Dutch Elm Disease: A Postscript

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Dutch elm disease (DED) is the preeminent shade-tree problem in North America and Europe. The enormous economic loss and the aesthetic desecration wrought by DED make it the most widely known of all plant diseases. Recent articles on this infamous malady include those by Newbanks *et al.* and Karnosky in this issue of *Arnoldia*. Together, these papers provide a rather complete picture; yet some important points remain unmade, and a few of the statements printed are, in my opinion, misconceptions. This postscript to the *Arnoldia* articles ventures a few amendments to the previous papers and presents my view of the state of the art of DED control.

Differences of Opinion on Specific DED Control Operations

An important problem confronting the DED-control practitioner is the apparent controversy among "experts" on the effectiveness of specific practices. Another is lack of knowledge of new developments.

One perspective in consideration of DED control measures arises from the desire to protect or cure individual trees; another from the wish to minimize tree losses within a population. The owner of a magnificent elm will probably concentrate on prophylactic protection

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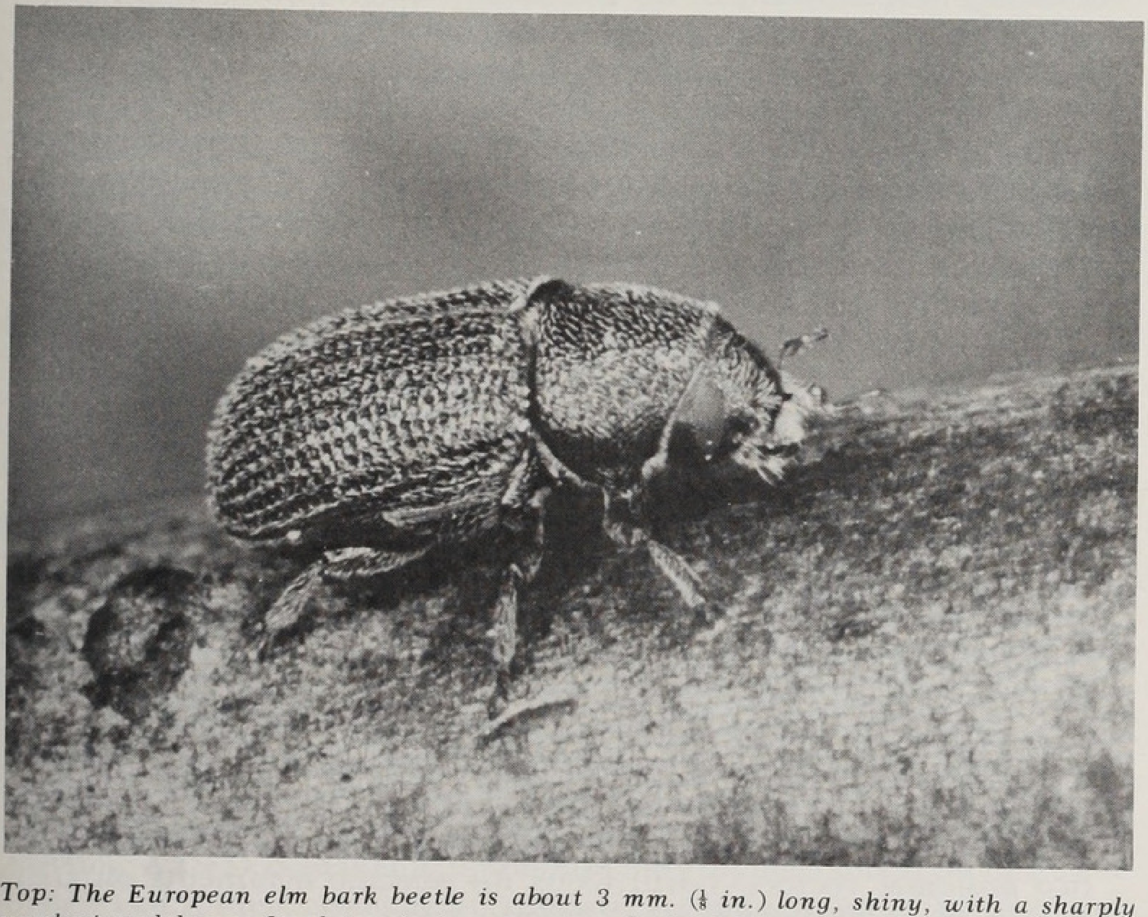


