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DUTCH ELM DISEASE AND ITS CONTROL

Dutch elm disease (DED) is known by many as the most destructive shade tree disease in the United States. Dutch elm disease owes its name to the fact that it was first identified on elm in the Netherlands in 1921. Since then the disease has spread throughout Europe, parts of Asia, and much of North America. In the United States, the disease was first found in Ohio in 1930, and in several states on the east coast (Connecticut, Maryland, New Jersey, and New York) in 1933; it has since spread through the Midwest and South, reaching the Pacific Coast in the 1970s. DED was first reported in Illinois in 1950. By 1959 it had spread throughout Illinois and killed many thousands of elms. Many believe this disease is a thing of the past since so few elms remain in Illinois. This is simply not true – DED is still alive and well in Illinois, killing many remaining and newly-planted elms each year.

Figure 1. American elm infected by Ophiostoma ulmi with leaves turning green to yellow, then brown and dropping prematurely (courtesy D.F. Schoeneweiss).

Dutch elm disease is caused by two closely related species of fungi: *Ophiostoma ulmi* (formerly known as *Ceratocystis ulmi*) and *Ophiostoma novo-ulmi*. While the latter, more aggressive, species is thought to have caused much of the DED through the 1970's and beyond, it was only recently recognized as a separate species. In fact, many experts believe that the more aggressive species has more or less replaced the weaker *O. ulmi*. In locations where DED appeared to die out, only to return again, one might imagine that the pathogen became more aggressive once again. While this is certainly possible, there is no evidence to support such a claim at this time. A simpler and more likely reason for such a resurgence is that the community-wide DED management efforts that worked so well to get the disease under control, have been relaxed.

For further information concerning diseases of Ornamentals Plants, contact Nancy R. Pataky, Extension Specialist in Plant Pathology and Director of the Plant Disease Clinic, Department of Crop Sciences, University of Illinois, Urbana-Champaign.

We thank Bruce E. Paulsrud, Extension Pesticide Applicator Training Specialist in the Department of Crop Sciences, for his revision of this document.

Only elms (*Ulmus* species) and closely related plants (*Planera*) are susceptible to the DED fungus. American elm (*U. americana*) is very susceptible. Lacebark or Chinese elm (*U. parvifolia*) and the Siberian elm (*U. pumila*) are the most resistant species, but natural infections of these species and their hybrids sometimes do occur. While Siberian elm is not recommended for use in most landscapes, it and other lesser-known elm species are used extensively to create elm hybrids with good resistance to DED (see Table 1). When selecting a new or replacement elm, it's important to consider not only the growth habit and reaction to DED, but also how it is expected to fare against other diseases and pests. For example, several of the DED-resistant Elm varieties shown in Table 1 are susceptible to a lesser-known, but just as lethal, disease called elm yellows (formerly called "elm phloem necrosis"). Currently, there is no adequate way to prevent or manage elm yellows. Disposal of diseased trees is necessary for aesthetic and safety reasons but has no known protective value for healthy elms (see Report on Plant Disease No. 660 for more information on elm yellows). A number of sources indicate that Eurasian elm species and clones are resistant to elm yellows. However, recent research suggests that it is not that simple – several are either tolerant or susceptible. For many Eurasian and American elm hybrids, the reaction to elm yellows remains unknown. However, several of these hybrids are being studied now and we should have good information within the next year. The bottom line is this: "When choosing trees, be informed and be diverse". If we ignore this advise, we can expect elm yellows to blight our boulevards just as DED did.

SYMPTOMS AND DIAGNOSIS

In Illinois, most new infections are first observed during June. Leaves on one or more branches wilt, turn dull green to yellow, then brown, curl, and usually drop prematurely (Figure 1). Branches with affected leaves usually die rapidly. Elms infected during early summer usually die in one year, small trees within a few weeks, and large elms die slower, sometimes over two or more years.

The pattern and severity of DED symptoms largely depends on when and where the infection occurs. For example, if infection begins in the upper crown, symptoms often first appear at the end of an individual branch (called "flagging"). Eventually, the infection and the flagging symptoms will progress downward, into the crown of the tree. If the fungus enters the tree through the roots, the entire crown may be affected very rapidly. Similarly, if the crown is infected during late summer, the symptoms develop the following spring on most or all the branches at the same time, and the tree may die within a few weeks. Late infections may be overlooked as early fall coloration.

