A Summary and Evaluation of Research on the Use of PLASTIC TUBING in Maple Sap Production

by Melvin R. Koelling
Barton M. Blum
Carter B. Gibbs

U.S. FOREST SERVICE RESEARCH PAPER NE-116
1968
NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

The Authors

MELVIN R. KOELLING, now extension specialist in forestry at Michigan State University, formerly served as associate plant physiologist with the Northeastern Forest Experiment Station. Dr. Koelling earned his Bachelor's degree in 1959, his Master's in 1961, and his Ph.D. in 1964 at the University of Missouri. He joined the Northeastern Station at Burlington, Vermont, in August 1964 and worked nearly 3 years in the maple sap production research project.

BARTON M. BLUM, associate silviculturist, joined the Northeastern Forest Experiment Station in February 1957 shortly after earning his Master's degree in forestry from Yale University. He had earned his Bachelor's degree at Rutgers University in 1954, and served about a year with the U. S. Air Force in 1954 and 1955. Mr. Blum has worked 3 years for the Station on forest surveys; 5 years on the silviculture project, then at Laconia, New Hampshire; and about 2 years on the maple sap production project at Burlington, Vermont.

CARTER B. GIBBS, silviculturist, joined the Forest Service in 1957. He earned his Bachelor's degree in 1950 and his Master's in 1956 from the University of New Hampshire. Mr. Gibbs worked for private industry, the State of New Hampshire, and the Department of Interior before coming to the Forest Service. In Forest Service research he has worked in silviculture of southern pines, silviculture of Appalachian hardwoods, and maple sap production techniques. He is now working towards a Ph.D. degree at the New York State University College of Forestry.

A Summary and Evaluation of Research on the Use of PLASTIC TUBING in Maple Sap Production

THOUGH use of plastic tubing for collecting maple sap has been hailed as the greatest advance ever made by the maple sugar industry, relatively few maple sugar producers are using tubing systems. To point the way toward greater and more efficient use of tubing systems, we summarize here the results and observations of our experiments with this method of sap collection.

The introduction and use of flexible plastic tubing in the maple sugar industry probably is the most significant change that has occurred since the beginning of this 300-year-old industry. The use of properly installed and maintained plastic tubing systems has made possible the expansion of sugaring operations into areas that formerly were unworkable because of rough topography. One- or two-man operations involving 1,000 or more taps now are possible because the use of tubing eliminates the need of a large labor force for collecting sap. Willits and Sipple *(1961)* estimate that use of tubing can eliminate as much as 40 percent of the cost of syrup-making.

Nevertheless tubing has not enjoyed widespread use, in spite of the fact that it was originally recommended as a panacea for all the ills of the maple industry. Only 9 percent of all maple producers are now using tubing.[1]

There are several reasons why this collection system has not been adopted widely by the industry. For one, the initial cost of a tubing installation is relatively high. Willits and Sipple *(1961)* estimated that the cost of a tubing installation is about $1.25 per taphole. Morrow *(1961)* reported that the cost of tubing exceeded the cost of buckets by 16 to 20 cents per taphole per year. Besides, most producers are already equipped for a bucket operation. The resale value and demand for buckets is very low; thus tubing represents both a new investment and a loss on equipment already on hand. Whether such reasoning is economically sound in view of the labor savings associated with tubing we do not know.

A second reason why tubing has not been more widely accepted is that some operators could not make the system work. Misconceptions about the operation of tubing systems were common *(Willits 1965)*. These affected the design of some systems in such a way that maximum yields were not obtained. Also, recommendations for laying out and setting up tubing systems were often based on observation rather than designed experiments. As a result, the maple producer who tried this new approach to

---

[1] Based on a talk by W. F. Cowen, Jr., at the Geauga County Institute of Forestry and Maple Syrup Production and Marketing, in Burton, Ohio, 27 January 1966.

sap collection was often dissatisfied with results, and it was not unusual for him to abandon tubing and return to using buckets. Although improvements and refinements in both tubing and its use have been made, many producers are still reluctant to try it.

Certainly, if the efficiency of plastic tubing can be improved, it will be more widely used, and the industry as a whole will benefit. In this report we have summarized the results and observations of tubing experiments conducted by the Northeastern Forest Experiment Station that suggest some ways in which this increased efficiency can be obtained.

