SOME INTERNAL EFFECTS OF MAUGET TREE INJECTIONS

by Alex L. Shigo, Walter E. Money, and Dale I. Dodds

Abstract. Negligible amounts of discolored wood and cambial dieback were associated with control Mauget injection wounds (no chemicals added) made 1 year earlier on red maple, white oak, and shagbark hickory. Columns of discolored wood and some cambial dieback were associated with wounds that had been injected with Bidrin or Meta-Systox-R. Columns of discolored wood and very little cambial dieback were associated with wounds that had been injected with Fungisol or Stemix. Injured tissues associated with all wounds were compartmentalized in the wood present at the time of injection; wood that formed subsequently was not infected.

The injection of diseased trees or those of poor vigor with a wide variety of therapeutic materials is currently receiving a great amount of attention (Gibbs and Dickinson 1975, Van Alfen and Walton 1974, Gibbs and Clifford 1974, Gregory and Jones 1973). The benefits to the tree are often obvious externally, but little is known about the internal effects of the injections.

Many factors can affect the internal condition of an injected tree: the type, position, and number of wounds; the skill of the operator; the condition of the tree at time of injection; the type and amount of material introduced; and the time of year of injection. Some of these same factors may affect the rate of uptake of the chemicals (Gibbs and Dickinson 1975).

The present study sought to determine the amount of discolored wood and the extent of cambial dieback associated with wounds from one type of injection; it did not attempt to gauge the efficacy of the materials injected. The observations and measurements were made 1 and 2 years after the injections.

Materials and Methods

The injection method involved the insertion of a metal tube, 3/16 inch in diameter by 2¾ inches long, into the tree to a depth of 3/4 inch, and the attachment to the tube of a capsule that contained a liquid chemical material. Details of the method have been published (Heffernan 1968). In all experiments, only trained and properly licensed professional arborists administered the materials, and all procedures were those recommended for commercial application.

Study location. Trees in all experiments were on land owned by the Gunbarrel Valley Wildlife Preserve and by Winfred Orndorff, near Yellow Springs, West Virginia. Trees were on gentle slopes and flat bottomland that had been pastureland more than 50 years earlier. As a result, and because of past fires, most of the trees were in even-aged stands. The predominant species were white oak, red maple, shagbark hickory and locust.

Trees studied. Three species of trees were used: red maple, *Acer rubrum* L.; white oak, *Quercus alba* L.; and shagbark hickory, *Carya ovata* (Mill.) K. Koch. Trees were approximately 40 years old, 7 to 20 cm in diameter at 1.4 m aboveground, and 12 to 18 m in height. Trees selected for study had few external signs of internal defects.

Injections, May 1974. A total of 50 red maple trees each received three injections of 2 ml of the insecticide, Inject-A-Cide B (Bidrin) (dimethyl phosphate of 3-hydroxy-N, N-dimethyl-*cis*-crotonamide); 50 red maples each received three injections of 4 ml of a nutrient material, Inject-A-Min (Stemix) (total nitrogen 0.7%, available phosphoric acid 1.0%, soluble potash 0.9%, copper 0.1%, iron 0.4%, manganese 0.1%, and zinc 0.4%); and 25 red maples received 4 ml of water as controls. The injections were made approximately 1.4 m aboveground at sites spaced evenly around the stem. The injection tubes, with the empty capsule attached, were removed after several hours.

Injections, May 1975. The same procedure as described above was used to inject 90 white oaks. Each experimental block of trees contained 10 injected with a chemical and 5 injected with water; all trees were on the same site. Six treatment blocks were established: Stemix 4 ml and Bidrin 2 ml/wound (S1B); Stemix 4 ml and a fungicide, Fungisol (a material similar to MBC from benlate) 4ml/wound (SF); Bidrin, 2 ml/wound (1B); Fungisol, 4 ml/wound, May injection (FM); and the insecticide Meta-Systox-R (S-[2-)ethylsulfinyl)ethyl] 0,)-dimethyl phosphorothionate), 3 ml/wound (MSR). In July, an additional block of 10 white oak trees was injected with Fungisol 4 ml/wound (FJ).

