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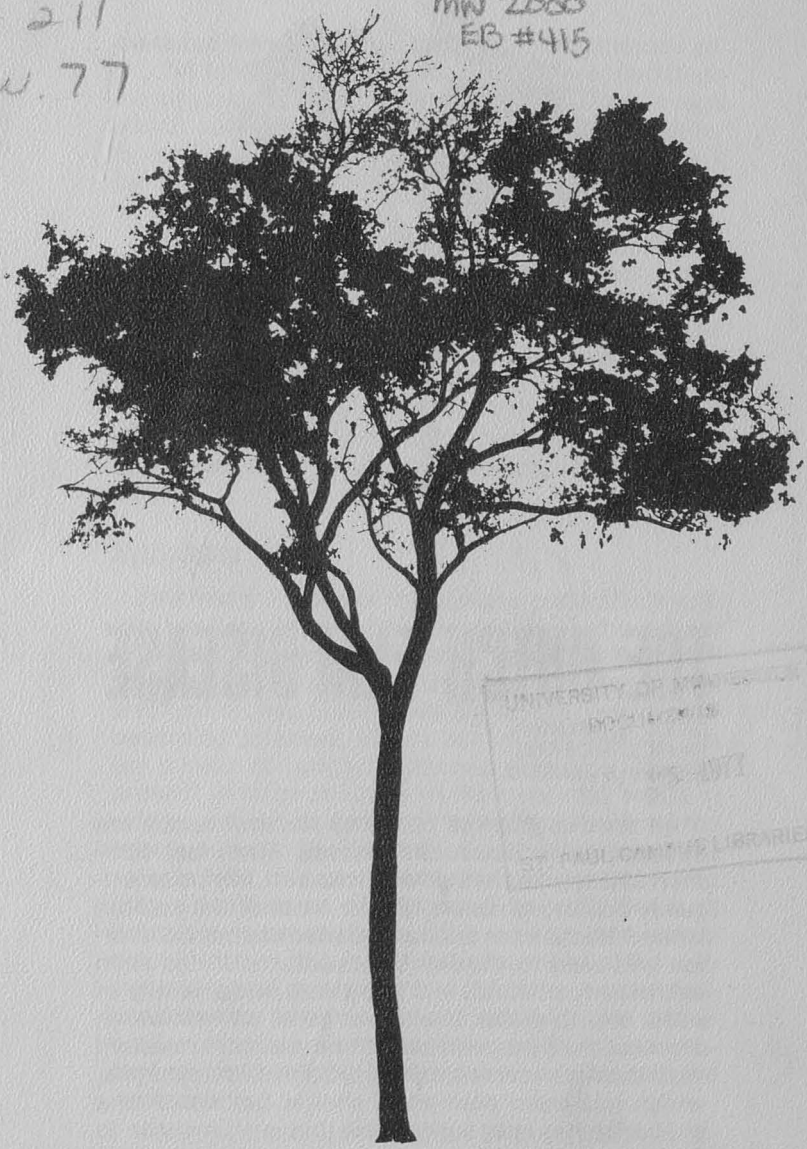
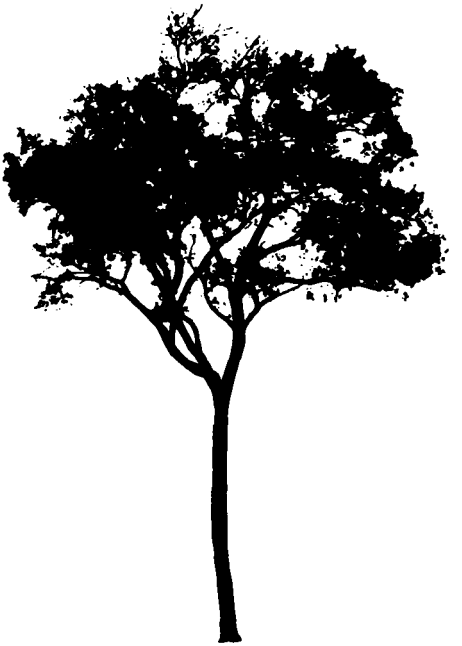


THE DUTCH ELM DISEASE

DAVID W. FRENCH
MARK E. ASCERNO
WARD C. STIENSTRA

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA



THE DUTCH ELM DISEASE

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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

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David W. French is a professor, Department of Plant Pathology. Mark E. Ascerno is an instructor, Department of Entomology, Fisheries, and Wildlife, and extension entomologist. Ward C. Stienstra is an associate professor, Department of Plant Pathology and extension plant pathologist.

diseased trees were found in Ohio. *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 Massachussetts 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 1976 season, the disease was reported in 69 of Minnesota's 87 counties, as far north as Roseau and St. Louis counties. The disease is more abundant in the southern third of the state. Each community should recognize the need to develop a program dealing with diseased trees.

