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THE DUTCH ELM DISEASE

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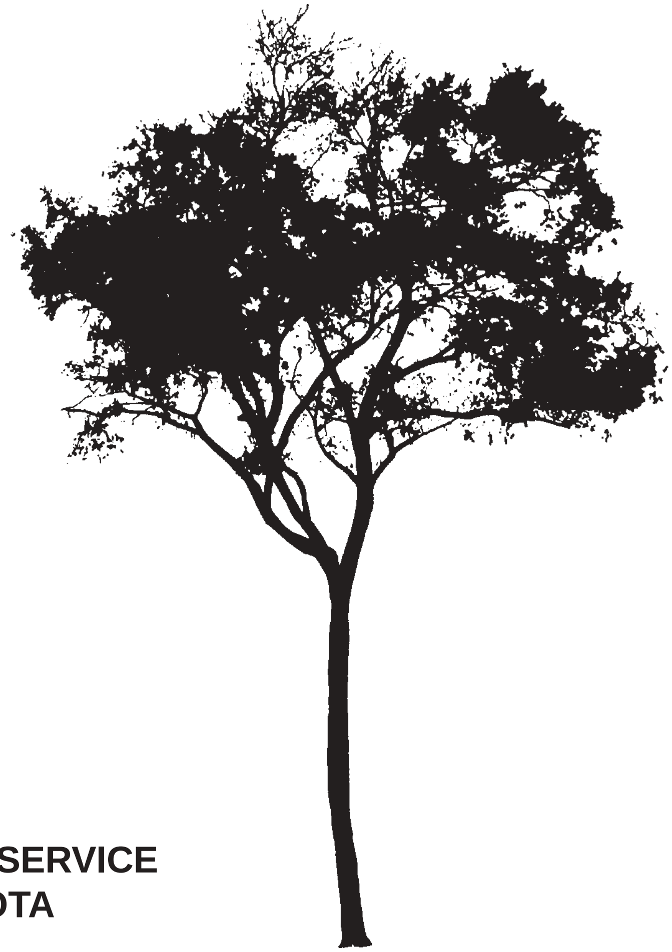

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All species of elms native to North America are susceptible to Dutch elm disease. The most common elm species is the American elm, *Ulmus americana*, occurring naturally over most of the eastern United States from southern Canada to central Florida and west to the Rocky Mountains. It has been extensively planted, will grow in a wide variety of soils, and tolerates a wide range of soil moisture. Some of the European selections are more resistant than the American elm. Siberian elm, *Ulmus pumila*, which has been planted in shelter belts and as a shade tree, is less susceptible but not immune to Dutch elm disease.

Dutch elm disease, as the name implies, was first described in the Netherlands in 1919. It spread rapidly in Europe and by 1934 was found in most European countries and the British Isles. In 1930 four diseased trees were found in Ohio. *Ophiostoma ulmi (formally Ceratocystis ulmi)*, the fungus which causes this disease, had been introduced to the United States from Europe in logs which contained both the fungus and the smaller European elm bark beetle. The European elm bark beetle, however, had been reported in Massachusetts as early as 1909.

Minnesota's first case of Dutch elm disease was found in St. Paul in 1961. Later the same year, seven infected trees were found near Monticello, 40 miles northwest of St. Paul. Through the 1979 season, the disease was reported in 82 of Minnesota's 87 counties, with only the Northeastern and Northwestern corners of the state reporting no disease. The disease is more abundant in the southern third of the State. In all, Minnesota has lost between 10 and 20 percent of its 140 million elms to the Dutch elm disease.

Symptoms

The first evidence of the disease generally is wilting or flagging in one or more of the upper branches. Leaves on affected branches turn dull green to yellow and curl, then become dry and brittle, and turn brown. Some trees die several weeks after becoming infected; others wilt slowly and survive for a year or longer. Systemic infection (fungus present in large sections of the tree) may result in wilting, as well as dead and dying shoots along the infected limbs. Peeling bark from wilted branches reveals light to dark brown streaks or solid blue to gray discoloration of the wood beneath the bark (figure 1). In cross section this appears as a brown discontinuous ring in the outer sapwood of the wilting, dead, and dying branches. Although other fungus diseases and wounds can cause similar discoloration, when Dutch elm disease is prevalent, then such discoloration is sufficient evidence of Dutch elm disease for sanitation measures to be initiated immediately.

