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THERAPY FOR DUTCH ELM DISEASE[1]

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Abstract. An aggregate of 82 American elms in Syracuse New York and Washington D.C. naturally infected with Dutch elm disease were given therapy by pruning infected limbs, injection of benzimizol fungicides, or combinations of these treatments. Pruning alone was applied only when there was a distance of 3 m or more from the last visible streak to the distal cut. Pruning without injection was successful in each of 10 current year infections, but in none of 3 residual infections. Fungicide injection without pruning succeeded in 76% of current year and 33% of residual infections. Fungicide injection plus pruning was successful therapy for 100% of the current year and 71% of the residual infections. Each of five "incurable" trees showed no further symptoms after fungicide was injected directly into infected wood in a large limb or the bole as well as into the root collars. Relatively massive injection of fungicide in trees with root graft-transmitted DED did not succeed.

Résumé. Un ensemble de 82 ormes américains à Syracuse, New York et à Washington, D. C., infectées naturellement par la maladie hollandaise de l'orme, reçurent un traitement consistant en un élagage des branches infectées, une injection de fongicides à base de benzimizol, ou une combinaison de ces traitements. L'élagage seul fut appliqué seulement lorsque qu'il y avait une distance de 3 m ou plus de la dernière strie visible à la coupe. L'élagage sans injection fut un succès pour chacune des 10 infections de l'année courante, mais pour aucune des 3 infections résiduelles. L'injection d'un fongicide sans élagage a réussi dans 76% des infections de l'année en cours et dans 33% des infections résiduelles. L'injection d'un fongicide avec un élagage fut un traitement efficace à 100% pour les infections de l'année en cours et à 71% pour les infections résiduelles. Cinq arbres "incurable" n'ont pas présenté d'autres symptômes après que le fongicide fut injecté dans le bois infecté dans une grosse branche ou dans de tronc, de même qu'à la base de l'arbre. Une injection massive de fongicides dans des arbres infectés par des greffes de racines n'a pas réussi.

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Therapy of elms affected with Dutch elm disease (DED) by eradicative pruning (1, 2, 6) or injection of benzimidazole fungicides (7, 8, 9, 10) is well established. By either method, rates of success have generally been predicted by the percent of the tree crown showing DED symptoms at the time of treatment. Guidelines for injection generally state trees that have less than 5-10% of their crown showing symptoms can be considered for treatment. Extent of symptoms are an indicator of possibility of successful therapy, but expressions such as percent of crown affected are not necessarily an accurate measure of the distribution of *C. ulmi* in the tree. For example, a tree infected via root graft may have very minimal symptoms, yet it is incurable (GNL observations). Rather than using percent of crown symptomatic, Campana (1) related rate of success to the length of clear sapwood between the cut and the lowest DED-caused streaking on the pruned limb; his success rate (percent of pruned trees that remained free of DED symptoms through the successive two growing seasons) was 87% when 3 m or more of clear wood was obtained and only 12% when this distance was 1.5 m or less. Highest rates of therapeutic success were obtained when a combination of pruning and stem injection of fungicides were administered (3, 4, 5).

In this paper I will relate the results of operational therapeutic treatments of 82 diseased elms, emphasizing accurate assessment of the infection within the tree and the delivery of fungicide directly into the diseased section.

Materials and Methods

The data presented here represent therapeutic treatments of diseased curb side and garden elms in Syracuse NY (31 trees, 1975-1983) and the Washington DC area (51 trees, 1981-1983). Data on tree parameters, foliar symptoms, sapwood streaking, types, amounts of fungicides injected, and descriptions of pruned limbs were recorded when treatments were made. Results were assessed by inspection (and sometimes sampling) of all trees in late summer or early fall of the year following therapeutic treatment. In six elms given further treatments, the final analyses of their conditions were made in the year following the last treatment.

Treatments employed included pruning of diseased limbs, injection of benzimizol fungicides in the root collar region or into diseased areas in the large limbs or the main bole, or combinations of these. Pruned limbs were always debarked to determine the lower limit of sapwood DED-induced streaking. If the distance between the basal cut and the lowest visible streaking was less than 3 m, the limb system was pruned at a lower crotch or the tree was considered for injection. In some cases the DED streak was traced downward by lifting 2-4 cm long V-shaped bark flaps cut with a sharp knife after the outer bark had been removed with an axe. Early injections in Syracuse utilized carbendazim phosphate (similar to LIGNASAN-BLP®), prepared in my laboratory from Benomyl, injected in amounts of active ingredient equivalent to 10-100 times the dosage recommended for the commercial product. We used a commercial formulation of thiabendzol (ARBOTECT-20S® , Merck & Co.Inc., Rahway, NJ) when it became available because it was as about as active against *C. ulmi* as carbendazim, but labeled for injection at much higher concentrations. Root flare injections of Arbotect were delivered at the label rate of 4 oz (118g) of formulation (26.6% AI, diluted 1:40 in tap water) per 5 inches of tree diameter for trees over 10" (25 cm) in diameter and at about half that rate for smaller trees. Arbotect was injected into limbs at the rate of 0.2-0.4 oz (28-56 g) per inch (2.5 cm) diameter. DED was confirmed by sapwood streaking on all pruned trees and about 50% of the trees that were injected without pruning. In about seven trees with atypical symptoms, the presence of *C. ulmi* was confirmed by culture of sapwood samples on potato dextrose agar. Year of infection was ascertained by dissection sections with the most advanced symptoms to determine the earliest annual ring that had DED streaking and by extrapolation from these dissections to foliar symptoms in other trees.