Top: The European elm bark beetle is about 3 mm. ($\frac{1}{8}$ in.) long, shiny, with a sharply up-sloping abdomen. Its elytrae (wing covers) are dark red-brown and the rest of the body is black. Bottom: The native elm bark beetle is about $2\frac{1}{2}$ mm. ($\frac{3}{32}$ in.) long, rough, uniformly dark brown, and shaped like a Volkswagen "Beetle."

or therapy for that particular tree. The city arborist, on the other hand, must be concerned with limiting elm losses while keeping costs within an operating budget. Like the practices of public health and medicine, the personal and population approaches to DED control are compatible and often synergistic. However, the specific measures effectively employed for the attainment of one objective are not necessarily efficient for fruition of the other. Hence, some of the differences of opinion about which particular DED operations should be applied often originate from different perspectives.

A second major source of controversy about specific DED control measures is that their effectiveness often must be gauged by the number of DED infections that do not occur. Rigorous proof of cause is elusive when many factors contribute to an effect. For example, it is possible to show quickly that a certain concentration of an insecticide kills a specific proportion of the elm-bark beetles exposed to it, yet several years of evaluation may be required to assess the contribution of operational spraying to DED control.

A third reason for confusion about the value of various DED control practices is the inherent variation among many of the factors that influence the DED loss rate. These include regional climate, local weather, soil characteristics, and genetic variation within beetles, elms and fungus. Many of the elm strains bred by Dutch workers for resistance to the prevalent DED fungus quickly succumbed to a more virulent strain imported from North America via Britain (Brasier and Gibbs, 1973).

Finally, variability in the effectiveness of specific practices arises from the different ways that they are applied. Effectiveness may be serendipitous for one application, while a similar approach may not yield the same benefits. For instance, DED rates rapidly declined when sticky traps baited with the aggregation pheromone of the European elm-bark beetle were positioned around isolated elm groves (Lanier, 1981), but a variation of this technique for city-wide application of mass trapping had no discernible impact on DED rates (Peacock *et al.*, 1981). The techniques as actually used may vary from guidelines developed by researchers, as in the case of a major mid-Atlantic city which for several years has applied the insecticide methoxychlor by mistblower at the concentration recommended for hydraulic application (2% rather than 12.5%). In addition, most of the trees were treated later than is necessary to protect elms from twig feeding by the spring generation of elm-bark beetles.

Earlier in this issue, Karnosky cogently reviews histories of DED and elm phloem necrosis and describes symptoms of both diseases. Newbanks *et al.* detail the infection process. Both articles deal with control tactics. Aside from a short description on the biologies of the two principal vectors, I will focus my specific comments on DED control strategies and tactics.

The Disease Vectors

The two known vectors of DED in North America are the native elm-bark beetle, *Hylurgopinus rufipes*, and the European elm-bark beetle, *Scolytus multistriatus*. Both insects breed in the inner bark of weakened or moribund elms and transmit DED when adults of contaminated broods feed on the bark of healthy elms. European beetles overwinter as larvae in brood trees, while native beetles spend the winter predominantly in the adult stage, in the bark at root collars of healthy elms. Native beetles leave their overwintering niches in the early spring and walk up their host to feed on limbs. European beetles emerge about a month later (when the first leaves are fully expanded) and fly to moribund elms, where they breed, or to healthy elms, where they feed in twig crotches.

In urban areas where the climate is milder, the more aggressive European immigrant has displaced the native species. The less winter-vulnerable native beetle is the only vector in the coldest regions where elms grow (much of Canada, northern plains states, Maine). In the intermediate areas such as New England, New York, and Minnesota, the relative abundance of the two beetles fluctuates with the severity of the preceding winter.

