WOUND DRESSINGS: RESULTS OF STUDIES OVER 13 YEARS

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Abstract. Many materials were used in and on experimentally inflicted wounds in many studies over a 13-year period. No material prevented decay. The individual tree had a greater effect on the wound than the treatments. Some individual trees of a species closed and compartmentalized wounds rapidly and effectively, regardless of treatment, while other trees did not close and compartmentalize treated or control wounds. The width of healthy wood behind wounds in red maple was the major factor affecting the course of the wound. Results are given from wounds on 275 treated and dissected trees.

Tree wound dressings do not prevent decay (Collins 1934, Marshall 1950, Shigo and Wilson 1977, Mercer 1979, 1982, Bonneman 1979, Dooley 1980), and are of limited benefit for wound closure (Neely 1970, McQuilkin 1950, Young and Tilford 1937).

Many arborists have known this for a long time. Results of research on wound dressings by many investigators during the last decade have further convinced these arborists, and they have stopped using wound dressings, or have discussed the treatment with their clients. Some arborists in this group — we will call them Group I — may paint wounds for cosmetic reasons, if the client still wants it done. Others in Group I refuse to paint wounds because they believe it reflects poorly on their professionalism.

Group II is arborists that doubt the worth of dressings for decay prevention, but want more proof. They are open-minded. Some have stopped using dressings; others are still using thinner coats of the materials.

Group III is made up of arborists who will not change their minds about wound dressings, or any other tree care practice, no matter what is said, done, or printed. Some members of this group manufacture wound dressings for profit. Others have just "grown up" with wound dressings and consider them a hallmark of professionalism. This is not bad, so long as the materials are not being sold or applied with the implication that they will prevent decay.

It is unrealistic to think that the use of wound dressings will ever cease; the search will continue for the perfect dressing. The increasing variety of new chemicals and the lure of easy profit encourage constant testing. The problem is that the emphasis is on the materials and not the tree, or profit first and tree second. The purposes of this paper are to present some additional data from wound dressing experiments to help Group II, and to discuss new directions for helping trees, especially for Group I. We respectfully recognize Group III, so long as they are professionals, but we will not try to convince them that wound dressings do not stop decay.

Materials and Methods

During the 1970s, several wound treatment studies were conducted near Bartlett and West Thornton, New Hampshire, and Alfred, Maine. The studies were similar in general design, but there were some specific differences. Trees were wounded — with drill holes, ax cuts, or chisel wounds — some material was applied immediately after wounding (controls received no materials), the trees were cut after different periods of time, the wounds were dissected, closure was measured as width of open wound after periods of months to 7 years, microorganisms were isolated, and columns of discolored and decayed wood were measured. Tree species were red maple, *Acer rubrum* L., red oak, *Quercus rubra* L., white oak, *Q. alba* L., beech, *Fagus grandifolia* Ehrh.,

[1] The use of trade, firm or corporation names in this publication is for the information and convenience of the reader; such use does not constitute endorsement or approval by the U.S. Department of Agriculture, or the U.S. Forest Service.

and paper birch, *Betula papyrifera*. Trees ranged in age from 40 to 100 years, and in diameter at 1.4 m above ground from 15 to 30 cm. A total of 375 trees were wounded and treated, and 275 were harvested. (We always treat more than we plan to cut.) Materials used for most treatments were bituminous and asphalt-based paints, orange shellac, and nine variations of rosin acids and styrene butadiene, alone and with a synthetic thickener. Some preliminary studies were done with Ethrel, sucrose, cinnamic acid, aspirin, and ascorbic acid. The rosin acids were kindly supplied by chemists at Uniroyal Chemical Company, Naugatuck, CT. The ingredients were:

Rosin acid formulations

I. *8619:* Naugatex 1405 — Rosin acid emulsified, 50% styrene butadiene copolymer
II. *Naugatex 2752:* A 50% styrene butadiene acid terpolymer polymerized on alkyl aryl sulfonate emulsifier
III. *Naugatex 3595:* 60% styrene butadiene copolymer polymerized on a synthetic oligomeric surfactant
IV. *Naugatex 9064:* 23% styrene butadiene copolymer polymerized on sodium oleate emulsifier
V. *Naugatex 3711:* A 50% styrene butadiene acid terpolymer polymerized on a synthetic-oligomeric surfactant. This sample had 8 parts of rosin acid added after polymerization.
VI. *Pyratex 1904:* A butadiene styrene vinyl pyridine terpolymer polymerized on a Rosin Acid emulsifier.
VII. A 50% styrene butadiene copolymer polymerized on rosin acid emulsifier (Naugatex 2000). This sample had 1 part of a nonionic surfactant (Triton X-1001) added after polymerization.
VIII. A 50% styrene butadiene copolymer polymerized on a rosin acid (Naugatex 2000) to which 4 parts of rosin acid emulsifier was added after polymerization.
IX. A 50% styrene butadiene copolymer polymerized on a rosin acid (Naugatex 2000).
X. Synthetic thickener (Wica 6038) sodium polyacrylate thickening agent.

Cabot's wound healing paint was the bituminous-based dressing, and Treekote, a tarlike material, was the other dressing. Ethrel is a plant regulator containing Ethephon (2-chlorethyl) phosphonic acid — 21.6%, and 78.4% inert ingredients. Ethrel used in experiments was in liquid form, 10% active ingredient. The orange shellac was a high quality commercial grade, the sucrose and cinnamic acid were high quality laboratory grades, and the aspirin was a common medical grade.

Here are some reasons for selection of materials: Orange shellac has a long reputation as a beneficial dressing. Treekote made no decay prevention claims on the container, and it was representative of the many tarlike dressings. Cabot's paint did make claims, such as "heals wounds; prevents decay—stimulates growth of new bark—stops rot." Ethrel is used to loosen fruit for harvest, and to accelerate ripening. We wanted to determine its affect on injured tissues. Sugar was used because we hoped to stimulate the growth of microorganisms that might be beneficial for biological control of destructive wood-inhabiting microorganisms. Cinnamic acid is a protective chemical produced by trees after injury and infection. Maybe we could supply some extra cinnamic acid and help the tree help itself. The Uniroyal products were tried because of the firm bonding most of the materials had with fresh wounds, and because preliminary trials with one emulsified rosin acid appeared encouraging after a short time. Aspirin was used because the active ingredients are found in some trees. Maybe it could do for trees what it does for people. Ascorbic acid was used as a novelty.