One block of 10 red maple trees was injected with Fungisol, 4 ml/wound, and a block of 10 hickory trees was injected with Bidrin, 2 ml/wound.

One block of 10 red maple trees was injected with solutions of metallic ions, i.e., solutions containing 4 ml each of manganese, 2%, iron, 2%, magnesium, 1%; or zinc, 3%.

Electrical measurements. All trees injected in 1975 had their cambial zone tissues measured for electrical resistance to a pulsed current with a Shigometer.[1] The Shigometer delivers a pulsed electric current and measures the resistance to it in thousands of ohms. Properly interpreted, electrical resistance of the cambial tissues provides information about the relative vigor of a tree (Wargo and Skutt 1975, Smith et al. 1976). At six points around the stem, two needle probes were forced into the cambial zone (Fig. 1), and the average electrical resistance for all points was determined. The lower the resistance reading, the higher the relative vigor of the tree. In trees that are all approximately the same age, as these were, diameter also serves as a measure of relative vigor.

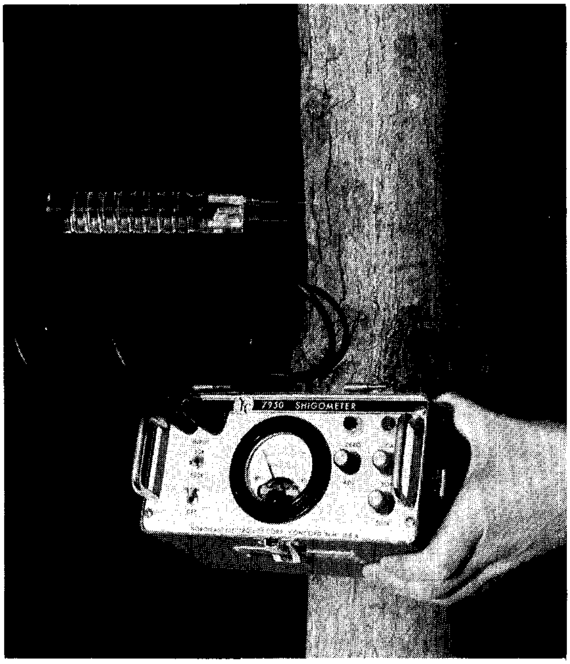

Fig. 1. Needle probes attached to Shigometer for resistance measurement of cambial zone tissues.

After the trees had been cut and dissected, the needle probes were used to measure the resistance to a pulsed current in discolored wood 5 cm above the injection wound and in clear healthy wood contiguous to the discolored wood. For these internal wood measurements, the lower the resistance, the more deteriorated the wood. The ratio of resistance in discolored wood to that in contiguous clear wood served as a measure of the degree of tissue deterioration of discolored wood associated with injection wounds. Detailed information about the Shigometer has been published (Shigo and Shigo 1974).

Harvests. In May 1975, 14 red maple trees that had been injected in 1974 were dissected and studied, 6 that had been injected with Stemix, 6 with Bidrin and 2 control trees. The lower 2-meter bolt from each trunk was cut into 5-cm discs, and the length of the column of discolored wood and the extent of cambial dieback associated with each wound were measured. Dieback was measured as the length of dead cambium above and below the wound.

In May 1976, the same procedure was carried out on 10 additional red maple trees from the same area, 4 that had been injected with Stemix, 4 with Bidrin, and 2 control trees.

In May 1976, 18 white oaks, 3 red maples, and 3 hickories that had been injected in 1975 were dissected and studied. The lengths of columns of discolored wood and the extent of cambial dieback above and below each wound were measured as above.

Trees for harvesting in 1976 were selected un-

[1] Model 7950, Northeast Electronics Corp., Airport Rd., Concord, N.H. The use of a trade name does not constitute endorsement by the U.S. Department of Agriculture.

seen on the basis of measurements of cambial zone electrical resistance taken before the trees had been injected in 1975. One tree with low cambial readings (high vigor) and one with high cambial readings (low vigor) were selected from each treatment group. In all cases, the trees were the same age, but those with low resistance readings were larger in diameter than those with high readings.