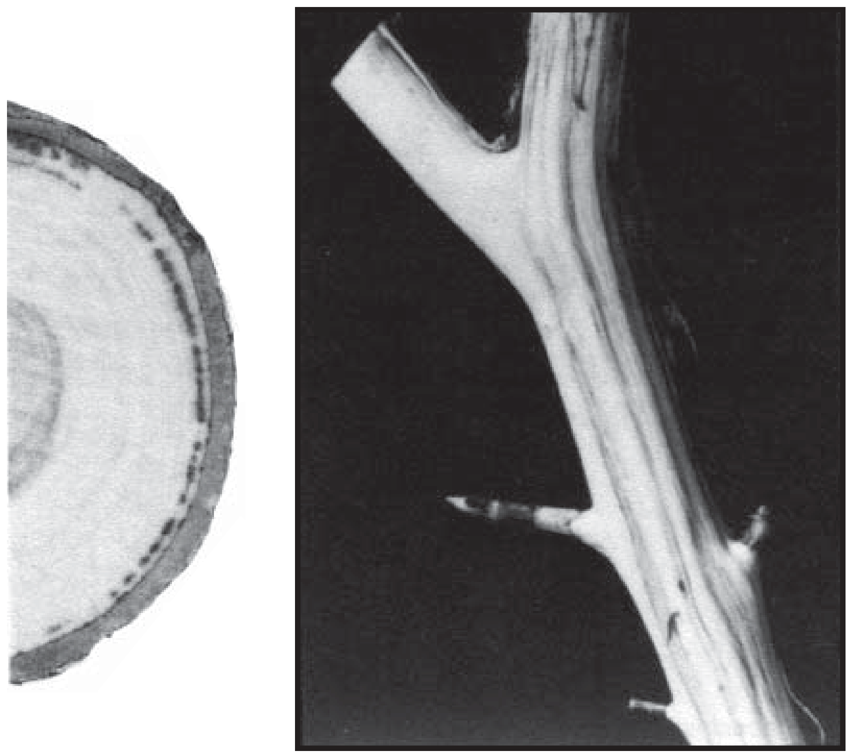


Figure 1. This cross section and stripped elm branch show the discoloration beneath the bark which can mean Dutch elm disease.

When positive identification of the disease is required, diseased portions showing vascular discoloration can be laboratory tested for the presence of the Dutch elm disease fungus. Samples should be about 1/2-inch diameter, 5-10 inches long, and must be from the branch which is wilting (the fungus cannot be isolated from dead, dried branches). Samples may be sent to:

Dutch Elm Disease Laboratory
90 West Plato Boulevard
Division of Plant Protection
St. Paul, MN 55107-2094

Cause

The fungus *Ceratocystis ulmi* invades and grows in the water conducting vessels of elms, inducing the host tree to produce tylosis (growths) and gums which, together with the fungus, plug the vessels, preventing water uptake. This causes the tree to wilt and die.

Fungus Transmission by Beetles

In the U.S. the fungus is spread by the smaller European elm bark beetle, *Scolytus multistriatus*, and the native elm bark beetle, *Hylurgopinus rufipes* (figure 2). The European beetle is the primary vector (disease carrier) in the southern portion of Minnesota, including the Twin Cities, while the native beetle is the major vector in the northern portion of the state.

Native and European elm bark beetles use dead or dying elms for breeding. In areas where disease is present, most dead elm wood is already infested with the Dutch elm disease fungus. Beetle breeding tunnels in infected wood become filled with fungus spores, resulting in contamination of the bark beetles. Emerging adult beetles carry fungus spores inside and outside their bodies. Thus, when beetles breed in infested elm material, it is the first step toward the spread of Dutch elm disease to healthy trees.

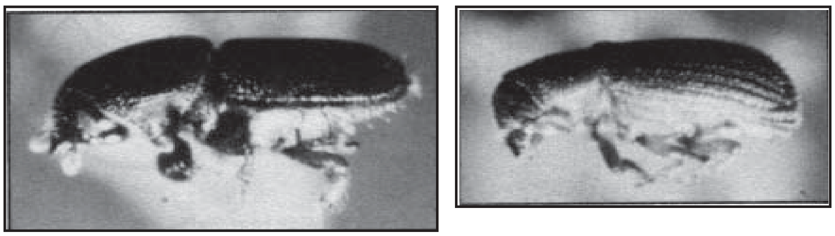


Figure 2.
European elm bark beetle (left) and native elm bark beetle (right). Both are about 1/8 inch long.