STUDIES & FINDINGS

The Question of Venting

One of the questions about use of tubing is whether or not the spouts should be vented. Some people think that a tubing system vented to allow air in will permit better flow of sap than one without vents. On the other hand, a few producers have found that, under the right circumstances, unvented tubing will yield more sap than vented tubing.

Venting is one of the major differences between the two commercially recommended methods of installation. Some research data on differences in sap yield between vented and unvented systems are available *(Laing, Marvin, and Chamberlain 1964)* but strong differences of opinion continue to exist *(Sipple 1967; Willits 1965)*. A recent study conducted by personnel of the Northeastern Forest Experiment Station *(Blum 1967)* provides detailed yield comparisons between vented and unvented aerial tubing systems.

In this study two tapholes were used on each tree. One taphole was fitted with a vented spout and the other was fitted with an unvented spout. Each of these paired tapholes was connected to a separate but identical tubing system. In all, we used fifteen pairs of tubing systems, one vented and the other unvented, each collecting sap from about 20 trees. All lines in both systems were suspended by stretching the tubing from tree to tree. Sap yield from the unvented tubing was about 40 percent higher than that from the vented systems during 1966.

In 1967, three similar studies were conducted in Vermont, New Hampshire, and Massachusetts. Yields from the unvented systems in all three states averaged 34 percent more than those from the vented systems.

In evaluating factors responsible for yield differences between the two methods, two possibilities were considered. (1) Either sap was lost through vents on the vented systems, or (2) sap yield was greater from the unvented system because of some attribute of that system.

Our studies indicated that very little sap was lost through the vents. Actual measured vent losses represented less than 3 percent of the total seasonal yield of the vented members. Though the size of this loss could be expected to exhibit some yearly variation due to temperature conditions and care in the installation of the lines, it is unlikely that it would ever account for the observed yield differences of 40 and 34 percent.

The Effect of Vacuum

Observation of the unvented tubing lines during periods when sap was flowing indicated that considerable vacuum was being developed as a result of sap movement in the closed system. This vacuum was evidenced by distortion of the tubing (but never to the point of collapse or closing) on some lines (fig. 1). The possibility of a relationship between vacuum levels and yield differences between vented and unvented lines was therefore suggested.

Vacuum levels were measured at the upper end of each line, and these values were plotted against the seasonal yield difference between lines for each pair. A strong linear relationship was found to exist (a correlation coefficient of 0.86 for 1966 data). Thus the difference appears to be an increased yield from the unvented system, which is related to the presence of vacuum in that system.

Two additional questions about venting and vacuum relationships remained to be investigated. (1) Will vacuum develop in

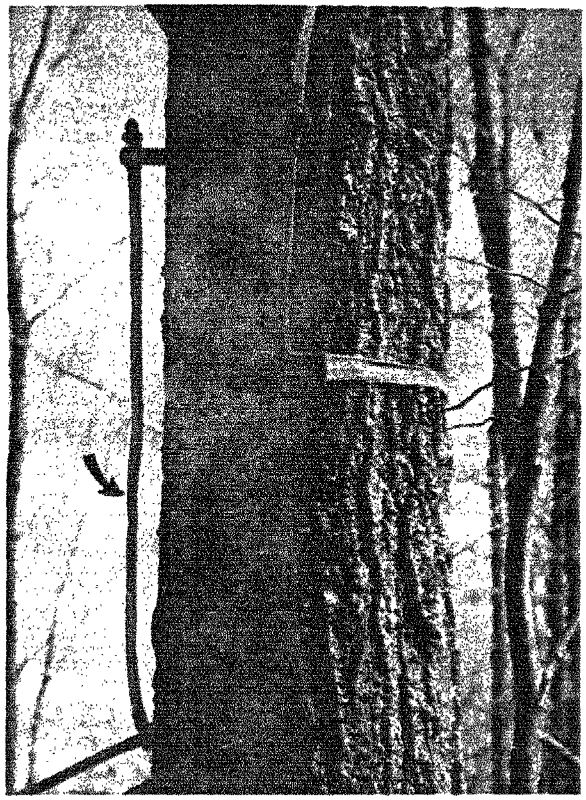

Figure 1.—Self-developed vacuum was strong enough to distort the tubing in the unvented line on the left.

unvented ground-line tubing installations the same as in these aerial installations? And (2) what would be the effect of sustained artificial vacuum on sap yield? Studies designed to answer these questions were made during the 1967 sugaring season.