In May 1976, four red maple trees were harvested; they had been injected in 1975 with manganese, iron, magnesium, and zinc, respectively.

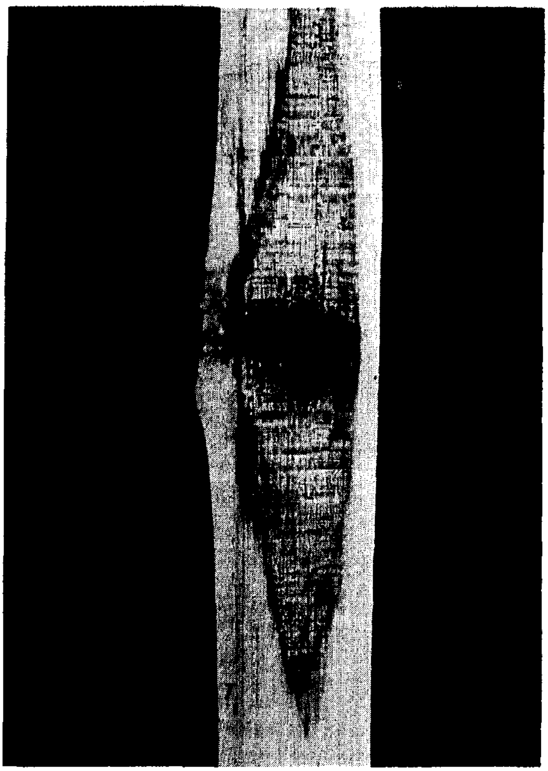

Fig. 2. Discolored wood associated with a closed 2-year-old control wound in red maple. The discolored wood is confined to the tissues present at the time of wounding.

Results

Red maples, 1974 injections. Harvests in 1975 and 1976 showed that the 12 control wounds on four trees all had short columns of discolored wood and a negligible amount of cabial dieback (Fig. 2) (Table 1). The discolored wood associated with the wounds was well compartmentalized.

Table 1. Length of column of discolored wood and extent of cambial dieback (in cm) associated with 1- and 2-year-old wounds in red maples made by Mauget injection of Stemix[1] and Inject-A-Cide B (Bidrin)[2].

Treatment and time before examination	Column of discolored wood		Cambial dieback above and below wound[6]
	Above wound	Below wound	
Stemix-1 year[3]	144	51	2
-2 years[4]	149	56	0.5
Bidrin-1 year[3]	130	47	35
-2 years[4]	90	40	11
Control-1 year[5]	6	6	0.8
-2 years[5]	7	8	0.0

[1] 4 ml/wound
[2] 2 ml/wound
[3] Average of six trees, 3 wounds/tree (18 wounds)
[4] Average of four trees, 3 wounds/tree (12 wounds)
[5] Average of two trees, 3 wounds/tree (6 wounds)
[6] Cambial dieback occurred mostly above wounds, thus only one measurement/wound.

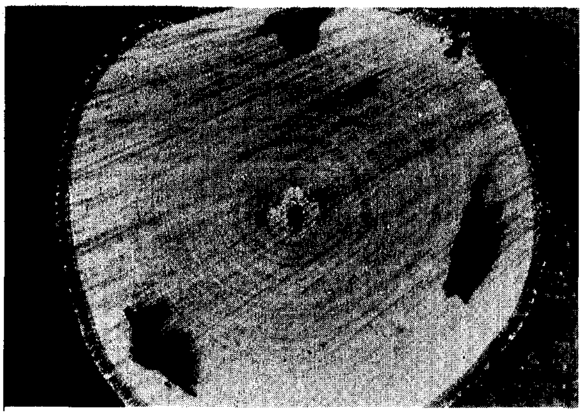

Fig. 3. Discolored wood associated with three 2-year-old wounds in red maple, each injected with Stemix, 4 ml/wound. The discolored wood has spread to form crescent-like configurations, as viewed in a transverse section.