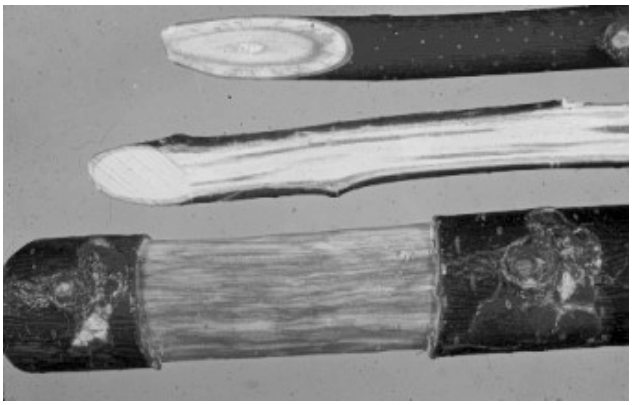


Figure 2. Vascular discoloration and streaking in DED affected branch.

Field diagnosis of DED can be difficult. Branches wilting from DED will commonly show discontinuous light to dark streaks in the white outer sapwood just under the bark. In cross section, the discoloration appears as a circle of brown dots or a ring, mostly in the springwood of the current-season growth (Figure 2). However, elms that are killed rapidly due to root graft transmission, may only show such discoloration in the main trunk. Elm yellows-infected trees will not have streaked or discolored sapwood, but rather the inner bark a a

sealed jar). Because other fatal wilt diseases of elms, such as Verticillium wilt and Dothiorella wilt, also show discoloration in the sapwood, positive identification is possible only through laboratory culturing.

For laboratory confirmation, send two to four branch sections from live, **freshly** wilting branches (**not** dead or dried ones). The sections should be at least thumb thickness and 6 to 8 inches long. The fresh branch sections should be sealed in a plastic bag attached to a completed Plant Clinic specimen data form. These forms are available at your nearest University of Illinois Extension office, or online at http://w3.aces.uiuc.edu/CropSci/Research/clinic/clinic.html. Do not add moisture to the branch sections, but do protect them from excessive heat and from drying out. Fresh branch sections should be mailed to the Plant Clinic, 1401 W. St. Mary's Road, Urbana, IL 61802. There is a charge of $12.50 per sample for culturing. Include a check, payable to the University of Illinois, with the elm-branch sections. The results of the laboratory diagnosis will be mailed as soon as they are known. The process usually takes one to two weeks of lab time.

HOW SPREAD OCCURS

The DED fungus is transmitted from a diseased to a healthy tree by elm bark beetles and root grafts between adjacent trees or by contaminated pruning tools.

Bark Beetles

In Illinois, the predominant DED vector is the smaller European elm bark beetle (*Scolytus multistriatus*). The adult beetles are attracted to weakened, dying, and recently killed elm trees, where they breed and bore into the bark to lay their eggs. The following spring, adults emerge from infected wood, carrying spores of the DED fungus in and on their bodies. The adults fly a short distance (usually less than 500 feet) to feed in twig crotches of healthy elms, where they introduce (inoculate) spores of the DED fungus into the upper crown. The beetles may also be attracted to fresh wounds (e.g. from pruning or injury) and can "hitchhike" long distances on all types of vehicles, trains, and other forms of transportation.

Root Grafts

Roots of the same or closely related tree species growing near one another often become intertwined and fused (grafted). If one of these trees becomes infected, these root grafts serve as natural “pipelines” for the DED fungus to spread, below ground, to the healthy tree. Where the disease is active and elms are planted close together (e.g. along a city street or boulevard), preventing the spread of the fungus through root grafts should be an important part of a control program.

Pruning Equipment

Although not a major means of infection, the use of contaminated tools may contribute to the spread of the disease. Therefore, it is recommended that any pruning or other tools that have come into contact with diseased trees be (1) cleaned of wood fragments, (2) soaked for several minutes in a disinfectant such as household bleach (diluted to one part bleach to five parts water), and (3) rinsed in clean water before being used on healthy trees. Rubbing alcohol or dilute Pine-sol are also effective disinfectants that are far less corrosive to the tools.

