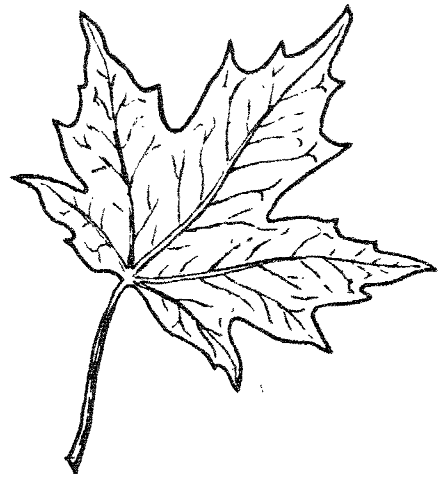

VACUUM PUMPING increases sap yields from sugar maple trees

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VACUUM PUMPING

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WHAT DOES THE VACUUM DO?

IN TWO RECENT studies of plastic tubing systems for collecting sugar maple sap, use of vacuum pumping increased the yield of sap. The evidence showed clearly that the vacuum actually draws extra sap from the tree.

Considerable work has been done in the past decade to develop plastic tubing systems for collecting maple sap. Though the labor-saving advantages and sanitary attributes of plastic tubing systems are well documented (*Willits 1965*), some aspects of installation and operation have received little attention. One is the use of vacuum pumps to aid the flow of sap through the plastic tubing.

Where vacuum pumps have been used in plastic tubing systems, taphole yields have been as much as three times larger than those obtained by gravity flow, from both vented and unvented tubing systems (*Morrow 1963, Laing et. al. 1962a*). However, this increase in sap yield has been attributed to a reduction of sap loss by removing sap from the tubing quickly and preventing reabsorption into the tree at night, or by preventing vent loss due to obstruction of the tubing by ice and air locks (*Morrow 1963*). The potential for drawing additional sap out of the tree with vacuum was not fully explored in these studies.

The possibility that vacuum could play a more direct role in increasing sap yields came to the attention of researchers at the Northeastern Forest Experiment Station research unit in Burlington, Vermont, during an experiment designed to compare sap yields from vented and unvented gravity tubing systems. The unvented tubing system in this study, which was completed in 1966, yielded 43 percent more sap than the vented system (*Blum 1967*). More important, the results indicated that the magnitude of the differences was closely related to the amount of natural vacuum developed in the unvented system. This vacuum, caused by the movement of sap in the tubing, varied according to the volume of flow for a particular period, the vacuum-holding capacity of the tubing system, and the length and general slope or grade of the installation. Additional evidence of this relationship between vacuum and increased yield was obtained during the 1967 sap season.

These results posed two questions. Was the vacuum in the unvented system actually drawing the additional sap out of the tree, or did the 43-percent increase in yield reflect losses of some sort from the vented system? What would be the effect of sustained levels of vacuum applied to large-scale installations by means of a pump?

In the spring of 1967, a vacuum pump was installed at a sugarbush located in Underhill, Vermont, to investigate these questions. This work proceeded in two phases: an individual-tree study designed to determine if sap could be drawn out of a tree in sufficient quantities to account for large yield differences; and a large-scale study of the effects of sustained levels of vacuum on yields from a nearly commercial-size network of tubing.

Figure 1.—Some of the 15 trees used in the individual-tree study.

INDIVIDUAL-TREE STUDY

This study was designed to determine if vacuum could increase yields over those obtained by gravity flow alone, by drawing additional sap out of the tree. We used 15 sugar maple trees in the 8- to 10-inch diameter class. These trees were tapped with two holes, paired 6 inches apart about 4½ feet from the ground, and drilled to a controlled 3-inch depth. One taphole in each pair was fitted with a tubing spile connected to a vacuum line; yields from these tapholes were collected by running the vacuum through a 500-milliliter side-arm distillation flask for each taphole. The other taphole in each pair was fitted with a similar tubing spile, and sap was collected by gravity flow through a short piece of tubing running into a covered bucket (figs. 1 and 2). Approximately 13 inches of mercury vacuum were applied to the vacuum tapholes while the pump was running.

