctor Farm since 1949 have also contributed to an understanding of how sugar content of sap varies during a season and from season to season. Sugar-content records on these Proctor Farm trees have been taken daily when sap ran enough to make testing feasible. The tests number at least 10 per year, with the exception of 1953, when six tests were made, and 1954, when nine were made. These same Proctor Farm trees are also on record as to total yield of sap, and, in some cases, rate of sap flow.

Testing of sap was done with a Zeiss hand refractometer. This instrument can be adjusted for temperature, an important point of technique when the refractometer is used throughout an early spring day or from day to day when marked temperature fluctuations are the rule. The refractometer, whose scale has divisions at 0.2 percent intervals, can be read to 0.1 percent. In making sap tests, readings have been made to 0.1 percent. Nevertheless, since percentages must be determined by establishing a dividing line between gray and light areas superimposed RG m reference. The identification of the taphole also served an important purpose in the testing operation, that of insuring that later tests, made in the same season, would be made, insofar as possible, at the same position.

The trees at the Proctor Farm, studied intensively over a period of years, were tapped mostly in southerly positions and, with one exception, always within an arc extending around the trunk from east through south to west. In 1954 all trees were tapped on the north side.

In order to get comparable samples and eliminate another possible variable, the following procedure was adopted early in the course of the project. Before starting tests on a given day a preliminary survey was made to make sure sap was running freely. The first drops of sap to leave the spout at the beginning of a run could give erratic readings due to melting of ice in the taphole or flushing out of "syrup" formed by evaporation during the previous rest period. Then, too, in the course of testing a stand of trees, an

must be boiled down to yield a gallon of syrup, whereas only 22 gallons are yielded sap of 3.7 percent sugar content in 1951. In 1952 tree 11 had its best record of 4.1 but it dropped to 3.6 in 1953. This seasonal fluctuation is also apparent in tree 12, as it is to a greater or less degree in all trees shown in Table 5. In other words, there is no such thing as a 3 percent tree or a 5 percent tree or any tree with an exact numerical tag from which represented by two readings of 3.8, it again rose over the 4.0 mark on April

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a-N

0 0

1.5

Fig. .5.
Sugar content of sap varies within a season. Bars represent ranges of variability for the trees in Table 6. Line connects the average sugar content for the 1950 season.

centages of 4.1, 4.0, 3.8, 3.8 (April 1 column in Table 6) are arranged in one

It is obvious that a sweet tree is a sweet tree year after year and that a tree which is low in sugar content, relative to its neighbors in one season, tends to stay in that position as the seasons come and go.

Tree 10 is in first place twice, second place once, tied for second once, and tied for third once (with tree 11). Actually there is little to choose between trees 10 and 11, for the latter is in first position in 1952 and 1953, in second position in 1949 and 1950, and tied for third in 1951. Tree 25 occupies one of the lowest positions in the scale each year, just as it did on the majority of sap days within the single season 1950. Tree 17 is, likewise, a consistent performer in what has previously been called the average group. Throughout the five-year period it always places in seventh or eighth position.

position in sugar content for a given tree; each square within the bar and in the proper quarter represents the position for a single year.

Tree 10, represented by 9.06n sl

the shaded area is determined by 10 sugar percentage readings for tree 10. The position of the lower boundary is similarly fixed by 10 readings for tree 24. The shaded area itself represents the difference in sugar content of sap produced by the two trees in each season. Two conclusions are unmistakable: (1) tree 10 produces sweeter sap than tree 24 throughout each of the seasons illustrated; (2) tree 10 is consistently sweeter than tree 24 year after year.

Variation in Sugar Content Among Sugarbushes

Stands of maple trees, growing on Vermont hillsides, vary in the sugar content of the sap they yield. As was the case with individual maples, sugarbushes, whose trees are used collectively as sources of sap, show wide variation in sugar percentage. Once again, in the making of this statement no classification and segregation of bushes on the basis of tree type, exposure, or age of stand have been attempted. The only point being made is that all producers, in using what nature has provided, do not start from scratch when they fire up under their evaporators. Some must expend considerable time, labor, and fuel just to bring their sap up to the sugar content of the untouched sap in a neighbor's buckets.

The magnitude of the differences between stands is shown in Table 11. This table gives average sugar percentages for nine bushes, tested on two occasions during the 1944 season. Early midseason records show bushes A and B to be more than twice as sweet as bush I, on the basis of refractometer tests of individual trees. Later in the season both still have a sugar content at least double that of I. Bushes C, D, E, F, and G seem to be intermediate. They are noticeably less sweet than A or B, yet produce sap with higher sugar content than H and I.

This comparison might be objected to because "early midseason records" cover a period from March 25 through April 1 and "late-season

Table 11. Sugar Content of Nine Bushes at Two Stages in the 1944 Maple Season

Bush	Early midseason records		Late season records	
	No. of trees	Average sugar %	No. of trees	Average sugar %

17 percent between 2.6 and 3.0. Other bushes have been similarly analyzed. Approximately 90 percent of the trees in each bush fall within the limits of five classes, representing a spread of only 2.5 percent sugar.

This pattern of distribution of trees by sugar content classes is not only interesting but important as well. In fact, when differences between bush averages are large enough to have real significance (Figure 2), bush averages constitute a sound basis for comparison as to efficiency of operation a basis which rules out the necessity for information on volume of sap produced. The truth of this statement is evident in Table 12. When bushes A and I are compared, it can be seen that only 8 plus 1 or 9 per-cent of the A trees fall within the same classes as do those of I which in no case test higher than 3 percent. Conversely, 91 percent of the trees in bush A have sweeter sap than the sweetest tree of bush I, and the trees in that 91 percent are bound to account for most of the sap produced. So, even if the owner of bush I could have the same yield per bucket as the operator of A (which is doubtful), his cost of producing a gallon of syrup would be higher for labor in gathering and for fuel and labor in boiling.

