Solubilization of Benomyl for Xylem Injection in Vascular Wilt Disease Control

by Percy McWain
and Garold F. Gregory

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

THE AUTHORS

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.

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.

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SOLUBILIZATION OF BENOMYL FOR INJECTIONS INTO TREES FOR DISEASE CONTROL

The need for an effective systemic fungicide for plant pathogens has long been apparent. Foremost among several chemicals now being evaluated for their prophylactic and therapeutic properties is benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate).

Several groups of scientists have tested benomyl for its potential in controlling Dutch elm disease (DED) (1,3,5). The chemical is usually applied to the soil in the root zone, with results ranging from fairly good protection to no protection. Most of these scientists recognize the need for a better means of getting the fungicide into trees. Smalley (5), in concluding his paper on soil application of benomyl to protect American elm from DED, states, "...a more effective means of introducing the chemical into elm trees needs to be discovered."

Hock and Schreiber (3) tried to feed benomyl in 50 percent aqueous ethyl alcohol into elms through tubes sealed into holes in the stem. They did not detect any fungitoxic material in bioassays of the young elm trees, so presumably no significant amounts were taken up.

We have used the pressurized system of fluid injection developed by Jones and Gregory (4) to introduce aqueous suspensions of benomyl fungicide into the two outer annual rings of *Acer saccharum*, *Ulmus americana*, and *Quercus rubra*. But only limited amounts of suspended benomyl could be injected, and these quantities did not move appreciably beyond the injection site.

The inability to inject significant amounts of suspended aqueous benomyl and the lack of significant uptake of alcoholic benomyl pointed out the need for solubilized benomyl that could be freely injected into trees. Desired solution characteristics are: solubility at relatively high concentration, solubility upon infinite dilution with water, low viscosity, adequate fungitoxicity, and little or no phytotoxicity. This paper reports our progress toward meeting these criteria.

EXPERIMENTAL

Benomyl (50WP) was added, in excess, to 95 percent ethyl alcohol, 50 percent ethyl alcohol, 1 N ammonium hydroxide, 0.1 N ammonium hydroxide, and 0.1 N acetic acid. The solutions were stirred for 1 to 2 hours at room temperature and were then clarified by filtration. All solutions were allowed to stand overnight and were refiltered if precipitate had formed. The 95 percent and 50 percent ethyl alcohol solutions deposited a relatively small amount of solute in standing whereas a considerable amount of solute was deposited from ammonium hydroxide solutions. Little or no deposition occurred from acetic acid.

The deposition from the various solutions undoubtedly altered the proportion of active benomyl to inert components, but bioassays showed that each solution remained highly fungitoxic. The solute concentrations of the filtrates determined gravimetrically ranged from 2.4 to 7.8 grams per liter (Table 1).

All these solutions had low viscosities. Benomyl in 0.1 N acetic acid, 1 N ammonium hydroxide, and 50 percent ethyl alcohol was not expected to be markedly phytotoxic in the amounts injected; and so it was selected for tree injection trials.

Additionally, solutions of higher concentration were obtained by treating benomyl (50 WP) with 91 percent acetic acid, 88 percent formic acid, hot 85 percent lactic acid, hot 42.5 percent lactic acid, and hot 10 percent aqueous gluconic acid. The solute concentrations obtained ranged from 10 to 380 grams per liter (Table 1).

Benomyl was added to these solutions with stirring; however, lactic acid and gluconic acid also required moderate heating. All solutions retained appreciable fungitoxicity. Only lactic and gluconic acid solutions could be diluted infinitely with water without forming precipitate, thus allowing the acids to be minimized in the solution for injection.

Of these concentrated solutions, benomyl solubilized in lactic acid seemed to be the most promising for injection into trees. The high concentrations of

this solution provided wide latitude for dilution with a minimum sacrifice of fungicide content.

The solution used for tree injection trials was prepared by adding 100 grams of benomyl (50 WP) to 1 liter of 42.5 percent lactic acid. The solution was heated and stirred until clear, diluted to 20 grams per liter with water, allowed to stand overnight, and filtered. This solution was nonviscous and remained essentially free of precipitate for more than a month. The addition of this solution to clarified red and bur oak leaf extract did not induce immediate or subsequent precipitation.

CONCLUSIONS

Varying amounts of benomyl have been solubilized in several solvents. This permits injection of the fungicide into trees for protection or therapeutic action against various fungal pathogens. Injection and distribution of some of these solutions in elms, oaks, and maples is reported in a concurrent article (2).

We believe that adequate amounts of fungicide for protection or therapy can be put into trees in this form without significant damage from the solvent, but this remains to be determined. Characteristics of the lactic acid solution make it the favored solution of the several prepared, but we are continuing research to find more desirable solutions of benomyl-derived fungitoxicant.

Table 1.--Solute concentrations from benomyl (50 WP) in various solvents

Solvent	Solute g/l
Water	0.75
95% ethyl alcohol	7.8
50% aqueous ethyl alcohol	3.5
0.1 N aqueous ammonium hydroxide	3.8
1.0 N aqueous ammonium hydroxide	6.8
0.1 N aqueous acetic acid	2.4
91% glacial acetic acid	48
88% formic acid	300
85% lactic acid (hot)	380
42.5% lactic acid (hot)	100
10% aqueous gluconic acid (hot)	10

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Benomyl, in varying amounts, was solubilized in several solvents, thus allowing injection into trees for fungus disease prevention and therapy. A large amount of benomyl can be solubilized in diluted lactic acid. The resulting solution can be infinitely diluted with water without precipitation. These characteristics make it the current solution of choice for our tree injection studies.

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.