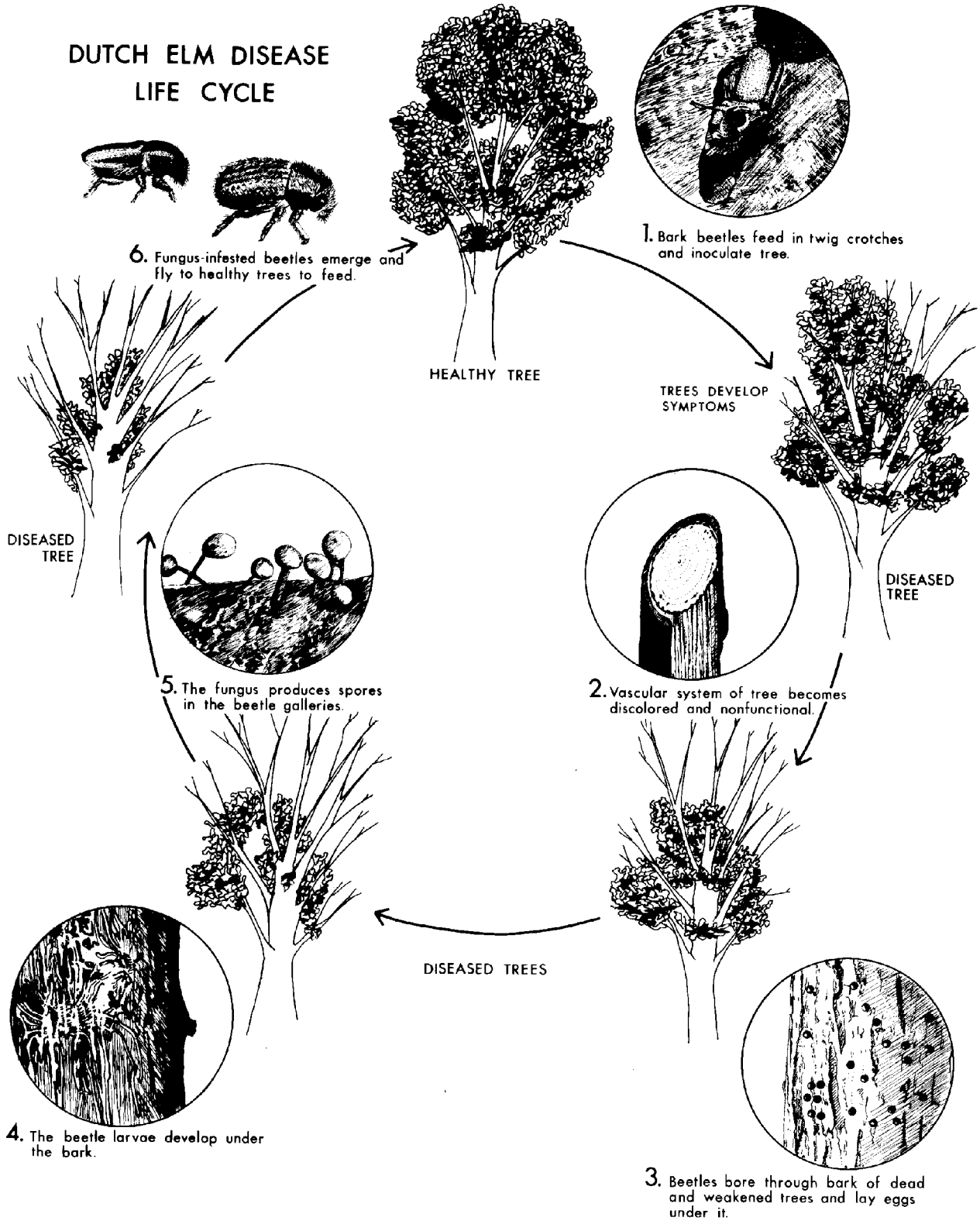


Figure 3. Dutch elm disease life cycle (drawing by Lenore Gray).