The second step occurs when the beetles feed on healthy trees. The European beetles fly to healthy elms during this phase and feed in small twig crotches, and the native beetles feed on larger branches. The water-conducting vessels (the xylem) are exposed to the beetle-carried spores as the insects feed through the bark. The tree responds to the fungus by plugging its vessels. This defense mechanism results in flagging (wilting) of one or more of the upper branches. Once established, the fungus can move throughout the tree's water-conducting system, resulting in systemic infection. The initial fungus spread, however, is often relatively slow and on occasion may not become systemic. Such slow-developing infections are not very apparent until the fungus moves into the larger branches and rapid wilting occurs.

Fungus Transmission Through Root Grafts

The fungus also can spread from tree to tree through root grafts (roots naturally fused together), especially if spacing is less than 30 feet between elms. Root grafting may occur between larger trees up to 60 feet apart (figure 3.) Death of a tree infected through root grafts is much more rapid (a few weeks or less) than that caused by beetles.

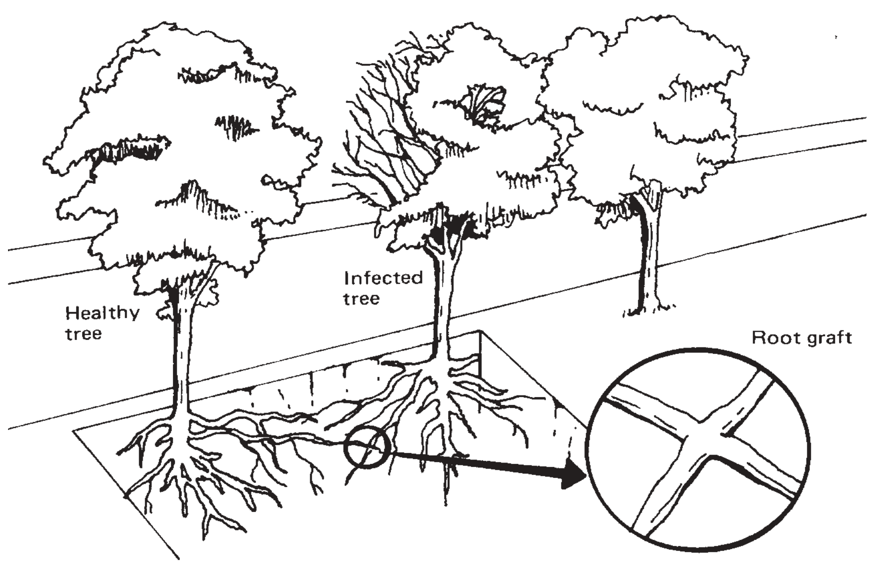


Figure 3. The Dutch elm disease fungus can spread through root grafts.

BEETLE LIFE CYCLE

European Elm Bark Beetle

The European elm bark beetle overwinters in the larval stage under the bark of dead or dying elm wood. Pupation occurs in spring and adult beetles emerge in June. Cool weather may delay emergence. After emergence, the adults fly to nearby elm trees to feed in the crotches of small branches. It is during feeding that fungus spores can be introduced into the large springwood (water-conducting) vessels of healthy trees (figure 4). If the tree encountered is not an elm, the beetles do not feed but continue to fly until an elm is reached or until they die. In this way the beetles and the fungus are occasionally dispersed up to several miles. After feeding in healthy trees, the adult beetles seek suitable breeding sites under the bark of recently dead or dying elm trees or logs. Elm trees or logs dead for reasons other than Dutch elm disease can serve as suitable breeding sites. Adults burrow into the bark and excavate tunnels for egg laying in the soft inner bark and adjacent wood. The egg tunnels of the European species run parallel to the wood grain. Eggs hatch and larvae feed at right angles to the egg-laying tunnel to produce a characteristic pattern (figure 5).