Data were collected during four separate flow periods with a total pump time of 6 hours 50 minutes. The distillation flasks were emptied when necessary while the pump was running. Flow into the buckets was by gravity; and this was measured only for the same period when vacuum was applied to the vacuum tapholes.

The results indicate that direct application of vacuum at the level used in this study increased sap yields almost 700 percent. The average per-taphole yields were 2,239 milliliters for the vacuum system and 278 milliliters for gravity flow. These data were subjected to a "t" test for paired replicates, and differences were significant at the 0.01-percent level.

The magnitude of these differences may be misleading in one respect. Three of the four flow periods used in the study were weeping flows, purposely chosen to determine if the vacuum was actually drawing sap out of the trees. Viewed in this light, these yield differences bear no relationship to differences that might be achieved by applying vacuum under all flow conditions for an entire season. However, these differences do point to the fact that sap can be obtained in considerable quantity with vacuum when conditions are poor for natural flow (table 1).

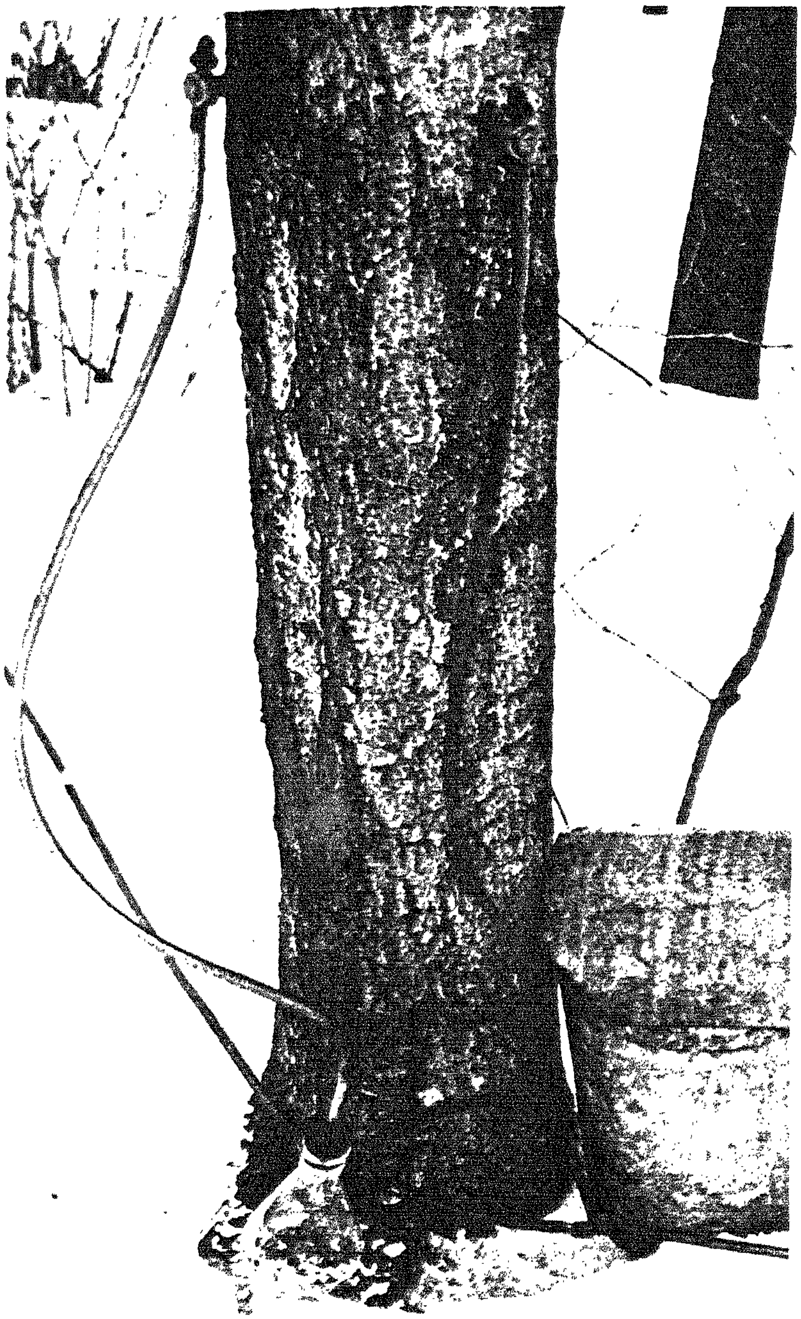

Figure 2.—A typical taphole pair used in the individual-tree study. The vacuum taphole is on the left.