The trees injected with Stemix had long columns of discolored wood, but negligible amounts of cambial dieback (Table 1). The discolored columns spread tangentially in the wood to form a crescent-like configuration, as viewed in a transverse section (Fig. 3). Most wounds were closed (Fig. 4).

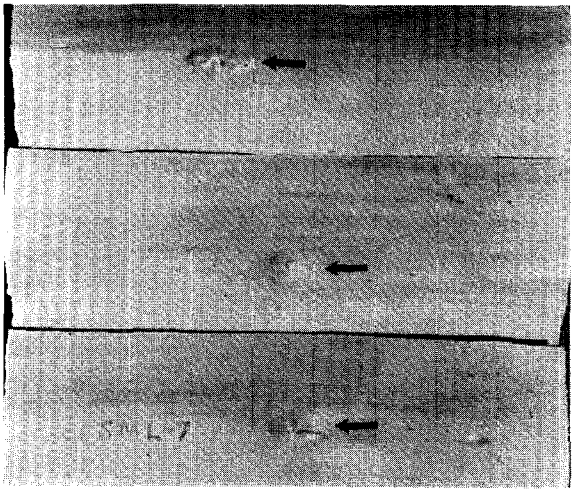

Fig. 4. Bark removed from a red maple to show closed wounds associated with 2-year-old wounds injected with stemix.

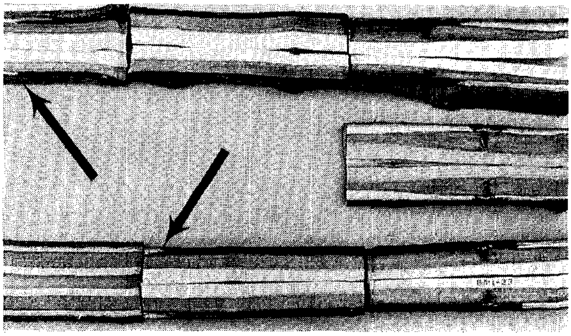

Fig. 5. Cambial dieback associated with two wounds, each treated with 2 ml of Bidrin, on one red maple. Arrows show extent of dieback. Wounds were 2 years old. The third wound on this tree had very little dieback (center section).

The trees injected with Bidrin had discolored columns shorter than those associated with Stemix-injected wounds, but the cambial dieback associated with Bidrin-injected wounds was extensive (Fig. 5) (Table 1).

The dieback zones were smaller in the trees cut in 1976, 2 years after injection, than in those cut after 1 year (Table 1). The many bark cracks observed during the harvest in May, 1975 had closed, and the exposed wood associated with the dieback zones had been compartmentalized by wood formed during the 1975 growing season. After dissection in 1976, the extent of the 1975 dieback zone could be seen easily. In all cases, the trees were actively compartmentalizing the injured tissues (Figs. 6 and 7).

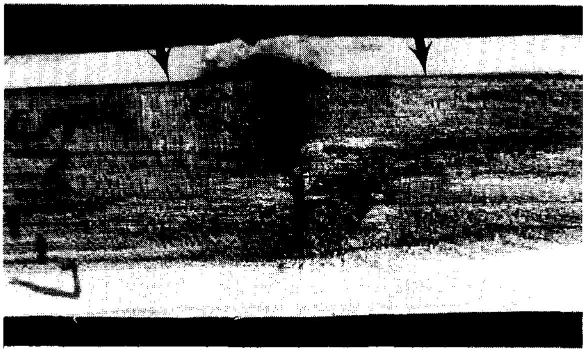

Fig. 6. A 2-year-old, well-closed and compartmentalized wound on red maple. The injected material was Stemix. Arrow shows the size of tree when wounded. An insect gallery is shown to the right of the wound. Such galleries occurred in some wounds, and extended the inward development of discoloration.