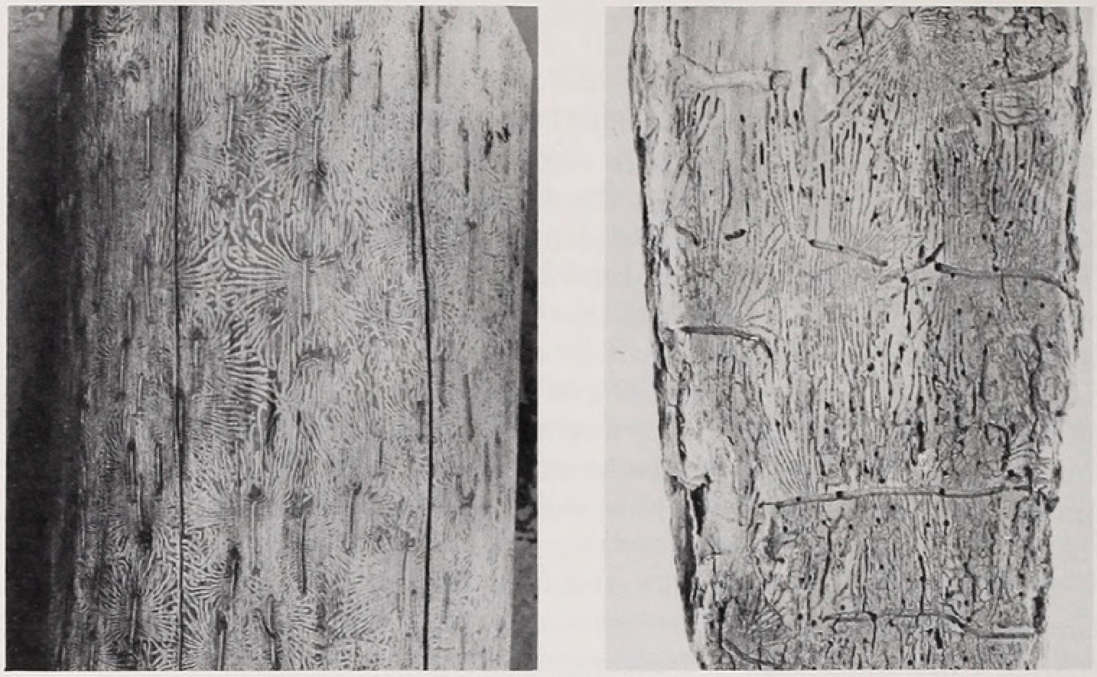
Determination of the relative abundance of the two DED vectors is important because some operations used to control one species are useless against the other. Removal during the winter of recently dead elms may decimate the European beetle population but will have little impact on the overwintering native beetles. Although spraying with methoxychlor just prior to foliation may prevent twig feeding by the European beetle, much of the feeding by the native beetle will already have occurred. Conversely, chlorpyrifos sprayed on lower boles of healthy elms will have no impact on the European beetle. Finally, the aggregation pheromone of European beetles is not attractive to the native species.

DED Management Strategies and Tactics

Basic strategies for limiting losses to DED include the following:

1. Reduce populations of disease vectors (i.e., elm-bark beetles);
2. Apply measures for prophylactic protection of individual trees against feeding by elm-bark beetles or colonization by the DED fungus;
3. Cure infected trees;
4. Increase disease resistance of the tree population.

Various tactics or practices can be employed under the above strategies. A DED management program may invoke more than one strategy and almost necessarily employs a combination of tactics. Karnosky and Newbanks *et al.* state that integrated programs are most effective. Enlightened integrated management should attempt to



Left: Wood engraved by the European elm bark beetles shows the vertical mines bored by egg-laying females. Right: Bark mined by native elm bark beetles shows the horizontal mines made by the egg-laying females.

maximize the cost effectiveness of the entire program. Therefore, an evaluation to determine which tactics to employ must consider their cost of application and their collective contribution to the net result. These elements are contrasted with the expenses of removal and replacement, plus the aesthetic value of trees expected to be saved by each tactic. Because disease severity, tree values, operating costs, and available expertise differ widely, DED management programs should also vary.

DED Control Tactics

Survey. One tactic not mentioned either by Karnosky or by Newbanks *et al.* is survey and inspection of the elm population. This operation is essential in order to maximize benefits of the more expensive tasks of sanitation, root-graft control and therapy. It is necessary for surveyors to be trained to recognize new infections. Frequency and intensity of inspections may vary with the level of control desired. If the control objective for a rather dense elm population is less than 1% annual loss, inspections must be made frequently and on foot. If the objective is 3–5% loss annually, two inspections during the growing season may be adequate. Binocular scanning of the elm population from aircraft or vantage points is very helpful in detecting new infections in the upper peripheral crowns of trees. A relatively small increase in funds spent for upgrading survey methods may yield high returns via improvements in the results of the entire program.