DISEASE CYCLE

As shown in Figure 3, the fungus mycelium grows in the bark beetle galleries and successively produces two spore stages, the asexual and sexual types. When hyphal cells from different mating or compatibility types come in contact, the sexual stage, which results in the production of perithecia and later ascospores, is formed. The sexual stage of the DED fungus is rarely observed. Both asexual and sexual spore types, produced in the galleries, contaminate elm bark beetles before they emerge through the bark.

The overwintering larvae (grubs) in the bark of recently dead or weakened elm wood pupate and then start to emerge as adults from galleries in the inner bark about the time elms break dormancy in early spring. The microscopic spores (conidia and ascospores) of the DED fungus are produced in slimy drops, carried on and in the bodies of the beetles, often in tremendous numbers, and are introduced into the water-conducting vessels of a susceptible healthy elm by the beetles feeding primarily in the 1- to 3-year-old twig crotches in the upper crown.

As the fungus grows in the water-conducting cells, it produces toxins that in turn induce the tree to form gums and tyloses which plug the cells. As a result, the flow of water from the roots to the foliage is greatly restricted. The fungal infection induces browning of the water-conducting vessels (Figure 2), probably through enzymatic oxidations of substances released by the elm tissues in reaction to toxic fungal secretions.

Elm bark beetles are attracted to weakened, dying, and recently killed elm trees, where they bore into the bark and lay eggs in the inner bark. The beetles emerge from infected wood with spores of the DED fungus on and in their bodies. The emerged beetles fly to nearby healthy elms where they feed on and inoculate healthy trees. They feed on living elms for only a short period before flying to dying or weakened elm wood where they breed, construct new brood galleries, and lay tiny, pearly-white eggs, thus completing the disease cycle. The beetle completes two or more generations (from egg to adult beetle) each year. Once a beetle becomes contaminated with fungus spores, it can carry the spores to both healthy and dying wood. Because the DED fungus can grow in both healthy and dead wood, it contaminates all the offspring of the elm bark beetles as well as other insects that visit the infected wood.

MANAGEMENT

As shown in Table 1, there is now a good selection of DED-resistant or tolerant varieties and hybrids to choose from, several will also develop the desirable vase-shaped form upon maturity. In addition to plant genetics, the growth rate of a tree can influence its susceptibility to DED. Experimental inoculations of elms often fail if the trees have slowed or ceased terminal growth, a situation that occurs during mid to late summer in field grown trees. Thus, a number of authors have suggested that vigorously growing trees are generally more susceptible to DED than slower growing trees. Increased susceptibility may be due to the larger water conducting elements that are produced in the spring. Plants "react" to pathogens in various ways. With the DED pathogen, an elm reacts by plugging the vascular elements which, in turn, limits internal spread of the pathogen. Simply stated, vigorous growth promotes large vessels which are more difficult to plug.

Several different biological-based products (e.g., "Dutch Trig" and "Elm Vaccine") are currently being

studied for their ability to protect elms against DED. Essentially, these products are preventatively injected into elms where they trigger the elm tree's own natural resistance. While the sponsoring companies claim encouraging results, we await peer-reviewed research reports and marketing of the commercial products in the US.

For a number of reasons, the use of insecticide sprays to suppress early-season beetle populations has become quite uncommon over the years. While you may find insecticides that may legally be sprayed on elms to control elm bark beetles, the University of Illinois Extension does not currently recommend such applications.

At present, the most effective means of combating DED is a community-wide program that integrates: 1) sanitation measures; 2) pruning out infected branches; 3) preventing transmission through root grafts; and 4) for particularly valuable trees, injecting a systemic fungicide into the base of the trunk.

SANITATION

Sanitation is the foundation of any community DED control program; without it, other actions are almost valueless. Basic to a good sanitation program is making systematic ground surveys throughout the growing season to detect symptoms early. All elm wood (including that from DED-resistant trees) from infected trees and all prunings from healthy trees should be promptly burned, buried a foot or more deep, or debarked to prevent the emergence of beetles or the colonization by beetles. All weakened, dying, and dead elms, together with their stumps, should be included. When stump removal is impractical or must be delayed, the bark should be completely removed and burned. A successful sanitation program requires a year-round, community-wide effort. All injured, weak, beetle-infested, and dead elm wood (with tightly attached bark) in trees or on the ground, including fireplace wood, should be eliminated before trees leaf out in early spring. Good tree maintenance - which includes periodic pruning and thorough watering during extended dry periods - will help promote healthy elms.

