Problem: Dutch elm disease - *Ophiostoma ulmi*

Host Plants: American elm, red or slippery elm, rock elm and cedar elm.

Description: The fungus (Ophiostoma ulmi), the causal agent of Dutch elm disease, is probably native to Asia. After World War I, the fungus was introduced into Europe. A Dutch biologist first described the pathogen; hence the name Dutch elm disease. Sometime in the 1920's, the fungus entered the United States. Since 1930, the pathogen rapidly spread in native and urban elm populations throughout North America. The disease first appeared in Kansas in 1957 and has now been reported throughout the entire state. The disease has eliminated most of the majestic American elms in the urban setting and continues to kill trees each year.

Symptoms: Dutch elm disease results in the blockage of the water-conducting tissue within the tree. Initial symptoms include discoloration and wilting of foliage. The pattern of wilting depends somewhat on when and how infection occurs.

Trees infected by bark beetle vectors typically develop symptoms in late May or occasionally in late August or September. The major vector in Kansas is the smaller European elm bark beetle. This insect feeds primarily on small branches high in the tree crown. Therefore, initial wilt symptoms are usually detected on one or more small branches relatively high in the tree. Foliage on diseased branches first appears off-color then turns yellow. The yellowing of leaves on a branch may be confused with wind injury or mechanical damage to the branch. However, wilt symptoms associated with Dutch elm disease continue to progress on other branches in the tree crown over successive weeks or months. Eventually, foliage throughout the crown wilts and the tree dies. Depending on the time of infection (fall or spring), diseased trees may survive for one year.

The Dutch elm disease fungus may also be spread through root grafts. Trees infected in this manner normally show massive wilt symptoms throughout the tree crown and die rapidly. Often, root graft infections show up in early spring soon after new leaves emerge on the tree.

Another diagnostic feature of the disease is the formation of brown streaks in infected sapwood. This is common in trees where infections started by beetle transmission. Discoloration may only occur in the main trunk on trees rapidly killed by root graft infection. If you suspect a tree has Dutch elm disease, remove a recently wilted branch and strip off the bark. This is relatively easy to do in spring and early summer. Those branches infected with the fungus typically have long brownish- red streaks running the length of a branch section. The sapwood of healthy branches should appear cream- colored without streaking. Do not try to look for vascular streaking on dry, dead branches or branches not showing wilt symptoms!

The only definitive means of diagnosing Dutch elm disease is to submit branch samples to the Plant Disease Diagnostic Laboratory at Kansas State University. Collect two to four branch samples, ½ to 2 inches in diameter and 6 inches long,

from limbs that have recently wilted and show streaking of the sapwood. Submit samples to the local county extension office. The county agent will forward the material to the diagnostic lab.

Pathogen - Insect Vector Relationships: Two species of bark beetles may be vectors of the Dutch elm disease fungus. They are the smaller European elm bark beetle and the native elm bark beetle. Both species of beetles are similar in appearance and measure only 1/8 inch in length. Therefore, differentiating between the beetles in the field may be difficult. However, there are significant differences in the life cycle, brood galleries, and habitat preference of the species.

The smaller European elm bark beetle is the most common vector in Kansas. This beetle has almost eliminated the native bark beetle over the past 40 years by occupying all breeding material. The smaller European elm bark beetle overwinters as larvae in recently killed elm wood. Adults emerge from wood in late April and begin maturation feeding in the crotches of small branches in the tree. Most beetles fly less than 1000 feet from the brood wood, but some will travel farther distances. If the beetle is contaminated with the Dutch Elm disease fungus, it may inoculate the tree during this feeding. After feeding, the adults seek elm wood recently killed by Dutch elm disease or other causes and begin to lay eggs. A second generation of adults emerges from the wood in early July. A third generation emerges in mid-September. It is larvae produced from the third generation that overwinter under the bark. The brood galleries are formed in the inner bark and are oriented parallel with the wood grain. Larvae that hatch tend to move out perpendicular to the main brood gallery.