LARGE-SCALE STUDY

This study was a demonstration of how vacuum affects a network of tubing installed under conditions approaching those of a commercial operation. This network was designed to compare sap yields between a vented, aerial tubing system utilizing short drops from the spile (*Lamb 1966*), and a matching unvented aerial system with applied vacuum. Except that one system was unvented and was supplied with vacuum, the two systems were identical in all respects and collected sap from the same trees (fig. 3). The unvented system was also designed to bypass the pump so that comparisons between yields from the two could be made during periods when the vacuum pump was not in use.

One hundred seventy-one trees were used in this study, each tapped with two tapholes paired 6 inches apart and bored to a 3-inch depth exclusive of bark thickness. The vented system was randomly assigned to one member of each taphole pair, and the unvented vacuum system was assigned to the other. Taphole pairs were placed at 4½ feet from the ground unless this had to be altered to insure adequate slope in the lines.

Each of the two systems consisted of a network of 2,500 feet of 5⁄16-inch tubing, which collected sap from a maximum of

Table 1.—*Rate of sap-yield increase for direct vacuum application compared to gravity, for selected flows*

Date	General flow condition	Average daytime temperature	Pump time	Rate of yield increase per hour due to pumping	
		°F.	*Minutes*	*Milliliters*	*Percent*
March 22	Poor	34°F.	95	93.6	66
March 23	Poor	36°F.	90	269.4	1,478
March 25	Poor	37°F.	105	334.8	3,256
March 31	Fair	60°F.	240	205.8	9,492
April 8*	Good	40°F.	270	346.2	3,895

*Based on five replicates only, not used in primary analysis.

Figure 3.—The tubing networks in the large-scale study were identical in all respects except for method of venting.

30 tapholes before running into a $\frac{3}{4}$-inch mainline tubing. Three hundred feet of mainline tubing were used for each system. This mainline was unvented for the pumped system and vented for the gravity system. Average slope in the study area was approximately 12 percent. Care was taken to be sure that the paired installations carried sap efficiently when both were operating as gravity systems.

The mainline from the vented system ran directly into a series of 55-gallon collection drums. The mainline for the pumped system went first to the vacuum pump, and then to an additional series of collection drums (fig 4). Gravity sap yields collected in the drums before pumping were measured immediately before the pump was started, and sap yields were again measured as soon as the pump stopped.

During the period March 15 to April 21, the pump was operated on many weekdays when the temperature was above freezing, whether sap was running naturally or not. On weekends, the pump was operated on days when conditions appeared

