Effect of vacuum pumping on LATERAL MOVEMENT OF SAP in the maple tree bole

by Barton M. Blum
and Melvin R. Koelling

U. S. FOREST SERVICE RESEARCH PAPER NE-107
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

Effect of vacuum pumping on LATERAL MOVEMENT OF SAP in the maple tree bole

DOES THE SAP MOVE SIDEWAYS?

IN OUR EXPERIMENTS with tubing systems and vacuum pumping to collect sap from sugar maple trees, this question arose: Does the sap move sideways from one taphole to another? The answer, our studies show, is No.

Our recent studies of maple sap production have shown that unvented tubing collection systems yield more sap than vented tubing systems, and that these increases are related to natural vacuum that develops in the unvented systems (*Blum 1967*). Application of additional vacuum with a vacuum pump produced a further increase in sap yield (*Blum and Koelling 1968*).

In these studies we used a paired-taphole type of experimental design. Two tapholes were drilled 6 inches apart on the same tree; one taphole of each pair received one treatment (vacuum) while the other was a control (no vacuum).

This design is very efficient because comparisons of yield are all based on the same trees, thus eliminating differences between trees as a source of experimental error. The design assumes that yields from each of the two tapholes on a tree are independent of each other; that a treatment applied to one taphole does not affect the yield of the other taphole. With most treatments, this assumption seems valid. However, with treatments involving the application of vacuum to one of the two tapholes, it appeared possible that the vacuum at the one might draw sap away from the other. If this occurs, the implication that sap yields were increased by the application of vacuum may be erroneous.

The longitudinal arrangement of the xylem elements in maple wood and their natural role in conduction in a longitudinal direction make it unlikely that sap would be drawn in a transverse direction. For sap to move in this direction, it would have to find its way through a complex network of vessel, fiber, and ray elements by means of pits and through pit membranes. However, the possibility that transverse movement might occur could not be overlooked, and a series of experiments were conducted to investigate this possible source of error.

DYE EXPERIMENTS

First, dye substances were used in three experiments to trace the possible transverse movement of sap when vacuum was applied to one member of a taphole pair. Safranin, fast-green, and crystal-violet dyes, each dissolved in sap, were introduced into tapholes paired at various distances from vacuum tapholes. The dyed sap was supplied to the treated tapholes from a reservoir, and was present in the tapholes for the duration of the experiment. This dyed sap was absorbed into the tree during periods when normal sap flow was not occurring.

The vacuum pump supplied approximately 6 pounds per square inch of vacuum to the vacuum tapholes. Vacuum was applied for a total of about 14 hours, in periods ranging from

$1\frac{1}{2}$ to $4\frac{1}{2}$ hours long. These periods occurred on ten separate days, and some natural sap flow occurred on each day.

Sap was collected from the vacuum tapholes in side-arm distillation flasks (fig. 1). For evidence of transverse movement of sap, we tried to detect dye color in this sap, and a pattern of dye streaks in the xylem tissue when the tree was dissected at the end of the experiments.

All tapholes used in this experiment were $\frac{7}{16}$ inches in diameter and 3 inches deep, exclusive of bark. All tapholes were bored radially toward the tree center.

Experiment 1

Transverse movement of sap between tapholes 6 inches apart.

In this experiment, vacuum was applied to one member of a standard pair of tapholes spaced 6 inches apart, and dyed sap was placed on the other. The experiment was replicated twice on trees approximately 10 inches in diameter. Safranin dye was used in one replication, and crystal violet in the other.

We found no visible evidence that vacuum in one taphole in-

Figure 1.—Typical experimental installation, showing dye reservoir (upper left) and vacuum taphole with distillation flask for collecting sap.

Figure 2.—Dissected tree bole, experiment 1. The dye streak above and below the taphole on the left shows no apparent movement of sap between it and the vacuum taphole on the right. Discolored area in the middle is the result of the old taphole above. These tapholes were 6 inches apart in the outside of tree; the tree is approximately 10 inches d.b.h.

fluenced the movement of sap in the other 6 inches away. No color was detected in the sap from the vacuum taphole, and the dye streaks above and below the dyed tapholes appeared to follow a symmetrical pattern (fig. 2).