This example is not an isolated one because a similar situation can be demonstrated using bushes B and H. By reading the columns for B and H horizontally one can see that 1 plus 2 plus 7 plus 21 plus 31 plus 22 or 84 percent of the trees in B are sweeter than 41 plus 44 plus 8 or 93 percent of those in H. With such a distribution it really makes little difference whether or not some trees within a given bush produce more sap than others. Under such conditions average sugar content provides a well-grounded criterion for predicting discrepancies in costs per gallon of syrup.

Season-to-Season Variation by Groups of Maple Trees

The group of trees tapped by the sugarmaker cannot be counted on to produce

When tests on the trees of a group are made at every reasonable opportunity, the annual averages do not show striking variation (Table 14). On the other hand, day-to-day variation by individual trees (Tables 6. 7) and within-season variation by individual bushes (Table 13) are marked. Further study, then, may reveal that the greater yields per bucket of certain seasons are due as much to climatic conditions which favor runs on "sweet days" as to inherent yearly differences in sugar content.

Within-Season Variation by Single Maple Bushes

Maple trees, considered collectively, produce sap which varies in sugar content throughout the season.

Table 13 shows that on different days during the 1944 season bush A tested 4.8, 4.0, and 3.4 percent. In 1946 tests for bush A were 4.1, 3.6, and 3.6, and in 1948 sap from this stand averaged 3.9, 3.8, and 3.2 percent sugar. Tests of 3.1, 3.6, 3.3, and 3.2 were recorded for this group of trees in 1950.

This within-season variation in sugar content is seen in records from bush B which has also been observed over a period of years. The extent of the variation, determined by subtracting the season's low average from the high, was 1.5 percent in 1944, 0.8 in 1945, 1.0 in 1946, 0.7 in 1948, 0.3 in 1949, and 0.6 in 1950.

In 1946, when the difference was 1.0 percent sugar, there would be a substantial difference in the quantity of sap required to make one gallon of syrup on the two days in question. Keeping in mind that average sugar percent is a good substitute for the sugar percent of a composite sample, but that it is still a substitute, one can calculate that on March 2, 1946, when the test was 2.4 percent, 36 gallons of sap would be required to produce one of syrup. Three weeks later, on the other hand, the ratio would be only 26 to 1 ______a saving of nearly one-third in the volume of sap to be handled in bush and sugarhouse.

In addition to the fact that there is marked variation, the pattern of this variation is of both scientific and practical interest. In the columns for bushes A and B (Table 13) it can be seen that late-season sugar percent-ages are generally lower than those of the early part of the season. Note bush A for 1944. In this instance there is a decrease from 4.8 percent through 4.0 to 3.4. Even in those years in which the daily averages do not show a progressive decrease, as in 1950 (3.1, 3.6, 3.3, 3.2), the pattern of reduction in sugar content toward the end of the season is still evident. This same tendency can be observed in the midseason and late-season records of Table 11.

Table 15. Relation of Progress of Maple Season to Sugar Content of Sap

Year	Days between first gathering and first test	Bush average first test	Bush average later test	Difference
			Percent	
		BUSH A		
1944	14	4.8	4.0	-0.8
1945	12	4.0	4.0	0.0
1946	12	4.1	3.6	-0.5
1948	9	3.9	3.8	-0.1
1949	27	3.3	3.0	-0.3
1950	2	3.1	3.6	+0.5
		BUSH B		
1944	9	5.0	4.6	-0.4
1945	0	2.6	3.4	+0.8
1946	- *	2.7	3.4	+0.7
1948	9	3.4	3.1	-0.3
1949	27	3.2	2.9	-0.3
1950	2	2.5	3.2	+0.7

*Trees of bush tested during first run before first gathering of sap.

bushes are available and have been used to place testing records in proper perspective, relative to the progress of maple seasons from 1944-50. It will be noted that only in' 1950 was bush A tested close to the time of first gathering and then it had an average sugar content 0.5 percent less than a subsequent figure of 3.6. In all other seasons, with an interval of more than a week elapsing between gathering and first test, there was a decrease in sugar content between first and second tests.

Records for bush B show the same phenomenon in operation. When tests were made early in the season, they showed relatively low sugar content, whereas relatively high percentages were uniformly encountered when the first test was made more than a week after the date of first gathering. Of course, the exact number of days presented in the column headed "days

Average sugar percentages for bushes, tested on the same day, are on record as differing by nearly 2.0 percent.

7. The sugarbush tapped by the producer cannot be counted on to produce sap with the same sugar content year after year. The degree of variation is probably not as great as might be suspected from an examination of daily average percentages. One small group of trees tested intensively over a seven-year period had yearly averages varying only within the limits of 2.5 to 3.2 percent.
8. When maple bushes are compared to one another, each one is consistent in its performance as to sugar content of sap year after year. Bushes whose average sugar percentages differ to a significant degree in one season will be found in the same, relative positions in later seasons.
9. A given sugarbush produces sap which varies in sugar percentage throughout the course of a single maple season. There is evidence that sap is low in sugar content early in the season. Later the sugar content quickly rises to a maximum and then decreases as the season progresses.
10. The average sugar content of a single maple bush may vary widely during a given season; yet, throughout the season, it remains remarkably constant in position relative to other bushes.

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