Injection of Benomyl into Elm, Oak, & Maple

by Garold F. Gregory
Thomas W. Jones
and Percy Mc Wain

USDA FOREST SERVICE RESEARCH PAPER NE-232
1971

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

THE AUTHORS

GAROLD F. GREGORY received a bachelor of science degree in agriculture from Kansas State University, a master's degree in plant physiology from Iowa State University, and a doctorate degree from Cornell University in plant pathology. He has been employed in forest disease research with the U.S. Forest Service since 1962. He is now a Principal Plant Pathologist at the Northeastern Forest Experiment Station's Forest Insect and Disease Laboratory in Delaware, Ohio.

THOMAS W. JONES received a bachelor of science degree in plant pathology from the University of Maryland and a master of forestry degree from Yale University. He has been employed in forest disease research with the U.S. Department of Agriculture since 1949 and has been with the Forest Service since 1953. He is now Project Leader at the Northeastern Forest Experiment Station's Forest Insect and Disease Laboratory at Delaware, Ohio.

PERCY McWAIN received bachelor of arts and master's degrees from Ohio State University. He has held the positions of chemist with the Atmospheric Nitrogen Corporation, associate professor at the North Carolina Agricultural and Technical College, and research associate at Ohio State University. Since 1968 he has been employed by the U.S. Forest Service as a chemist in forest disease research at the Northeastern Forest Experiment Station's Forest Insect and Disease Laboratory at Delaware, Ohio.

Manuscript received for publication 21 Dec. 1971.

INJECTION OF BENOMYL INTO ELM, OAK, AND MAPLE

BENOMYL (methyl 1-(butylcarbamoyl)-2-benzimidazole carbamate) is being widely investigated for its potential as a means of chemical control for various plant diseases. Efforts to protect trees from infection caused by vascular wilt pathogens, using this chemical, have met with limited success, but some critical problems have also been encountered.

The use of benomyl for prevention of or therapy for vascular tree diseases apparently requires that a biologically active form of the chemical or a derivative be distributed throughout the tree. Hock et al. (3) and Stipes (7) reported that benomyl applied as a soil drench to container-grown American elm seedlings prior to inoculation prevented Dutch elm disease symptoms and that the causal organism could not be reisolated. However, when benomyl was applied in this manner to field-grown American elms, differences in uptake, distribution of the fungitoxicant, and inhibition of disease symptoms were reported.

Biehn and Dimond (1) reported suppression of Dutch elm disease symptoms and fungitoxicant detection in field-grown American elms treated with a benomyl soil drench and subsequently inoculated. But Hock and Schreiber (2), following a similar procedure, found no symptom suppression and no detection of fungitoxicant. These conflicting results might be explained by differences in soil types.

The variable uptake of benomyl or its breakdown product, methyl 2-benzimidazolecarbamate, is only one of several problems associated with soil application. Effective treatment by soil application requires large amounts of benomyl. Much of this may be lost from the soil before it is utilized. The root zone of many trees in urban situations is inaccessible for this treatment method. Further, the heavy dosage required and the lack of control over subsequent movement of the chemical may be criticized as unacceptable contamination of the environment. Foliar applications, though not now known to be effective, might be similarly criticized.

Direct injection of benomyl into the tree would seem to offer many advantages and few of the drawbacks of soil applications. Hock and Schreiber (2) attempted to introduce an ethanolic suspension and an ethanolic solution of benomyl into elms through tubes inserted into the sapwood, but were unable to get much material into the trees. These applications did not suppress subsequent Dutch elm disease development, and bioassays did not detect the presence of fungitoxicant in the wood.

However, the development of an injection apparatus by Jones and Gregory (4) that permits injection of fluids under pressure into the outermost sapwood of trees and the solubilizing of benomyl reported by McWain and Gregory (5) suggested that the stem injection method of benomyl application holds considerable promise and should be further investigated. This paper reports the results of our initial trials using several benomyl solutions and the injection apparatus.