Ground Line Installations

To study venting in ground-line installations, we used the same methods as those we used in our studies of suspended installations except that 4-foot drop lines were added, and the most recent recommendations for ground-line installation were followed *(Sipple 1967)*. Vacuum measurements on the unvented lines were recorded twice during the season when sap was flowing. Losses of sap through the vents were also measured.

The total sap yield from this experiment for the 1967 season averaged 7.9 percent greater for the unvented lines. This difference was not significant, although a significant correlation coefficient of 0.73 was obtained between vacuum levels and sap yield differences between lines. Vent losses amounted to less than 1 percent of the total vented yield.

The relatively small and nonsignificant increase in yield from the unvented lines in this study appeared to result from a reduction in the amount of vacuum developed in the ground-line installation. Any obstacle to natural movement of the sap by gravity, such as slight hummocks or elevation in tubing caused by too short a drop line (fig. 2), will reduce the amount of vacuum developed. If all such restrictions to flow had been eliminated, yield increases from the unvented line might have been substantially larger. This assumption is supported by the significant correlation between yield differences and the measured vacuum levels.

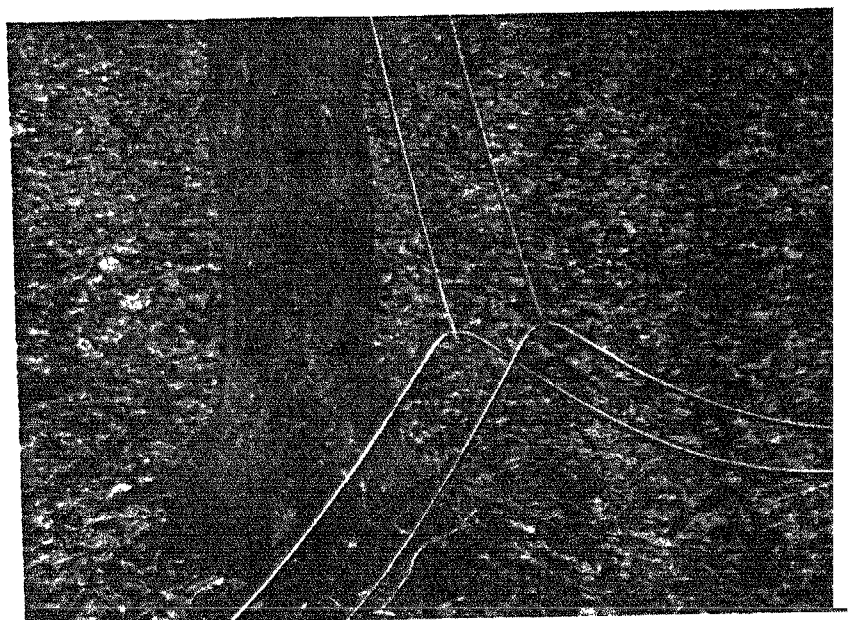

Figure 2.—Elevation in tubing caused by too short a drop line could result in decreased sap yields on unvented ground-line installations on gentle slopes.

Pumping Studies

The effects of artificially applied vacuum on sap yield were investigated next. Approximately 171 trees were tapped with two tapholes each, spaced 6 inches apart at breast height. One taphole was fitted with an unvented spout and the other with a vented spout. Each of the spouts was fitted with an 18-inch drop line, which led to separate tubing systems, one vented and the other unvented. Branch lines were aerially installed and main lines were laid on the ground. These systems were parallel to one another, and both were installed so they could operate efficiently by gravity alone.

An electric jet-type vacuum pump operating on the venturi-tube principle was installed at the collection tank for the unvented system. A vacuum line from the pump was attached to the unvented main line in such a way that vacuum could be directed to all the unvented tapholes; or when vacuum was not applied, sap could bypass the pump and flow by gravity into the collection tank. Measurements of sap flow were kept both when the pump was operating and when flow was occurring naturally.

Our results showed that for a gravity system, use of unvented tubing increased sap yield 43 percent (184 gallons or 1.1 gallons per tap) over that obtained with vented tubing; and that vacuum pumping increased yield 385 percent (567 gallons or 3.3 gallons per tap) over that obtained by natural flows.