Some specifics of ethrel treatments. On August 15, 1972, 15 trees, 5 each of red maple, American beech, and paper birch on the Hubbard Brook Experimental Forest near West Thornton, New Hampshire each received 12 drill hole wounds; 4 each at .5, 1, and 1.5 m above the ground. The wounds were spaced 90° from each other. The holes were 5 cm deep and 1.5 cm in diameter. Two holes at 180° from each other received 1 ml of liquid Ethrel. One tree of each species was cut on 16 October, 1972. Each wound was dissected longitudinally to measure the extent of discolored wood. Six wood chips, 3X8 mm, were extracted from above each wound and six from below. Chips were placed into malt-yeast agar (10 g malt extract, 2 g yeast extract, 1000 ml distilled water) for 10 days and the microorganisms identified when possible. The trees were observed periodically for 3 years, and in 1975 the remaining trees (only the beech were still standing) were cut and dissected.

Preliminary experiments with many substances. Wounds on red maples were treated with cinnamic acid (saturated aqueous solution), aspirin, 5% sucrose solution, and ascorbic acid.

Ascorbic acid: 15 red maple trees at Bartlett, New Hampshire were treated October 27, 1978, with drill hole wounds slanted slightly downward, four holes per whorl, one whorl per tree; one hole as control, second hole one tablet, third hole two tablets, and fourth hole three tablets, 500 mg in each tablet. The drill holes were 3 cm deep and 1 cm wide. Five trees were cut October 28, 1980. Measurements of cracks above and below holes were made on November 1, 16, and 22, and December 8, 1978.

Aspirin: 16 red maple trees at Bartlett, New Hampshire, were treated November 16, 1978; the procedure was the same for the ascorbic acid. Each tablet contained 5 grains of active ingredient. Five trees were cut October 10, 1980. Cracks were measured on November 22 and December 6, 1978.

Aspirin and ascorbic acid: 10 red maple trees, and 5 American beech trees at Bartlett, New Hampshire. Two and three whorls per tree, three drill holes per whorl; one hole control, one hole received two tablets aspirin, and one hole two tablets of ascorbic acid. Drill holes as in other experiments. Trees treated January 29, 1979; two trees harvested July 11, 1979.

Sugar: 20 red maple trees at Bartlett, New Hampshire, were treated with four template drill hole wounds per tree. The template was oval, 14 cm high and 10 cm wide; drills holes were evenly spaced, five of them in the form of a cross. Each hole was 3 cm deep and 1 cm wide. A sugar solution of 5% sucrose was painted over the wound and into the drill holes. Two wounds were treated and two not treated as controls on each tree. Seven trees were harvested; two on July 17, 1978, four in July, 1979, and one on October 28, 1980.

Cinnamic acid: The number of trees and wounds were the same as for sugar-treated trees. A solution of cinnamic acid was painted on two wounds of each tree. Six trees were harvested; two in July 1978, and four in July, 1979.

Rosin acids: 260 trees were treated; 170 red maple, 50 red oak, and 40 American beech. Of these, 165 were harvested; 115 red maple, 30 red oak, and 20 American beech, wounded from 1972 to 1974. Wounds were drill holes 5 cm deep, 1.5 cm wide, slanted downward slightly, and shallow oval wounds, 14 cm vertical and 10 cm horizontal. A template was used to make the size of the wound uniform. After the bark was removed, four horizontal chisel wounds .5 cm deep were made into the wood at a 45° angle downward. Four wounds of this type were inflicted on each tree. These wounds are called template-chisel wounds in this paper. Trees were harvested from 6 months through 3 years. To determine the area of cambial dieback, bark was removed from the wounded trunk and a centimeter grid was used. On some trees, the area of discolored wood on the cut surface 5 cm above the original wound was measured, also with a centimeter grid.

Cabot dressing: 10 trees each of red maple, red oak, and white oak were wounded on the Massabesic Experimental Forest, Alfred, Maine. Maples and white oaks were wounded on May 23, 1978, and red oaks on June 14, 1978. Five trees of each species were harvested on July 3, 1979, and the remainder of the trees on June 16, 17, 1980. All trees received four wounds, two treated and two not treated as controls. Wounds were template type; bark was removed from an oval 14 cm long and 10 cm wide, and five drill holes, each 1.4 cm wide and 1 cm deep, were spaced equidistant on the wound surface in the form of a cross. This type of wound is called template-drill type in this paper. Measurements made for each wound were: closure as width between callus at center of wound, cambial dieback as cm^2 after bark removal, and length of discolored wood above and below wound. For isolation of microorganisms, 12 chips of wood were taken and placed in two culture plates within a medium of yeast and malt extract as defined in a previous section. The area of discolored wood on the surface of a disk cut 5 cm above the edge of the original wound was measured.

Mixed treatments: 20 each red maple and red oak trees, maples on Hubbard Brook Experimental Forest, West Thornton, New Hampshire, and oaks on the Massabesic Experimental Forest, Alfred, Maine, were wounded and treated, the maples on August 23, 1976, and the oaks on August 24, 1976. Treatments were Treekote, shellac, Uniroyal type I, and control. Each tree received four template-chisel type wounds. The lowest wound was .5 cm aboveground, and the other wounds were placed so that no wound was directly above or below another one. On September 3, all Treekote-treated wounds were treated as directed on the label. On July 13, 1977, 12 red maples were harvested, and areas of cambial dieback were measured. On July 12, five red oaks were harvested and the wounds were dissected to determine the amount of discolored wood behind the wounds.

On September 2, 1982, seven red oaks and seven red maple trees were harvested. After dissecting the trees, we measured cambial dieback about the wounds and the area of discolored and decayed wood on the face of 2 disks cut 5 cm above the top of the original wound. Microorganisms were isolated from 12 chips in two plates of malt-yeast agar as described in a previous section. On the red maple wounds the width of sound wood from the original wound to the margin of any internal column of defect was measured.