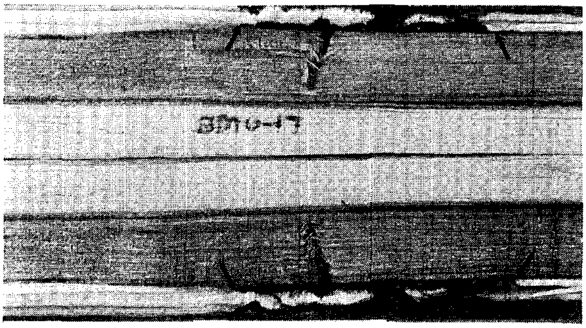

Fig. 7. A 2-year-old wound on red maple. The injected material was Bidrin. The arrows show the extent of dieback after the first year. Vigorous callus formation closed the wound the second year. The defect has been compartmentalized.

White oaks, 1975 injections. The 18 control wounds on six trees had negligible amounts of discolored wood and cambial dieback (Fig. 8) (Table 2).

Wounds that had been injected with material containing Stemix—Stemix and Bidrin or Stemix and Fungisol—had the longest solumns of discolored wood. Dieback was most severe in the case of wounds treated with Bidrin or Meta-

Table 2. *Length and severity of discoloration of wood and extent of cambial dieback associated with 1-year-old Mauget injection wounds treated with various materials, and electrical resistance of cambial zone tissues to a pulsed current.*

Tree no. species[1] and treatment[2]	Diameter[3]	Dieback above and below wound	Discoloration: Above wound	Discoloration: Below wound	Discoloration: Severity[4]	Electrical resistance of cambial zone: 1975[5]	Electrical resistance of cambial zone: 1976[6]
	cm						*k*Ω
1W-S1B	14	12	187	6	0.16	13.5	12
11W-S1B	18	17	270	5	0.33	8	6
3W-C	12	0	3	2	1.00	13	10
4W-SF	13	88	180	2	[7]	[7]	12
8W-SF	21	2	303	4	0.60	6	6
12W-C	14	0.5	2	2	1.00	15	10
4W-1B	11	60	85	1	0.26	17	15
11W-1B	14	27	90	3	0.25	8.5	8
8W-C	10	0	2	2	0.83	15	12
4W-FM	13.5	0	100	6	0.46	21	13
9W-FM	17.5	0	70	6	0.44	13	9
6W-C	15.5	0	2	2	0.90	11	10
1W-FJ	9	7	23	5	0.38	20	16
15W-FJ	17	3	47	5	0.50	7.5	8
2W-C	12	1	2	2	0.84	10	13
3W-MSR	14	56	80	9	0.80	11	10
2W-MSR	16	67	153	13	0.33	7.5	9
4W-C	15	0	2	2	0.77	10	9
2M-F	11	2	47	13	0.61	15	13
9M-F	14	3	48	16	0.25	9	12
15M-C	14.5	3	7	5	1.15	10	13
3H-1B	16	7	536		0.57	10	7
7H-1B	13	4	70	2	0.50	4.5	6
2H-C	16	0	0.5	0.5	1.16	7	6

[1] W, white oak; M, red maple; H, shagbark hickory
[2] S1B, Stemix 4 ml and bidrin 2 ml/wound
SF, Stemix 4 ml and Fungisol 2 ml/wound
1B, Bidrin 2 ml/wound
FM, Fungisol 4 ml/wound; May injection
FJ, Fungisol 4 ml/wound; July injection
MSR, Meta-Systox-R 3 ml/wound
F, Fungisol 4 ml/wound
[3] Diameter at 1.4 m aboveground. Trees all approximately 40 years old.
[4] Ratio of electrical resistance of wood 5 cm above the hole (average of three measurements) to that of wood between the holes (average of three measurements)
[5] Average of six cambial measurements made with needle probes on July 31, 1975
[6] Average of three cambial measurements made with needle probes on May 7, 1976
[7] No measurement wood dried (casehard)

Systox-R (Fig. 9). One wound on white oak treated with Fungisol did have a long dieback streak. The wounds treated with Fungisol in May had no dieback (Fig. 10), whereas wounds treated with Fungisol in July had some dieback. Almost all of the dieback and the discoloration occurred above the wound (Fig. 11). The degree of tissue deterioration, or severity of discoloration of wood, was greatest where Bidrin, alone or in combination with Stemix, had been injected. Meta-Systox-R was associated with severe dieback, but the degree of tissue deterioration or