Fungicide solution was delivered at less than 2 atmospheres of pressure from 20 L gravity (Dewill Inc., Elmhurst IL) or 12 L pressure (Smith & Co., Utica NY) plastic tanks through ¼" holes drilled 1-2 cm into the sapwood. Crown and upper bole injections required climbing and roping of a tank in

the tree.

The techniques used on the various trees were chosen at the time of treatment and based upon evaluation of the symptoms and upon practical limitations of what we able to do and the quantities of fungicide on hand. We did not randomize treatments nor assign some trees to experimental control groups.

Results

In both Syracuse and Washington, approximately 90% of trees that were given therapy during the year they were infected (= current year infections) and about 50% of treated elms infected in previous years (= residual infections) were free of DED symptoms the year following treatment. Data for the two areas are combined in Table 1.

Pruning without injection was successful in each of 10 current year infections, but in none of 3 residual infections. Pruning alone was applied only when there was a distance of 3 m or more from the last visible streak to the distal cut; failure of pruning residual infections may have resulted from layering of uncolored new sapwood over infected wood. It is clear that fungicide injections is advisable for any tree pruned after the initial year of infection.

Fungicide injection without pruning succeeded in 76% of current year and 33% of residual infections. All 5 of the injected elms with current year infections that eventually died of DED were young (<20 cm dbh) and had infections well established in the bole at the time of treatment. However, in two other such cases, therapeutic injections succeeded.

Fungicide injection plus pruning was successful therapy for 100% of the current year and 71% of the residual infections. In five of the elms with DED streaks 1-15 cm wide at the last possible pruning cut, fungicide was injected directly into the streaked and the adjacent wood as well as into the root collars of the trees. In this manner we were to cause the injected liquid to "bleed" from the pruning cut, as was advocated by Kondo (7). All of the trees treated in this manner recovered, although one of them required additional pruning and reinjection the following year.

Relatively massive injection of fungicide in roots of trees with root graft-transmitted DED slowed symptom progression but did not cure any of the 4 trees that we treated.

Discussion

Decisions for the delivery of fungicide injection for DED therapy is best based on whether the tree in question has a current year or a residual infection, rather than on the percentage of the crown with foliar symptoms. The degree of success reported in operational use of benzimidazol fungicides for therapy of Dutch elm disease has been related to the extent of foliar DED symptoms at the time of treatment (8), delivery of an appropriate dosage of active ingredient (10), distribution of compound within the tree (9, 11), and susceptibility of the strain of the DED-causing fungus *(Ceratocystis ulmi)* to the fungicide (5). Manufacturer's guidelines generally state that elms showing 5-10% of the crown symptomatic are suitable candidates of therapeutic injections. While useful, this simplistic approach can lead to disappointment when trees in which there is little possibility of success are injected or in unnecessary condemnation of other trees that might be saved.

The assumption that elms with 5% crown symptoms of DED can be effectively treated is valid if

Table 1. Results of operational Dutch elm disease therapy: (number) of trees treated and percent without symptoms in the year following last treatment

	Treatments							
Infection type	*Prune*		*Inject*		*Prune & inject*		*Total*	
Current year	(10)	100	(21)	76	(18)	100	(49)	89.8
Residual	(3)	0	(12)	33	(14)	71	(29)	48.3
Root graft	(0)	-	(4)	0	(0)	-	(4)	0
Total	(13)	77	(37)	54	(32)	88	(82)	70.7

the DED assessed is the result of an elm bark beetle inoculation *during the current year;* it does not pertain to infections that ocurred in previous years or to infections that ocurred through root grafts. Any DED symptoms that appear within eight weeks of foliation are almost certainly those of residual or root graft infections. Symptoms that first appear in more than one limb system either reflect two or more independent beetle-induced infections, systemic DED, or root graft transmission. Conversely, a systemic or root graft infections sometimes are manifest by DED symptoms in a very limited section of the crown, especially in low vigor trees. For these reasons assessment of DED symptoms is best done by following *C. ulmi*-induced streaking of the sapwood as revealed by debarking pruned branches and/or small cuts through the bark of the intact tree.

Even intensive root and root collar injections may result in sporadic distribution of active ingredient in large and complex elm trees. It seems possible that achievement of sufficient concentrations of fungicide in diseased sections of the tree may be further complicated by a reduction of water movement associated with wilting. In order for root collar injections to deliver a therapeutic dosage of fungicide at the site of the infection high in the tree, it is probably necessary to inject excessive amounts of material of which the vast majority is deposited away from the site of the infection. Delivery of fungicide directly to the infected wood probably greatly increases the rate of therapeutic success. The five trees that we streak-injected would have been considered hopeless cases according to conventional guidelines, yet all remained free of DED symptoms after the treatments were terminated. Since the work summarized here we have apparently cured elms of DED by injecting small amounts (2-10 oz or 56-280 g of formulation) of Arbotect into the streaked wood without injecting at the root collar. On the other hand, our pruning of large elms was usually successful; I agree with Campana's (2) statement that "DED can most easily be eradicated from large trees with small infections".

Contrary to conventional wisdom, residual DED infections can be successfully treated, even if the fungus has reached, to a limited extent, the main bole. Rate of success of therapeutic injections is considerably enhanced by pruning and, especially, by direct injection of the streaked wood within the crown of the tree. Nevertheless, the most important ingredient for successful DED therapy is detection of new infections when first symptoms appear.

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