Results

Ethrel-treated drill wounds. One tree each of red maple, paper birch, and American beech was cut 3 months after treatment. *Trichoderma* sp. was isolated frequently from treated wounds, but not from control wounds (Table 1). Treated wounds on red maple yielded many decay-causing fungi, but only one wood chip from a control wound yielded a decay-causing fungus (Table 1). Species of *Ceratocystis* were common in all wounds. A *Cytospora* sp. was isolated only from red maple.

The average length of columns of discolored wood in the 3-month-old drill wounds was 1.5 cm for the four control wounds, and 8.0 cm for the four treated wounds (Fig. 1).

Ethrel-treated drill wounds were so decayed in the four red maple and four paper birch trees that the trees died and broke at the wound sites within 3 years.

The three remaining American beech trees were cut and dissected after 3 years. Fruit bodies of *Panus stipticus* were on decayed wood associated with treated wounds on the three trees (Fig. 2). Large columns of decayed wood were associated with all treated wounds (Fig. 3). All columns of decayed wood were similar in

Table 1. Relative occurrence (in percent) of most common fungi isolated from discolored and decayed wood associated with drill wounds inflicted in a red maple, paper birch, and American beech, and treated with Ethrel. Wounds inflicted August 8, 1972, and August 15, 1972; trees harvested November 16, 1972.

Tree species	*Treatment*[1]	*Ceratocystis*	*Graphium*	*Cytospora*	*Trichoderma*	*Hymenomycete*
Red maple	Control	58	7	38	0	2
	Treated	13	52	5	72	30
Paper birch	Control	85	23	0	0	3
	Treated	57	57	0	90	7
American beech	Control	25	45	0	0	13
	Treated	35	53	0	30	8

[a]Each tree had 3 whorls of drill wounds; 4 wounds, 2 treated and 2 control, per whorl. Twelve wood chips for isolation of microorganisms from each wound, 6 chips above wound and 6 below, 2 plates; malt-yeast agar, 60 wood chips for treated and 60 chips for control, per tree species. Relative occurrence = number of successful isolations/total isolation attempts × 100.

appearance.

Preliminary experiments with many substances. Results of wound experiments with sugar solutions, cinnamic acid, aspirin, and ascorbic acid in red maple did not differ significantly from the controls.

After 1 year, the average lengths of columns of discolored wood associated with drill holes treated with ascorbic acid were 44 cm, treated, and 50 cm, controls (two trees, two control wounds, and six treated wounds).

After 1 year, the average lengths of columns of discolored wood associated with aspirin were 54 cm, treated, and 55 cm, controls (two trees, two control wounds, and six treated wounds).

After 1 year, the average lengths of columns of discolored wood associated with drill holes treated with aspirin, and other holes on the same tree treated with ascorbic acid, were 48 cm for aspirin, 52 cm for ascorbic acid, and 37 cm for controls (two trees, four holes for each treatment and controls).

After 1 year, the average lengths of columns of discolored wood associated with drilled template wounds treated with 5% sucrose solution were 40 cm, treated, and 40 cm, control (two trees, two control wounds and four treated wounds). Average dieback areas were 194 cm^2 for controls and 225 cm^2 for sugar treated (four trees, eight controls, and eight treated wounds).

After 1 year, dieback areas on drilled template wounds treated with cinnamic acid were 583 cm^2 for controls, and 409 cm^2 for treated (three trees, six control and six treated wounds).

Other observations made on the wounded trees were measurements of cracks above and below the wounds, whether the wounds were oozing sap, and for how long. These factors appeared to be tree-related, more than treatment-related. When large vertical cracks appeared, they were associated with all wounds on a tree, treated and control. The same was true with oozing of sap after wounding and treatments. The genetic characteristics of individual trees within the same species were evident.

Rosin acids, Uniroyal products — short-term experiments. Preliminary experiments on red maple with rosin acid I, and several others were encouraging for reduction in area of cambial dieback over controls, and for decreases in length of discolored wood (Table 2). Harvests of red maple trees 6 and 12 months after treatment of drill wounds showed 9 to 56% less cambial dieback than in controls. Rosin acid I was one of the best materials in early tests that used all nine variations of the rosin acids and combination of the acids with the thickeners.

After 2 years, the results were different for red maples (Table 3). Decayed wood was associated with 9 control holes and 42 treated drill holes (all treatments except II and IV), and no treatment was significantly better than the control for discoloration (Table 3).

On red oak and American beech (Table 3), many treatments reduced discoloration associated with drill wounds, but after 2 years all the wounds were closed and only one treated wound had decayed wood.

The seven best treatments were used on template-chisel wounds on red maples (Table 4). The response of individual trees to the wounds was striking. All control wounds on some trees formed thick bands of callus (Fig. 4), while control wounds on other trees had large areas of dieback and very small bands of callus (Fig. 5). The same patterns were seen on trees with treated wounds. Some trees formed thick bands of callus (Fig. 6), and some trees did not (Fig. 7). There were slight decreases in cambial dieback associated with the treated wounds (Table 4, Figs. 8 and 9). The amount of dieback appeared to be more tree-related than treatment-related: large patches on some trees, (Fig. 8), and small patches on others (Fig. 9).

Table 2. Mean length (in cm) of columns of discoloration and dieback after 1 year of experiments testing 4 variations of rosin acids on 12 red maple trees. Each tree had 3 drill wounds, each treated with a different material, and 3 non-treated control wounds; a total of 15 drill wounds at 3 whorls on the trunk of each tree. Dieback measurements on 4 trees.

Treatment	*Discolored wood, length, cm*[a]	*Dieback, length, cm*[b]
Control	16	10
I	8	4
II	13	5
III	14	4
IV	14	6

[a]Mean of 27 wounds on 12 trees.
[b]Mean of 12 wounds on 4 trees.