Native elm bark beetles overwinter as larvae in bark or as adults. Beetles emerge in late April and begin to bore into branches 2 to 4 inches in diameter. Feeding by the native elm bark beetle generally occurs lower in the tree than the smaller European elm bark beetle. As native bark beetles feed below the bark, they may

deposit spores of the pathogen. Galleries of the native bark beetle are oriented perpendicular to the wood grain.

Both species of beetles are attracted to elms recently killed by Dutch elm disease. Sporulation by the fungus is enhanced in the egg-laying galleries, and beetles emerging from wood are often contaminated with spores. In addition, beetles may contaminate clean wood by introducing fungal spores during egg laying. The fungus may survive in dead wood for 6 to 12 months. Therefore, recently killed elm wood serves as a potential large inoculum source for the fungus and breeding wood for the beetle.

Root Graft Infection: The Dutch elm disease fungus may also enter healthy trees through root grafts. The roots of adjacent American elms tend to fuse together over time, resulting in a "common" root system among several trees along a street or planting. This type of root grafting may occur anytime elm trees are within 50 feet of one another. When a single elm tree in a row becomes infected, the fungus may move systemically down the diseased tree into the roots and then into an adjacent healthy tree through a root graft. This can result in rapid progression of the disease in an urban environment.

Recommendations: The key to controlling Dutch elm disease is sanitation. Sanitation programs should be implemented on a community-wide basis. Check with the local city forester for more information. Homeowners can help by identifying and removing dead, dying, or weak elm wood with the bark still attached. This means all elms, including the resistant Siberian and Chinese elms. Elm wood should be buried, burned, or chipped immediately. Do not place elm wood in firewood piles! This is the major source of inoculum and beetles! Any elm wood collected in October should be burned before beetle emergence in April. All elm wood collected in the summer should be destroyed immediately. Any stored elm wood should be debarked.

Eradicant pruning. Monitor American elms for wilt symptoms throughout the summer, but particularly in April and May. Remove any suspicious branches and send them to the diagnostic laboratory for analysis. Trees can be saved by eradicant pruning if the disease is detected early (from beetle inoculation). Locate the wilted branch and remove the bark until clean sapwood (not discolored) is found. Remove the branch approximately 10 feet below the junction of clear and discolored sapwood. Be sure to disinfest pruning tools after cutting in a 10% household bleach solution. Eradicant pruning may result in the loss of a major tree limb. Nevertheless, many American elms can be saved by this pruning method. Carefully watch the tree for any signs of further wilting.

Tree removal. If wilt occurs in more than 25% of the tree crown, it cannot be saved. Remove the tree as soon as possible to prevent further spread of the pathogen. Check to see if adjacent elms are within 25-50 feet before removal. If so, disrupt root grafts by trenching or fumigation before cutting the tree down.

Disrupt root grafts. You must assume that all American elms within 50 feet of a diseased tree are root-grafted. Trenching is a relatively quick and effective means of breaking root grafts. Mark a line or arc at the mid-point between two adjacent trees. The line or arc should extend such that all potential root grafts can be broken. A straight line may be more convenient on tightly spaced trees, but the line should extend beyond the tree drip line. Dig a trench 24 inches deep following the line or arc using a ditch witch, vibratory plow, or spade. Be sure to check with local utilities before digging! After trenching the soil may be replaced. Place another trench beyond the second tree in situations where there are multiple elms and the disease in the first tree was not diagnosed early. Unfortunately, obstacles such as sidewalks and fences may interfere with trenching. Root grafts still can occur in these locations, so modifications of trenching method described may be needed. A combination of trenching and fumigation is often required.

Root grafts may also be severed with the fumigant metam sodium (sold as Vapam). Fumigation is practical when sidewalks, utility lines, etc, prohibit trenching. Mark a line as previously described and drill one- to two- inch-diameter holes every 12 inches and 24 inches deep with an auger. Pour the fumigant in each hole and tamp it shut. The chemical fumigant is dangerous and should be applied only by trained applicators.