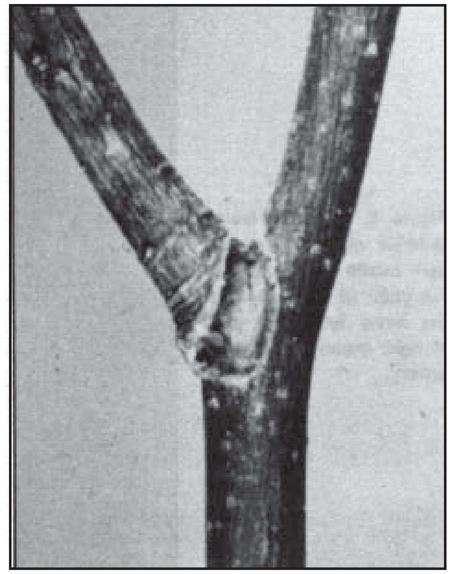


Figure 4. Eurpoean elm bark beetles feed inside the crotch of the branch, spreading the fungal spores of Dutch elm disease

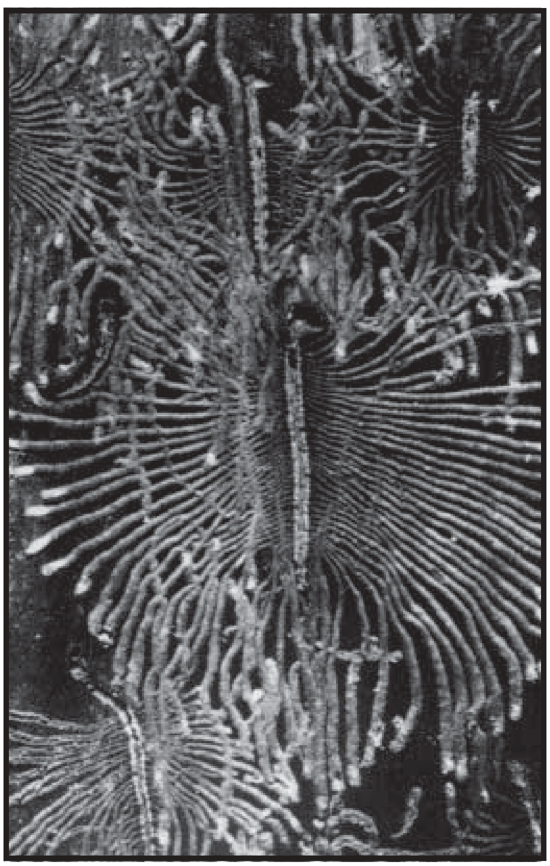


Figure 5. The egg-laying galleries of the European bark beetles run parallel to the grain of the tree, with the larval feeding tunnels at right angles to the main gallery.

A second generation of adult beetles is produced in July, August, or September, with the time of emergence depending on when the eggs where laid, the moisture content of the wood, and weather. Trees with severe wilt after spring leafing are capable of producing second generation adults by July 15. Slow-wilting trees and trees infected later in the season produce beetles later in the summer. However, conditions within a tree vary, making it possible for more than one group of second generation adults to emerge from the same tree. After emergence, the second generation adults, like their first generation counterparts, fly to healthy trees to feed. After feeding, the second generation adults seek elm material suitable for breeding to construct egg-laying tunnels. Some of the resulting larvae will become the overwintering population; others, because of favorable weather, produce a partial third generation of adult beetles in October (figure 6).

Native Elm Bark Beetle

Native elm bark beetles in Minnesota normally have one generation a year and overwinter as adults. However, they can overwinter as larvae (grubs) where beetle population levels are high and brood wood is abundant. Thus sanitation programs appear to force the beetle to winter as an adult.

Native adults overwinter in bark or bark crevices of elms, often within the first six inches at the base of healthy elm trees. They become active in April as the weather warms and some may seek healthy elms for feeding, an important factor in early-season disease transmission. But some seek dead and dying elm material for breeding. As with the European elm bark beetles, this wood does not have to be diseased. Eggs are laid in tunnels the adults excavate under the bark. Unlike those of the European species, these tunnels run across the wood grain. Grubs feed at right angles to the egg tunnels, producing characteristic galleries. Adult beetles emerge in July and August and may fly to healthy elms to feed on the bark of larger branches (4-10 inches in diameter). It is during this feeding phase that healthy trees can be inoculated with fungus spores. By late September the adults seek locations on healthy elms, near the ground, to spend the winter (figure 7).

Under conditions of large populations and an abundance of elm breeding wood, approximately 1/3 of the native population is capable of starting a second generation that overwinters as larvae. Overwintering native larvae, like European larvae, are found in galleries under the bark of dead and dying elm material. Pupation occurs in the spring and adult beetles emerge in June, fly to healthy elms to feed, and then find dead or dying material for breeding. Galleries are constructed, eggs are laid, and the resulting larvae produce an overwintering generation of adults.

