Coniferous Understory Influences Sugar Maple (Acer Saccharum Marsh.) Sap Production

by Russell S. Walters

FOREST SERVICE RESEARCH PAPER NE- 398
1978
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA 19008

THE AUTHOR

Russell S. Walters is a silviculturist for Sugar Maple Sap Production and Sugarbush Management Research at the George D. Aiken Sugar Maple Laboratory of the Northeastern Forest Experiment Station in Burlington, Vermont, a position he took in 1970. He was graduated from Michigan State University in 1951, and received with degree of M.S. in 1953 from Oregon State University with a major in forest management and a minor in range management. He began his Forest Service research career in 1955.

MANUSCRIPT RECEIVED FOR PUBLICATIONS 28 JUNE 1977

ABSTRACT

Sap and maple syrup equivalent production increased after a coniferous understory was removed from a sugarbush in northwestern Vermont. These increases, which became apparent the sixth year after treatment, were 14 and 17 percent for sap and syrup respectively, relative to the yields from an adjacent open sugarbush. The open sugarbush yields were used as the control in the analysis, to indicate the influence of weather conditions in each sapflow season. Understory removal also stimulated growth of the overstory maple trees.

INTRODUCTION

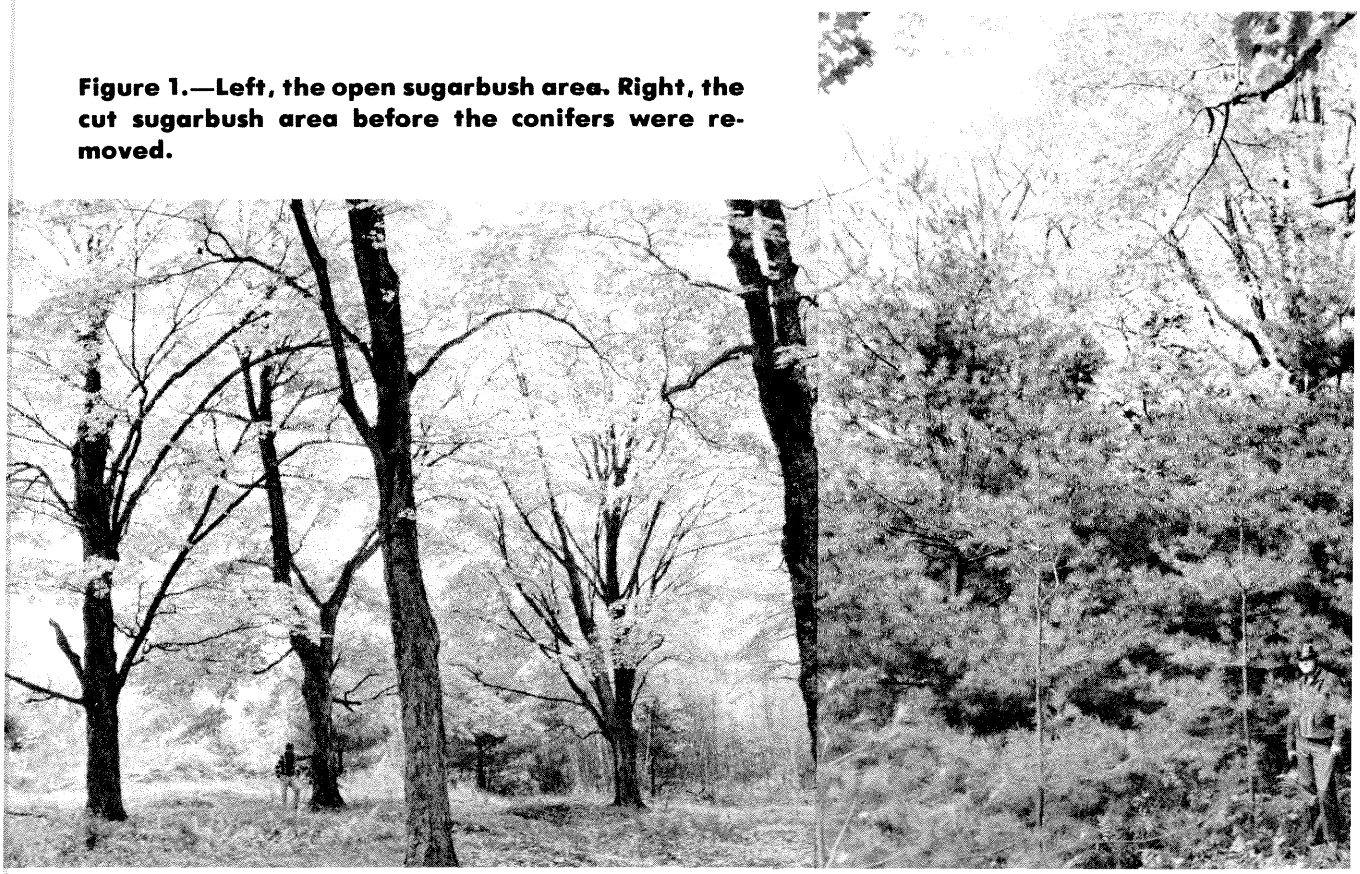
CONIFERS IN a sugarbush are thought to compete with the sugar maple trees for soil moisture and nutrients, thus reducing sapflow and lowering sap sugar production. It is an accepted practice to remove these conifers, but it was not known whether this practice was really beneficial or merely convenient.