DISCUSSION

In view of these study results, we can make several observations about the installation and use of tubing for maple sap collection. We can also make inferences pertinent to the use of tubing in other locations under other environmental conditions.

Venting versus Not Venting

The question of whether to vent or not to vent all spouts in a tubing installation is one that the individual maple producer must answer for himself. The primary factor related to increased sap yields from an unvented system is self-developed vacuum.

In all studies, a significant relationship was obtained between yield increases from an unvented system and the amount of vacuum at the head of each line. This vacuum is principally a result of the slope, length of the tubing line, and amount of sap in the line. When slope is sufficient (8 to 10 percent or more) and a fairly continuous grade can be maintained, greater sap yields can be expected from an unvented system than from a vented system.

At least 20 taps are desirable for each line in order to have the system work efficiently. There is some indication that an increase in the number of tapholes up to 35 per 5/16-inch branch line will result in greater yields. Whether this effect will be obtained by more than 35 tapholes remains to be determined.

Aerial versus Ground Lines

The yield increases obtained from using unvented tubing were found to be greater with aerial systems than with ground-line systems (about 38 percent versus about 8 percent). As stated previously, much of this difference seems to be due to restrictions in natural downhill flow of sap, which reduces vacuum in the ground-line system.

In aerial systems, minor variations in topography are eliminated by varying the taphole height and stretching the tubing to maintain a more uniform grade. If all such restrictions to flow were eliminated, unvented ground lines could be expected to compare favorably with unvented aerial lines. Although care is important in laying out and setting up either tubing system, it seems easier to obtain a satisfactory installation and the accompanying increases in sap yield with suspended tubing.

There are some additional advantages to an aerial system. In the initial installation, considerably less tubing will be used than in a ground-line system. The actual amount of tubing saved is about 3 to 4 feet per taphole. At the current price of $0.04 per foot for 5/16-inch tubing, this will result in a financial savings of $120 to $160 on a 1,000-tap operation. The reduction in the amount of tubing required is the result of shorter drop lines and less tubing required to go from tree to tree.

A second advantage of an aerial installation over a ground line is the reduction in time required to pull the tubing out of the snow. This advantage will vary by region, and is more important in areas of heavy snowfall. With ground lines, considerable labor is required to complete this task, while in an aerial system the problem does not usually occur.

However, an aerial system is not without some disadvantages. Its effectiveness may be reduced in sugarbushes where the trees are widely spaced and where much sag occurs in the lines between trees. This problem may be greatly alleviated by placing a few temporary supports between widely spaced trees and by careful planning of the initial installation. If considerable slope is present between widely spaced trees, sag is not a problem.

Care in taphole location and initial layout of the tubing is also more critical for an aerial system than for a ground-line system. Taphole height is especially important in sugarbushes with gentle slopes. However, this disadvantage can also be an advantage in sugarbushes with little or no slope, as some artificial grade may be built into the aerial system by varying taphole height.

Vacuum Pumping

Increases in sap yield from a pumped vacuum system were noted during days of both good and poor sap flow. However, the greatest advantage in pumping was obtained during periods when natural flow was very slow, and it was possible to obtain a considerable volume of sap by pumping on days when natural sap flow was almost nil. The sap obtained under such conditions represents a yield that would not have been obtained at all by bags, buckets, or tubing operating by gravity.

Aside from increasing the yield of sap, vacuum pumping reduces some of the problems associated with tubing. Since vacuum empties the tubing lines, freezing of sap may not be a major problem. And the maintenance of a uniform slope or grade in all tubing lines is not as critical as for a gravity-flow system. However, a pumped system that will let sap flow by gravity is desirable, because some flow may occur when vacuum is not being applied.

A question of primary importance to maple producers who might use vacuum pumping is: How many tapholes may be connected to a central vacuum pump? Certainly, the number is greater than the 171 used in our study; however, an absolute maximum number has not been established. It will probably depend on the integrity of the tubing system, the efficiency and capacity of the vacuum pump, and the amount of vacuum desired at each taphole. Since even a small amount of vacuum is of value in increasing sap flow, the actual number of tapholes per pump may be large.