In southern Minnesota, where native and European beetles coexist, the native tends to be found in parks, woods, and along rivers, and less frequently on boulevard trees. In northern Minnesota, where native elm bark beetles predominate, they are found on boulevard trees as well as in wooded areas.

MANAGEMENT

The primary emphasis in a Dutch elm disease management program is preventative action. The basic elements are:

1. Detection. The systematic inspection for Dutch elm disease of every elm in a control zone (that area defined by the community as a Dutch elm disease management area) and the detection of all dead elm wood, including firewood piles.

2. Isolation. The disruption of root grafts between infected and healthy trees.

3. Removal. The prompt elimination of all dead and dying elm material from the control zone.

4. Disposal. The destruction (burning, burying, chipping, debarking) of elm material with intact bark.

These measures, collectively called sanitation, are the key to successful management of the disease. They can significantly limit the spread of the disease. Other management techniques include pruning of early infections, spraying insecticide, and injecting fungicide.

Importance of Sanitation

The purpose of sanitation is to remove elm bark beetle breeding sites and sources of the fungus, so as to limit the spread of the disease. Failure to employ sanitation measures will lead to higher beetle populations and more dead trees.

The need for complete removal of dead and dying elms becomes apparent when one finds that a piece of elm branch the size of a small fireplace log, 22 x 4 inches, can produce up to 1,800 beetles. Left to stand, a complete tree could produce hundreds of thousands of beetles. If this tree is infested with the fungus, each emerging beetle carrying the fungus spores could then inoculate healthy trees during feeding. However, early detection and proper tree disposal prevents ALL these beetles from spreading the disease.

In addition to eliminating the beetle population, sanitation also eliminates a potential reservoir for the disease. The fungus, introduced by contaminated beetles in the breeding phase, can become established in uninfected (nondiseased), nonliving elm wood. Once infested, this otherwise disease-free material becomes a source for continued beetle spread of Dutch elm disease to healthy trees.

Sanitation Timetable

All dead and dying elm wood from the previous year must be properly disposed of prior to April 1 since adult native elm bark beetles can become active on this date. This also guarantees destruction of overwintered larvae of both the European and native elm bark beetles prior to their June emergence (figures 6 and 7).

Figure 6. Life cycle of European elm bark beetle.

Overwintering larvae					Active adults		Larvae (H* / S**)		Active adults	Overwintering larvae	
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

*H-Adults from high-risk trees
**S-Adults from slow-wilting trees

Figure 7. Life cycle of native elm bark beetle

Overwintering adults			Active adults		Larvae	Active adults		Overwintering adults			
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
								Overwintering larvae[1]			

[1]Under certain conditions (high beetle populations, abundant brood wood) native elm bark beetles can overwinter as larvae, which then emerge as active adults the following year by June 1.

Detection of dead and dying elm trees in early June is the next essential step in the sanitation program. Delays caused by attempts to positively detect the presence of the fungus could reduce the effectiveness of the program, by allowing time for infested beetles to emerge. Regardless of the cause of death, the tree is a potential breeding site for contaminated beetles.

Once detected, dead and dying elm trees should be promptly isolated as necessary, removed, and destroyed. However, the epidemic proportion of the disease in many areas creates removal and disposal difficulties that require the wisest and most effective use of resources. These communities will need to concentrate initial efforts on trees which pose the greatest threat and then on trees which are a less serious threat.

High-risk trees are those which have severe or rapid wilt after spring leafing, for they are capable of producing a second generation of European adults by July 15. It is imperative that high-risk trees be removed and disposed of by July 15. Removal by July 15 will also be effective against the native elm bark beetle, which can be found on dead or dying elms until that date. Removal after July 15 will be ineffective against the native, since it is no longer to be found on dead or dying trees.

Slow-wilting trees do not become a hazard until late in the summer, but by then the water-conducting vessels have become smaller and thus are less susceptible to the disease. In sanitation programs with limited resources, slow-wilting trees and trees detected later should be removed as soon as possible over the remainder of the year (prior to April of the following year).

It is important to understand that delays in tree removal and disposal can permit beetle population increases and impair disease management. Therefore, every community should constantly strive for prompt removal and disposal of all dead and dying elms. For those communities without resources for immediate removal and disposal, selective removal and disposal of high-risk trees will produce the best results.