Experiment 2

Transverse movement of sap between tapholes ¼-inch and 1-inch apart.

In this experiment, a taphole was placed ¼-inch to the left of a vacuum taphole, and another was placed 1-inch to the right of the same vacuum taphole. Safranin-dyed sap was placed in the left-hand taphole, and fast-green-dyed sap in the right-hand taphole.

Traces of safranin dye were detected in the sap from the vacuum taphole in this experiment, indicating some transverse movement of sap. On dissection, we found that the tapholes converged slightly; and the actual thickness of the xylem tissue through which movement took place was about ⅛ inch (fig. 3).

No fast-green dye was detected in the sap from the vacuum taphole. However, on dissection, the dye streak surrounding the taphole (1 inch away from the vacuum taphole) indicated that the vacuum apparently had an influence on sap movement (fig. 2). Dyed sap had moved transversely through the 1-inch segment of xylem tissue, but not in sufficient quantity to be detected in the sap from the vacuum taphole. In fact, the movement of dye appeared to stop just short of the vacuum taphole.

Experiment 3

Radial movement of sap between tapholes 1 inch apart.

Two tapholes were drilled directly opposite one another so that approximately 1 inch of xylem separated them in a radial direction. Crystal-violet dye dissolved in sap was used in one taphole and vacuum was applied to the other. No evidence of radial movement of sap was indicated from the dye streak, nor was dye detected in the sap extracted from the vacuum taphole (fig. 4).

In summary, we found in these experiments no visible evidence of transverse movement of dyed sap between tapholes paired 6 inches apart, when vacuum was applied to one member of the taphole pair. However, some transverse movement of sap due to vac-

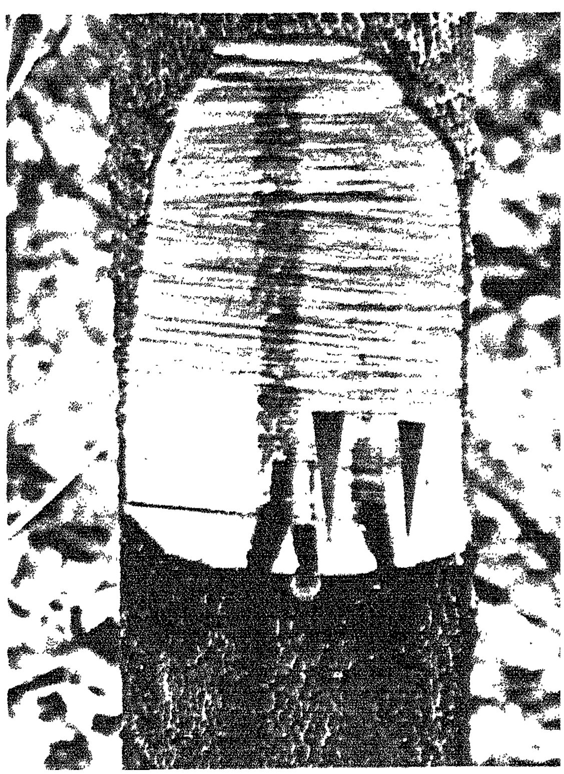

Figure 3.—Experiment 2. Dye tapholes approximately 1/8 inch and 1 inch from middle vacuum taphole. Pointers indicate the outer limits of the dye streak around the right-hand taphole.

