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Sap-Sugar Content of Grafted Sugar Maple Trees

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Abstract

In March and April 1983, 289 and 196 young grafted sugar maple trees were tapped and evaluated for sap-sugar content. In April, sap was collected from taps both above and below the graft union. Diameter of all tapped trees at 18 inches above the ground was measured. Analysis of the data revealed that: (1) trees selected for high sugar yield cannot be reproduced by grafting on rootstock of unknown but varying sugar content without encountering large fluctuations in sap sweetness of the trees produced; (2) diameter is not correlated with sap sweetness of young grafted trees; (3) numerous sap-sugar readings over time may be necessary to identify the sap-sugar characteristics of a candidate sweet tree; and (4) the cause of the variation in sap-sugar content of trees over time needs to be investigated more fully.

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The production of maple syrup from the sap of sugar maple (*Acer saccharum* Marsh.) is an important industry in the Northeastern United States and Eastern Canada. If sap-sugar content is under strong genetic control and sweet trees can be identified reliably, then vegetative propagation by grafting is one method of mass producing sweet trees. For grafting to be effective for the mass production of sugar maple with a high sugar yield, (1) a method for selection of sweet trees has to be verified; (2) sap-sugar content needs to be under strong genetic control; and (3) there has to be little effect of rootstock on sugar content of the scion. In this study, only items 2 and 3 were investigated.

Methods and Materials

All trees in the study are growing in a grafted sugar maple clone bank at Grand Isle, Vermont. The bank consists of 3 to 10 ramets of each of 65 trees; 56 of these trees were selected for production of sap at least 30 percent sweeter than the average and 9 were of several surrounding comparison trees. In this study, sap was obtained from ramets of 48 select trees (2.1 to 8.6 percent sap sugar) and all 9 comparison trees (2.1 to 3.7 percent sap sugar). The sampled ramets were 10 to 16 years old. The grafts were made on seedling rootstocks that were grown in the State of Vermont Nursery, Essex Junction, Vermont. The rootstock were grown from seed collected from sugar maples of unknown sugar content growing near the nursery.

The grafted trees were mini-tapped (in March and April) by a technique similar to one described by Gabriel (1982). A No. 20 cannula was used as a spile. When a drop of sap appeared at the end of the spile, it was tested for sugar concentration with a refractometer. In March and April, 289 and 196 of the tapped trees produced sap and were evaluated for sugar content, respectively. In April, sap was collected from taps both above and below the graft union. Diameter of all tapped trees at 18 inches above the ground was measured.

Variation among and within clones was tested for significance by one-way analysis of variance. Simple correlations between March and April sap-sugar measurements above the graft, between April sap-sugar measurements above and below the graft, and between March sap-sugar measurements and diameter were calculated on individual-tree data. Simple correlations between ortet and average March ramet sap-sugar measurements, between ortet and average April ramet sap-sugar measurements, and between March and April average ramet sap-sugar measurements also were calculated.

Results and Discussion

There were significant differences in sugar content among sugar maple clones (Tables 1-2). However, there was as much variation among clonal ramets as among clones (components of variance of 0.556 and 0.547, respectively). Santamour and Cunningham (1964) found that variation in sugar content among grafted ramets was as great as the variation among seedlings of unknown parentage. They speculated that rootstock influence on sap sugar of the scion is the most likely cause of the variation among clonal members.

Individual-Tree Analyses

The correlation coefficient (r) of sugar content above and below the grafts of 196 individual trees was 0.836 (Table 3). This high correlation indicates that either the rootstock has an influence on the sugar content of sap from the scion or vice versa. The average above-graft sugar concentration was 2.80 percent compared with 2.58 percent below the graft. However, 47 of the 196 trees had rootstock sugar concentrations greater than or equal to those found in the scions.

These clonal and individual-tree analyses indicate that sugar content in sugar maple is under moderate genetic control. My interpretation of the data is that there is too much variation in sugar content among ramets to make grafting a viable method for mass production of sweet trees. However, before this method is completely ruled out, grafted trees should be evaluated at a more mature age, i.e., at 20 to 25 years and 10 to 15 inches in diameter. At that age, the effects of crown on variation in sap-sugar concentration among ramets could be taken into consideration.