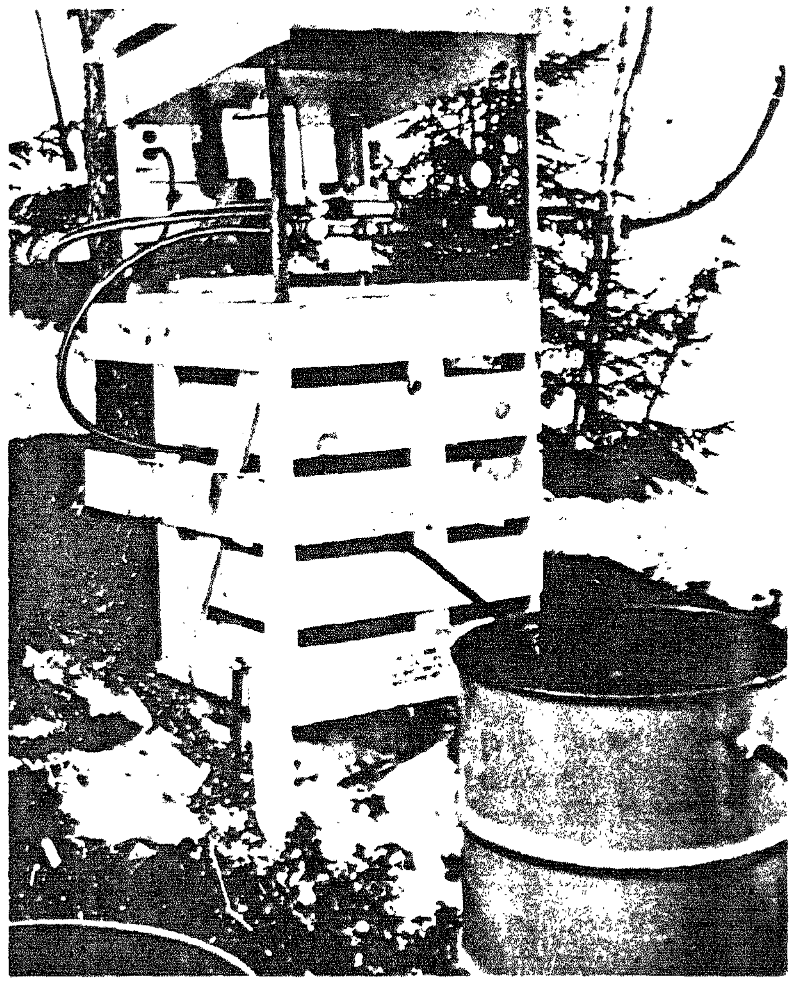

Figure 4.—The pump installation, showing the first drums in the collection series. Note yield from the pumped system entering barrel on the right.

to be adequate for a relatively good flow. The total operating time for the pump was 40.3 hours. When operating, the pump pulled approximately 15 to 18 inches of mercury vacuum. This vacuum was distributed evenly throughout the system with relatively little loss; it averaged about 13 inches of mercury at the tapholes.

Sap yields from the vacuum system averaged 385 percent greater than yields from the vented system for the 40.3-hour period the pump was operated. This large yield difference is primarily the result of yields obtained with the pump during periods when natural flow was very slow and yields from the vented system were negligible. On 6 of the 14 days when the pump operated, flow from the vented gravity system was less than 1 gallon per hour. On these same 6 days the flow from the pumped lines ranged from 9½ to 24 gallons per hour while the pump was operating (fig. 5). In fact some sap could be obtained from the pumped system on many days when the temperature went above freezing and the lines thawed, regardless of natural flow conditions. This sap represents a yield unobtainable with ordinary collection equipment.

No doubt the large percentage difference obtained with the pump reflects to a certain extent the relatively poor season in the spring of 1967. However, it serves to illustrate that vacuum pumping on tubing systems could gain enough additional sap in a poor season to be of great economic importance. Two producers using vacuum in New York and Vermont reported making up to 80 percent of their normal syrup crop in 1967, a season when most producers made much less.

In this study, the vacuum pump increased sap yields over those obtained from the gravity system during good flow conditions as well as poor flow conditions. The two best flows occurred on March 22 and April 8, when the 171 tapholes on the vented system were flowing at the rate of 8.0 and 9.1 gallons per hour. The flow rates on the pumped system for these dates were 11.2 and 33.2 gallons per hour (fig. 5).

As mentioned previously, sap was collected by gravity flow from both tubing systems when the vacuum pump was not running. These gravity yields provided a comparison between a network of vented and unvented tubing, including mainline. For the season as a whole, excluding the yields obtained when the pump was running, the 171 taps on the unvented system yielded 43 percent more sap than those from the vented system (table 2). This result parallels that obtained in Vermont in

1966. It is also in accord with the results of similar studies made by the Northeastern Forest Experiment Station and its Cooperators in Vermont, New Hampshire, and Massachusetts in 1967. This study thus provides further evidence of the greater yields from an unvented gravity system.