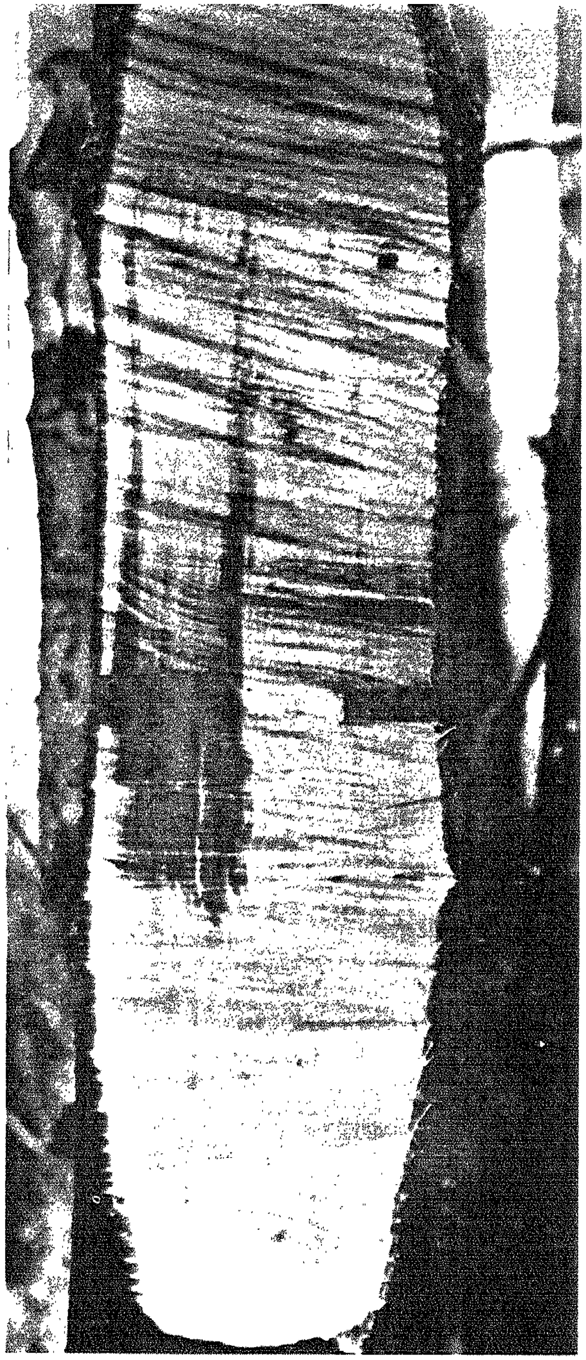

Figure 4.—Experiment 3. Dye streak indicates that radial movement of sap did not take place in the 1 inch of xylem tissue between the two tapholes.

uum was evident between tapholes very close together — through 1/8 inch of xylem tissue and through nearly 1 inch of xylem tissue. There was no evidence that vacuum influenced the radial movement of sap through xylem tissue 1 inch thick or thicker.

PRESSURE EXPERIMENTS

Still the possibility remained that sap might move transversely through 6 inches of xylem tissue while the dye substances could not. So we tried a different approach, using pressure dissipation as an indication of sap movement.

When conditions for sap flow are present, considerable sap pressure is developed in the tree bole. This pressure is relieved by drilling a taphole, and the pressure immediately above and below a flowing taphole is lower than that elsewhere (*Jones et al. 1903*). It seems logical that, if vacuum or negative pressure were drawing sap from the tree in a horizontal plane, this would be accompanied by reduced pressure in a horizontal plane.

Two comparable sugar maples about 20 inches in diameter were chosen and tapped at the same height on their south, east, and north faces. Pressure gages calibrated in pounds per square inch were threaded tightly into each taphole so no leaking occurred.

Six inches to the left of the pressure gage on the south face an additional taphole was bored on each tree. On one tree, the