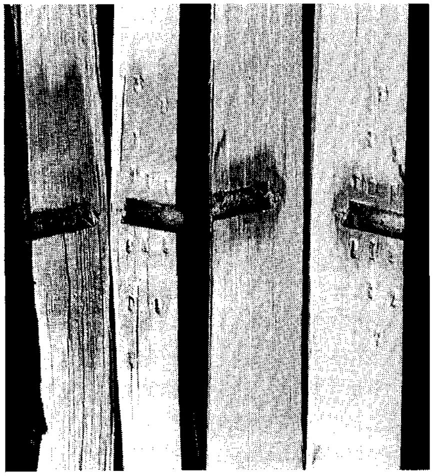


Figure 1. Drill wounds in red maple 3 months after treai ment with 1 ml of Ethrel, left, and control, right. The small depressions show where the chips of wood were extracted for isolation of microorganisms. This pattern of isolations was repeated on many other wounds. Six wood chips were placed into agar in one Petri dish.

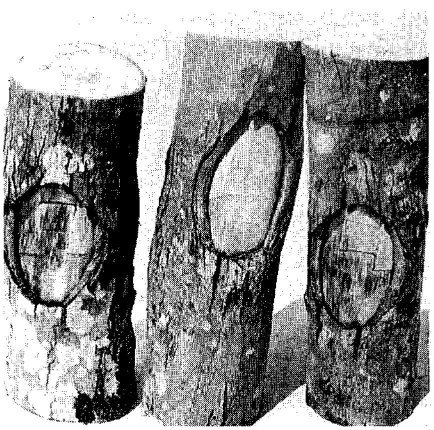


Figure 4. Thick bands of callus associated with 2-year-old control wounds on one red maple. There was very little cambial dieback.

Figure 7. Thin bands of callus and extensive areas of cambial dieback associated with 2-year-old wounds on one red maple treated with rosin acids (three wounds on right) and control (wound on left).

Figure 2. Sporophores of *Panus stipticus* on wounds treated with Ethrel after 3 years.

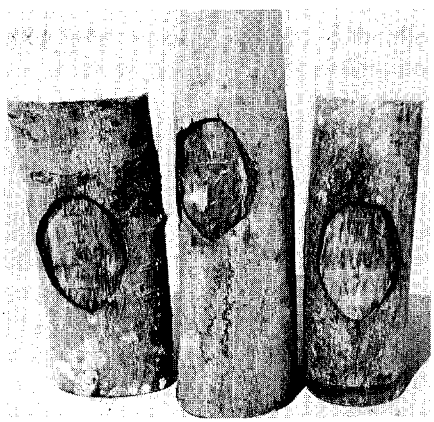


Figure 5. Thin bands of callus associated with 2-year-old control wounds on one red maple. Large area of cambial dieback were associated with the wounds.

Figure 8. Small areas of cambial dieback associated with 2-year-old wounds on one red maple, treated with rosin acids (three wounds on right) and with the control (wound on left). Bark is peeled to show extent of dieback.

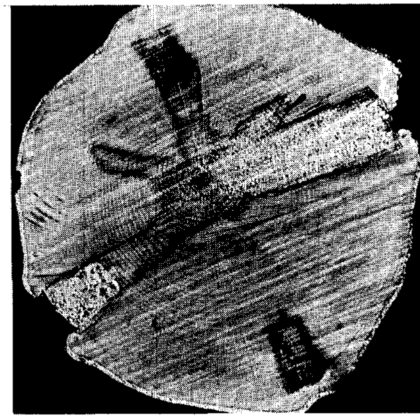


Figure 3. Decayed wood associated with wounds treatec with Ethrel (A and B). The decayed wood supportec sporophores of *Panus stipticus*.

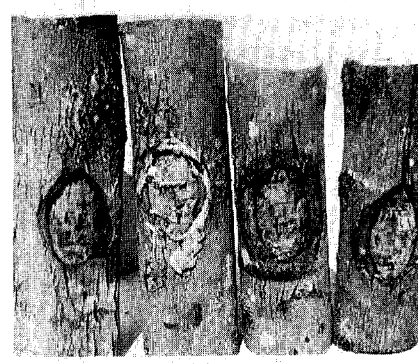


Figure 6. Thick bands of callus associated with 2-year-ol wounds on one red maple treated with rosin acids (thre wounds on right), and control (wound on left).

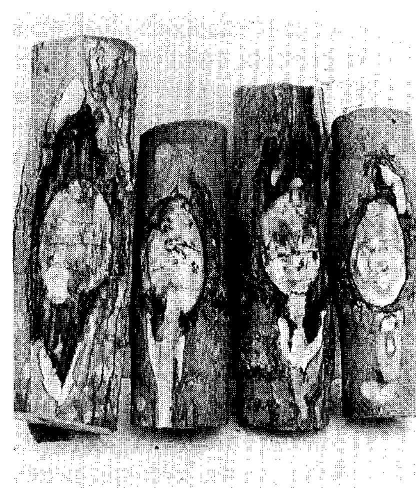


Figure 9. Large areas of cambial dieback associated witl 2-year-old wounds on one red maple treated with rosii acids (three wounds on right) and the control (wound oi left). Bark peeled to show extent of dieback.

Table 3. Mean length (in cm) of columns of discolored wood found in 2 years of experiments testing 16 variations of rosin acids and rosin acids with thickeners (Th) on red maple, red oak, and American beech. Wounds were deep drill holes, 4 per whorl, 4 whorls per tree.[a]

	Red maple		*Red oak*		*American beech*	
Treatment	*Control*	*Treatment*	*Control*	*Treatment*	*Control*	*Treatment*
I	12	11	13	6*	8	3
II	27	24				
III	27	27				
IV	27	28				
V	9	9	13	6*	8	4
VI	9	9	13	6*	8	5
VII	8	8	13	6*	8	2*
VIII	8	7	13	7*	8	2*
IX	8	8	13	4*	8	2*
I + Th	9	8	13	8*	8	5
V + Th	9	9	13	8*	8	5
VI + Th	9	10	13	8*	8	5
VII + Th	8	9	13	7*	8	3*
VIII + Th	8	9	13	4*	8	3*
IX + Th	8	11	13	4*	8	3*
Th	9	10	13	11	8	5*

[a] *Mean of 8 to 16 obs. for maple (except II, III, IV - 3 obs. and Th 24), 7 to 8 obs. for oak (Th 15), and 4 obs. for beech (Th 8).* (*) indicates that mean for treated wounds differs significantly from controls by ANOVA, P ◄ 0.05.