Disposal

Disposal of diseased elms is the final important step in a successful sanitation program. The goal is to destroy the beetles and to eliminate their breeding sites. Burning and burying are the most effective means of disposal but are not productive from the standpoint of wood utilization. Chipping is a good alternative to burning and burying since chipped wood cannot support beetle development. Elm should not be used as firewood unless it has been debarked. All attempts at elm utilization must take into account the primary concern of wood disposal - the timely elimination of beetles and beetle breeding material.

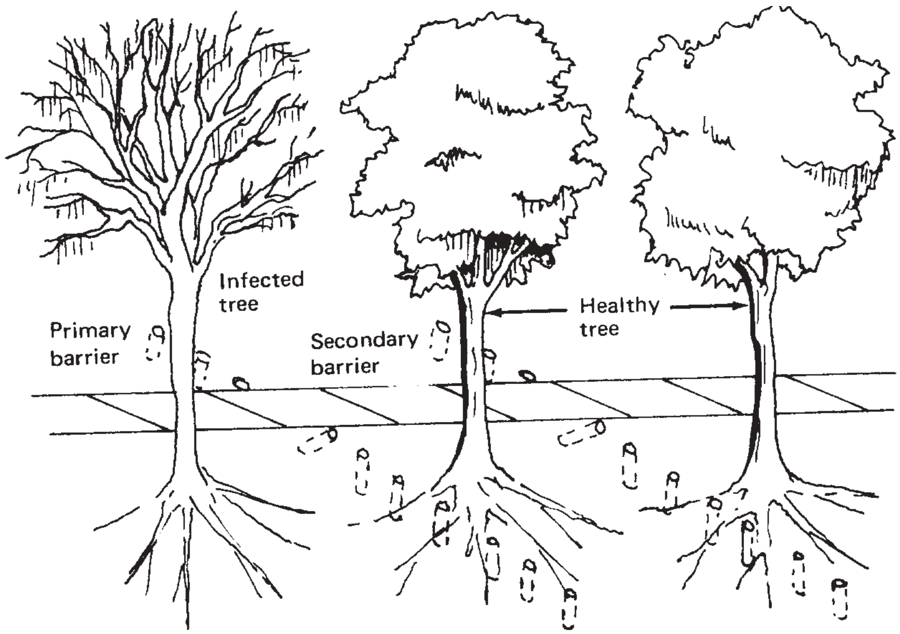
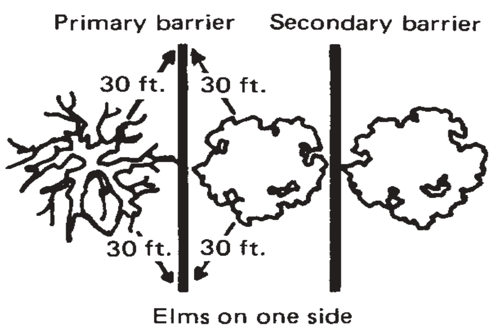


Figure 8. Typical root graft barrier installation.



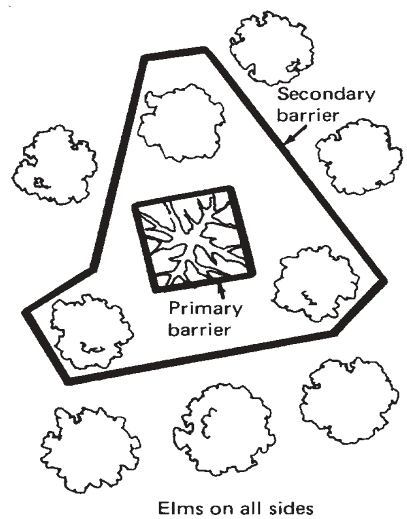


Figure 9. Root graft barriers on one side and on all sides.

Prevention of Root Graft Spread (Isolation)

The fungus causing Dutch elm disease commonly spreads from infected to nearby healthy trees through naturally grafted root systems. This spread can be prevented by isolation of the diseased tree (i.e., by disrupting the root grafts) either by mechanically trenching around infected trees, using a soil trencher or vibratory plow, or by using a chemical, SMDC (Vapam). A secondary barrier is suggested between the trees closest to the diseased tree and the second closest trees, since some apparently healthy trees may already be infected at the time of treatment (figure 8). Root graft barriers should completely encircle the diseased tree when elms are present on all sides. If elms are only on one side, the barrier should extend to a point at lease 30 feet from the diseased tree and from the healthy tree (figure 9).