PRUNING

If a new, upper-crown DED infection is detected early enough, the DED fungus can be eradicated from the tree by pruning out the diseased limb or limbs. While this can be a fairly aggressive procedure, it can be quite successful. Such pruning is most likely to work when less than 5% of the crown is affected. Since infection the fungus may be further down the branch than symptoms indicate, it is important to peel off the bark of infected branches and locate the streaking, which indicates the presence of the fungus. Remove each infected branch at least 5 feet (preferably 10 feet) below the point where you last found streaking. Be sure to disinfect pruning tools, as previously described, before making cuts. Although pruning paints/sealants are no longer recommended because they can prolong the healing process, they should be used whenever elm branches are cut during the growing season, and especially during spring and early summer when the trees are most susceptible to infection. Late season infections have been known to occur as the beetles are active all season. Researchers and practitioners tend to agree that pruning out of infected branches is more likely to be effective if augmented by injection with a systemic fungicide.

ROOT GRAFT CONTROL

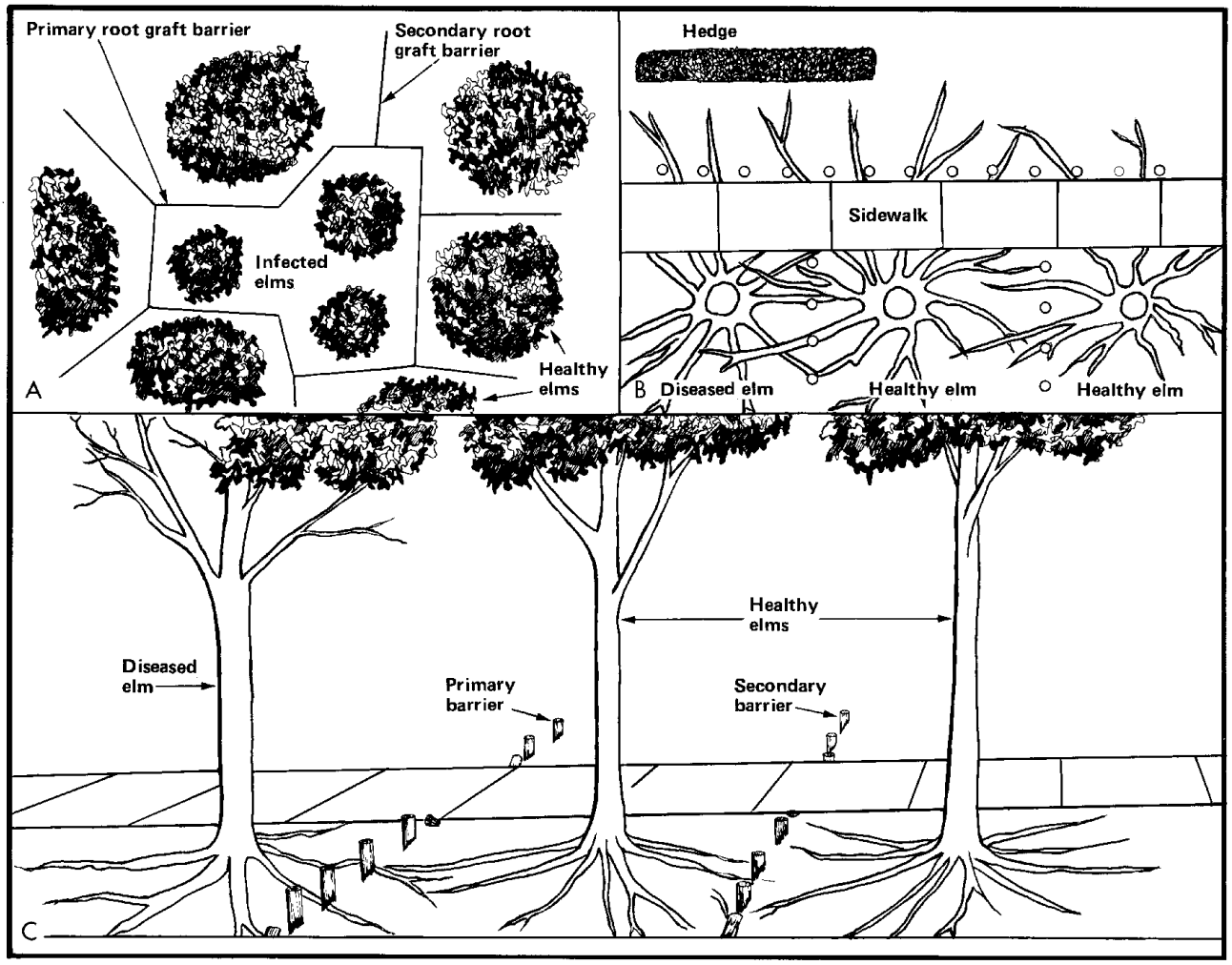


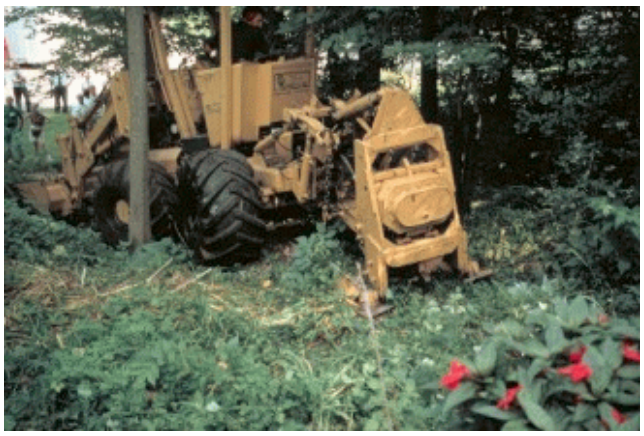
Figure 4. Typical root graft barrier installations to stop underground spread of DED: (A) Fumigation lines or soil trenches to isolate infected elms; (B) Two different patterns of applying Vapam. The rows of circles represent points where the soil fumigant is injected. If the diseased elm is showing more than 10 percent advanced wilt symptoms, it may be necessary to apply a second barrier between the first and second healthy trees; (C) Primary secondary barriers (fumigation lines) where Vapam solution is applied to the soil.