MATERIALS AND METHODS

Elms (*Ulmus americana* L.), oaks (*Quercus velutina* Lam.), *Q. coccinea* Muench., and *Q. rubra* L.), and maples (*Acer saccharum* Marsh.), 5 to 14 inches d.b.h., were injected in October and November at one, two, or four locations in the stem of each tree, 2 to 3 feet above the ground. Injection pressures ranged from 25 to 80 p.s.i., and the total volume injected per tree ranged from 80 to 4,000 milliliters.

Each of the following benomyl solutions were injected into several trees of each genus: 2.4-2.8 grams per liter of benomyl (50 WP) in 0.1N acetic acid; 2.5-3.2 grams per liter of benomyl (50 WP) in 50 percent aqueous ethyl alcohol; 3.0-4.4 grams per liter of benomyl (50 WP) in 0.5 or 1 N ammonium hydroxide; and 20 and 50 grams per liter of benomyl (50 WP) in 8.4 percent and 21 percent aqueous lactic acid, respectively.[1] In addition, a 13.3 grams per liter suspension of benomyl in water was injected into one red oak.

---

[1]For details of solution preparation see citation (5).

The trees were sampled 1 to 3 weeks after injection. Branch tips were collected from eight locations in each tree--four from the upper crown and four from the lower crown--for bioassay of fungitoxicant. The bioassay procedure was as follows: Penicillium conidia were added to sterile liquid potato dextrose agar at 48 degrees C. to give 10,000 conidia per milliliters of PDA. The conidia and the agar were mixed briefly and then were poured into petri plates (about 30 milliliters per plate). When the Penicillium-seeded PDA had solidified, a 0.5-inch long section of branch tip was surface-sterilized or peeled of bark and embedded horizontally into the agar at the center of each plate. After 48 hours, average distance across the zone of inhibition was measured and recorded.

RESULTS AND DISCUSSION

All solutions were successfully injected in varying quantities into each of the tree species tested. Details of treatment and results for each tree, including solution injected, volume injected, benomyl content, time required, and bioassay results are listed in Table 1.

The time required to inject a given volume of fluid varied with the fluid, tree, tree species, and date of injection. Generally, the most fluid per unit time could be injected into oaks, followed closely by elm. Maples could be injected but at a considerably slower rate. Increased pressure resulted in more rapid uptake of all solutions.

Solution uptake and distribution were checked for red oaks injected in late September and mid-November. Injection rate for 0.5 percent azosulfamide dye in water was 5 to 10 minutes per liter per injection site in September and 10 to 15 minutes per liter per injection site in November.

Dye distribution was quite different for the 2 months. Two liters of dye injected into an 8-inch d.b.h. red oak on 30 September 1971 were immediately distributed throughout the tree in the current sapwood and leaves and at least in some roots. But 4 liters of dye injected into a 12-inch d.b.h. red oak on 18 November 1971 moved up the bole a maximum of only 27 feet. Uptake of dye in elm and maple was not checked in September; but in November, it was not very rapid--less than 1 liter per injection site per hour. In elm, the dye moved up the bole a maximum of 15.5 feet; and in maple, it moved up only 8 feet. Hence, it appears that immediate distribution of injected fluids is affected by season of the year.

On the other hand, results of bioassays show that subsequent movement of fungitoxicant does occur, even in dormant trees. Some positive bioassays were obtained from oaks injected with all solutions except the ammonical solution and the aqueous suspension of benomyl. Only the lactic acid solution of benomyl gave any positive bioassays in elm and maple.

Although positive bioassays were not recorded for all trees or for all parts of trees injected with solutions of benomyl, it seems reasonable to suspect that further distribution of fungitoxicant will occur as growth resumes in the spring. Smalley (6) reported that at the time of inoculation, no positive bioassays could be obtained from wood of elms that had been treated with soil applications of benomyl; but that even so, significant protection from Dutch elm disease damage was provided. So it is also possible that the amount of fungitoxicant now distributed in the trees that we have treated may be ample to prevent vascular wilt infection.

Because considerable quantities of benomyl can be injected in relatively short periods of time into oaks, elms, and to a lesser extent into maples, it might be possible to protect trees from fungus-caused diseases, particularly vascular wilts. The positive bioassays obtained from some trees injected with solubilized benomyl strengthen this possibility.