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, 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, this is sufficient evidence of Dutch elm disease so that sanitation measures should be initiated immediately.

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 ½-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
670 State Office Building
Division of Plant Industry
St. Paul, MN 55155

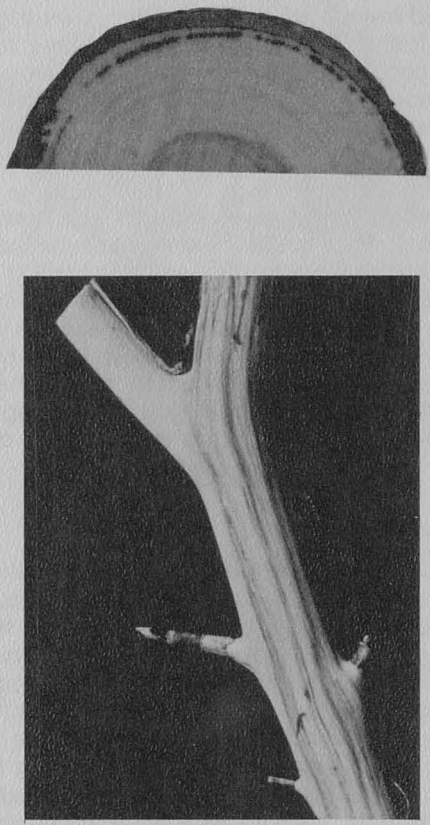


Figure 1. This cross section and stripped elm branch show the discoloration beneath the bark which can mean Dutch elm disease.

Cause—Life History

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

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.* The European beetle is the primary vector 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 (figure 2).

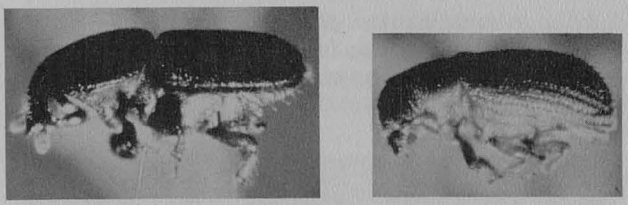


Figure 2. European elm bark beetle (left) and the native elm bark beetle (right). Both adults are about 1/8 inch long.

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 3). 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

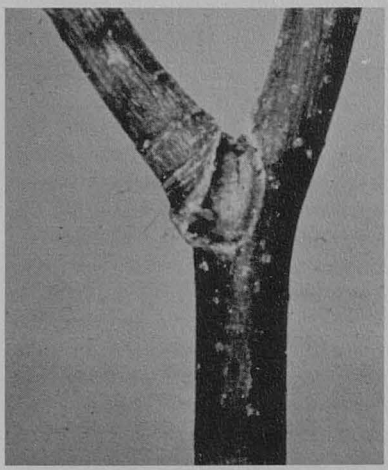


Figure 3. Smaller European beetles feed inside the crotch of this branch spreading the fungal spores of Dutch elm disease.

European species run parallel to the wood grain. Eggs hatch and larvae feed at right angles to the egg-laying tunnel to produce the characteristic pattern (figure 4).