We found that it is beneficial. A closed sugarbush with a coniferous understory consistently produced less syrup equivalent per taphole than an adjacent bush of similar trees growing in an open, parklike stand. After the understory was removed, the difference disappeared and the two sugarbushes produced almost equal amounts per taphole. This information is of practical value for sugarbush improvement. It also indicates that the sapflow mechanism can be manipulated to increase sap and sugar production through modification of the sugarbush timber stand characteristics and thus, the microclimate characteristics.

STUDY METHODS

This study was installed on two adjacent portions of the Mitchell sugarbush in the town of Essex in Chittenden County, Vermont. Each area covered about 0.5 hectare. One part, in addition to the overstory of sugar maple *(Acer saccharum* Marsh.), was heavily populated with a mixture of hemlock *(Tsuga canadensis* (L.) Carr), and white pine *(Pinus strobus* (L.)) in the understory. A few conifers also reached into the overstory. We call this the "closed" sugarbush before the understory was removed, and the "cut" sugarbush thereafter. The other area had a very open, parklike sugar maple stand with no conifers; we call it the "open" sugarbush (Fig. 1). The cut and the open sugarbushes are actually portions of the same sugarbush; the understory developed in part of the stand that was protected from cattle grazing. After the coniferous understory was removed from the cut portion, the entire sugarbush appeared very uniform in sugar maple size, spacing, stand density, and site quality. The entire area has

Figure 1.—Left, the open sugarbush area. Right, the cut sugarbush area before the conifers were removed.



been protected from grazing since the establishment of this study.

The Mitchell sugarbush is at 250 meters elevation in the foothills of the Green Mountains east of the Champlain Valley. The soil is Lyman very rocky loam, and is shallow, with numerous outcrops and ledges and excessively drained. Lyman soils are less than 50 cm to bedrock; they are usually saturated during early spring but dry out quickly and are low in available moisture capacity. They have low natural fertility and are rated only fair for timber production (Allen 1974). The terrain is nearly level, but undulating, with numerous hummocks.

Before the conifers were removed, the maple trees in each portion of the sugarbush were tapped and sap was collected over a 3-year calibration period to determine the average annual sap-volume yield and sap-sugar percentage for each tree. This was done during the 1965, 1966, and 1967 sapflow seasons.

We then selected 28 of the highest-yielding trees in the open sugarbush and 28 of the highest yielding trees in the closed sugarbush. Grouping the trees this way on the basis of previous sap-yield data makes it possible to detect smaller treatment differences (Blum and Gibbs 1968). The selected trees ranged in dbh from 30 to 84 cm; the average diameter in the open sugarbush was 53 cm, in the closed area, 46 cm.

During October 1967, all the white pine and hemlock stems 2.5 cm or more in diameter, a total of 656 stems, were cut and removed from the closed sugarbush (Fig. 2). This area was 0.5 hectare. The basal area of cut material was equivalent to 14.9 m^2 per hectare. Most of the conifer stems were in the overtopped or intermediate crown class. The diameters and numbers of pines and hemlocks were:

Diameter class *cm*	*White Pine*	*Hemlock*
2.5 — 12.6	117	421
12.7 — 17.7	16	34
17.8 — 22.7	2	20
22.8 — 27.8		17
27.9 — 32.9	2	15
33.0+		12
Total	137	519

Each year, standard-size tapholes (1.1 cm in

Figure 2.—A portion of a cut sugarbush area after the conifers were removed.

diameter) were drilled into the southern side of each sample tree to a wood depth of 7.5 cm at approximately 1.5 m above ground. The same tapping procedures were followed every year. Extreme care was exercised to insure that all tapholes were as nearly uniform in dimensions as possible.