Sanitation. Karnosky calls sanitation "the cornerstone of all successful programs," yet Newbanks *et al.* say that "it is only effective if done promptly and consistently." Removal of *any* dead and dying elms before new beetle adults emerge from them will have some impact on DED rate. Prompt removal is important because infections in adjacent trees are caused by beetles attracted by elm wood being colonized, as well as by the brood that emerges later. Prompt removal reduces the opportunity for the fungus to move to the roots, through which infection may occur via grafts to adjacent elms. Expenditures to remove elms after beetles have emerged and fungus has invaded the roots contribute nothing but a reduction in the hazard from falling limbs. Optimal DED control programs mandate elimination of all potential beetle-breeding material, including diseased wild elms in green spaces within and adjacent to the elm population being managed. Elimination could also be accomplished by the trap-tree technique or by felling and spraying.

Prophylactic spraying. Since the ban on DDT, methoxychlor has generally been the insecticide used to protect twigs from feeding by the European elm-bark beetle.

There is no doubt that this material prevents feeding and can reduce risk of infection (Barger, 1976). However, there is considerable disagreement about the usefulness of methoxychlor in general practice. Neely (1972) found no difference in the level of DED control when Illinois communities sprayed or did not spray with this insecticide. The statement by Newbanks *et al.* that "these insecticides [including chlorpyrifos, used against the native beetle] are effective only for a short period of time" is contrary to analysis of insecticidal activity by Cuthbert *et al.* (1973), and to our bioassays (Rabaglia, 1980) which show that the recommended 2% dormant hydraulic spray of methoxychlor completely inhibited twig feeding by the European beetle for at least 10 weeks after treatment. The apparent lack of effectiveness in reducing DED rates by prophylactic sprays probably results from one or more of the following: 1) coverage is inadequate; 2) beetle feeding has occurred before the spray was applied; 3) new shoots produced after spraying are not protected; 4) the principal vector in the area may be the native elm-bark beetle, for which methoxychlor is not very effective.

The insecticide of choice against the native beetle is chlorpyrifos (Gardiner and Webb, 1980). An exemplary DED program in Sault Ste. Marie, Ontario, utilizes treatment of the lower boles of healthy elms with chlorpyrifos in fall or spring to virtually eliminate the adult beetles that attempt to overwinter in the root-collar region. Spraying whole trees will protect them from beetle feeding in the spring, but as is the case for methoxychlor, adequacy of coverage may be a problem.

It is my opinion that prophylactic treatment of elm crowns at $25–$100 per tree should be undertaken only after expenditures for alternative operations are considered. The much less costly operation of treating the lower boles against overwintering adult native beetles is likely to be economically justifiable because it is inexpensive, easily accomplished, and necessary only once every two years. If a spray program is undertaken, there should be some evaluation of both conformation to standards (including concentration and timing) and thoroughness of coverage. Municipal spray operations usually cost

Example of a diseased American elm (Ulmus americana).

tens to hundreds of thousands of dollars annually; it seems that at least 1% of the amount spent could be devoted to evaluation of the operation.

Preventing infection through root grafts. Prompt detection and removal or therapy of diseased trees will usually preclude movement of the DED fungus through root grafts between adjacent elms. Preemptive trenching about once every five years should be considered for protection of valuable elm groves wherever conditions permit it. Trenching or chemical severance of roots around trees that have systemic DED is justifiable only after careful inspection of the diseased tree for DED-caused discoloration indicates that the fungus has not yet infected the root-collar region. Too often, disruption is done after the trees to be protected are infected.

Pheromone-baited traps. Sticky traps baited with Multilure, a synthetic copy of the aggregation pheromone of the European elm-bark beetle, have recently been registered for aid in the control of DED. Traps placed on utility poles and trees other than elms capture large numbers of beetles and cause many others to exhaust themselves in fruitless flights to areas devoid of elms. Newbanks *et al.* are incorrect in implying that the method is expensive and subject to interference by weather. Traps may be positioned long before the first possible beetle flight. The pheromone bait remains attractive for at least 100 days, regardless of temperature, and the trap remains effective until it is covered with beetles (about 25,000) or debris. The cost of traps plus deployment and removal should be about $0.50 to $5.00 per tree per year. In addition to eliminating beetles that might otherwise transmit DED fungus to healthy elms, pheromone-baited traps monitor beetle flight and relative population. Trapping beetles is no substitute for sanitation; in fact, the effectiveness of trapping appears to increase as the number of competing pheromone sources (elm wood being colonized) decreases (Lanier, 1981).