Tree disease therapy may also be possible, particularly for diseases that do not envelop the entire tree immediately, such as oak wilt in white oaks, Dutch elm disease, and Verticillium wilt in maple.

The stem injection technique appears to have great advantages over soil applications or foliar sprays. Uptake of prescribed dosages is assured, smaller quantities of the chemical are required, and its placement and subsequent movement are highly controlled. This is not only economically advantageous but also largely avoids the environmental pollution hazards associated with other methods of application.

Year-round treatment schedules, if called for, may be followed regardless of wind and rain and are limited only by very low temperatures. And this technique of injection need not be limited to solubilized benomyl but might be used for other systemic fungicides, insecticides, herbicides, and perhaps, even hormones and nutrients.

Results reported here have shown that quantities of solubilized benomyl can be injected into oaks, elms, and maples and that subsequent distribution within the tree occurs. However, much more research is required before the apparent potential of this technique for control of tree diseases can be realized. Inoculation studies must be completed to evaluate prophylactic and therapeutic properties of solubilized benomyl, possible phytotoxicity problems must be recognized and minimized, and optimal dosages, volumes, concentrations and treatment schedules must be determined. We believe that these problems can be resolved and that their solution will permit a major advance in our ability to cope with diseases of trees.

Table 1.--Treatment details and bioassay results for trees injected with benomyl

Tree no.	Tree species	D.b.h.	Number of injections*	Date injected	Total time for injection	Type of fluid injected	Total volume injected	Concentration of crude benomyl injected	Total crude benomyl injected	Date sampled for bio assay	Bioassay results: Zones of inhibition for branch tip samples: Upper crown 1	2	3	4	Lower crown 1	2	3	4
		In.		1971	Min.		ml	g/l	gm	1971	mm				mm			
0	*Quercus rubra*	14	4	10- 5	120	Aqueous suspension	565	13.35	7.5	10-14	0	0	0	0	0	0	0	0
1	*Ulmus americana*	8	2	10-18	315	50% aqueous ethanol	1290	3.2	4.1	10-27	0	0	0	0	0	0	0	0
2	*U. americana*	6	1	10-18	145	IN NH_4OH	150	3.2	.5	10-27	0	0	0	0	0	0	0	0
3	*U. americana*	6	2	10-19	20	0.1N acetic acid	1300	2.5	3.2	10-27	0	0	0	0	0	0	0	0
4	*Acer saccharum*	9	2	10-19	120	0.1N acetic acid	1240	2.4	3.0	10-27	0	0	0	0	0	0	0	0
5	*A. saccharum*	10	2	10-19	150	50% aqueous ethanol	750	3.2	2.4	10-27	0	0	0	0	0	0	0	0
6	*A. saccharum*	8	2	10-20	120	0.5N NH_4OH	80	4.4	.4	10-27	0	0	0	0	0	0	0	0
7	*Quercus velutina*	8	2	10-21	15	0.1N acetic acid	2000	2.8	5.6	11-10	0	0	0	0	12	11	10	6
8	*Q. velutina*	9	2	10-21	4	0.1N acetic acid	2000	2.8	5.6	11-10	0	0	0	0	0	0	0	0
9	*Q. coccinea*	7	2	10-21	11	50% aqueous ethanol	2000	2.5	5.0	11-10	14	12	11	13	12	7	10	16

