Some Effects of 
PARAFORMALDEHYDE
on Wood Surrounding Tapholes
in SUGAR MAPLE Trees

by Alex L. Shigo
and Frederick M. Laing

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BUT WHAT DOES THE PILL DO TO THE TREE?

PILLS OF PARAFORMALDEHYDE (trioxymethylene) are commonly used in tapholes in sugar maple trees (Acer saccharum Marsh.) to increase the yield of sap collected for making syrup and sugar (2, 4, 5, 8). The explanation offered for this increase in sap yield is that microorganisms in the tapholes (7) cause premature decline and stoppage of the sap flow (1, 6), but that paraformaldehyde increases sap yield by inhibiting their growth (2).

But what happens to the tree? To determine the effects of paraformaldehyde on the tissues surrounding tapholes, and on the microorganisms in those tissues, sugar maple trees were dissected and studied. This paper is a report on that study.

MATERIALS & METHODS

On 13 March 1969, five sugar maple trees on the Proctor Maple Research Farm, near Underhill Center, Vermont, and five trees on the Mitchell Farm, near Jericho, Vermont, were tapped. The diameters of the trees at 1.4 m. above ground ranged from 25 to 45 cm. In each tree 10 tapholes were drilled: 5 spaced equally around the tree at 60 cm. above the ground, and 5 at 120 cm. The tapholes, 1 cm. in diameter, penetrated the tree 6 cm. Paraformaldehyde pills—250 mg. each—were inserted into 5 of the 10 tapholes, at random, in each tree. The tapholes containing the pills were marked. A plastic spout of the type used for collecting sap was inserted into each taphole, although no sap was collected. The spouts were removed on 24 April.

The five trees on the Proctor Farm were felled on 5 May, as low on the stump as possible. After felling, a second cut was made 60 cm. above the upper tapholes. The ends of these approximately 180-cm. bolts were wrapped immediately with plastic sheets and heavy paper. The bolts were delivered to the Northeastern Forest Experiment Station’s laboratory in Durham, New Hampshire, the morning of 6 May. The five trees on the Mitchell Farm were cut on 12 May, and the bolts were delivered to
Durham on 13 May. They received the same treatment as the bolts from the Proctor Farm.

Ten billets, approximately 30 x 8 x 8 cm., with the taphole in the center (figs. 1 and 2), were dissected from each bolt. The bark was removed from each billet. The billets were taken into a clean room and split longitudinally through the taphole with a sterile ax. Care was taken so the ax did not touch the tissues surrounding the taphole, from which wood chips were taken for isolating microorganisms.

Isolations for microorganisms were made by extracting with a

![Figure 1. — Dissection of a taphole that did not receive a paraformaldehyde pill; after 60 days. The discolored area above and below the taphole was very faint and, after the wood dried, it was difficult to see the discolored area. The small holes above and below the tapholes mark the position of the chips of wood taken for isolating microorganisms.](image)
sterile gouge chips of wood approximately 1 x .3 cm. in a row 1 cm. above and below the taphole, and near the margin of the discolored area (figs. 1 and 2). At least 24 chips were taken from each billet. The chips were placed in a growth medium consisting of 10 g. malt extract, 2 g. yeast extract, and 20 g. agar per liter of distilled water.

The cultures were incubated at 25°C. and were examined several times over a period of a month. The bottoms of the chips were also examined, for bacteria.

After the chips had been extracted, the freshly cut halves of the billets were placed under an ultraviolet light. The margins of the discolored areas floresced. The vertical limits of the discolored areas were measured to the boundaries of the fluorescing zones. Streaks of discolored tissues often extended far beyond these boundaries.
In addition, seven trees on the Roger Grimes Sugar Orchard in North Hyde Park, Vermont, were dissected and examined. These trees had tapholes that had received the 250-mg. paraformaldehyde pills 2 and 3 years before dissection (fig. 3). Isolations for microorganisms were made in the same manner as described above. Observations were made on the healing of tapholes in this orchard and in a neighboring one where the pills were also used.