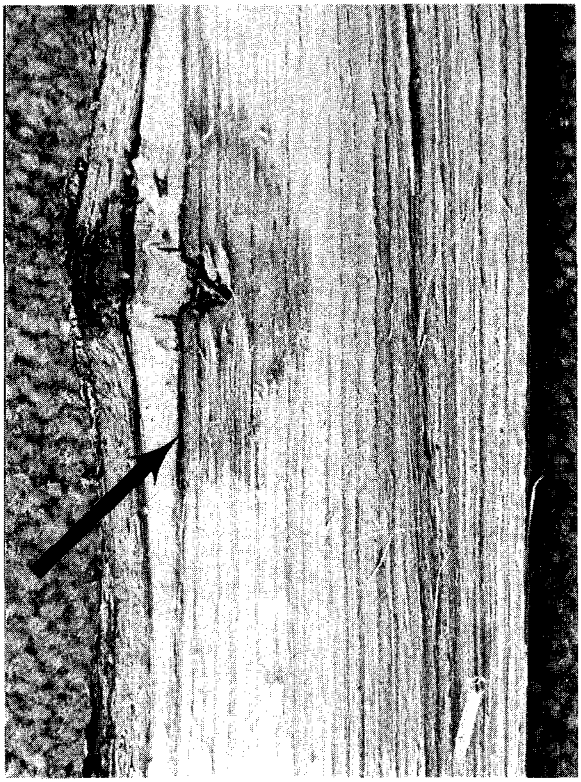

Fig. 8. A 1-year-old control wound in white oak. Arrows show the size of the tree when wounded. The defect has been well compartmentalized. The wound was closed and there was no cambial dieback.

Fig. 9. Severe cambial dieback associated with a 1-year-old wound on white oak after treatment with Meta-Systox-R.

Fig. 10. A closed 1-year-old wound on white oak treated in May with Fungisol. Arrows show line of compartmentalization. The wood that formed after the wound was not infected. Discolored wood developed only a few centimeters below the wound.

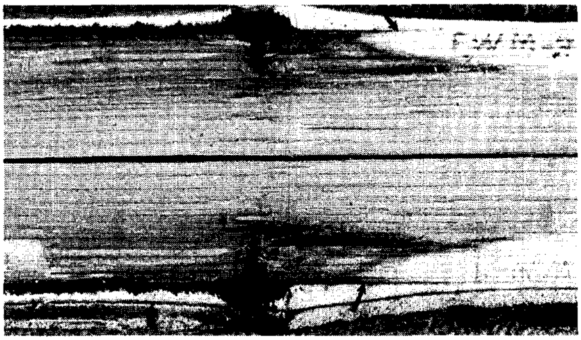

Fig. 11. The dieback column associated with this 1-year-old wound on white oak that had been treated with Fungisol in May ended abruptly below the wound. The arrow shows the compartmentalized barrier that formed after wounding. A crack that formed above the hole soon after it was made closed rapidly.

severity of discoloration of wood was not great.

The trees were all approximately the same age and all stood on the same site, but their growth rates, as reflected by diameter, varied greatly. The variation in diameter was further reflected in the electrical measurements of the cambial zones. In each set, the smaller tree had the higher electrical resistancd (Table 2).

Red maples and Hickory, 1975 injections. In the maples, small columns of discolored wood and very little dieback were associated with the injection of Fungisol (Table 2).

In hickory, some dieback was associated with the injection of Bidrin (Table 2).

Table 3. Length and severity of discoloration of wood and extent of cambial dieback (in cm) associated with 1-year-old Mauget injection wounds in red maple trees treated with manganese, magnesium, iron, or zinc, and electrical resistance of cambial zone tissues to a pulsed current.

Tree no. and Treatment[1]	Diameter	Dieback above and below wound	Discoloration: Above wound	Discoloration: Below wound	Severity[2]	Electrical resistance of cambial zone 1975[3]	Electrical resistance of cambial zone 1976[4]
	cm	cm	cm	cm		kΩ	kΩ
7 MN	13	5	15	11	0.42	13	19
13 MG	7	2	12	9	0.43	8	23
14 Fe	14	6	60	32	0.33	12	21
15 Zn	11	5	30	11	0.45	5	22

[1]Mn, 4 ml (2%)/wound; Mg, 4 ml (1%)/wound;
Fe, 4 ml (2%)/wound; Zn, 4 ml (3%)/wound.