A trench 36-40 inches deep between diseased and healthy trees immediately disrupts root grafts between these adjacent trees. The easiest way to trench is with a vibratory plow or a mechanical trenching machine, but their use may be limited in rocky soils or where underground utilities are present. After the trench is dug, refill it, and immediately remove the diseased elm trees.

The chemical barrier is established on a line midway between the diseased tree and the adjacent healthy tree and should extend as far as necessary to disrupt all potential root grafts. A series of holes, 15-18 inches deep, 3/4-1 inch in diameter, and 6-12 inches apart, are made along this line. One part of Vapam is mixed with 3 parts water, and 2-8 fluid ounces of the diluted chemical are placed in each hole. Vapam should be applied 2 weeks before the tree is removed. Vapam should not be applied within 8-10 feet of a healthy tree since injury may occur because of root loss and chemical uptake. Soil temperatures below 50^{o}F. and waterlogged soils reduce effectiveness of treatment. Regrowth of roots across the control barrier is not a problem since the diseased tree and its root system die and grafting can no longer take place. Root grafts can occur under sidewalks and driveways; therefore, it is advisable to angle the holes beneath asphalt or concrete to disrupt root grafts. All root grafts must be disrupted if this means of spread is to be stopped.

Pruning Diseased Trees

Early beetle infections can be removed from elm trees. A minimum of 8-10 feet of disease-free wood (no discoloration beneath the bark) below obviously infected branches must be removed. The entire circumference of the branch must be examined to be certain that the fungus has been removed. If elms are pruned when beetles are active, tree wound dressings should be applied to all pruned surfaces more than two inches in diameter. These trees should be examined regularly for any further development of the disease so that they do not become a source of the fungus and beetle. It is very unlikely that the Dutch elm disease fungus can be spread on pruning equipment, but it is advisable to wipe equipment clean when moving from diseased to healthy trees.

Insecticides

Although a few insecticides are labeled for application to the crowns of healthy trees to prevent or reduce insect feeding, they add only a small amount of protection and are not nearly as effective in reducing bark beetle numbers as proper wood disposal. Therefore, this type of application is generally not recommended.

The insecticide chlorpyrifos (Dursban) can be applied to the base of healthy trees to prevent or reduce overwintering by native elm bark beetle adults. It is recommended as a supplement to sanitation in areas where the native beetle is a significant factor in the spread of Dutch elm disease. Dursban must be applied on a community-wide basis to be effective. It is not recommended for individual homeowners. Before spraying is initiated, sampling techniques should be used to determine the presence of the native bark beetle in the area. Details on sampling and application can be found in Minnesota Tree Line 27, *Native Elm Bark Beetle Control*.

Trunk spraying does not affect the European elm bark beetle because it overwinters as a grub in dead or dying elm wood and not as an adult at the base of healthy trees. The best method for controlling elm bark beetles that overwinter as larvae (grubs) is sanitation - promptly removing and disposing of brood wood.

Fungicides

Systemic fungicides, when properly administered, will protect healthy elms from infection and will cure trees in an early stage of beetle infection. Benomyl (Lignasan BLP or Corex) and thiabendazole (Arbotect 20-S) have been approved for elm tree injection. Of the two chemicals, Arbotect 20-S is the most effective because it may provide protection for two and possibly three growing seasons and can save diseased elms not infected via root grafts, provided the infection is in an early stage, the chemical distribution is complete, and the dosage is adequate.

Complete distribution of the chemical can be achieved with a root flare injection below grade with two injection sites per inch of trunk diameter (hole diameter: 3/16 to 5/16 inch). Elms can be injected when they have leafed out fully but should not be treated before June 1. Best long-term protection results from treatments administered after July 1. Effective use of either chemical is expensive and injurious to the tree. Injection is recommended only for highly valued trees, and then only if the tree is in imminent danger of becoming infected. Therapeutic treatment of trees with minor infections, less than 5 percent of the crown, may be the most cost-effective. Step-by-step instructions for injecting fungicides are provided in Extension Folder 504, *How to Inject Elms With Systemic Fungicides*. Although promising and useful in certain situations, systemic fungicidesmust be viewed only as an aid. Sanitation - removal of dead and dying elms - is the key to Dutch elm disease management.

