THE INFLUENCE OF SITE ON THE DISTRIBUTION OF BENZIMIDAZOLE FUNGICIDES IN ELM[1]

by Arthur H. McCain

The value of benonyl [methyl 1-(butylcarbamoyl)-2-benzimidazole carbamate] in the control of Dutch elm disease has been demonstrated (5,14,15) and was registered for use as a foliar spray and trunk injection (1). Benomyl undergoes hydrolysis in acid solution to form methyl-2-benzimidazole carbamate (carbendazim) which is water soluble. Various products formulated for tree injection (2,10) have been evaluated and the phosphate form is the most toxic to spores of *Ceratocystis ulmi* (7,11). A 0.7% liquid formulation (Arboral, Correx, Lignasan BLP® , etc.) is registered for use. A water soluble formulation of thiabendazole (Arbotect® 20-S) 20% 2-(4-thiazolyl) benzimidazole hypophosphite, also is registered for use for injection into elms as an aid in the control of Dutch elm disease.

Pressure injection of fungicide solutions into elms offers several advantages over sprays and soil treatments. Environmental contamination is minimal and considerably less fungicide is required. The fungicide is introduced into the xylem, where the pathogen is present, resulting in the most rapid possible control.

There are a number of systems and various apparatuses for introduction of solutions into elm trees (3,4,8,10). The distribution of MBC in the crown of elm trees treated by root injection has been studied by Kondo (10) who reports that large volumes of solution are necessary for adequate coverage of the crown. Introductions of solutions by root injection is limited to situations where soil excavation is possible; this would seem to limit this method for many elms in California that are bounded by pavement, curbs, and sidewalks. In addition, the root injection method requires 24 to 48 hours for completion.

It is generally believed that large volumes of solution must be injected for adequate distribution of the chemical in the tree. Gregory and Jones (2) suggest 325 ml of MBC solution (24,000 ppm) per inch of tree diameter at breast height (dbh) injected at 40 psi while Kondo and Huntley (12) suggest using the formula; volume (liters) = 70 + 2.22 × centimeters dbh, using 250 ppm.

Arbotect 20-S is diluted 1:40 (0.5%) for use and injected at the rate of 40 to 80 fluid ounces for each five inches of trunk diameter as a preventative treatment or at 80 to 160 fluid ounces per five inches of trunk diameter as a therapeutic treatment. Arboral is diluted 1:32 (0.0021%) and injected at two gallons for each four inches of trunk diameter as a preventive treatment. A higher concentration; 1:16 (0.0041%), at 2 gal/4 inches diameter is used as a therapeutic treatment.

Instructions accompanying injection equipment, and most researchers, suggest locating injection holes as low in the trunk as possible and on the root flares. It is claimed that distribution in the crown is improved by injection into the root flare. However, there are no data to support this claim. It seems more reasonable to believe that improved distribution would be achieved by injecting into the trunk where more even spacing of injection holes is possible.

Elm trees are attacked by many insects, including aphids, scales, and leaf consuming beetles. These pests can be controlled by injection of insecticides into the xylem (9). Both oxydemetonmethyl (Meta Systox R®) and dicrotophos (Bidrin®) are registered for use for this purpose. It would be efficient to combine an insecticide with the systemic fungicide when control of both the disease and insect problem is necessary.

Materials and Methods

Large *Ulmus americana* L. trees in Curtis Park, Sacramento, California were selected and four

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pairs of similar trees were injected with carbendazim solution and four trees with thiabendazole solution in July 1976. Thiabendazole was diluted to a 1.0% solution and carbendazim to a 0.1% solution. Trees were injected from 1 to 5 PM on sunny, warm (27 to 32 C) days. Both fungicides were applied at 15 ml/mm trunk circumference measured at 1.66 m above the soil.

The injection holes were drilled 5 cm deep using a 6.4 mm wood bit. Holes were spaced every 15 cm on the trunk or on the root flares where the spacing between injection holes varied from 20 to 43 cm. Hollow screws were turned in 3 cm from the surface of the bark which varied in thickness from 13 to 16 mm. The required amount of fluid was placed in a glass fiber reinforced plastic tank and pressurized with air to 4.2 kg/cm^2.