[2]Ratio of electrical resistance of wood 5 cm above the hole (average of three measurements) to that of wood between the holes (average of three measurements).

[3]Average of six cambial measurements made with needle probes on July 31, 1975.

[4]Average of three cambial measurements made with needle probes on May 7, 1976.

Red maple; Mn, Mg, Fe, and Zn treatment. Small columns of discolored wood were associated with the injection of Mn, Mg,,Fe, or Zn. Wounds treated with Mg had little dieback, whereas wounds treated with the other metallic ions had larger dieback areas (Table 3).

Discussion

Negligible amounts of discolored wood and cambial dieback were associated with all control wounds (Figs. 1 and 7), an indication that the type of wound made by the injection tube is not serious. The wound is smaller than that made by most increment borers, which remove a core of wood and leave a hole. Large columns of discolored wood, and sometimes decay, can develop from increment borings (Lorenz 1944, Hepting et al. 1949, Toole and Gammage 1959, Houston 1971). The hole made by the 3/32-inch drill bit used with the Shigometer as part of the decay detection method is also a wound, and small columns of discolored wood will develop after drilling (Shigo and Shigo 1974). Any break in the bark that exposes the wood is a wound, but there are many degrees of injury caused by wounds. The type of wound made by the 3/32-inch drill bit and by the Mauget injection tube is one that causes little injury. The type of wound made by increment borers causes much greater injury.

The introduction of materials into a wound is a more serious matter than the wound itself. In most cases, the chemicals introduced in the experiments reported here caused little cambial dieback, but other materials have caused cambial dieback. Our results were similar to those of Houston (1971), who introduced a wide variety of chemicals into red maple wounds made by an increment borer; some caused large areas of cambial dieback and long columns of decay. Similar results occurred when paraformaldehyde pills were inserted into tapholes in sugar maple (Shigo and Laing 1970). Whenever a tree is wounded and any kind of material is inserted into the wound, the tree will manifest some response. In some cases, the amount of therapeutic material presently used could probably be reduced and still yield the desired results, thereby decreasing the internal injury.

In the experiments discussed herein, the results of only one injection period have been analyzed. In commercial operations, injections are often repeated for several years. In such a case, the position of the wound is very important. A tree has built-in systems that confine, wall-off, or compartmentalize injured and infected tissues, as shown graphically in the dissections (Figs. 2, 6, 7, 8, and 10). Even the long cracks that formed the first year, and the large dieback areas associated with some wounds treated with Bidrin, were well compartmentalized after the second year. Compartmentalization is the major reason why trees are not invaded rapidly after they have been wounded. It is the major reason why injection wounds are usually not fatal to a tree. An understanding of the concept of compartmentalization in trees will help those interested in injections to judge the limits of safe injection for some trees. Details of the compartmentalization concept have been published (Shigo 1975, 1976).

The Shigometer was a useful tool for measuring the severity of discoloration. Some discolored columns were very long, but the tissues had been altered only slightly. The Shigometer also gave information that can be used to determine the relative vigor of trees (Wargo and Skutt 1975). The trees were all approximately the same age, but those with smaller diameters had slightly higher resistance measurements.

This study will continue for 3 more years. Since it takes several years for decay to develop, the 1977 dissections will make clear which wounds have not developed decay.

Acknowledgements

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ABSTRACT

Smith, R.C. 1977. **Using a mechanical tree planter.** Grounds Maintenance 12(2): 44, 46.

In talking with numerous landscape contractors who have used mechanical tree planters, I have found them reporting these tools worth the investment. They saved labor, had a high tree survival rate (usually around 95 percent) and reduced planting costs. The modern day tree spade can save the nurseryman, landscape contractor, and conservationist three valuable commodities — time, money, and trees.