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TRAP TREES FOR CONTROL OF DUTCH ELM DISEASE[1]

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Abstract. Diseased or unwanted elms treated with cacodylic acid or monosodium methylarsonate (MSMA) by injection or topical application to axe or chain saw cuts are colonized by elm bark beetles, but herbicide-induced drying of the bark suppresses brood production. Treated trees need not be removed for the sake of Dutch elm disease (DED) control and their wood can be utilized for fuel and other purposes. Experimental and operational applications of this technique have been followed by reduced rates of DED infection. Time required to treat a tree averages about 15 min and per tree cost of materials ranges from a few cents to about $10. A one or two person crew working full time during the growing season can apply the trap tree technique to all diseased trees in a population of about 100,000 elms.

Résumé. Des ormes malades ou indésirables traités avec de l'acide cacodylique ou du méthylearsonate monosodique, par injection ou par application lors de coupes à la scie mécanique ou à la hache, sont colonisés par les scolytes, mais un assèchement de l'écorce provoqué par l'application d'un herbicide supprime la reproduction des insectes. Les arbres traités n'ont pas besoin d'être enlevés pour contrôler la maladie hollandaise de l'orme (MHO) et ils peuvent être utilisés comme bois de chauffage ou à d'autres fins. Des applications expérimentals et opérationnelles de cette technique ont entraîné une diminution des taux d'infection par la MHO. Le temps de traitement requis est de 15 min en moyenne et le coût de revient par arbre est de 10$. Une équipe composée d'une ou deux personnes travaillant à temps plein durant la saison de croissance peut appliquer cette technique à tous les arbres atteints d'une population d'environ 100,000 ormes.

Publications on the control of Dutch elm disease (DED) usually assign paramount importance to sanitation—the elimination of wood infested, or in a condition to become infested, by elm bark beetles. The rationale for sanitation is straightforward; if the beetles that spread the causal fungus, *Ceratocystis ulmi*, have no place to breed, the disease cycle will be broken.

Almost eight decades ago Dutch scientist Maria Schwartz (23) and Cristinia Buisman (3) unraveled the mystery of *de lepenziekte* or sudden wilting of elms that appeared after World War I as an evil phoenix from ashen battlefields of France and Belgium. The Dutch, with virtually their entire shade and windbreak tree population at stake, were probably the first to institutionalize sanitation to save their elms. Today, large old elms lining the canals of Amsterdam still whisper testimonials to the effectiveness of this practice.

With the widespread agreement on the effectiveness and the need for sanitation in DED control, one ought to wonder why it has not become a universal practice and why so many fine elms have disappeared from the streets and gardens of Europe and North America. The naked truth is that the sanitation practices was (is) too often too imperfect to produce the desired result.

Deficiencies in time to identify, sample, contract, and remove diseased elms and of money to support these operations are most often cited as reasons why good sanitation was (is) either not instituted or not maintained. Other important contributing factors have been difficulties in access for removal of elms in certain locations (e.g. back yards and greenspaces) and a common misconception that European elm bark beetles, *Scolytus multistriatus*, would fly no more than 1000 feet (320 m); brood trees beyond this distance from the elms to be protected were thought to be of no serious concern. We now know that the usual minimum initial flight of the European elm bark beetle is over 12000 ft (400 m) (11) and that flights longer than 5 miles (8 km) are possible (1). A good sanitation program must

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include all elms up to at least ½ mile (800 m) of elms to be protected.

Himelick and Neely (9) recognized the threat of feral elm populations to amenity value elms and investigated the use of several chemicals to eliminate this hazard. Unfortunately, the methods they researched were not operationally adopted, probably because the chemical they found to be most effective (sodium arsenite) was considered too dangerous for general use.