The advantages of vacuum for increasing sap yield have been demonstrated. However, the decision of the maple producer on whether or not to use vacuum pumping will probably hinge on two other questions: (1) How much will a vacuum installation cost?; and (2) How will sustained vacuum pumping affect the health of individual trees in his sugarbush? To be of value, vacuum pumping must not only be economically feasible; it must also not adversely affect the health of trees in the sugarbush.

The vacuum pump used in our study cost $175[2] and the power source, a 3,300-watt generator, cost $300. The installation of valves so sap could bypass the pump added another $15. Operation of the generator during the season cost approximately $14. Total cost was about $504. This represents the added cost above that for an unvented aerial tubing system. Total cost would have been approximately $300 less if commercial power had been available.

If the increase of 3.3 gallons of sap per taphole obtained in this study as a result of pumping were applied to a 1,000-tap operation, an increase of 3,300 gallons of sap could be expected. At $0.05 per gallon for sap, this would represent a value of $165. If this value were applied to the fixed costs of pumping, then the complete system would pay for itself when the second season of use is approximately one quarter over if commercial power is available, and at the end of the third season if a generator must be purchased. While these values serve only as a relative indication of the costs

[2] This price is f.o.b. Leader Evaporatory Co., St. Albans, Vermont. Mention of a trade name should not be construed as endorsement by the Forest Service or the U.S. Department of Agriculture.

of vacuum pumping, it is apparent that cost should not be a major problem.

We have little information about how vacuum pumping affects tree health. However, the effect is believed to be minor because the amount of sap removed by either natural flow or pumping represents an extremely small portion of the total moisture capacity of a tree. The 40 gallons or so of sap removed throughout the season from an average-size tree is only a fraction of the amount of water that may be transpired through the leaves on a summer day. Furthermore, observation of approximately 1,000 trees that have been vacuum-pumped for the past 10 years have revealed no peculiar disease problems, insect infestations, or other harmful side effects.[8]

SUMMARY AND CONCLUSIONS

The use of plastic tubing can significantly reduce the labor and cost involved in collecting maple sap. However, only about 9 percent of the present producers were using tubing in 1966; this is due to a combination of factors, including high initial cost, disagreements on design and installation methods, and poor initial success on the part of some users.

Results of designed studies reported here provide infomation about the effectiveness of various tubing design and installation methods, and suggest certain ways in which tubing can be used to increase sap yields. These results emphasize the potential advantages of tubing as a collection system, and should encourage its increased use. Specific conclusions from our studies include the following:

- Increased sap yields may be obtained from an unvented tubing system under certain conditions. This increased yield is related to self-developed vacuum in the unvented lines. To obtain this vacuum and the associated yield increases, the tubing must be installed with sufficient slope in the lines, and restrictions to natural gravity flow must be avoided.

---

[8] These trees are located on the farm of Gerard Caron, Westford, Vermont. His average yield has been about 1/3 of a gallon of syrup per taphole.

- In general, an aerial unvented tubing system requires less tubing and will function better than a similar ground-line system, especially on gentle slopes. However, a combination of factors should be considered in deciding which system is preferable for an individual producer.
- The application of artificial vacuum to an unvented tubing system results in large yield increases — nearly a four-fold increase in our studies. Though this effect was found during both heavy and weeping flows, its effect was especially pronounced on days when natural flow was very slow.

LITERATURE CITED

Blum, Barton M.
1967. Plastic tubing for collecting maple sap: a comparison of suspended vented and unvented installations. U. S. Forest Serv. Res. Paper NE-90. 13 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Laing, F. M., Marvin, J. W., and Chamberlain, W. J.
1964. Results and evaluation of new maple techniques—progress report No. 3. Vt. Agr. Sta., Misc. Pub. 42: 5-6.

Morrow, R. R.
1961. Plastic tubing for maple sap. N. Y. State Agr. Exp. Sta. and Cornell Univ. Agr. Exp. Sta. Farm Res. 27(2): 12-13.

Sipple, L.
1967. Let's talk about tubing. Nat. Maple Syrup Digest 6(2): 10-15.

Willits, C. O.
1965. Maple syrup producers manual. U. S. Agr. Res. Serv. Agr. Handbook 134, 112 pp.

Willits, C. O., and Sipple, L.
1961. The use of plastic tubing for collecting and transporting maple sap. U. S. Agr. Res. Serv. ARS 73-75, 19 pp.