DETECTION METHODS

Ground Survey

Ground survey crews, able to work in most weather conditions, will detect a high percentage of the disease trees, which can be marked for removal. These crews should be able to recognize early symptoms of Dutch elm disease and understand how it is spread. They can observe more of the elm crown if the area to be examined is approached from several different directions rather than following the same pattern on each survey. Weekly surveys during June, July, and early August will detect most diseased trees.

Ground surveys are slow and difficult in wild or undeveloped areas. Early infections evident only in the treetops can be missed from below. Ground survey by community residents may be effective as long as there is coordination and leadership. Experience indicates communities cannot depend on every neighborhood to be as effective, efficient, and accurate as is required.

Aerial Survey

Aerial photography results in detection of 50-70 percent of the diseased trees. Advantages of this technique are the speed and low cost of the operation. The lack of accuracy, weather limitations on flying time, problems in mapping locations of diseased trees, and dependence on ground crews to mark trees for removal are disadvantages. Aerial inspection after infected trees have been removed from an area is a good followup method and may detect additional diseased trees.

While aerial photography lacks the accuracy of a ground survey, it does provide an accurate up-to-date map of diseased trees and information on total tree populations. Aerial photography can be done quickly, if weather is suitable and aircraft available. The complexity of aerial photography requires a specialist to insure maximum results. Ektachrome infrared film with a Wratten 12 or 21 filter at a scale of 1:9600 is recommended. Various cameras are available for aerial photography and, although 9-inch is excellent, 70 mm or even 35 mm are suitable.

Aerial photography will be of most value to the community if done in early July when trees are wilting and color contrasts are at a maximum. A second survey should be completed before August 15 to avoid fall coloration or discoloration of foliage due to other causes.

PROSPECTS FOR MANAGEMENT IN MINNESOTA

Excessively cold winters and highly fluctuating spring temperatures may assist in managing Dutch elm disease. An effective sanitation program, however, is absolutely necessary to reduce elm losses.

What your area or neighborhood does greatly determines the future of elms in the control zone. The movement of disease from wild areas outside the neighborhood into control areas is hard to manage and will eventually reduce the population of trees along the common border. But that should not deter efforts to manage the disease within the control zone, since most Dutch elm disease in Minnesota occurs from sources within a control area rather than from outlying wild areas. Wild areas should not be given high priority until the disease in the control zone has been successfully managed.

Resistant Elms

All species of elm are more or less susceptible to Dutch elm disease. Individual trees, especially in the Chinese and Siberian elm group, have some resistance but are not immune. Despite the resistance of Siberian elm, the species is not recommended because it is subject to winter injury and can support bark beetle populations. The resistant elms which have been developed do not have the size or growth form of the American elm. The best alternative is to plant a variety of tree species, other than elm, to avoid future disasters such as Dutch elm disease.

RECOMMENDED TREES FOR MINNESOTA

Soil type, moisture, winter temperatures, and exposure are factors affecting the choice of tree species for replacing American elm. There is no perfect tree for every location in the state, and each species has advantages and disadvantages. All trees may at times be attacked by insects or diseases, but fortunately most are not as serious as Dutch elm disease. Further information about recommended trees is available from Agricultural Extension publications, your county extension office, the Minnesota Landscape Arboretum, and experienced nurserymen. A partial list of available shade trees follows:

Sugar maple *(Acer saccharum)*
Red maple *(Acer rubrum)*
Silver maple *(Acer saccharinum)*
Norway maple *(Acer platanoides)*
Northern pin oak *(Quercus ellipsoidalis)*
Eastern pin oak *(Quercus palustris)*
Northern red oak *(Quercus borealis)*
Ohio buckeye *(Aesculus glabra)*
Kentucky coffee tree *(Gymnocladus dioicus)*
Honey locust *(Gleditsia triacanthos)*
American linden *(Tilia americana)*
Littleleaf linden *(Tilia cordata)*
Ginkgo *(Ginkgo biloba)*
Pagoda dogwood *(Cornus alternifolia)*
Black cherry *(Prunus serotina)*
Ironwood *(Ostrya virginiana)*
Green ash *(Fraxinus pennsylvanica)*
White pine *(Pinus strobus)*
European larch *(Larix decidua)*
Hackberry *(Celtis occidentalis)*
Bigtooth aspen *(Populus grandidentata)*

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