Experiments with several treatments — short-term. After many measurements on dissected trees, rosin acid I was selected in 1976 as the best material, and new experiments were started to test it against a commercial wound dressing (Treekote), orange shellac, and controls. On red maple trees after 1 year, rosin acid I significantly reduced dieback area (Table 5, Fig. 10). On red oak very little dieback was associated with any wounds (Fig. 11). On red maple the strong tree relationship to wounding was seen again. On some trees, dieback was extensive about all wounds (Fig. 12), while on other trees all wounds had little dieback (Fig. 13).

Wood-boring insects often infested the dying wood above and below the treated and control wounds (Fig. 13). The insect wounds extended greatly the area of cambial dieback.

Cabot dressing. In 1978, additional experiments were started with another material, a bitunimous-base dressing called "Cabot's Tree Healing Paint." Template drill wounds were used. The black paint often peeled after one year (Fig. 14). Control wounds blended with the bark color after 1 year on oaks (Fig. 15). On some trees, especially the white oaks, thick bands of callus formed on all wounds (Fig. 16). On other trees,

Table 4. Distance between collar ridges around wounds (in cm); results of 2 years of experiments testing 7 treatments of rosin acids and thickeners (Th) on wound closure in red maple. Template chisel-type wounds, 4 wounds/tree, 3 treated and 1 control.

	Distance between callus ridges around wound, cm[a]			
	Length		*Width*	
	Control	*Treated*	*Control*	*Treated*
I	23	20	8	7
I + Th	23	16*	8	7*
V + Th	29	25	9	8
VI + Th	25	17*	9	7*
VII + Th	26	17*	9	8*
VIII + Th	30	23*	9	8*
IX + Th	29	21*	9	8*

[a]Means of 5 to 6 obs. (*) indicates mean for treated wounds differs significantly from controls by ANOVA, P ◄ 0.05.

Table 5. Mean area of dieback (in cm^2) about 48 wounds on 12 red maple trees 1 year after treatment with rosin acid (Uniroyal Product), Treekote, orange shellac, and control. Wounds were template-type with chisel slits.

Treatment	*Mean area of dieback - cm^2*
Control	210
Shellac	175
Treekote	146
Uniroyal	84[a]

[a]Uniroyal treatment significantly different from control (P◄ 0.05.)

Table 6. Results of experiments with Cabot wound dressing after 1 and 2 years on 10 each red maple, red oak, and white oak. Wounds were template-type with five drill holes.

Measure	*Years after wounding*	*Tree Species*					
		Red maple		*Red oak*		*White oak*	
		Control	*Treated*	*Control*	*Treated*	*Control*	*Treated*
Area of discolored wood 5 cm above wound (cm^2)[a]	1	5.6	3.3	12.1	7.9*	0.9	0.8
	2	5.2	1.3*	8.7	7.9	1.9	0.4*
Area of cambial dieback around wound (cm^2)[a]	1	42	49	74	60	15	6*
	2	11	9	56	19*	4	1
Relative frequency of decay-causing organisms (%)[b]	1	—	—	—	—	—	—
	2	—	30	50	75	20	75*
Relative occurrence of decay-causing organisms (%)[c]	1	—	—	—	—	—	—
	2	15	20	18	45	7	37*

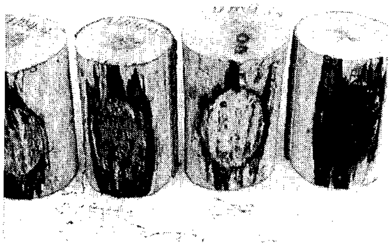
[a] Mean of 10 observations, 2/tree, 5 trees each species. (*) indicates treated differs significantly from control by ANOVA $P < 0.05$.
[b] Mean % of 4 Petri dish cultures/tree yielding decay-causing organisms, 5 trees each tree species.
[c] Relative occurrence = $\frac{\text{Number of successful isolations}}{\text{Total isolations}} \times 100$
Mean of 5 trees, 24 isolation attempts/tree/treatment.

especially red oaks and red maples, callus formation was poor on all wounds (Fig. 17). After 1 year, the treated wounds on red oak had smaller columns of discolored wood than the controls, but after 2 years there was no difference (Table 6). The opposite was true for red maples and white oaks. The treatment also reduced cambial dieback on the oaks (Table 6). The treatment had no effect on the relative frequency and occurrence of decay-causing organisms in red maple, and red oak, but in white oak the treated wounds had a significantly higher relative frequency and occurrence of decay-causing organisms than the control (Table 6). When all wounds on all three tree species were considered, there was no significant difference in the number of decayed wounds by treatment — dressing or no dressing (Table 7). *Alternaria* sp. was isolated much more frequently from the treated wounds (Table 7).

Experiments with several treatments — long term. After 7 years, seven red maple trees, and seven red oak trees, were dissected and studied. Each had four template-chisel wounds, each wound had four template-chisel wounds, each wound treated with either shellac, Rosin acid I, or Treekote, or not treated. On two red maple trees and two red oak trees, all four wounds were without decayed wood. For trees with decayed wood, there was no significant difference among treatments and controls (Table 8, Figs. 18 to 24). There were also no significant differences in area of dieback and area of discolored wood (Tables 8, 9; Figs. 18 to 24). The area of dieback was measured as the area of the still-exposed wood. This measurement reflects the opposite of closure.

Table 7. Percentage of control and treated (Cabot wound dressing) wounds that yielded decay-causing organisms and *Alternaria* sp. after 2 years. Five trees each of red maple, red oak, and white oak, 4 wounds/tree, 2 control, 2 treated. Wounds were template-type with 5 drill holes.

Tree	*Decay-causing fungi*		*Alternaria sp.*	
	Control	*Treated*	*Control*	*Treated*
Red maple	80	30	0	80
Red oak	60	80	60	80
White oak	30	90	40	100



ı 10. Cambial dieback associated with 1-year-old ls on one red maple; from left to right: control, c, rosin acid I, and Treekote. The wound treated with ɜcid had the least dieback. There was no significant ınce among the other treatments and control.