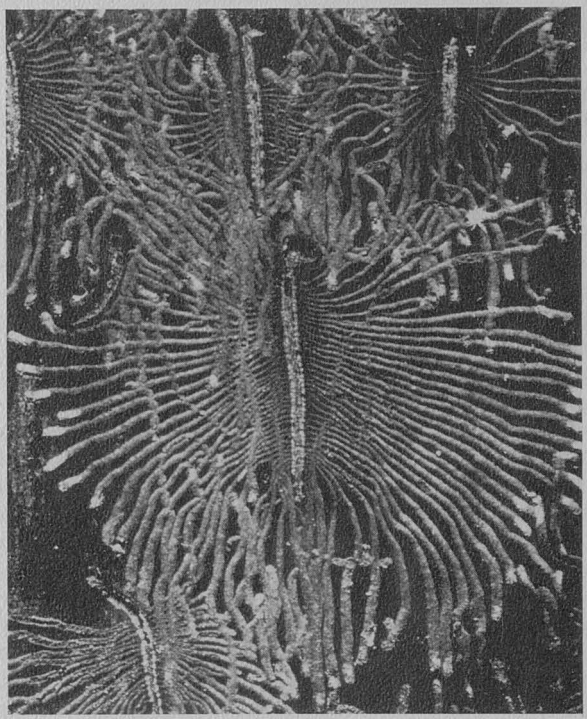


Figure 4. The egg-laying galleries of the European bark beetle run parallel to the grain of the tree and the larvae tunnel at right angles to the main gallery.

A second generation of adult beetles is produced in July, August, or September with the time of emergence depending on when the eggs were 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.

Native Elm Bark Beetle

Native elm bark beetles overwinter as adults and larvae . The preponderance of overwintering individuals in an area may be larvae one year and adults the next. Overwintering native adults hide in bark or bark crevices of elms, often 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 most seek dead or dying elm material for breeding. As with the European elm bark beetle, this wood does not have to be diseased. Eggs are laid in adult-excavated tunnels under the bark; unlike the European species these tunnels run across the wood grain. Larvae feed at right angles to the egg tunnel producing characteristic galleries. A second generation of native adult beetles, produced in July and August, flies to healthy elms and feeds 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. After feeding, the second-generation adults seek dead or dying elms for breeding. The resulting larvae become the overwintering generation. Overwintering native larvae, like the European larvae, are found in galleries under the bark of dead or dying elm material. Pupation occurs in spring and adult beetles emerge in June, fly to healthy elms to feed and then find dead or dying elm material for breeding. Galleries are constructed, eggs are laid, and the resulting larvae produce a second generation of adults in September. These adults, following the usual pattern, fly to healthy trees to feed and in October seek protected locations in or on elm bark to spend the winter.

Fungus Transmission by Beetles

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 internal and external contamination of the bark beetles. Emerging adult beetles carry fungus spores inside and outside their bodies. The occurrence of the breeding phase in infested

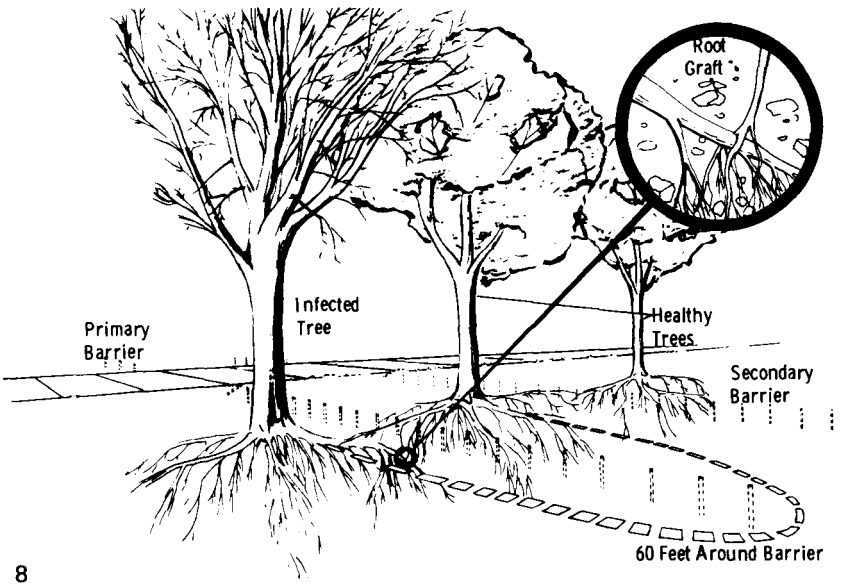
elm material is the first step toward spread of Dutch elm disease to healthy trees.

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 or the xylem of the tree is 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 5).