Tree-trap Technique. Perhaps the greatest detriment to DED control has been an enormous supply of brood wood in green spaces where wild elms proliferate. In addition, removal of diseased trees from streets and yards has been delayed due to fiscal, mechanical, or political reasons. The trap-tree technique is an extremely powerful tool for coping with either situation. Hopelessly diseased trees and unwanted "weed" elms are injected with an herbicide, cacodylic acid. Treated trees are very attractive to both the native and the European elm-bark beetles; attraction of the latter can be enhanced by baiting the tree with Multilure. Attracted beetles colonize the tree, but the beetle brood substantially (average more than 90%) fails due to herbicide-induced desiccation of the bark (O'Callaghan *et al.*, 1980). Treated trees do not have to be removed immediately, and no special provisions must be made for disposal of the wood. Trap trees in green spaces can be left standing to fill the ecological role of a naturally dying tree.

Because it is inexpensive, effective and quick, the trap-tree technique is probably the most efficient means of gaining control in a DED outbreak or of managing an area that includes large numbers of elms in green spaces.

Fungicide injections. Fungicides injected into elms can provide a high level of prophylactic protection; they can also arrest symptom development if distribution of the DED fungus within the tree is not advanced. Newbanks *et al.* reviewed the development and application of Benomyl derivatives and thiabendazole and cited the problem of Benomyl products being tightly held by the vessel walls and not easily moving within the tree, especially not into wood produced after the injection. Thus, the trees would have to be treated annually for continued protection. Very recent work (Stennes, 1980) confirmed the lack of perennial effect even for very high dosages of a Benomyl derivative (MBC-phosphate) but demonstrated that excellent protection could be maintained for three years by injecting thiabendazole (Arbotect®) in the root collar at three times the registered therapeutic dosage. Registration of this dosage is apparently being undertaken by Merck & Co., producers of Arbotect.

Injection of fungicides for prophylaxis is probably the best means of protecting one or a few elms within areas where incidence of DED is very high, but the expense of this practice may make it a relatively inefficient way to spend DED control funds on a municipal level. On the other hand therapeutic treatments should usually be cost effective. A program employing frequent survey and proper technique for therapeutic pruning and injection should be able to cure 70% of the newly infected trees. Assuming costs of $200 per tree for therapy, and a total of $750 for tree removal and replacement, only 30% of the treated trees must be cured in order to realize a savings in direct program costs.

Antibiosis. Regardless of the reliability of injections of chemical fungicides, prophylaxis by this means faces the prospect of substantial expense over the lifetime of a tree (which itself might be shortened by injection wounds). An exciting possibility for the attainment of long-term protection is the development of a strain of the bacterium *Pseudomonas syringae* that can maintain itself within the sapwood of elms while it produces antibiotics that kill the DED fungus (Strobel and Lanier, 1981). The concept has worked well enough in research tests for Chevron Chemical Company to undertake its commercial development.

Replanting. Karnosky reviewed the development of a number of DED-resistant elm varieties. Planting these is common practice in Europe, but except for Siberian (*Ulmus pumila*) and Chinese elms (*U. parviflora*), DED-resistant stock is not commonly available in North American nurseries. Keeping in mind the generalization that diversity promotes stability, I believe that in areas largely devoid of wild elms, even DED-susceptible American elms can be prudently planted as scattered individuals to compose 5–10% of the tree population.

Outlook

The advent of new technologies has brightened the prospects for maintaining existing elm populations and reestablishing elms in devastated areas. Yet, there is no *cure* for the DED problem. Individual trees may be cured of the disease, but DED within an area must be *managed.* Management involves the enlightened application of a combination of practices that optimize the cost effectiveness of the entire program. Because uncontroverted data may not be available, because available information on cost and effect of various technologies is rarely mustered, and because efforts devoted to evaluation and management seldom match the magnitude of the problem, the majority of DED control programs are less effective than they could be and more costly than necessary.

From a study considering only the cost of tree removal (not aesthetic value or replacement cost) Cannon and Worley (1976) concluded that good DED management was cheaper than poor management, which, in turn, was cheaper than no management. Removal costs have increased since this study, and development of cost-powerful tactics such as tree therapy, mass-trapping beetles, and trap-tree technique should increase the difference in relative costs. With the reiteration of the value of traditional DED tactics and the advent of new techniques, there is seldom economic justification for a community not to manage DED.

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