We have advanced a trap tree technique which involves the injection of unwanted or hopelessly diseased (but still living) elms with safely handled chemicals, cacodylic acid (sodium dimethylarsenate) and MSMA (monosodium methylarsonate) (18, 11, 12, 15). These herbicides quickly kill treated trees and make them very attractive to European and native elm bark beetles, *Hylurgopinus rufipes* (8, 15, 17, 18). Many of the beetles attracted colonize the trees, but herbicide-induced drying of the bark causes broods to substantially or entirely fail (17, 18, 12, 15) (Fig. 1).

Figure 1. European elm bark beetles egg galleries in this trap tree failed to produce brood adults owing to herbicide-induced drying of the bark.

The trap trees absorb many more in-flight elm bark beetles than they contribute to the next generation; thus the positive feed-back that normally fuels a DED epidemic is reversed so that reductions of elm bark beetles and diseased trees occur at each generation (Fig. 2). Since production of beetle brood from trap trees is not a problem, there is no imperative to remove them for the sake of DED control. Trap trees along streets and in gardens can be removed at a convenient schedule and those in green spaces can be left standing.

The trap tree technique can overcome difficulties in mechanical sanitation and quickly and cheaply control Dutch elm disease. Its speed ease, and low cost make the trap tree technique a practical method of reducing beetle immigration

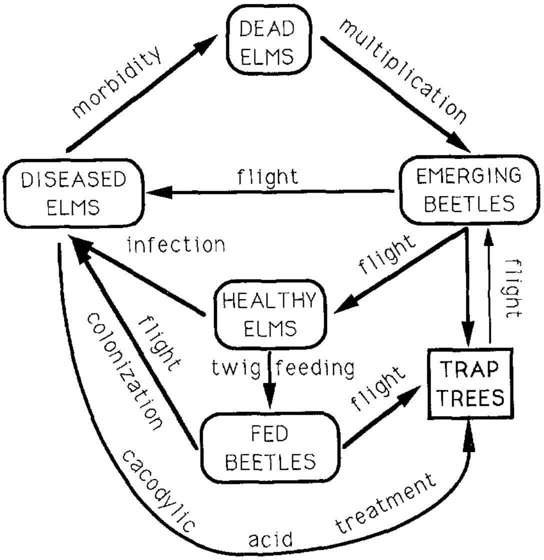

Figure 2. Bark beetles multiply in deseased elms and the growing population infects additional trees during twig feeding; the new disease increases breeding spaces and results in a further increase in the beetle population. This positive feed-back between diseased elms and the bark beetle population leads to ever increasing intensity of Dutch elm disease until scarcity of elms becomes limiting. Traps trees exert negative feed-back by absorbing in-flight adult beetles and yielding little or no beetle brood to carry the disease cycle. If most diseased elms are treated, the beetle induced DED infection rate must decrease with each generation.

from greenspaces and areas such as railroad rights-of-way.

Development of the trap tree technique. Sodium arsenite and sodium arsenate were the first chemicals found to be suitable for killing diseased elms and eliminating beetle broods (9). Following the discovery of failed broods in conifers killed in thinning operations, several studies showed that cacodylic acid and MSMA could be useful for control of bark beetles (5, 2, 7, 6). Rexrode (22) reported 100% mortality of elm bark beetle broods in small elms pressure-injected with cacodylic acid, but Hostleter and Brewer (10) found no significant mortality of European elm bark beetles in diseased trees topically treated with cacodylic acid in Colorado. (The timing of the treatment (August) and examination for emergence (December) indicates that the infestation was already established when trees were treated.) In Syracuse, New York, O'Callaghan et al. (17) experienced a first year decrease of 56% in DED infection rate in a 3.6 km^2 residential area within which all detected diseased elms were treated with cacodylic acid; at the same time DED increased by 126% in a similar untreated area. By the third year of continuous treatment, the DED infection rate had decreased from 5.3 ± 1.0% to 1.4 ± 0.8% (12). Production of elm bark beetle broods in treated trees was reduced by 87%, compared to that from untreated diseased elms (17).