Large elms growing within 25 to 50 feet of each other are likely to have root grafts. All possible root grafts between healthy and suspect or infected trees should be severed mechanically or chemically before the diseased trees are removed. These two methods are described below - choose the best method for the particular situation. You should work with a experienced forest pest specialist, forester, or consultant trained in DED management to determine the location of barriers. In addition, before placing any type of barrier, it is important that you call JULIE (800-892-0123) or, in the Chicago area, DIGGER (312-744-7000). These folks will arrange to have your underground wires, pipes, etc. located and marked within 48 (business) hours after your request. While it is important that you sever root grafts as soon as possible after a DED diagnosis, do it right and don't be careless.

Where there is a mixture of diseased, suspect, and healthy elms, you should make two barriers – one between the healthy and suspect trees and another between the suspect and diseased trees (Figure 4).

If you plan to mechanically disrupt the roots, be on the cautious side and make the barriers in the above order. Also plan to check that the disease has not crossed over barriers in subsequent years. The goal is to sever all roots to a depth of 3-5 feet in a line midway between the two trees. Experience and limited research indicates that deeper (4-5 feet) barriers are more effective than shallow barriers. When sidewalks, driveways, curbs, or other obstacles prevent establishing a completed barrier, extend the barrier along the obstruction and sever all root connections.

Figure 5. A. Vibratory plow operating in tight conditions. B. Sod being repositioned after tree roots were disrupted by a Vibratory plow.



In residential areas, infected trees commonly involve more than one homeowner. For best results, all homeowners in the neighborhood must: 1) be informed; 2) understand the necessity of establishing barriers regardless of property boundary lines; and, 3) carry out a continuing neighborhood-control program.