The combined vacuum and gravity yields from the pumped-unvented tubing system in this field study were 130 percent greater than the total seasonal yield from the vented gravity system. It is this total yield difference that the average maple producer is most interested in when considering the use of an unvented vacuum-pumped tubing system. The longer the pump is operated, of course, the greater the possibility of increasing this difference. In this study, for instance, the pump was not operated during one or two all-night weeping flows, when the pump might have increased yields considerably.

Table 2.—*Seasonal yields and yield differences for sap obtained by gravity in the vented tubing system and in the unvented system (excluding yields obtained while pump was operating)*[1]

Date of measurement[2]	Vented system	Unvented system	Yield difference
	Gallons	*Gallons*	*Gallons*
March 11	60.8	76.6	15.8
March 15	47.6	60.8	13.2
March 26	41.2	47.5	6.3
March 30	34.9	44.9	10.0
March 31	13.2	13.2	0
April 4	19.8	9.2	–10.6
April 5	55.5	105.7	50.2
April 9	11.9	26.4	14.5
April 14	46.2	76.6	30.4
April 16	22.5	18.5	– 4.0
April 27	15.9	15.9	0
April 28	61.0	118.9	57.9
Total	430.5	614.2	183.7

[1]Based on 171 tapholes.

[2]Actual flow of sap could have occurred at any time between date of measurement and previous measurement.

