University of Vermont
Agricultural Experiment Station Journal Article 229

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

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U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-161
1970

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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

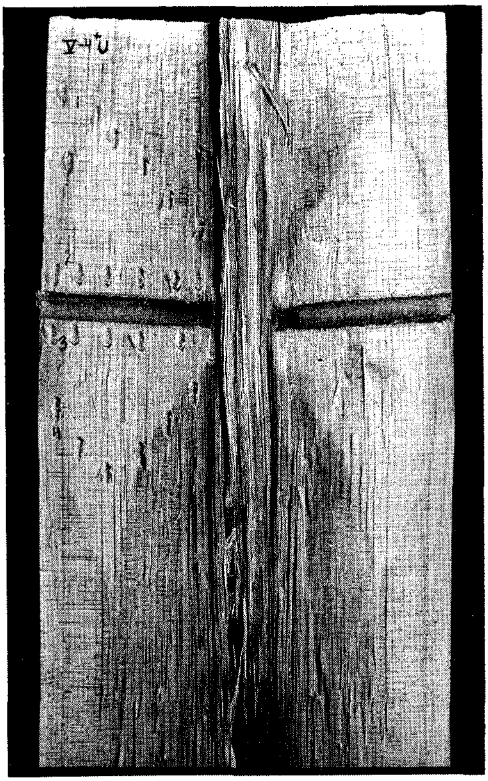
Durham on 13 May. They received the same treatment as the bolts from the Proctor Farm.

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.

Figure 2. — Dissection of a taphole that did receive a paraformaldehyde pill; after 60 days. The discolored area appeared as a bleached zone after the wood dried. The tissues in this zone were killed. The small holes in the wood mark the position of the chips of wood taken for isolating microorganisms. The distal margins of the bleached zones fluoresced under ultraviolet light.



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 fluoresced. 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.

had not. Other trees on the Proctor Farm were used in these studies.

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

Tree	250 mg. paraformaldehyde added per taphole — Lengths of lesions associated with 5 tapholes per tree: cm[1]					No paraformaldehyde added — Lengths of lesions associated with 5 tapholes per tree: cm				
PROCTOR FARM: 53 DAYS AFTER TAPPING										
1	15,	12,	12,	12,	11	5,	4,	4,	4,	4
2	20,	20,	15,	14,	14	4,	4,	4,	4,	4
3	15,	10,	10,	10,	9	4,	4,	4,	3,	3
4	14,	12,	12,	10,	5	12,	8,	7,	5,	5
5	14,	12,	10,	8,	8	5,	5,	5,	4,	3
	Average 12.16 cm.					Average 4.72 cm.				
MITCHELL FARM: 60 DAYS AFTER TAPPING										
6	25,	24,	23,	22,	14	5,	4,	4,	4,	4
7	26,	20,	15,	15,	15	6,	5,	4,	4,	3
8	30,	22,	18,	17,	15	5,	5,	5,	4,	4
9	30,	25,	16,	15,	15	6,	3,	3,	3,	3
10	20,	20,	18,	18,	17	6,	6,	5,	4,	3
	Average 19.8 cm.					Average 4.96 cm.				

[1] 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

	250 mg. paraformaldehyde added per taphole			No paraformaldehyde added		
Tree	Number of wood chips from 5 tapholes	Yielded bacteria	Yielded fungi	Number of wood chips from 5 tapholes	Yielded bacteria	Yielded fungi
PROCTOR FARM: 53 DAYS AFTER TAPPING						
1	90	84	10	60	60	1
2	120	109	20	120	119	8
3	96	85	13	108	108	2
4	138	131	39	96	96	42
5	126	119	22	120	120	13
Total	570	528	104	514	503	66
Percent	—	93	18	—	98	13
MITCHELL FARM: 60 DAYS AFTER TAPPING						
6	120	108	25	96	96	13
7	120	96	41	108	108	28
8	120	107	35	120	117	22
9	120	100	69	120	115	41
10	120	104	42	96	93	32
Total	600	515	212	540	529	136
Percent	—	86	35	—	98	25

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.

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 *Pseudomones* 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 microorganisms—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 tissues 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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