(A) **Cut the roots mechanically**. While neither method is foolproof, it has been shown that mechanical barriers are much more effective than chemical barriers. Any trenching machine or vibratory plow (sold by Ditch Witch or Vermeer or other companies) that will cut or break the roots to a depth of 3-5 feet (see above discussion) can be used. Many practitioners prefer to use a vibratory plow (Figures 5 and 6) because it slices through the soil and does not require backfilling. Root-cutting equipment is commonly available from a local forester, commercial arborist, utility company, or irrigation installation company. However, it may be difficult to find a vibratory plow with a shank longer than 3 feet (5 foot shanks can be custom-built). The trenching technique is not suitable near sidewalks, driveways, buried pipes, power lines, or telephone cables. In those situations, chemical treatment might be necessary.

(B) **Kill the roots chemically**. Metam sodium (sold as Metam Sodium or Vapam) will kill segments of grafted roots. Fumigants are restricted-use pesticides so they must be applied by a licensed pesticide applicator who has been trained in their use. Typically the fumigant is placed into 1-2 inch-diameter holes drilled 18-24 inches deep and spaced 4 to 6 inches apart. The fumigant diffuses into the soil to various degrees and kills all roots (including grass and other plants along a strip about 18 inches wide), blocking the spread of the DED fungus from diseased to healthy trees. **Because they are inherently dangerous, difficult to apply properly, costly, and less effective than mechanical barriers, fumigants should only be used as a last resort.**

Note: Do not use metam-sodium within 8 to 10 feet of healthy trees and within 3 feet of shrubs. The treatment will kill a small circle of turfgrass around each hole. The turf can be reseeded or sodded in two

or three weeks. If left alone, the turf usually recovers in the next year. Two weeks after fumigation, all diseased trees should be removed and burned or buried.

Fungicide Treatment for High-value Elms

Researchers and practitioners continue to investigate the use of systemic fungicides in an attempt to provide safe, long-lasting protection against DED. While there are a number of fungicides in or entering the DED-control market (Abasol, Alamo, Arbotect 20-S, Eertavas, Elm Fungicide, Fungisol, Imisol, Phyton 27, and Tebuject), a recent literature review by Stennes and Haugen (Plant Disease Quarterly 1999 20[2]:29-38) points to Arbotect 20-S and Alamo as being the most effective and well documented products for use against DED. Both Arbotect 20-S and Alamo are labeled for use as preventative and therapeutic injections. Certainly, preventive injections are more effective and reliable than therapeutic injections. However, keep in mind that fungicides move primarily upward upon injection and therefore are not effective against infections that come from root grafts.

Compared to Alamo, Arbotect 20-S carries a somewhat higher risk of causing phytotoxicity (tissue damage) to the injection site and crown. However, this risk may be offset by the fact that Arbotect 20-S is known to last longer in elm than Alamo, providing protection for up to three growing seasons in northern climates. While Alamo can be applied using the newer "micro-injection capsules", most practitioners prefer the traditional "macro-injection" (or root flare) technique. The drawback to using any of the current fungicides is cost (typically $300 or more per tree) and the need for re-treatment in one to three years. In addition to the cost of treatment, there is still the issue of risking tree health due to many years of injections. While there are many trees that have been safely injected over a period of 15 to 20 years, there are cases where trees have been essentially girdled due to too many injections. Thus, fungicides are suggested only where high value trees are in danger and only when used in conjunction with a good community wide sanitation and root graft control program.

Tree injections should ONLY be made by trained arborists or others trained in injection techniques and diagnosis of DED. Consult the Illinois Commercial Landscape and Turfgrass Pest Management Handbook (updated annually) for current chemical recommendations.

Table 1. Incomplete list of commonly propagated elms and hybrids with moderate to high levels of resistance against Dutch elm disease.