Control of DED in natural "green space" areas using trap tree technique was demonstrated in Hennepin County, Minnesota parks where two years of treatment in Rebecca Lake Park (36,000 elms) was coincident with a 52% reduction in disease among trees in high use "amenity and threatening" zones, while losses increased to 130% of the base rate in untreated Baker Park (26,000 elms) (12) (Fig. 3). Since 1981 the trap tree strategy has controlled DED among a population of ca. 10,000 elms in natural areas within the National Capital Parks in Washington, DC (Fig. 4). In addition to Washington greenspaces, we have applied the trap tree technique operationally as part of integrated management programs in Syracuse NY, Williamstown MA, Ward 5 in Washington DC, Chevy Chase MD, and Gosse Pointe Park MI; in each case, DED losses decreased by about 50% the year following the initial application and continued to fall as long as the program was maintained. Carlson (4) reported that city foresters are extremely pleased with the trap tree technique.

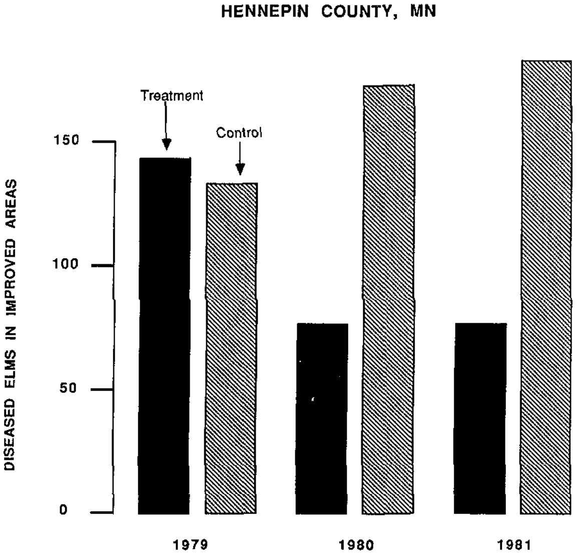

Figure 3. Loss of elms in treatment (Rebecca Lake Park, 36,000 elms) and control (Baker Park, 26,000 elms) areas in a trap tree study in Hennepin County Park Reserves, Minnesota, 1979-1980. The impact of the treatment was delayed one year because flight of the native elm bark beetle, the principal disease vector, occurred before trap trees were available in 1979. From Lanier (12).

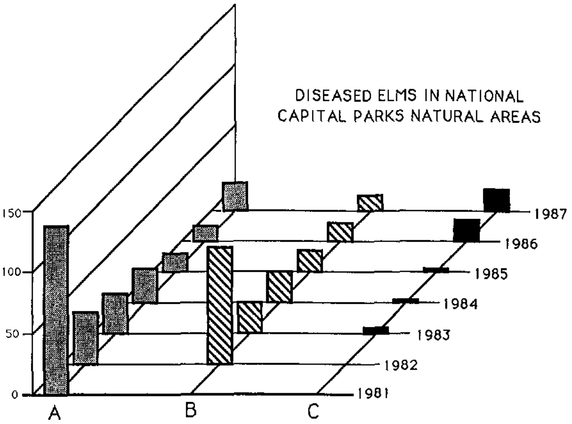

Figure 4. Diseased elms in National Capital Parks natural areas during periods when all elms identified as being diseased were treated with cacodylic acid (except for 9 given therapy). Treatments in different groups of areas began in 1981 (A), 1982 (B) or 1983 (C). The increase in cases in 1986 resulted from bark beetle attacks on elms injured by herbicide applied by a rail road company.

In a trial of the trap tree technique in two 6.5 km^2 areas in the northern England County of Merseyside (19), treated trees were attacked by large numbers of bark beetles (*Scolytus scolytus* and *S. multistriatus*) whose reproduction was inhibited by 66 to 83%, relative to that in untreated diseased elms. DED rates in both treatment areas was lower than in experimental check plots during both years of the experiment, but the levels of DED control attained (10-23%) were not impressive.