A plastic sap spout with a piece of plastic tubing attached was inserted into each taphole. The sap from individual tapholes was collected in separate plastic containers and measured to the nearest 0.5 liter (Fig. 3) to determine the total yield for the season for each tree in the study. Sap was measured during the calibration period and also, after the conifers were removed during the "sugaring seasons" of 1968 through 1976, except for the 1971 and 1972 sapflow seasons, when sap was collected from only 9 trees in the open bush and 11 trees in the cut bush.

Figure 3.—Maple sap from each taphole was collected separately in covered plastic containers. The total sap volume per season for each taphole was determined to the nearest 0.5 liter.

Sap-sugar percentages were computed as the average of three or more readings per season made with a sap-sugar refractometer, which measures sugar concentrations to the nearest 0.1 percent.

Annual syrup-equivalent yield was computed for each tree from the sap-volume and sap-sugar data. This is the amount of syrup that could have been produced from the sap collected, and is a useful measure of the performance of the tree.

The data were analyzed by multivariant analysis of variance, carried out by making simultaneous comparisons among the average annual yields during the posttreatment period, and the corresponding average yields during the calibration period. The yield data from the open sugarbush were used as controls to indicate the magnitude of influence exerted on sapflow by the weather conditions in each season.

Growth response to the removal of the understory was assessed by extracting increment cores from a sample of 16 trees. Radial growth for the 9-year period before the treatment and for the 9-year period after treatment was measured in each portion of the sugarbush. These data were compared by a t-test for paired replicates.

RESULTS

During the 3 sap seasons of the calibration period and the 3 following years, an average of 14 percent less sap was collected from the trees in the cut sugarbush than from those in the open sugarbush (Table 1), but only in 1965 was the difference statistically significant. In 1973, the sixth sap season after treatment, and each year thereafter, the annual average sap volume per taphole from the cut sugarbush was slightly greater than that from the open sugarbush.

Sap sweetness, as indicated by the percentage of sugar in the sap, was significantly greater in the closed sugarbush than in the open sugarbush for 2 of the 3 years before the conifers were removed (Table 1). After removal of the conifers, the average sugar contents were similar. Only in one posttreatment year (1969), was the difference in sugar content great enough to be significant, and that difference was only 0.3 percent.

The understory removal did stimulate radial growth. In the trees within the cut sugarbush, the radial growth averaged 16 mm during the 9 years after treatment; during the preceding 9 years, it averaged 11 mm, an increase of 5 mm ($p \leq .01$). The resultant increase in the width of annual

Table 1.—Average maple sap volume, sap-sugar content, and syrup equivalent from "open" and "cut" portions of a northwestern Vermont sugarbush before and after removal of a coniferous understory

Year	n		Sap volume		Sugar concentration		Syrup equivalent	
	Open	Cut	Open	Cut	Open	Cut	Open	Cut
			—*Liters*—		—*Percent*—		—*Liters*—	
Pretreatment								
1965	28	28	79.5	54.1**	2.7	3.0**	2.58	1.88**
1966	28	28	89.4	76.3	2.9	3.3**	3.15	2.96
1967	28	28	69.4	67.5	3.0	2.2**	2.41	1.80*
Posttreatment								
1968	28	28	46.3	41.8	2.6	2.5	1.42	1.20
1969	28	28	75.6	73.9	2.6	2.3*	2.25	2.02
1970	28	28	84.5	71.0	2.5	2.4	2.43	1.93*
1971	9	11	102.2	87.4	2.5	2.5	2.93	2.71
1972	9	11	95.0	87.4	2.8	2.9	3.20	2.92
1973	27	28	54.7	58.1	2.4	2.4	1.57	1.65
1974	28	27	45.1	46.8	3.2	3.2	1.76	1.74
1975	28	28	64.3	69.5	2.5	2.6	1.91	2.07
1976	26	27	55.6	58.2	2.3	2.0	1.48	1.32

* Difference between open and cut sugarbushes significant at 5-percent level.
** Difference between open and cut sugarbushes significant at 1-percent level.

growth rings became visible in 50 percent of the sampled trees the second year after release, and by the third year, it was apparent in all the sampled trees. In the open sugarbush, the average radial growth was the same (13 mm) for the 9 years before and the 9 years after the time of the understory removal.