Elm species or hybrid	Elm Yellows	Elm leaf beetle	Comments
U. americana (American Elm)	Susceptible	Resistant	
'American Liberty'	Susceptible	Resistant	Multiclonal variety composed of six selections propagated by cuttings. Vase-shaped.
'Delaware'	Untested	Resistant	
'Independence'	Untested	Resistant	A named clone belonging to the 'American Liberty' multiclonal variety. Vase-shaped.
'New Harmony'	Untested	Resistant	Vase-shaped. Hardier than 'Valley Forge' (possibly to zone 4).
'Valley Forge'	Untested	Resistant	Vase-shaped.
'Princeton'	Untested		A clone sold by Princeton Nurseries, claimed to be resistant to *O. ulmi*
U. japonica	Variable: susceptible to moderately tolerant	Resistant	Primarily used as a parent in hybrid breeding programs.
U. parvifolia (Lacebark Elm is the preferred name; also called Chinese Elm)	Variable: susceptible to moderately tolerant	Resistant	There are many good cultivars and all have resistance to DED. They also have good resistance to elm leaf beetle, but some may be damaged by low temperatures in zones 4 and 5. Some cultivars are vase-shaped like American elm and others are broader than tall.
U. pumila (Siberian Elm)	Generally tolerant; some are resistant	Susceptible	Resistant to DED and elm yellows but highly susceptible to elm leaf beetle feeding. This species should not be used in the landscape in most locations. Often mistakenly called "Chinese" elm.
U. wilsoniana	Tolerant		
'Prospector'	Perhaps resistant (remained healthy when tested)	Resistant	Smaller than American elm and must be pruned to achieve vase-shape. Hardy in USDA zones 4-7.
Elm hybrids			
'Accolade'	Untested	Resistant	*U. japonica* x *U. wilsoniana*. Reported to be resistant to elm leaf miner. Vase-shaped.
'Cathedral'	Untested	Susceptible ?	*U. pumila* x *U. japonica*. Reported to be highly tolerant to Verticillium wilt and resistant to elm leaf miner. Broad vase shape.
'Triumph'	Untested	Resistant	Hybrid between 'Accolade' and 'Vanguard'
'Danada'	Untested	Susceptible	*U. japonica* x *U. wilsoniana*. Vase-shaped.

'Frontier'	Moderately tolerant	Resistant	*U. carpinifolia* x *U. parvifolia*. Some winter damage has been reported in the Great Plains region. Pyramidal shape.
'Homestead'	Apparently resistant	Susceptible	Multispecies hybrid. Probably not suitable where elm leaf beetle is a problem. Vase-shaped with age. Hardy in USDA zones 5-8.
'New Horizon'	Untested	Susceptible	*U. japonica* x *U. pumila*. Reported to be resistant to Verticillium wilt and elm leaf miner.
'Patriot'	Moderately tolerant	Resistant	Cross between 'Urban' and 'Prospector'. Must be pruned to achieve vase-shape. Considered cold-hardy through USDA zone 4.
'Pioneer'	Susceptible	Susceptible	*U. glabra* x *U. carpinifolia*. Probably not suitable where elm leaf beetle is a problem. Broad, spreading habit. Hardy in USDA zones 5-8.
'Regal'	Untested	Susceptible	Complex hybrid. Reported to be highly tolerant to Verticillium wilt. Pyramidal shape. Hardy in USDA zones 4-7.
'Sapporo Autumn Gold'	Untested	Susceptible	*U. pumila* x *U. japonica*. Reported to be highly tolerant to Verticillium wilt. Vase-shaped with age. Hardy in USDA zones 4-8.
'Urban'	Untested	Susceptible	Pyramidal shape. Should not be used in areas where elm leaf beetle is a problem.
'Vanguard'	Untested	Susceptible ?	*U. japonica* x U. *pumila.*

Susceptible = 1) Dies when infected with Elm Yellows; 2) Comparatively high elm leaf beetle damage.
Tolerant = Susceptible to Elm Yellows, but capable of sustaining satisfactory growth and appearance.
Resistant = 1) Resists pathogen infection and/or internal spread; 2) Comparatively low elm leaf beetle feeding damage.
Immune = Completely unaffected by the pest (no infection or feeding; this descriptor is not used in this table).

This table was adapted and revised from "Dutch Elm Disease" (PP01-4/98) written by Dr. Ned Tisserat, Kansas State University Extension (www.ksu.edu/plantpath/extension/facts/tree3.html).

Special thanks to Dr. Wayne Sinclair (Cornell University, Ithaca, NY), and to Dr. Karel Jacobs and Dr. George Ware (The Morton Arboretum, Lisle, IL) for their comments and guidance during the revision of Table 1 and other parts of this document.