On the other hand, the low correlation coefficient of $r = 0.22$ of individual-tree diameter at 18 inches, range of 1.2 to 6.7 inches, and sugar content indicated that tree size at an early age was not a major factor influencing sugar content. Diameter differences among trees accounted for only 5 percent of the variation in sugar content.

Table 1.—Percent sugar for selected sugar maple and their grafted ramets

Tree number	Percent sugar	Ramet percent sugar: March	Ramet percent sugar: April	Tree number	Percent sugar	Ramet percent sugar: March	Ramet percent sugar: April
		Average range	Average range			Average range	Average range
1	3.2	3.4(2.7–4.3)		33	3.2	3.3(2.7–4.1)	2.3(1.8–2.6)
2	4.2	3.4(2.8–4.2)	2.4(2.3–2.4)	34	3.0	3.4(2.8–4.2)	
3	3.6	3.6(2.7–4.5)	2.3(1.7–3.0)	35	3.1	3.4(2.8–3.7)	2.6(2.3–2.9)
4	5.6	3.6(2.9–4.2)	4.5(4.3–4.7)	36	3.9	6.1(5.1–7.0)	3.6(2.4–5.7)
5	3.0	3.8(2.9–5.0)	3.4(3.0–3.7)	37	3.3	3.4(2.8–3.8)	2.1(1.9–2.2)
6	3.2	4.7(2.9–6.3)	3.0(2.7–3.2)	38	3.3	5.3(4.7–6.5)	2.2(2.2)
7	4.8	3.3(2.5–4.7)		39	2.8	3.9(2.9–5.0)	3.0(2.5–3.8)
8	5.2	4.0(2.9–4.9)	3.0(2.8–3.7)	40	4.2	3.4(2.7–4.0)	2.0(1.6–2.4)
9	5.0	3.3(2.3–3.9)	3.0(2.1–3.7)	41	3.1	3.6(3.0–4.5)	2.9(2.2–5.2)
10	3.7	5.5(3.9–7.6)	3.8(2.7–5.7)	42	2.3	4.0(2.7–6.4)	2.4(1.5–3.1)
11	3.8	4.5(3.1–6.6)	3.3(2.3–5.8)	43	4.3	4.1(3.7–5.0)	2.8(2.4–3.4)
12	4.3	4.5(3.7–5.4)		44	3.6	3.4(2.6–5.0)	2.5(2.2–2.9)
13	4.6	3.8(3.0–5.2)	2.1(1.9–2.2)	45	3.1	4.1(3.1–6.5)	2.3(1.7–2.9)
14	4.0	4.5(3.7–7.8)	2.6(2.4–2.9)	46	4.6	3.0(2.4–4.0)	
15	5.2	4.0(2.6–4.7)	3.1(3.1)	47	2.8	3.4(2.7–3.8)	2.6(1.9–3.0)
16	2.7	4.5(3.8–5.2)	3.8(2.7–4.6)	48	3.1	4.1(3.5–5.7)	2.6(2.4–2.7)
17	5.5	6.3(4.6–7.4)	4.1(3.0–6.6)	49	5.3	3.5(1.8–5.4)	2.3(2.3)
18	5.3	4.1(2.6–6.2)	2.3(1.7–2.8)	50	4.1	5.4(4.3–7.7)	3.5(2.1–4.8)
22	4.4	4.1(3.3–4.8)	2.7(2.5–2.9)	51	4.1	4.1(3.1–5.7)	2.4(2.2–2.6)
24	3.8	4.7(3.2–6.3)	3.5(2.7–4.2)	52	4.0	4.0(2.9–4.6)	3.0(2.6–3.6)
26	4.1	4.0(3.3–5.0)	2.7(2.2–3.2)	53	4.5	4.1(3.0–5.3)	2.7(2.0–3.2)
27	4.0	3.4(2.9–3.7)	2.2(1.3–3.1)	54	3.7	4.2(3.2–6.0)	2.3(2.1–2.5)
31	3.6	5.7(4.5–7.1)	3.0(1.9–3.8)	55	3.0	3.7(3.1–4.6)	3.1(3.1)
32	5.1	3.9(2.7–4.6)	2.7(2.5–2.9)	56	8.6	3.1(2.2–4.0)	2.6(2.3–2.7)