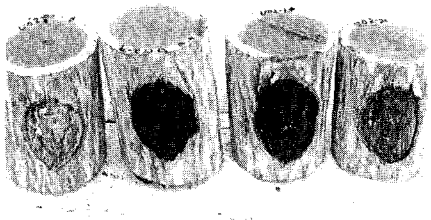


Figure 11. Four 1-year-old wounds on one red oak; from left to right: rosin acid I, Treekote, shellac, and control. Very little cambial dieback was associated with these wounds.

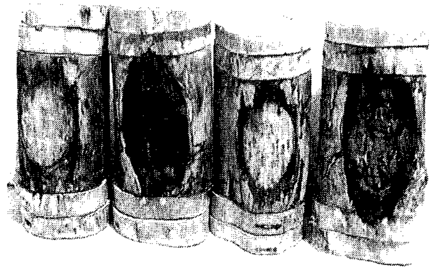
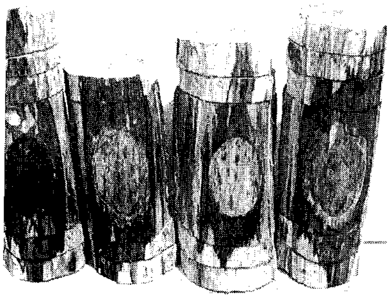


Figure 12. All 1-year-old wounds on this red maple had similar areas of cambial dieback; from left to right: control, Treekote, rosin acid I, and shellac.



e 13. All 1-year-old wounds on this red maple had . similar areas of cambial dieback; from left to right: ote, control, rosin acid I, and shellac. Boring insects :ed the wood above and below the wounds, and were ınsible for the large areas of dieback.

Figure 14. Template drill wounds on red oak after 1 year. The Cabot dressing often peeled.

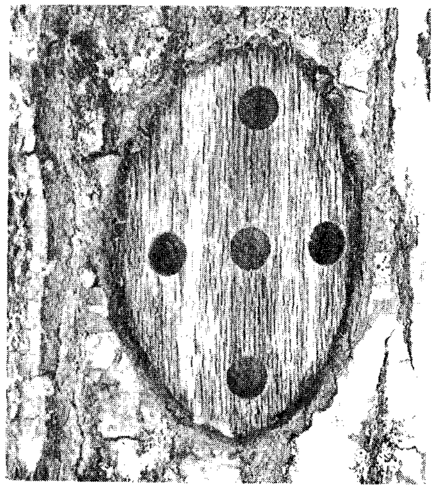
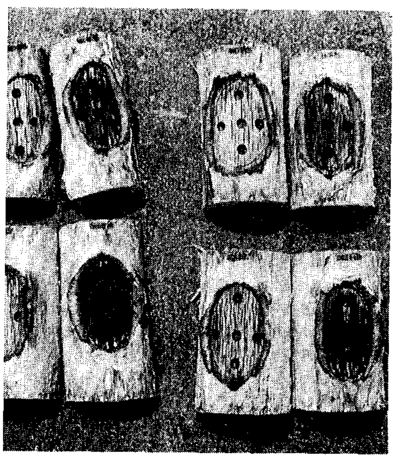


Figure 15. Template drill wound on red oak after 1 year. The wound surface blended with the bark.



e 16. Thick bands of callus formed on control wounds hose treated with Cabot paint on white oaks after 1 Four wounds on one tree, left, and four wounds on er tree, right. Note peeling of paint on treated ds.

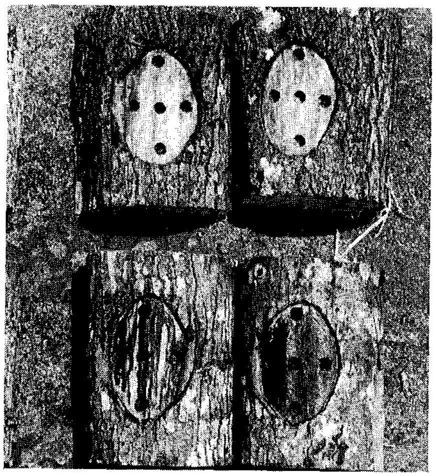


Figure 17. Poor callus formation on two control wounds, upper, and two Cabot-treated wounds, lower, on one red maple after one year. Note peeling of paint.

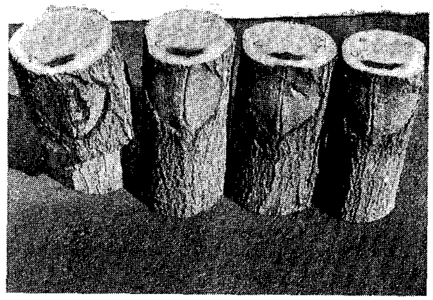


Figure 18. All wounds on this red oak were closed after 7 years, and only small pockets of discolored wood were associated with the wounds; left to right: Treekote, control, shellac, and rosin acid I.

The strong effect of the individual tree on the wounds was shown again. One oak tree had closure of all wounds, and no decay (Fig. 18), while another oak had poor closure of all wounds and large pockets of decay (Fig. 19). Yet another tree had poor closure on all wounds, and small pockets of decay (Fig. 20).

On red maples, some treatments were associated with large amounts of decayed wood, while no decayed wood was associated with the same treatments on other trees (Figs. 21 to 24). There was a strong correlation between decayed wood and the width of sound, healthy wood behind the wound at the time it was inflicted (Table 8, Figs. 25 and 26). Trees with large central columns of discolored and decayed wood had narrow bands of healthy wood, and new wounds inflicted at such locations developed decay rapidly. The data suggest for red maples, that if the width of sound wood behind a wound was less than 4 cm, the infection associated with the new wound spread rapidly (Table 8).

Discussion

The wound response mechanisms of individual trees and their wounding history were the major factors affecting the patterns of infection started by new wounds, whether treated or not. Some individual trees of a species closed wounds and walled off infections rapidly and effectively, regardless of treatment. Other individual trees did not close wounds rapidly, and did not wall off infections to small volumes, regardless of treatment. The exception was the treatment with Ethrel which, under the conditions of the experiment, overwhelmed most of the trees, and encouraged rapid decay that led to breakage. None of the materials tested was better than the con-

Table 8. Results of experiments with wounds on 7 red maple trees 7 years after treatment with rosin acid (Uniroyal product), Treekote, orange shellac, and untreated control. Wounds were template-chisel type, 4 wounds/tree, 3 treated and 1 control.