DISCUSSION

I believe that removing the coniferous understory made more moisture, nutrients, and growing space available, which resulted in faster growing, more productive trees with large crowns. The response in growth rate to the release treatment shows that physiological activity increased. The influence of fast growth, increased tree vigor, and large crown area on sap and total sugar production is well documented (Blum 1973; Moore et al. 1951; Jones et al. 1903).

Sap yield and syrup equivalent yield generally followed the same trends. In 9 of the 11 sap seasons observed, the sugarbush with the greatest sap yield per taphole also gave the most syrup equivalent per taphole (Table 1). The 1974 and 1976 sap seasons were exceptions; differences in these years were minimal. On the other hand, the percentage of sugar was relatively unimportant in computing syrup equivalent volumes. The sugarbush with the higher sugar concentration was usually the one that also produced the higher sap volume. Blum (1973) also observed that sap volume was very important in explaining total sugar yield, and sugar concentration relatively unimportant.

I observed that in the closed sugarbush there was less variation in daily air temperatures from January to April than the open sugarbush, and that the temperature rose more gradually during the day.

The maple sapflow mechanism is known to be extraordinarily sensitive to temperature changes; a 2- or 3-degree rise is often sufficient to initiate a good flow. The twigs are regarded as being the most sensitive to air temperature changes, but the best flows usually occur when the entire tree is warmed rapidly (Marvin 1969).

I believe that trees warm faster when there is no understory. If so, sapflow would begin earlier in the day, during the usual time of peak flow. On some days, the closed sugarbush may not warm enough to produce a flow, or only enough to trigger a "weeping" flow, while the open bush produces a good flow. Jones et al. (1903) noted that on good flow days most of the sap and sugar was generally yielded before noon (63 percent of the total). The flow then diminished gradually until about 3 p.m., then declined rapidly.

The differences in sugar concentration noted during the calibration period are interesting and confusing. In 1965 and 1966, the average sugar concentration was significantly ($p \leq .01$) greater in the closed sugarbush. Then the relationship reversed, and the open sugarbush produced a significantly higher sugar concentration. The year after removal of the understory, and at each observation since, the differences in sugar concentration between the two areas were much smaller. In only 1 of the 9 years after treatment was the difference statistically significant.

I believe that this effect is due to the influence of the coniferous understory on daily air temperature variation. Changes in sap-sugar content can be induced by temperature change. The enzymes that convert starches to sucrose are more active at lower temperatures (Kramer and Koslowski 1960). The peak rate of conversion occurs at about 4° C. As the temperatures rise above 5° C, the process reverses, and starch is resynthesized (Höll 1975). Marvin et al. (1971) also found in the laboratory that temperatures of 4° C induced the conversion of starch to sucrose in the cells of maple tissue. When the temperature pattern in the closed sugarbush differs from that in the open bush, starch conversion would proceed at different rates, and thus the sugar percentages would differ.

The sapflow mechanism is thought to function at the cellular level, and differences in sapflow and sugar content may be explained by different numbers of certain cell types (Marvin 1958). Reserve carbohydrates are stored mainly in parenchyma, and in sugar maple the bulk of this storage is in the ray cells. Sauter et al. (1973) have shown that release of sucrose in sugar maple depends on respiratory activity within specialized cells of ray and axial parenchyma called "contact cells". These connect the axial and radial parenchymal systems with the vessels,and have numerous large elliptical pits facing the vessels. It is conceivable that the number of contact cells increases as the ray cell population increases. This, in turn, could increase both sapflow and sugar release, producing larger sapflows and increased sugar production, although not necessarily higher sugar concentrations. Xylem ray abundance can be silviculturally manipulated: it increases when the tree's growth rate is increased (Gregory 1977).

This hypothesis explains the increased sugar production observed in our study, because we also observed the increase in growth rate. It also helps to explain the time lag before the increased production became evident. If a change in cambial activity caused a change in the number of xylem ray cells, and this, in turn, changed the trees' sapflow pattern, several years would be required before sufficient wood could be produced to establish these new sapflow characteristics.

The increased yield from the treated area did not become evident until the sixth season after treatment (1973), but it is possible that it could have been detected in 1971 or 1972 (Table 1). Our data for these 2 years suggest the possibility, but are too limited to fully support such a conclusion.

CONCLUSION

We found that the coniferous understory in this sugarbush did inhibit syrup equivalent production and tree growth. Removing it increased sugar production after a lag of several years, as well as improving accessibility and working conditions in the sugarbush. We recommend removing any coniferous understory from sugarbushes.

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