Properties of cacodylic acid and MSMA. As pentavalent organic arsenicals, cacodylic acid and MSMA are much less toxic than metallic trivalent arsenicals such as sodium or calcium arsenate. Neither organic arsenate causes significant eye or skin irritation nor are they carcinogenic (24). The material that I have usually used is registered as Rad-E-Cate 35^R(Vineland Chemical Co., Vineland, NJ. Now available as MOTAR, Monterey Chemical Co., Fresno, CA) for aid in control of DED.

Most samples of cacodylic acid-treated elm contained less than 1 ppm arsenic, although samples taken at the point of treatment had a high of 32.5 ppm (27). Lodgepole pines treated with MSMA to control mountain pine beetle, *Dendroctonus ponderosae,* had concentrations of 2.4 and 1.8 ppm in the phloem and sapwood, respectively, compared to 1.2 and 0.9 ppm in untreated pines (16). The levels of arsenic in the treated pines were similar to those common in untreated Douglas-fir (25). The form of the arsenic (pentavalent, oxidized) and low amounts indicates that use of wood from treated trees poses no serious hazard. Burning wood from treated trees would produce exposure to arsenic species at levels often much lower than those released in burning coal (ave. 45 ppm) (26). Herbicide properties of both chemicals are quickly inactivated upon contact with soil (24).

Administering treatment. To achieve quick kill and rapid desiccation of the bark, the herbicide is administered undiluted into the water-conducting outer sapwood rings of the diseased elm. Techniques for application are illustrated in Fig. 5. The liquid can be applied by a plastic squeeze bottle or pressurized spray tank into an axe frill (Fig. 5A) or plunge cuts made with the tip of a chain saw (Fig. 5C), or it is injected under low pressure (.5-15 lb/in^2) into the root collar (Fig. 5B). The axe frill technique works well on small trees (20 cm dbh or less) but thick, tough bark makes this approach more difficult for larger trees. Generally, low pressure injection gives the best results, while the chain saw technique is the quickest.

The herbicide can be transmitted to adjacent elms through root grafts. For cases with root grafting potential, movement of herbicide to healthy elms can be avoided by making a double girdle with a chain saw about 2" into the sapwood and administering the herbicide above the girdle (Fig. 5D). However, if the fungus is present in the roots of the tree to be treated, transmission of infection through root grafts is probably inevitable; therefore, the streaked roots can be treated without attempting to avoid transmission of the herbicide. Herbicide-caused wilting of the adjacent tree within 7 days of treatment will herald inevitable loss of the tree to DED and, it too, can be treated before further root graft transmission of DED occurs. When the girdle reveals that streaking in the bole is limited, the healthy and streaked sections can be separated by vertical chain saw

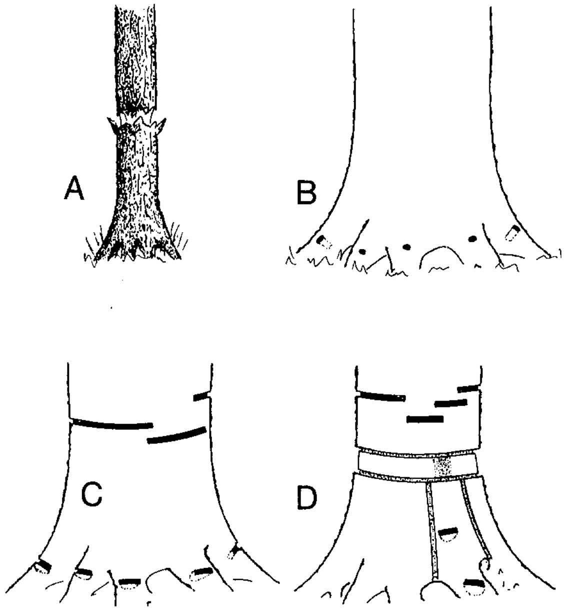

Figure 5. Cacodylic acid or MSMA can be applied in an axe frill into the sapwood (a), by low pressure injection into each major root swelling (b), and into chain saw plunge cuts (c). When root grafting is likely, diseased areas can be compartmentalized by a double chain saw girdle and vertical cuts separating diseased and healthy wood (d).

incisions ½ inch into the sapwood at least 3 inches on either side of the visible streak (Fig. 5D). The streaked roots can be injected with herbicide with minimal risk to any adjacent elms that might be root grafted to yet healthy roots of the diseased tree.