Histological studies were conducted to compare the tissues surrounding tapholes that had received the pills with those that

![Figure 3. — An unhealed taphole in a sugar maple tree 2 years after a 250-mg. paraformaldehyde pill was inserted to increase yield of sap. The bark must be pulled away from the hole, and the tree must be dissected to assess properly the injury caused by paraformaldehyde.](image-url)
RESULTS

Discolored Wood Associated with Tapholes

Areas of discolored wood with margins that fluoresced under ultraviolet light (fig. 2) were associated with every taphole that had contained a paraformaldehyde pill (table 1). The tapholes that had not contained pills had areas of only slightly discolored

Table 1. — Lengths of discolored lesions associated with 100 tapholes in 10 trees; 5 tapholes treated and 5 not treated with paraformaldehyde per tree on two farms

<table>
<thead>
<tr>
<th>Tree</th>
<th>Lengths of lesions associated with 5 tapholes per tree: cm&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Tree</th>
<th>Lengths of lesions associated with 5 tapholes per tree: cm&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250 mg. paraformaldehyde added per taphole</td>
<td></td>
<td>No paraformaldehyde added</td>
</tr>
<tr>
<td>PROCTOR FARM: 53 DAYS AFTER TAPPING</td>
<td>No paraformaldehyde added</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>15, 12, 12, 12, 11</td>
<td>5</td>
<td>4, 4, 4, 4, 4</td>
</tr>
<tr>
<td>2</td>
<td>20, 10, 10, 10, 9</td>
<td>4</td>
<td>4, 4, 4, 3, 3</td>
</tr>
<tr>
<td>3</td>
<td>14, 12, 12, 12, 10</td>
<td>5</td>
<td>5, 5, 5, 4, 3</td>
</tr>
<tr>
<td>4</td>
<td>14, 12, 10, 8, 8</td>
<td>5</td>
<td>5, 5, 5, 4, 3</td>
</tr>
<tr>
<td>5</td>
<td>15, 14, 10, 8, 8</td>
<td>5</td>
<td>5, 5, 5, 4, 3</td>
</tr>
<tr>
<td></td>
<td>Average 12.16 cm.</td>
<td></td>
<td>Average 4.72 cm.</td>
</tr>
<tr>
<td>MITCHELL FARM: 60 DAYS AFTER TAPPING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>25, 24, 23, 22, 14</td>
<td>6</td>
<td>5, 4, 4, 4, 4</td>
</tr>
<tr>
<td>7</td>
<td>26, 20, 15, 15, 15</td>
<td>7</td>
<td>6, 5, 4, 3, 3</td>
</tr>
<tr>
<td>8</td>
<td>30, 22, 18, 17, 15</td>
<td>8</td>
<td>5, 5, 5, 4, 4</td>
</tr>
<tr>
<td>9</td>
<td>30, 25, 16, 15, 15</td>
<td>9</td>
<td>6, 3, 3, 3, 3</td>
</tr>
<tr>
<td>10</td>
<td>20, 20, 18, 18, 17</td>
<td>10</td>
<td>6, 6, 5, 4, 3</td>
</tr>
<tr>
<td></td>
<td>Average 19.8 cm.</td>
<td></td>
<td>Average 4.96 cm.</td>
</tr>
</tbody>
</table>

<sup>1</sup> Boundary of lesion fluoresced under ultraviolet light. Measurements were made to these boundaries.
wood (fig. 1), a few cm. above and below the taphole (table 1). In these, the fluorescence under ultraviolet light was very weak at the margins. The most intense fluorescence was in the tissues immediately behind the taphole. The slightly discolored wood surrounding the tapholes that did not receive the pill faded in a few hours, and there was no difference in color between these tissues and healthy tissues. The discolored areas of wood sur-

Table 2. — Number of wood chips that yielded microorganisms from above and below 100 tapholes in 10 trees; 5 tapholes treated and 5 not treated with paraformaldehyde per tree on two farms

<table>
<thead>
<tr>
<th>Tree</th>
<th>250 mg. paraformaldehyde added per taphole</th>
<th>No paraformaldehyde added</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of wood chips from 5 tapholes</td>
<td>Yielded bacteria</td>
</tr>
<tr>
<td>PROCTOR FARM: 53 DAYS AFTER TAPPING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>90</td>
<td>84</td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>109</td>
</tr>
<tr>
<td>3</td>
<td>96</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>138</td>
<td>131</td>
</tr>
<tr>
<td>5</td>
<td>126</td>
<td>119</td>
</tr>
<tr>
<td>Total</td>
<td>570</td>
<td>528</td>
</tr>
<tr>
<td>Percent</td>
<td>—</td>
<td>93</td>
</tr>
</tbody>
</table>

10

Percent | — | 86 | 35 | — | 98 | 25 | 6
rounding the tapholes that had contained the pills appeared bleached after the wood dried.