Table 2.—Percent sugar for comparison trees and their grafted ramets

Tree number	Percent sugar	Ramet percent sugar	
		March	April
		Average range	Average range
2-3	2.6	2.9(2.5-3.2)	—
4-4	3.2	3.2(2.8-3.8)	—
5-4	2.1	3.2(2.7-4.0)	1.8(1.4-2.1)
8-2	3.1	3.1(2.3-5.0)	2.5(1.7-3.2)
13-1	3.5	3.1(2.6-3.9)	2.6(2.3-2.9)
15-1	3.1	2.9(2.5-4.0)	2.1(2.0-2.1)
20-3	3.7	2.5(2.2-3.0)	1.7(1.7)
21-4	2.4	4.0(3.2-6.0)	3.9(2.8-7.8)
22-1	2.9	3.2(2.7-3.7)	3.2(2.8-4.0)

Table 3.—Simple correlation coefficients for selected sugar maple data comparisons

Individual Tree	*Coefficient*
March vs. April sap sugar	0.47
April above vs. below graft	0.84
March vs. diameter	0.22
Ortet and Ramet	
Selections	
Ortets vs. ramet March	−0.08
Ortets vs. ramet April	0.09
March ramet vs. April ramet	0.51
Comparison	
Ortets vs. ramet March	−0.59
Ortets vs. ramet April	−0.31
March ramet vs. April ramet	0.85

Since measurements of sugar content of 196 trees were made on two dates, the correlation of sugar content between tapping dates was obtained (Table 3). The correlation of 0.47 was disheartening because it indicated that sugar concentrations on individual dates may not be as good a predictor of a tree's overall sugar content as one would need to make effective selections. The average scion sugar content in March and April was 4.07 and 2.80 percent, respectively. Only six trees had as high or higher sugar readings in April as in March.

Kriebel (1963) stated that yearly, daily, and hourly variation in percent sugar is sufficient to require several tests a year over at least 2 or 3 years to accurately assess a tree's relative sweetness. With only 22 percent of the variation in sugar among tapping dates accounted for, and the trees growing on a common site with little noticeable size variation, one has to wonder what factors cause the variability of sugar content observed during the tapping season.

Ortet and Ramet Analyses

There were no meaningful correlations between sugar content of selected ortets and their respective ramets for March and April tappings, $r = -0.08$ and 0.09 respectively (Table 3). There was a high correlation ($r = 0.51$) between mean ramet sugar content for March and April tapping dates.

There were negative correlations between comparison trees and the mean sugar content of their ramets for March and April tapping dates. This means that ortets with high sugar content produce ramets with lower sugar content. This data should be interpreted with caution because so few trees were analyzed, nine for March and seven for April. There was a strong correlation ($r = 0.85$) between average March and average April sugar content for comparison-tree ramets.

The lack of a correlation between sap-sugar content of selections and their ramets and the negative correlations between comparison trees and their ramets lead one to speculate on how effective this tapping method is for identifying sweet trees. However, one has to remember that the ortets are growing on different sites, are different ages, and have been tapped under different conditions and are being compared to their young ramets on one site. There is a possibility that correlations will increase as the ramets approach the age and form of their ortet.

Conclusions

The results of this study indicate that:

1. Sweet trees cannot be reproduced by grafting on unknown rootstock without encountering large fluctuations in sap sweetness of the trees produced. It remains to be determined if vegetative propagation by rooting sweet-tree scions will be an acceptable alternative.
2. Diameter is not highly correlated with sap sweetness of young grafted trees.
3. Numerous sap-sugar readings on a tree over a period of time may be necessary to identify the sap-sugar characteristics of a candidate sweet tree.
4. The cause of the variation in sap-sugar content of trees over time needs to be investigated more fully.

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