LIMITATIONS OF CHEMICAL INJECTION TO CONTROL DUTCH ELM DISEASE[1]

by Richard J. Campana

Benomyl, or one of its derivatives, is one of more than 500 chemicals tested against the Dutch elm disease fungus over the past 30 years. To the best of my knowledge, it is the only one giving consistently satisfactory results within elm trees tested over several years. It is now well established that given proper dosage, proper formulation, early and proper application, solubilized benomyl (MBC) *does* prevent infection and *arrest* disease development. It has probably saved thousands of healthy elms from infection, as well as hundreds of trees already infected when TREATED. However, because of the information substantiating a moderate degree of success, it is easy to emphasize or even overemphasize the positive aspects of its use as a control measure, and neglect the negative ones.

The research investigator is trained to be cautious, critical, and everdemanding of all sides of a given question. When the question is controversial, he must be unusually careful. As plant pathologists we would be remiss not to seek, explore, and expose information negative to a given hypothesis (however popular), as well as that positive. In this light, I want to review briefly the theory and practice of disease control through systemic fungicides to see how current information from experimental evidence squares with the early data on success in disease control with solubilized benomyl compounds. Accordingly, I shall discuss the following in sequence: the concept of plant chemotherapy; positive and negative influences of injected chemicals on Dutch elm disease; difficulties which pose problems for successful use of systemic injection as a control method; and the significance of limitations to chemical injection.

Almost everyone who understands Dutch elm disease, knows that no single method of accepted disease control (i.e., sanitation, spraying, root severance, and pruning) is always effective or is completely effective when used alone. Even where used in combination, these methods are only partially effective, even with the most knowledgeable, thorough, and skillful application. Accordingly, we should not be surprised when a new tool, however promising, fails to work all the time, or with complete success even part of the time. Such is the case with systemic chemicals and chemical injection.

The mechanics of plant chemotherapy

According to the late Dr. A.E. Dimond, one of the most knowledgeable plant pathologists of the recent past, the mechanism of chemotherapy in plants is similar to that in human medicine. Three theories are posed to explain disease control from infecting micro-organisms: 1) the pathogen is destroyed (the chemical is essentially a *biocide*); 2) the pathogen is inactivated but not destroyed (the chemical then is a *biostat*); or 3) the metabolism of the plant is changed so that the pathogen is unable to develop.

In the chemotherapy of Dutch elm disease, the pathogen is inactivated and not killed. The inactivation appears to be only temporary; following initial suppression of symptoms in the year of infection, disease recurrence is likely to occur in the next season unless one of the following things happens; 1) the fungus is pruned out; 2) it is sealed in by walling off (compartmentalization); or 3) it is kept inactivated by continued injection, pruning, or both.

The influence of injected chemicals on Dutch elm disease

Following introduction of solubilized benomyl into elm stems, where it may be distributed systemically, the following results occur which are of **positive benefit** to the infected tree:

1. Disease symptoms are arrested; the progress of advancing disease development is visibly halted.

2. Rapid, massive increase of the fungus is prevented, as the pathogen is inactivated; the chemical is believed to interfere with cell division of the pathogen.

3. Rapid, extensive vertical movement of the pathogen downward in the vessels is substantially limited; the chemical prevents or slows spread of the pathogen down into larger branches, and into new branch system.

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4. The tree is provided with an opportunity to heal itself by walling the pathogen off (localization, followed by compartmentalization), so that disease recurrence will be prevented in the following year.

There may be **negative results** following stem injections. Such results may occur for the following reasons:

1. The pathogen is not killed, inactivation is only temporary and the pathogen may continue development later.
2. Even under the most advantageous circumstances, the chemical is not uniformly distributed. Thus, in effect, some branch systems receive chemical that is too little, too weak, or none at all.
3. Complete prevention of downward vertical movement of spores is not always possible.
4. The chemical does not move into tissues already heavily infected; these tissues then are irretrievably lost.
5. As the chemical moves upward from points of introduction in basal stems, it loses strength as dosage decreases, so that it is often ineffective high in the tree.
6. Symptoms may be masked as the chemical prevents visible disease progress, but does not destroy the pathogen.
7. Phytotoxicity may occur to foliage of the tree, if the solution is too acid.
8. Precipitation (and thus ineffectiveness) may occur if the mixing water is too alkaline.
9. The chemical exerts selective pressure on the pathogen to develop resistance in asexual spores in the vessel sap.