Insecticides. The use of insecticides to suppress early beetle populations has diminished in recent years. Sanitation and removal of firewood is more effective in controlling beetle populations. Certain insecticides may be applied to trees in April to prevent feeding by emerging beetles. Although this technique will help suppress beetle populations, I do not highly recommend it.

Fungicides. Certain systemic fungicides are labeled for preventive and therapeutic control of Dutch elm disease. These chemicals are injected into root flares and are translocated throughout the tree. Tree injection should only be attempted by trained personnel. Do not attempt injections unless you have been trained to do so! Therapeutic injection is risky! It is only effective on trees showing less than 5-10% crown symptoms and not at all on trees infected through root grafts. Even under these conditions, there is no guarantee that the treatment will be effective. Injection should be used in conjunction with eradicant pruning. Consult a trained arborist before proceeding with therapeutic injections.

Elms can be protected from Dutch elm disease by preventive fungicide injections. This technique is more effective than therapeutic injection. However, injection is expensive, so only specimen trees should be considered for treatment. Fungicides currently labeled for preventive injection specify that the fungicide activity in the tree will last for approximately three years. Trees must then be re-injected. Injection is not a substitute for sanitation! Do not expect to save your elms by injection alone.

Resistant elms. All American species of elms, including American elm, red or slippery elm, rock elm and cedar elm are very susceptible to Dutch elm disease. The Siberian elm (Ulmus pumila, sometimes incorrectly referred to as Chinese elm, and the true Chinese or lacebark elm (Ulmus parvifolia) are resistant to the disease and also are adapted to growing conditions in the state. Siberian elm has certain other undesirable characteristics that may limit planting.

More recently, university researchers have developed resistant hybrid elms. These elms should be considered for planting in the urban environment even though some do not have the same appearance as American elm. They include: Prospector (*U. wilsoniana* - recently released), Frontier (*U. carpinifolia X parvifolia* -new release), Urban (*U. carpinifolia X pumila*), Homestead, Pioneer, American Liberty (*U. americana*), Delaware #2, and Sapporo Autumn Gold (*U. japonica X pumila*).

References:

1. Dutch Elm Disease. K-State Research and Extension, Plant Pathology. Disease fact sheet (2/95).

Last Update:

Dutch Elm Disease

Ned Tisserat Extension Plant Pathology

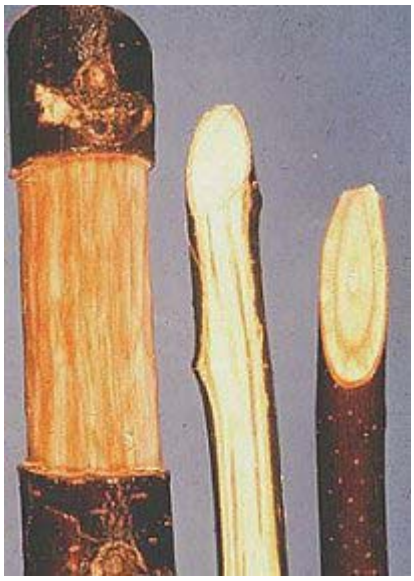

Figure 1. Discolored sapwood associated with infection by the Dutch elm disease fungus

Figure 2. Early wilt symptoms in a large American elm

The fungi *Ophiostoma ulmi* and *O. novo-ulmi*, the causal agents of Dutch elm disease, are native to Asia. After World War I, *O. ulmi* was introduced into Europe. A Dutch biologist first described the pathogen; hence the name Dutch elm disease. Sometime in the 1920's, the fungus entered the United States. Since 1930, the pathogen rapidly spread in native and urban elm populations throughout North America. The disease first appeared in Kansas in 1957 and has

now been reported throughout the entire state. More recently, a more aggressive fungal species, O. novo-ulmi, was introduced into the country. This fungus has more or less replaced the less virulent O. ulmi.

Dutch elm disease is a classic example of the catastrophic devastation that can occur when an exotic pathogen is introduced into a previously unexposed population of trees with little or no genetic resistance. The disease has eliminated most of the majestic American elms in the urban setting and continues to kill trees each year.