Augmentation with pheromone and insecticide. Timely treatment of diseased elms with cacodylic acid or MSMA prevents them from contributing substantially to the next beetle generation. These trees also absorb adult beetles of the current generation that might otherwise feed in and infect healthy elms. However, as the bark dries and becomes colonized by saprophytic fungi, many beetles that land on the tree leave without attempting to establish galleries (18, 15). Mortality inflicted on the extant generation of European elm bark beetles can be maximized by baiting the tree with the pheromone Multilure (DeWill Inc., Elmhurst, IL) (21) and treating the lower bole (4-5 cm) with an insecticide. In tests of several insecticides for this purpose, chlorpyrifos (Dursban, Dow Chemical Co., Wilmington, DE) emerged as the compound of choice; a 10-sec exposure on bark sprayed with 0.5% chlorpyrifos killed 90% or more of the European and native elm bark beetles six weeks after treatment, while 1-min exposures were lethal to nearly 100% of the beetles throughout the 10-week experiment (14). Recent work (20) found that several pyrethroid insecticides (Esfenvalerate (ASANA), DuPont; cypermethrin (AMMO) and permethrin (POUNCE), both FMC Inc. and Fluvalinate (MAVRIK Aquaflow), Sandoz Crop Protection) could also be very effective for this treatment.

Time of application. To eliminate elms as potential bark beetle breeding material, trees can be treated with cacodylic acid or MSMA at any time that the sapwood is not frozen. However, my experience suggests that movement of the herbicide through root grafts is more pronounced when trees do not have functional foliage than during the growing season. To maximize absorp-

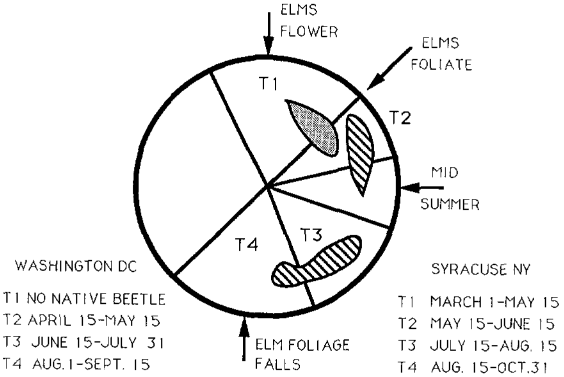

Figure 6. Flight periods of native (shaded) and European (cross hatched) elm bark beetles and optimal times for cacodylic acid or MSMA treatment of trap trees. Early spring treatment (T1) will absorb native beetles that overwintered as adults at the root collars of healthy elms. Lake spring treatment (T2) will absorb European beetles which mature from overwintering larvae in elm wood that died the previous summer. Mid-summer treatment (T3) absorbs the summer generation of European beetles. Late summer and fall treatment (T4) absorbs the fall-emerging portion of the summer European beetle progeny and native beetles that will seek breeding material the following spring. Native elm bark beetles brood adults are extant from mid-July through early October, but at this time these insects are not attracted to diseased elms or trap trees.