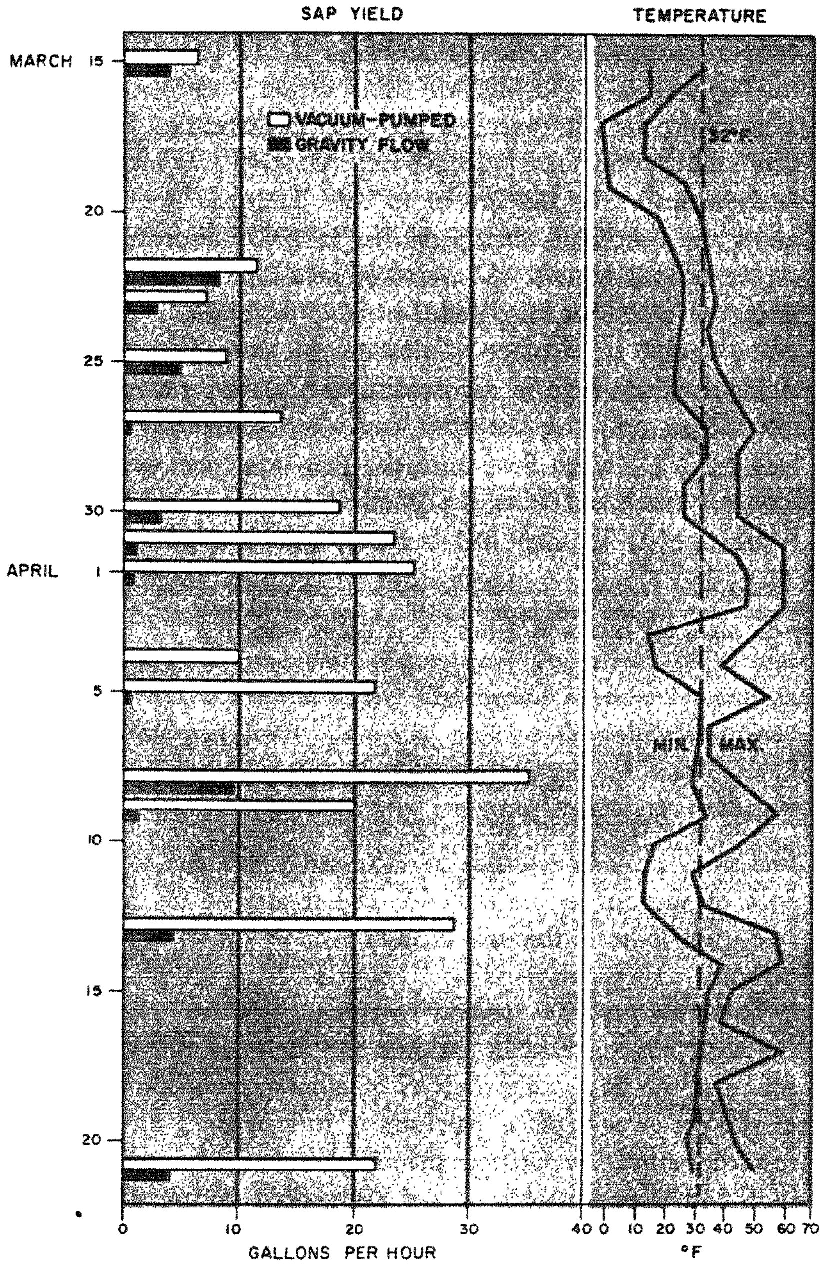

Figure 5.—Rates of flow for pumped and gravity systems, during periods of pump operation only. Daily maximum-minimum temperatures are shown at the top of the graph.

Two logical questions that arise when discussing the use of vacuum pumps with tubing are: (1) Does pumping shorten the sap season by "drying up" trees earlier? And (2) is there a difference in sap sweetness between that obtained by gravity flow and that obtained with a pump? Observations made in this study indicate that the answer to both questions is no, at least under the conditions that prevailed in 1967. Sweetness of the sap from both systems was measured periodically and was invariably the same; it compared favorably with the sweetness of sap collected from other studies on the same bush. Pumping yields remained high in comparison with gravity yields throughout the season. The last flow day when the pump was used was April 21, when flow from the gravity system was 3.9 gallons per hour and from the pumped system 21.1 gallons per hour (fig. 5). This sap had begun to turn buddy.[1]

[1]Buddy sap denotes a change in the chemical composition of the sap late in the season when the tree buds begin to swell. It has a strong odor and a disagreeable taste, and is not suitable for production of quality syrup.

DISCUSSION

The results of both the large-scale study and the individual-tree study provide evidence of increased yields due to the presence of vacuum in the taphole. The results of the individual-tree study indicate that the vacuum actually draws sap from the taphole.

These results have several important practical implications. Certainly any increase in seasonal sap yields of the magnitude found in the large-scale study is of economic importance to the maple producer. This is particularly true in light of the trend toward central evaporation plants where capital investment is high and large amounts of sap are needed during a relatively short season. Labor and equipment costs for a gallon of sap are also reduced considerably, since higher yields are obtained from a given outlay. Estimates made from our data indicate that on a 1,000-tap operation, the cost of the pump would almost be met from sap increases obtained the first year.

While it appears that vacuum is effective in increasing yield during good flow periods, the possibility of increasing yields during weeping flows may be more important—not only in contributing to the overall increase in seasonal sap production, but also by enabling a steadier supply of sap to reach the evaporator. Salvaging a poor or mediocre season through the use of vacuum pumping is an even more exciting possibility.

There are qualifications, however. Our results are limited to installations having the same vacuum levels we had. The pump used in our study was a commercially available jet type of pump operating on a venturi principle.

Even though the large-scale study was not replicated, conclusions drawn from the results should be valid when considered in the light of previous work. The relationship found between natural vacuum and yield (*Blum 1967*), and the yield increases due to pumping reported by Morrow (*1963*) and Laing et al. (*1962b*) all help to substantiate these results.

There are many unanswered questions. The effects of various levels of vacuum are unknown. The period of pump operation in our study was short, primarily because the sugarbush used was relatively inaccessible and transportation of fuel was a problem. The effects of longer pumping times on yield are unknown. And while the vacuum pump in a sense appears to have partially overcome temperature as a factor in volume yield, how temperature will in turn affect yield increases due to vacuum are unknown.

Based on our research results during the past 2 years, as well as the experience of others, enough evidence is available to justify the use of vacuum pumps in conjunction with tubing systems. We should caution that much remains to be learned about types of pumps and various levels of vacuum. The best approach would be to begin on a small scale and expand slowly as results warrant.

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