Branches were sampled for determination of the presence of the fungicides on 8/24/76, 5/17/77, 9/13/77, and 7/7/78. Carbendazim was extracted from the twigs and leaves by placing 1 g of frozen chopped tissue in 1 ml 0.12N hydrochloric acid and heating for 5 minutes at 100C. After cooling, lost liquid was replaced with distilled water. The liquid was assayed using the method of Irwin (6). The presence of thiabendazole was determined by placing a frozen split section of twig on potato-dextrose-agar medium seeded with conidia of *Penicillium expansum.*

In another trial 36 ml of 25% EC oxydemeton-methyl or 18 ml 8% EC decrotophos was combined with 8 liters of 1.0% thiabendazole solution or 0.1% carbendazim solution and injected into elms infested with European elm scale and aphids. The solutions were injected 1 meter above the soil line in June 1976.

Results

Root-flare vs. Trunk Injection. With trunk injection an average of 34% of the twigs and 73% of the leaves sampled contained carbendazim. With root flare injection 27% of the twigs and 62% of the leaves contained the fungicide. When thiabendazole was injected into the trunk, 62% of the twigs contained the chemical.

Insecticide-Fungicide Combinations. Both oxydemetonmethyl and dicrotophos were compatible when mixed with carbendazim phosphate and thiabendazole hypophosphite. Dripping of insect-produced honeydew from trees injected with the insecticide-fungicide combinations ceased while honeydew continued to drip from non-treated trees. The insecticides did not interfere with movement of the carbendazim as evidenced by detection of the fungicide by bioassay of foliage from injected trees. No adverse effects from the injections were observed.

Persistence of fungicides. Carbendazim was not detected in any twigs or leaves of treated trees 10 months after injection at the second (spr-

Table 1. Distribution and concentration of fungicides in crowns of elms injected in the root flare or trunk.

Tree pair	*Injection site*	*Circum. (mm)*	*Number of sites*	*Quantity Injected*	*Time of inject.*	*Coverage[a] twigs*	*Concent. in twigs*	*Coverage[a] leaves*	*Concent. in leaves*
				(liters)	*(minutes)*	*(%)*	*(ppm)*	*(%)*	*(ppm)*
Carbendazim 0.1%									
1	root flare	1760	12	26.4	11	9	1.2	59	5.0
	trunk	1770	12	26.6	5	22	1.6	61	3.5
2	root flare	1620	11	24.3	6	37	2.0	80	4.0
	trunk	1475	10	21.1	6	57	1.6	96	3.0
3	root flare	1610	13	24.2	7	18	1.1	49	3.1
	trunk	1310	9	19.7	10	47	1.5	84	3.8
4	root flare	1650	11	24.8	5	44	5.1	63	7.9
	trunk	1600	11	24.0	5	11	1½6	50	2.7
Thiabendazole 1.0%									
—	trunk	1660	11	24.9	7	77	—[b]	—	—
—	trunk	1650	11	24.6	6	41	—	—	—
—	trunk	1960	13	29.4	12	69	—	—	—

[a]Trees injected on 7/16/76. Twenty to 30 branches samples on 8/24/76. Current season growth assayed.

[b]— not sampled

ing) sampling on May 17, 1977. Thiabendazole was detected in 70% of the one-year-old twigs and also the new (1977) flush of growth from the tree that had 77% coverage in 1976. In the fall of 1977, 14 months after injection, thiabendazole was still present in 57% of the one-year-old and current season twigs. No thiabendazole presence was detected at the last sampling date, July 7, 1978 (24 months after injection).

Discussion

Trunk injection of the water soluble systemic fungicide, carbendazim phosphate results in better distribution of the fungicide than does root flare injection. However, where the native American bark beetle is active protection of the trunk is necessary and it would be advisable to inject the tree as low in the trunk as possible.

Carbendazim did not persist in the trees through the winter, thus the summer injections of this fungicide do not provide protection for the following spring when the smaller European elm bark beetle is most active. Thiabendazole not only persisted in the twigs for over one year, but it moved into the new growth where it was capable of protecting the tree for two full years.

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