Figure 5. Typical root graft barrier installations stop underground spread of disease.



Control

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

1. Detection. The systematic inspection of every elm in a control zone for the early symptoms of Dutch elm disease.
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 (burn, bury, chip, debark) of elm material with tight bark.

These sanitation measures are the key to successful management of the disease. Sanitation of dead and dying elm material each year can suppress the disease to minor proportions. Other control techniques are pruning of early infections and insecticide and fungicide applications.

Sanitation

Sanitation includes early detection, isolation, removal and disposal of all weakened, dying and dead elm trees with intact bark. This removes elm bark beetle breeding sites and sources of the fungus. The failure of sanitation 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, 22½ x 3½ inches, can produce up to 1,800 beetles. Left to stand, a complete tree could produce hundreds of thousands of beetles. If this tree was 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.

Sanitation , in addition to eliminating the beetle population, 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.

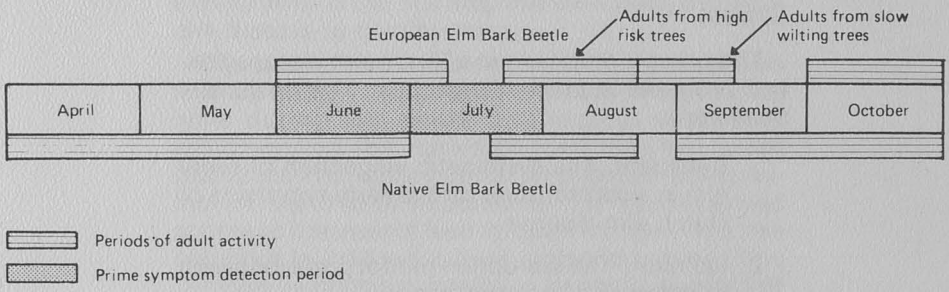


Figure 6. European and native elm bark beetle calendar: periods of peak adult activity.

Implementation

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 (figure 6). This also guarantees destruction of overwintered European elm bark beetles and overwintered native elm bark beetle larvae prior to their June emergence.

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 allow development and emergence of infested bark beetles. This reduces the effectiveness of the disease control program since sanitation is concerned with beetle population reductions.

Once detected, dead and dying elm trees should be promptly isolated, 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.

The high-risk trees are those which have severe or rapid wilt after spring leafing as they are capable of producing a second generation of adults by July 15. Slow-wilting trees do not become a hazard until later in the summer when small diametered water-conducting vessels may be less susceptible to infection. It is imperative that high-risk trees be removed and disposed of by July 15. 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).

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

Disposal

Proper disposal of elm material requires that developing beetles be destroyed and the material be made unsuitable for elm bark beetle development. This is the final important phase in a successful sanitation program. Detection and removal of declining elms is only important if beetle breeding can be prevented or eliminated. 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. Never lose sight of the primary concern of wood disposal--the timely elimination of beetles and beetle breeding material. All attempts at elm utilization must recognize this.

Prevention of Root Graft Spread

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 mechanically trenching (a soil trencher or a vibratory plow) around infected trees or by using a chemical SMDC (Vapam). A secondary trench is suggested between the trees closest to the diseased tree and the second closest trees since some apparently healthy trees may be infected at the time of treatment (figure 7). 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 be placed so the distance around the barrier is at least 60 feet (figure 5).

The trench, 36-40 inches deep, between diseased and healthy trees immediately disrupts root grafts between these adjacent trees. A vibratory plow or mechanical trenching machine is the easiest way to trench, but its 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.