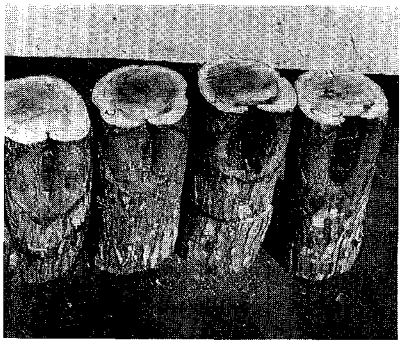
		Wound Treatments			
Width of sapwood at wound[a]	*Control*	*Treekote*	*Uniroyal*	*Shellac*	*Mean*[c]
		Relative occurrence of decay fungi, %			
Thick (► 4 cm)	3	0	11	0	4
Intermediate	50	33	0	21	27
Thin (2 cm)	66	55	70	40	69*
Overall[b]	34	30	25	40	
		Area of discolored wood[d] 5 cm above wound, cm^2			
Thick (► 4 cm)	2	5	2	5	3
Intermediate	30	6	2	25	15
Thin (2 cm)	59	52	32	34	43*
Overall	26	10	10	24	
		Area of dieback around wound, cm^2			
Thick (► 4 cm)	183	201	138	240	185*
Intermediate	189	239	197	199	210
Thin (2 cm)	441	276	177	299	298*
Overall	258	239	166	254	

[a] Of 28 wounds observed, 9 had thin sapwood (2 cm) exposed by wounding, 20 had thick sapwood (► 4 cm, range 5-12, mean 7 cm), and 9 were intermediate (3 or 4 cm).

[b] Mean of 9 or 10 observations made on wounds that exposed thick (► 4 cm), thin (◄ 2 cm), or intermediate (3-4 cm) sapwood. (*) indicates that thick sapwood means differ significantly from those of thin sapwood by ANOVA *P* ◄ 0.05. Of 28 wounds made on 7 trees, 10 exposed thick sapwood ► 4 cm (range 5-12, mean 7), 9 exposed thin sapwood, all 2 cm, and 9 exposed an intermediate amount averaging 3 or 4 cm.

[c] Means within sapwood thickness classes (thick, intermediate, thin) based on 2 or 3 observations, overall means based on 7 obs. 7 wounds on 7 trees). (*) indicates that treatments differ significantly from controls within classes by wounds or over all classes by trees by ANOVA, *P* ◄ 0.05. No significant differences were observed between treatments among wounds within classes, nor over all wounds on 7 trees.

[d] Area of discoloration includes decayed wood.



re 19. All wounds on this red oak were still open after 7 s, and large pockets of decayed wood were associated all wounds. Left to right: shellac, rosin acid I, Treekote, control.

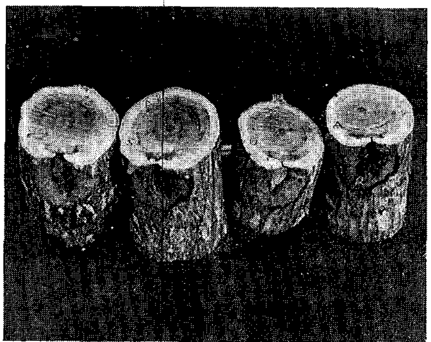


Figure 20. All wounds on this red oak were still open after 7 years, and similar-sized pockets of decayed wood were associated with the wounds. Left to right: control, shellac, rosin acid I, and Treekote.

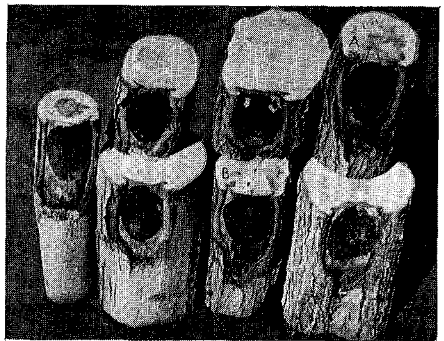
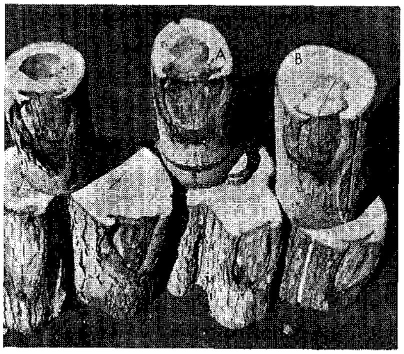


Figure 21. Seven wounds, each 7 years old, from seven red maple trees. All wounds treated with Treekote. Note the great variation in dieback, callus formation, and amount of decayed wood. Note extensive decay in two wounds (A and B).



re 22. Seven wounds, each 7 years old, from seven red le trees. All wounds treted with rosin acid I. Note variain dieback, callus formation, and decayed wood. Note nsive decay in two wounds (A and B).

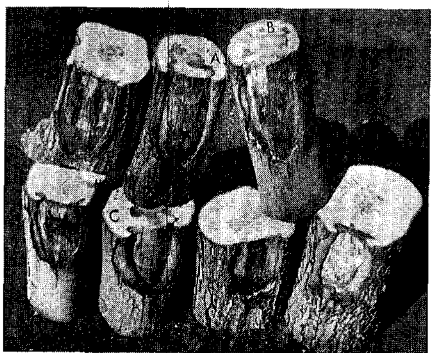


Figure 23. Seven wounds, each 7 years old, from seven red maple trees. All wounds treated with shellac. Note decayed wood in three wounds (A, B, and C).