10	*Q. coccinea*	10	2	10-21	7	50% aqueous ethanol	2000	2.5	5.0	11-10	5	0	0	0	0	0	5	0
11	*Q. rubra*	12	2	10-21	60	1N NH_4OH	1210	3.0	3.6	11-10	0	0	0	0	0	0	0	0
12	*Q. rubra*	7	2	10-21	4	1N NH_4OH	1800	3.1	5.6	11-10	0	0	0	0	0	0	0	0
13	*Q. rubra*	8	2	11- 9	60	21% lactic acid	500	50	25	11-22	8	0	5	0	5	9	2	8
14	*Q. rubra*	11	4	11- 9	120	21% lactic acid 8.4% lactic acid	500 1650	50 20	58	11-22	0	0	0	0	0	0	0	0
15	*Q. rubra*	9	4	11- 9	112	8.4% lactic acid	3340	20	67	11-22	0	0	0	0	0	8	0	5
16	*Ulmus americana*	6	4	11-12	90	8.4% lactic acid	2760	20	55	11-23	8	0	0	0	5	0	0	0
17	*U. americana*	5	2	11-12	16	8.4% lactic acid	1240	20	25	11-23	0	0	0	0	0	0	0	0
18	*U. americana*	6	2	11-12	45	8.4% lactic acid	2000	20	40	11-23	0	0	0	0	0	0	0	0
19	*Acer saccharum*	14	4	11-12	120	8.4% lactic acid	780	20	16	11-23	0	0	0	0	0	0	0	0
20	*A. saccharum*	12	4	11-15	125	8.4% lactic acid	770	20	15	11-23	0	0	0	0	0	5	0	0
21	*A. saccharum*	12	4	11-15	120	8.4% lactic acid	600	20	12	11-23	0	0	0	0	0	0	0	0
22	*Quercus rubra*	10	2	11-16	25	8.4% lactic acid	1200	20	24	11-22	1	0	0	0	0	0	0	0
23	*Q. rubra*	13	4	11-16	60	8.4% lactic acid	3000	20	60	11-22	0	0	0	0	0	0	0	0
24	*Q. rubra*	12	4	11-16	105	8.4% lactic acid	3250	20	65	11-22	0	0	0	0	0	0	0	0

*Injections for trees 0-4 made one at a time with one injector--injections for trees 5 to 24 made two at a time with two injectors operating simultaneously.

LITERATURE CITED

1. Biehn, W.L., and A.C. Dimond.
   1970. PROTECTIVE ACTION OF BENOMYL AGAINST DUTCH ELM DISEASE. (Abstr.) Phytopathology 60: 571.

2. Hock, W.K., and L.R. Schreiber.
   1971. EVALUATION OF BENOMYL FOR THE CONTROL OF DUTCH ELM DISEASE. USDA Plant Dis. Rep. 55: 58-60.

3. Hock, W.K., L.R. Schreiber, and B.R. Roberts.
   1970. SUPPRESSION OF DUTCH ELM DISEASE IN AMERICAN ELM SEEDLINGS BY BENOMYL. Phytopathology 60: 391-392.

4. Jones, T.W., and G.F. Gregory.
   1971. AN APPARATUS FOR PRESSURE INJECTION OF SOLUTIONS INTO TREES. USDA Forest Serv. Res. Paper NE-233.

5. McWain, P., and G.F. Gregory.
   1971. SOLUBILIZATION OF BENOMYL FOR XYLEM INJECTION IN VASCULAR WILT DISEASE CONTROL. USDA Forest Serv. Res. Paper NE-234.

6. Smalley, E.B.
   1971. PREVENTION OF DUTCH ELM DISEASE IN LARGE NURSERY ELMS BY SOIL TREATMENT WITH BENOMYL. Phytopathology 61: 1351-1354.

7. Stipes, R.J.
   1969. CHEMOTHERAPEUTIC PATTERNS OF METHYL 1-(BUTYLCARBAMOYL)-2-BENZIMIDAZOLE AND THIABENDAZOLE IN THE CONTROL OF DUTCH ELM DISEASE. (Abstr.) Phytopathology 59: 1560.

ACKNOWLEDGMENTS

The authors thank the E. I. du Pont de Nemours Co. for supplying Benlate (Benomyl). Mention of a particular brand name does not imply endorsement by the Forest Service.

Gregory, Garold F., Thomas W. Jones, and Percy McWain.
1971. Injection of benomyl into elm, oak, and maple. NE. Forest Exp. Sta., Upper Darby, Pa. 7 pp. (USDA Forest Serv. Res. Paper NE-232)

A newly devised apparatus using pressure to inject fluids into trees was used to inject solubilized benomyl into elms, oaks, and maples. In October and November, injections were made into the outer two annual rings of sapwood at points 2 to 3 feet above ground line. One to 3 weeks after injection, the trees were sampled; and positive bioassays were obtained from branch tips of some of the elms, oaks, and maples. Injection of benomyl into elms, oaks, and maples may provide protection from infection by fungal pathogens or may provide therapy for diseased trees.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

Caution about Pesticides

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.