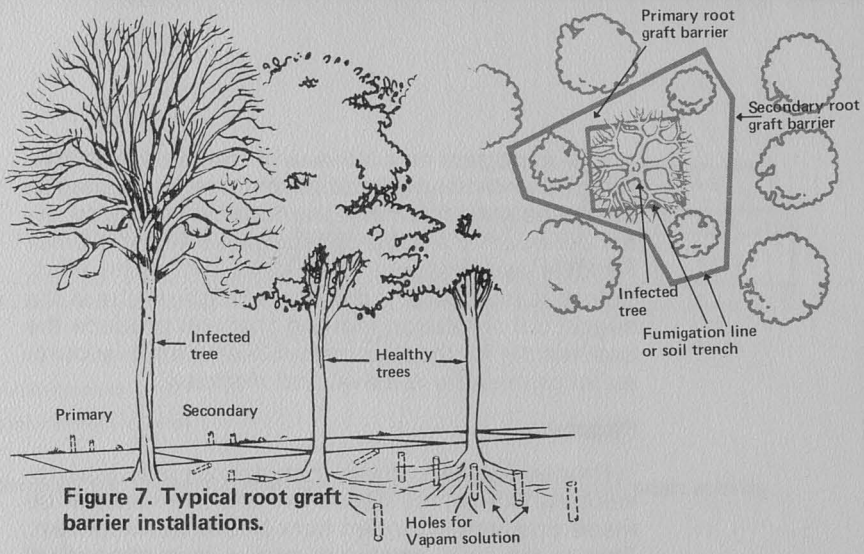


Figure 7. Typical root graft barrier installations.

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, ¾-1 inch in diameter, and 6 inches-1 foot apart, are made along this line. One part of Vapam is mixed with 3 parts water and 50-200 milliliters (2-8 fluid ounces) of the diluted chemical are placed in each hole. The hole must be closed immediately after adding the Vapam. The 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° 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. 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 infections can be removed from elm trees. A minimum of 8-10 feet of streak-free wood (no vascular discoloration) 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 2 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.

Insecticides

Insecticides can be applied to healthy trees to prevent or reduce insect feeding; however, only methoxychlor is registered, and it adds only a small additional increment of protection. No amount of insecticide spraying could be as completely effective in reducing bark beetle numbers as proper wood disposal nor would the insecticide have any effect on the fungus in the tree. Without thorough sanitation and disruption of common root systems of infected trees, methoxychlor will be ineffective.

Fungicides

Systemic fungicides are much sought after methods of control but their value remains questionable. Benomyl was registered by the Environmental Protection Agency for use on elm trees as a foliar spray or for trunk injection, but is now known to be ineffective. More recently, a solubilized form of Benomyl, (methyl 2-benzimidazolecarbamate phosphate) MBCp, has been approved for pressure injection. Other systemic fungicides are being studied and may be approved for use in the near future. The systemic fungicides, while promising, must be viewed only as an aid to the sanitation program. Systemic fungicides are not recommended for trees with more than 5 percent symptoms, or for trees infected via root grafts. Strains of the Dutch elm disease fungus exist as part of a normal population that are tolerant of MBCp, and present injection techniques often permanently damage the trees' water-conducting system. While systemic fungicides have been effective in protecting healthy elms, sanitation is the key to Dutch elm disease control.

Detection

Ground Survey

Ground survey crews, able to work in most weather conditions, will detect a high percentage of the diseased 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 directions rather than following the same

pattern on each survey. Weekly surveys during June, July, and early August will detect most hazard 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 each 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 diseased trees have been removed from an area is a good followup method and may detect hazard trees.

Aerial Photography

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 film is excellent, 70 mm or even 35 mm has possibilities.

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

Prospects for Control 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.

The great majority of Dutch elm disease in Minnesota occurs from sources within a control area .

What your area or neighborhood does greatly determines the future of elms in that area. The movement of disease from wild areas or areas outside the neighborhood into control areas is hard to control and will over time reduce the population of trees along the common border.

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 readily available shade trees follows:

Norway Maple *(Acer platanoides)* and its varieties such as

Cleveland Norway Maple (*Acer platanoides* 'Cleveland')

Schwedler Norway Maple (*Acer platanoides* 'Schwedleri')

Silver Maple *(Acer saccharinum)*

Sugar Maple (Acer saccharum)

Green Ash *(Fraxinus pensylvanica subintegerrima)* and its cultivar

Marshall's Seedless Ash

Thornless Honeylocust *(Gleditsia triacanthos inermis)* cultivars 'Imperial' and 'Skyline'

American Linden *(Tilia americana)*

Greenspire Linden (*Tilia cordata* 'Greenspire')

Redmond Linden (*Tilia x euchlora* 'Redmond')

Native trees not always available in large numbers:

Red Maple *(Acer rubrum)*

Ironwood *(Ostrya virginiana)*

Kentucky Coffeetree *(Gymnocladus dioicus)*