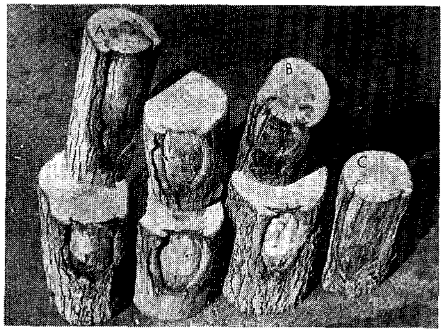
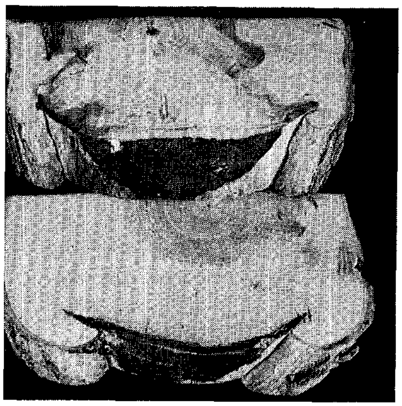


Figure 24. Seven wounds, each 7 years old, from seven red maple trees. All wounds were not treated — controls. Note decayed wood in three wounds (A, B, and C).



re 25. Two 7-year-old Treekote-treated wounds from red maple trees. The upper sample had extensive yed wood, while the lower sample had no decayed *l. The lower sample had a wide band of healthy wood* nd the wound. The upper sample had a narrow band of lthy wood separating the experimentally inflicted nd from the large central column of discolored wood ıdy present. The width of healthy wood behind wounds n important factor affecting the development and ad of decayed wood.

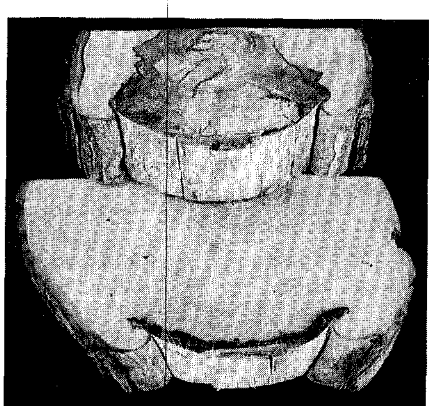


Figure 26. Two samples showing the same patterns as in figure 25, except that the wounds were not treated.

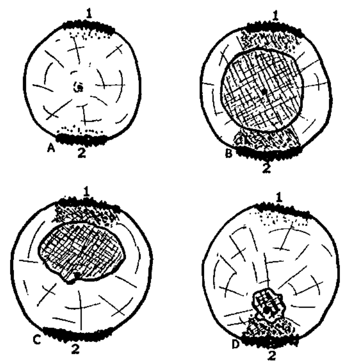


Figure 27. Summary of basic patterns in red maple that affect the development and spread of decay after wounding. Tree A has a wide band of healthy wood. Wounds inflicted at positions 1 and 2 will rarely develop decay, regardless of whether the wounds are treated or not. Tree B has a large column of central defect and a thin band of healthy wood. Wounds inflicted at positions 1 and 2 will usually develop decay rapidly, regardless of whether they are treated or not. Tree C has a wide band of healthy wood *on one side, and a thin band of healthy wood* on the other side. A wound inflicted at position 1 will usually develop decay rapidly, whether treated or not. A wound inflicted in position 2 will seldom develop decay, whether treated or not. Tree D has the pith far on one side, and a small column of central defect. A wound at position 1 will seldom develop decay, whether treated or not. A wound at position 2 will usually develop decay, regardless of treatment.

trols for prevention of decay.

Short-term experiments with wound treatments can be very deceptive because decay usually takes several years to develop. Any wound treatment study that does not produce decay in at least 25% of the control wounds is of absolutely no value! Even in our experiments, the short-term results were very different from the long-term results, and our long term — 7 years — is still a very short time in the life of the tree.

Dissection of wounds is absolutely essential. Studies that do not dissect wounds confuse more than clarify. We have had too many of these.

When insects infested, they bored into the dying wood above and below the wound where there was no wound dressing.

On small wounds, closure was rapid and columns of discolored wood were usually small. Some treatments did reduce discoloration. Whether this is beneficial to the tree is questionable, because some types of discolored wood result from the accumulation of protective materials (Shortle 1979, Green et al. 1981). The white oaks in the Cabot paint study shed some light on this. The columns of discolored wood in treated wounds were significantly smaller than in the controls, yet there was significantly higher relative frequency and occurrence of decay-causing fungi in the white oaks with treated wounds than in the controls. A similar trend was shown by Houston (1971), where columns of discolored wood were shortest in glue-treated wounds, but the incidence of decay was higher in glue-treated wounds in yellow birch.

The strong role of tree genetics in the wound response cannot be discounted. Several studies show that the ability of a tree to compartmentalize infections is under moderate to strong genetic control in several species (Shigo et al. 1977, Garrett et al. 1979, Lowerts and Kellison 1981). Trees that compartmentalize weakly will have larger columns of defect associated with dying branches and roots, and with mechanical wounds. The same individual tree that has had a life of poor compartmentalization will respond just as poorly to new wounds regardless of treatment. A summary of these conditions is given in Figure 27.

It is time to start a new direction with many tree care practices. New tools, new problems, new political pressures, and new information make it necessary to adjust many practices that were developed when conditions were different. New emphasis must be focused on the tree. If trees are well understood, then the ways to help them stay healthy will also be understood (Shigo 1982b). Ignorance is our main problem. Understanding is the answer. We should not rely on medicines and wound dressings to correct problems we create. It is not so important to start new practices as it is to STOP many old practices that do more harm than good. If adjustments can be made in many tree care practices, then there will be no need for dressings. For example, branch pruning has been a major tree treatment for centuries. The recommendation for 400 years has been to cut branches as close as possible to the joining stem, and then paint (Von Mayer-Wegelin 1936). If such cuts are made, the tree will be injured so seriously that even if a magic dressing were known, it would not help. If pruning cuts are made properly (Shigo 1982a), there is no need for a dressing. If cuts are made improperly, dressings will not help.

In the end, arborists of Group I will continue to make adjustments based on new information. Group II will consider the new information and begin to make some adjustments. And, Group III will not understand what is happening because they will be out painting wounds.

Acknowledgements

We thank Mr. Wilson White and others at Uniroyal Corporation, Naugatuck, Connecticut for providing the rosin acids, and funds to support portions of the studies. We thank Cabot Company for providing wound dressings.

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INDEX
JOURNAL OF ARBORICULTURE
Volume 9, 1983