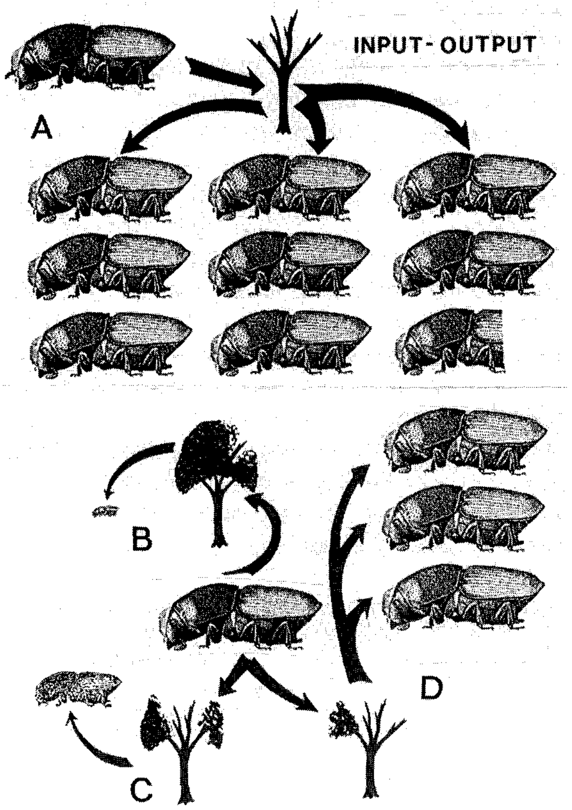

Figure 7. Impact of trap trees on the European elm bark beetle population: untreated diseased wood (A) produced 8.5 new beetles for every one that infested it; production of trap trees was differentially reduced, depending upon whether the tree was ◄50% (B), ►50% (C), or ►90% (D) dead at the time of treatment.

tion of in-flight adults, elms should be treated immediately prior to flight periods. In trials in Minnesota, Vermont, Massachusetts and New York, we found that in spring overwintering native beetles attacked elms treated in September, April and May. European beetle attacks were usually heaviest on trees treated one to two weeks after foliation and 8-10 weeks later, in mid-summer (Fig. 6). Sections of the tree on which all of the foliage is wilted will not be affected by the treatment.

Trials in Washington, DC found that 98% of the potential brood was eliminated if less than ½ of the crown was wilted at the time of treatment while 52% was eliminated if only 1/10 of the crown was alive when the tree was treated (12) (Fig. 7). Therefore treating the tree before the tree progresses too much is probably more important than timing treatment to maximize impact on in-flight adult beetles.

Economics. Application of the trap tree technique requires only ordinary equipment (axe, chain saw, corrosion-resistant pressure tank such as a low volume insecticide spray rig) and herbicide (Monterey Chemical Co., Fresno, CA) that can be pruchased for about $30-40/gal. Cost of herbicide per treated tree ranges from a few cents to about $10, depending upon the bark surface area, as indicated by diameter (Table 1). Treatment time ranges from less than 5 to about 45 min; 15 min is a reasonable average. Time required for detection of diseased trees varies with the density of the elm population, the vegetation type, and accessibility. A one or two person crew devoting full time to this operation during the growing season should have little difficulty administering timely treatments to all diseased trees within a population of 100,000 elms. During recent years we have annually spent 3-4 person-weeks to work a population of approximately 10,000 elms in widely scattered and sometimes rugged natural areas in National Capital Parks. This operation has maintained DED infection rates of less than 1% at an annual cost of about $3,000 ($0.30/per elm) for labor, transportation, and materials.

Table 1. Dosage for treatment of trap trees with cacodylic acid and MSMA based on bark surface area[a].

Diameter		*Minimum amount[b]*	
in	*cm*	*fluid oz.*	*ml*
◄15	*◄38*	*1-4*	*25-120*
15	*38*	*5*	*150*
20	*50*	*8*	*250*
25	*60*	*13*	*400*
30	*75*	*20*	*600*
35	*90*	*27*	*800*

[a] *Formula of O'Callaghan et al. (18).*

[b] *Based on material which is 27% AI; the label on Rad-E-Cate-35^R (Vineland Chemical) allows for up to twice these amounts.*

Conclusion

The trap tree technique is a powerful and inexpensive technique for control of Dutch elm disease. Treated trees absorb in-flight beetles and produce new brood adults at a very reduced rate, compared to untreated trees. There is no imperative to remove treated trees for the sake of DED control and the wood can be utilized for fuel or other purposes. The technique is best applied as one aspect of an integrated DED management plan.

DED control programs that do not utilize the trap tree technique are probably less effective than that achievable and more expensive than necessary.

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