SYMPTOMS

Dutch elm disease results in the blockage of the water-conducting tissue within the tree. Initial symptoms include discoloration and wilting of foliage. The pattern of wilting depends somewhat on when and how infection occurs. Trees infected by bark beetle vectors typically develop symptoms in late May or occasionally in late August or September. The major vector in Kansas is the smaller European elm bark beetle. This insect feeds primarily on small branches high in the tree crown.

Therefore, initial wilt symptoms are usually detected on one or more small branches relatively high in the tree. Foliage on diseased branches first appears off-color then turns yellow. The yellowing of leaves on a branch may be confused with wind injury or mechanical damage to the branch.

However, wilt symptoms associated with Dutch elm disease continue to progress on other branches in the tree crown over successive weeks or months. Eventually, foliage throughout the crown wilts and the tree dies. Depending on the time of infection (fall or spring), diseased trees may survive for one year.

The Dutch elm disease fungus may also be spread through root grafts. Trees infected in this manner normally show massive wilt symptoms throughout the tree crown and die rapidly. Often, root graft infections show up in early spring soon after new leaves emerge on the tree. Another diagnostic feature of the disease is

the formation of brown streaks in infected sapwood. This is common in trees where infections started by beetle transmission. Discoloration may only occur in the main trunk on trees rapidly killed by root graft infection. If you suspect a tree has Dutch elm disease, remove a recently wilted branch and strip off the bark. This is relatively easy to do in spring and early summer. Those branches infected with the fungus typically have long brownish-red streaks running the length of a branch section. The sapwood of healthy branches should appear cream-colored without streaking. Do not try to look for vascular streaking on dry, dead branches or branches not showing wilt symptoms!

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Figure 3. Preventive fungicide injection. Note the placement of injection tees on the base of the trunk.

Pathogen - Insect Vector Relationships

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Both species of beetles are similar in appearance and measure only 1/8 inch in length. Therefore, differentiating between the beetles in the field may be difficult. However, there are significant differences in the life cycle, brood galleries, and habitat preference of the species.

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Native elm bark beetles overwinter as larvae in bark or as adults. Beetles emerge in late April and begin to bore into branches 2 to 4 inches in diameter. Feeding by the native elm bark beetle generally occurs lower in the tree than the smaller European elm bark beetle. As native bark beetles feed below the bark, they may deposit spores of the pathogen. Brood galleries of the native bark beetle are oriented perpendicular to the wood grain.

Both species of beetles are attracted to elms recently killed by Dutch elm disease. Sporulation by the fungus is enhanced in the egg-laying galleries, and beetles emerging from wood are often contaminated with spores. In addition, beetles may contaminate clean wood by introducing fungal spores during egg laying. The fungus may survive in dead wood for 6 to 12 months. Thus, recently killed elm wood serves as a potential large inoculum source for the fungus and

breeding wood for the beetle.

Root Graft Infection

The Dutch elm disease fungus may also enter healthy trees through root grafts. The roots of adjacent American elms tend to fuse together over time, resulting in a "common" root system among several trees along a street or planting. This type of root grafting may occur anytime that elm trees are within 50 feet of one another. When a single elm tree in a row becomes infected, the fungus may move systemically down the diseased tree into the roots and then into an adjacent healthy tree through a root graft. This can result in rapid progression of the disease in an urban environment.

Control of Dutch Elm Disease

Sanitation. The key to controlling Dutch elm disease is sanitation. Sanitation programs should be implemented on a community-wide basis. Check with the local city forester for more information. Homeowners can help by identifying and removing dead, dying, or weak elm wood with the bark still attached. This means all elms, including the resistant Siberian and Chinese elms. Elm wood should be buried, burned, or chipped immediately. Do not place elm wood in firewood piles! This is the major source of inoculum and beetles! Any elm wood collected in October should be burned before beetle emergence in April. All elm wood collected in the summer should be destroyed immediately. Any stored elm wood should be debarked.

