THE INFLUENCE OF SITE ON THE DISTRIBUTION OF BENZIMIDAZOLE FUNGICIDES IN ELM†

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 hypophosphate, 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 oxycarbomethyl (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 carben-
dazim 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/cm².

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 ex-
tracted 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 100°C. 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 combin-
ed 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 injec-
tion 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 thiaben-
dazole was injected into the trunk, 62% of the
twigs contained the chemical.

**Insecticide-Fungicide Combinations.** Both oxy-
demeton methyl 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>
<thead>
<tr>
<th>Tree pair</th>
<th>Injection site</th>
<th>Circum. (mm)</th>
<th>Number of sites</th>
<th>Quantity Injected (liters)</th>
<th>Time of inject. (minutes)</th>
<th>Coveragea (% in twigs)</th>
<th>Concent. in twigs (ppm)</th>
<th>Coveragea (% in leaves)</th>
<th>Concent. in leaves (ppm)</th>
</tr>
</thead>
</table>
| Carben
dazim 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 | — | — | — |

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a— Trees injected on 7/16/76. Twenty to 30 branches samples on 8/24/76. Current season growth assayed.
b— not sampled
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.

Literature Cited