Problems with chemical injection

In addition to the reasons already posed to explain part or complete failure with chemical injection in the therapy of Dutch elm disease, there are often other difficulties which merit examination for both therapy of established infections or prevention of new ones, as indicated below:

1. Once an injection program is initiated for disease prevention, for continued effect it must be maintained indefinitely (forever is a long time).
2. Trees already infected with bacterial wetwood may be impossible to inject because of reverse flow of sap reflected in bleeding.
3. The probability of new bacterial wetwood infections is enhanced with the multiple wounding required for sustained prevention or therapy.
4. The increase of wound reaction tissue from multiple injections may interfere with upward distribution of chemical in xylem tissue from new wounds.
5. Increased areas of wound reaction tissue may interfere with normal translocation of food in the phloem and water in the xylem.
6. Multiple wounds enhance the probability of cankerous infections by parasitic fungi and bacteria.
7. Devitalization of the tree by multiple wounds may enhance vigorous development of the Dutch elm disease pathogen.
8. Devitalization by wounding attracts bark beetles for breeding.
9. Creation of wounds initiates the long process of discoloration and decay of stem tissues. While not an imminent problem to threaten the life of the tree (as Dutch elm disease does), a long-range problem is initiated that could be accelerated by continuous wounding.
10. If the active benomyl ingredient (MBC) is precipitated out by high alkalinity of the water used, it will not move into distal tissues; if the water is too acid, phytotoxicity may result.

Significance of limitations to chemical injection

From the information currently at hand, it is clear that injection of solubilized chemicals into elms for prevention or therapy of Dutch elm disease has many serious limitations as a control measure. It is certainly clear that limited distribution of the chemical into numerous small twigs of large trees fails to prevent their infection. For trees already infected, the failure of the chemical to destroy the pathogen makes disease recurrence probable from the original infection. The hopes of curtailing the pathogen for sustained periods by multiple injection, or sustained prevention by annual injection, are marred by the consequences likely from multiple wounds. For these and other reasons noted above, various conclusions may be drawn:

1. The success of chemical injection is likely to be limited to relatively small numbers of trees.
2. Success in prevention can only be sustained on an annual basis with careful location of wounds in trees with unusual vigor for wound healing and new annual growth.
3. Success in therapy is likely to be only ap-

parent in the majority of cases, and only in trees with limited infections. It is likely to be most effective where light infections can be pruned out at an early stage.

4. More intensive research is needed: 1) to find new chemicals that will destroy the pathogen in elm tissue without serious toxicity to the elms; 2) to enhance more uniform distribution of the chemical in small twigs; and 3) to detect and evaluate probabilities for vigorous growth and healing of wounds.

Department of Botany and Plant Pathology,
University of Maine,
Orono, Maine

EASTERN WHITE PINE IRON DEFICIENCY

by Elton M. Smith and Cynthia D. Mitchell

Eastern White Pine yellows is manifested by a general light green or yellow cast to the foliage, shorter needles, and reduced growth of branches. Growth of white pines seems most affected when trees are located in poorly drained, alkaline soil regions.

A research program was initiated at The Ohio State University in 1974 to determine if the limiting factor in the growth of Eastern White Pine (*Pinus strobus*) was pH-induced iron chlorosis. Knowing that high pH was detrimental to a number of trees including many Oaks, a number of trees were treated with an iron compounds. The pH of the clay-loam soil in the area of the trees ranged from 6.9 to 7.4.

Capsules, marketed as Iron Medicaps and containing ferric ammonium citrate, were implanted in a spiral pattern into the trunks of the pines during the last week of March in 1974 and 1975. All trees were between 5 and 8 inches in diamter, measured 1 foot from the soil line, and received between three to six capsules/tree. Although pine resin exuded from the implantation sites, all the ½-inch wounds healed completely by the following September.

Periodic examinations of the treated trees during both years indicated a positive response to the iron implantations. Vegetative growth of treated pines was improved, needle length increased, and curling of needles was no longer evident. The most dramatic difference, however, was in the change in overall tree foliage color from a yellow-green to a more normal medium green as noted in Table 1. Laboratory studies have indicated that both the foliage iron level and total chlorophyll content were increased in treated trees.

TABLE 1. The Effect of Trunk Implantations of Ferric Ammonium Citrate Capsules into Eastern White Pine Trees. Implantations in March and Evaluations in September 1975. Figures Represent Averages from Six Trees.

	Untreated pines	Treated pines
Foliage color*	4.5	8.0
Total chlorophyll content of foliage	156 mg./g.	225 mg./g.
Foliage iron level	331 p.p.m.	461 p.p.m.

*Values based on visual scale of 1-10 with 10 a dark green.