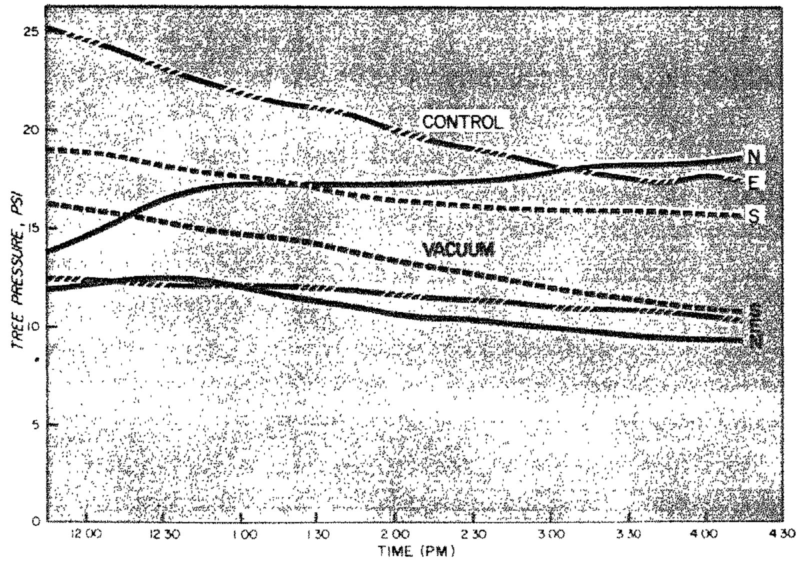

Figure 5.—Pressure patterns for the north, east, and south faces of the two study trees. The control tree was tapped 6 inches away from the south pressure gage, and sap was allowed to flow by gravity. The vacuum tree was tapped 6 inches from the south pressure gage, and sap was extracted by vacuum.

control, this taphole was allowed to flow by gravity. On the other tree, a tubing spile with attached vacuum line was placed in this taphole, and 13 inches of mercury vacuum was applied. Yields from the vacuum taphole and the gravity taphole were measured periodically.

This experiment was run on three separate flow days. Tree pressures, which were recorded every 15 minutes, were generally highest in the morning and gradually diminished throughout the day on both trees.

Reduced pressure in a horizontal plane from the vacuum taphole would have been indicated on the south-face pressure gage by a lower relative reading than would be expected from the normal pattern of pressure observed on the three faces of the control tree.

No such lower reading was observed. And no distinct pattern in tree pressure could be established among the faces on either of the trees (or between the south faces of both trees) that could be attributed logically to the presence of vacuum in the taphole on the vacuum tree (fig. 5). Nor did the pressure of the south taphole on the vacuum tree dissipate more rapidly during the day than the pressure of the same taphole on the control tree (table 1).

Our conclusion that vacuum did not appreciably affect the positive pressure in a taphole 6 inches away is somewhat in accord with that reached by Jones et. al. (*1903*), who stated that lateral transfer of positive pressure in maple tissue may not extend over 1/8 inch.

Jones also stated that positive pressure is transmitted vertically. In similar exploratory work, we found that negative pressure is also transmitted vertically at least 1 foot in the tree bole.

Table 1.—*Rates of sap yield and pressure dissipation per hour from a taphole pair on the south faces of control and vacuum trees*

Date	Sap yield		Pressure dissipation[1]	
	Control tree	Vacuum tree	Control tree	Vacuum tree
	Milliliters	*Milliliters*	*PSI*	*PSI*
April 9	(*)	(*)	1.5	1.5
April 10	428.00	776.00	.7	1.3
April 13	695.79	1,035.79	.7	1.2

[1]Tree pressure dissipates slowly after an initial rapid rise on warm days that are preceded by an extended cold period.

*Not measured.

However, after numerous attempts, we were unable to detect a lateral transfer of negative pressure between tapholes paired 6 inches apart.

CONCLUSION

Neither dye nor pressure experiments gave any indication that transverse movement of sap occurs between tapholes placed at least 6 inches apart on the tree bole, when one of the two tapholes is supplied with a vacuum source as high as 6 pounds per square inch. The results also indicate that vacuum has little influence on the radial movement of sap between tapholes placed opposite one another on the same horizontal plane, separated by as little as 1 inch of xylem.

On the basis of this evidence, it appears that the presence of vacuum in one member of a taphole pair will not affect the yield of the other taphole.

■

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.

Blum, Barton M., and Melvin R. Koelling.
1968. VACUUM PUMPING INCREASES SAP YIELDS FROM SUGAR MAPLE TREES. U.S. Forest Serv. Res. Paper NE-106, 16 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Jones, C. H., A. W. Edson, and W. J. Morse.
1903. THE MAPLE SAP FLOW. Vt. Agr. Exp. Sta. Bull. 103, 144 pp.