The trees from the Mitchell Farm contained the pill a week longer than the trees from the Proctor Farm. The average length of the discolored areas in these trees was greater (19.8 cm.) than the average length of those from the Proctor Farm (12.16 cm.). Yet there was very little difference between the average lengths of the discolored areas in the trees on the two farms that did not receive the pill (table 1).

**Microorganisms Associated with Tapholes**

There was very little difference in the frequency of isolation of microorganisms from tissues surrounding tapholes, whether or not the tapholes had contained the paraformaldehyde pills (table 2).

By comparison with identified cultures from sugar maple, the

![Figure 4. — The removal of the bark surrounding the taphole of the tree shown in figure 3 reveals the wood killed by paraformaldehyde. Tissues to the side of the hole were killed also. Wood-inhabiting microorganisms rapidly invade these killed tissues.](image)
Figure 5. — Dissection of a taphole 2 years after a 250-mg. paraformaldehyde pill was inserted. The bleached wood is decayed. The tissues were killed several inches above and below the taphole.

principal bacteria were identified tentatively as species of *Pseudomonas* and *Bacillus*.

The fungi isolated were of the genera *Phialophora, Ascocoryne, Margarinomyces, Phoma, Alternaria, Penicillium, Fusarium, Gliocladium, Cephalosporium, Cladosporium*, and *Candida* (a filamentous yeast).

There was no noticeable difference between the species of microorganisms isolated from the treated and untreated tapholes.
Observations on Other Trees

Decayed wood was associated with tapholes that had received the pill 2 and 3 years ago in many of the trees examined in the Roger Grimes Orchard (figs. 4 and 5). The injury was not obvious until the bark surrounding the taphole was removed (fig. 4). On many trees there were dead areas lateral to the taphole (fig. 4). On trees in a neighboring farm, some injury was found, but not as extensive as that in the Grimes Orchard.

Histological Studies

Vessels in the wood surrounding tapholes that had not received the pill were plugged with an amber-colored material. This material is similar to that reported by Good et al. (3) as normally found in vessels in tissues surrounding wounds. In wood tissues surrounding tapholes that had received the pill, no such plugs were found in the vessels. These tissues were bleached. However, vessel plugs were found in the distal margins of the bleached tissues.

CONCLUSIONS

All tapholes that had received the 250-mg. paraformaldehyde pills had associated with them discolored areas that appeared bleached after the wood dried. Tapholes that did not receive the pill did not have such discolored areas.

Vessel plugs were absent in the bleached tissues. These results indicate that paraformaldehyde killed tissues in the tree. Vessel-plug formation is the result of a dynamic process. When tissues are killed quickly, they cannot respond; and no plugs form.

Decay was advanced above and below tapholes in trees that had received the pill 2 and 3 years ago, probably because the tissues were killed quickly around the taphole. The microorganisms that invade wood and incite discoloration and decay could then easily invade the dead tissues. In this way, the pill greatly enhances the establishment of wood-destroying microorganisms. And, even more damaging, killing of tissues around the taphole may result from the use of paraformaldehyde.

Paraformaldehyde indeed will kill and inhibit the growth of a
wide variety of microorganisms (2). There is little doubt that
this chemical does inhibit the growth of microorganisms in the
taphole (8). But paraformaldehyde does little to inhibit the
growth of microorganisms once they have invaded the wood.
Paraformaldehyde may even enhance the growth of certain wood-
inhabiting microorganisms by inhibiting the growth of competing
microorganisms on the inside surface of the taphole. Regardless,
there were just as many microorganisms in the wood surrounding
the tapholes that contained the pill as in the wood surrounding
tapholes that did not contain it.

A taphole is a wound. Trees have repair processes, as do all
organisms, to heal wounds. Many factors affect these processes:
the vigor of the tree, the severity of the wound, and microorga-
nisms—to mention a few. If wound-healing did not occur, there
would be no trees to tap. It appears that paraformaldehyde blocks
the repair system of a tree. Microorganisms that destroy wood
then invade.

Paraformaldehyde increases yield of sap not only by inhibiting
the growth of microorganisms in the taphole, but by killing tis-
sues that surround the taphole. The vessels in these dead tissues
do not contain plugs. In a sense, paraformaldehyde makes a larger
hole in the tree.
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