Pruning. Monitor American elms for wilt symptoms throughout the summer, but particularly in April and May. Remove any suspicious branches and send them to the diagnostic laboratory for analysis. Trees can be saved by removing diseased branches as soon as they show wilt symptoms (from beetle inoculation). Locate the wilted branch and remove the bark in strips until clean sapwood (not discolored) is found. Remove the branch approximately 10 feet below the junction of clear and discolored sapwood. Be sure to disinfest pruning tools after

cutting in a 10% household bleach solution. Pruning out diseased wood may result in the loss of a major tree limb. Nevertheless, many American elms can be saved by this pruning method. Carefully watch the tree for any signs of further wilting. If the discoloration continues into the main trunk, then it is unlikely the tree can be saved.

Disrupt root grafts. You must assume that all American elms within 50 feet of a diseased tree are root-grafted. Trenching is a relatively quick and effective means of breaking root grafts. Mark a line or arc at the mid-point between two adjacent trees. The line or arc should extend such that all potential root grafts can be broken. A straight line may be more convenient on tightly spaced trees, but the line should extend beyond the tree drip line. Dig a trench 24 inches deep following the line or arc using a ditch witch, vibratory plow, or spade. Be sure to check with local utilities before digging! After trenching the soil may be replaced. Place another trench beyond the second tree in situations where there are multiple elms and the disease in the first tree was not diagnosed early. Unfortunately, obstacles such as sidewalks and fences may interfere with trenching. Root grafts still can occur in these locations, so modifications of trenching method described may be needed. A combination of trenching and fumigation is often required.

Root grafts may also be severed with the fumigant metam sodium (sold as Vapam). Fumigation is practical when sidewalks, utility lines, etc, prohibit trenching. Mark a line as previously described and drill one- to two-inch-diameter holes every 12 inches and 24 inches deep with an auger. Pour the fumigant in each hole and tamp it shut. The chemical fumigant is dangerous and should be used with care. Unfortunately, metam sodium is very difficult to purchase in small quantities in Kansas. Hence, it is rarely used to sever root grafts in the urban landscape.

Insecticides. The use of insecticides to suppress early beetle populations has diminished in recent years. Sanitation and removal of firewood is more effective in controlling beetle populations. Certain insecticides may be applied to trees in

April to prevent feeding by emerging beetles. Although this technique will help suppress beetle populations, I do not highly recommend it.

Fungicides. Certain systemic fungicides are labeled for preventive and therapeutic control of Dutch elm disease. These chemicals are injected into and are translocated throughout the tree. Injection is not a substitute for sanitation! Do not expect to save your elms by injection alone.

Therapeutic injections. Injecting elms after infection has occurred is very risky! It is only effective on trees showing less than 5 to10% crown symptoms and not at all on trees infected through root grafts. Even under these conditions, there is no guarantee that the treatment will be effective. Consult a trained arborist before proceeding with therapeutic injections.

Therapeutic injection should be used in conjunction with removal wilted branches. For example, locate the recently wilted branch and strip the bark off to follow the path of discolored sapwood. Once clear wood has been reached, cut 10 feet below this area. Inject the tree with the fungicide just before or after branch removal.

Preventive Injections. Elms can be protected from Dutch elm disease by routine, preventive fungicide injections. This technique is more effective than therapeutic injection. Fungicides currently labeled for preventive injection specify that the fungicide activity in the tree will last for approximately three years. Trees must then be re-injected. Trees should be injected after the tree has fully leafed out in the spring (late May) but before leaf senescence begins (September). Inject in the morning on days with minimal cloud cover. Avoid injecting during rainy or cloudy periods.

Tree injection is expensive, so only specimen elms should be considered for treatment. Furthermore, routine injections may cause permanent injury to the trunk and lead to discoloration and decay problems.

Several different injection methods are currently being used. The most widely

used method involves injecting a diluted fungicide solution in water (5 to 40 gallons) through a series of small injection tees inserted into the root flares at the base of the tree. This is sometimes referred to as the macroinjection method. The fungicide is often injected under low pressure (<15 lbs. PSI). Microinjection techniques involve injecting small quantities of highly concentrated fungicides through a series of small plastic capsules inserted around the tree trunk. The small capsules are easier to install on the tree and require less time for chemical uptake. However, the capsules are often more widely spaced than macroinjection tees and may not provide as uniform of chemical distribution inside the tree. Thus, I recommend the macroinjection technique in most situations. Tree injection should only be attempted by trained personnel. Do not attempt injections unless you have been trained to do so! Several fungicides, including Alamo, Fungisol, Phyton 27, and Arbotect are labeled for injection on elms. University research has shown that Arbotect is effective when injected preventively. Less information is available on the efficacy of the other fungicides.

Figure 4. Root graft on American elm. The Dutch elm disease fungus may move from diseased to healthy trees through the root grafts.

Tree removal. If wilt occurs in more than 25% of the tree crown, it cannot be saved. Remove the tree as soon as possible to prevent further spread of the pathogen. Check to see if adjacent elms are within 25-50 feet before removal. If so, disrupt root grafts by trenching or fumigation before cutting the tree down.

Resistant elms. All American species of elms, including American elm, red or slippery elm, rock elm and cedar elm are very susceptible to Dutch elm disease. The Siberian elm (Ulmus pumila) sometimes incorrectly referred to as Chinese elm, and the true Chinese or lacebark elm (Ulmus parvifolia) are resistant to the disease and also are adapted to growing conditions in the state. Siberian elm has certain other undesirable characteristics that may limit planting.

More recently, university researchers have selected or developed resistant elms (see Table 1). These elms should be considered for planting in the urban environment even though some do not have the same appearance as American elm.

Selected References

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Table 1. 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 Liberty	S	R	multiclonal variety; juvenile trees may be susceptible to aggressive strains of O. ulmi .
Delaware	S	R	Originally designated as Delaware #2
Independence	S	R	One of the clones of

			"American Liberty'
New Harmony	S	R	Recently released selection from U.S. Forest Service
Valley Forge	S	R	Recently released selection from U.S. Forest Service
U. japonica	R	?	Primarily used as a parent in hybrid breeding programs.
U. parvifolia	R	R	There are many cultivars of Chinese or lacebark elm and all have resistance to Dutch elm disease. They also have good resistance to elm yellows and elm leaf beetle, but cultivars may be damaged by low temperatures in zones 4 and 5.
U. parmila	R	S	Resistant to Dutch elm disease and elm yellows but highly susceptible to elm leaf beetle feeding. This species should not be used in the landscape in most locations.
U. wilsoniana			
Prospector	R	R	
Elm Hybrids			
Accolade	R	R	U. japonica x U. wilsoniana; also reported to be resistant to elm leaf miner
Cathedral	R	S?	U. pumila x U. japonica; also reported to be resistant to Verticillium wilt, elm leaf miner
Charisma	R	?	hybrid between Accolade and Vanguard
Danada	R	?	hybrid between U. japonica x U. wilsoniana

Frontier	R	R	U. carpinifolia x U. parvifolia; some winter damage has been reported in Great Plains region
Homestead	R	S	multispecies hybrid; probably not suitable where elm leaf beetle is a problem
New Horizon	R	S?	U. japonica x U. pumila; also reported to be resistant to Verticillium wilt and elm leaf miner
Patriot	R	R	cross between 'Urban' and 'Prospector'
Pioneer	R	S	U. glabra x U. carpinifolia; probably not suitable where elm leaf beetle is a problem
Regal	R?	?	U. 'Commelin x U. 'Hoersholmiensis', resistant to Verticillium wilt
Sapporo Autumn Gold	R	S	U. pumila x U. japonica; also resistant to Verticillium wilt
Urban	R	S	should not be used in areas where elm leaf beetle is a problem
Vanguard	R	S?	U. japonica x U. pumila

R = resistance and S = susceptibility

Web updated 9/01/06
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