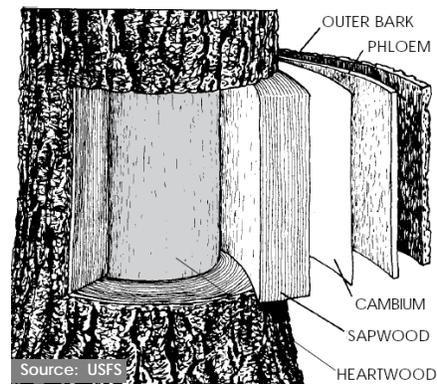


Oak Wilt

Oak wilt has been described as "*The most destructive tree disease in the United States*", responsible for "*killing thousands of oaks each year in forests, woodlots, and home landscapes*", and is at "*epidemic proportions in central Texas*".

The Disease

Oak wilt is an infectious, lethal vascular disease caused by the fungus *Ceratocystis fagacearum*, which invades and disables the water-conducting system in susceptible trees. The fungus lives and grows in the current year's xylem (sapwood) of oaks. The fungus grows into and throughout the water conductive tissues of the host and plugs the vessels with its own body (mycelium) and spores. It also causes a defensive reaction by the tree to stop the fungal spread by actively plugging its own vessels with gummy substances called tyloses. These processes interfere with water uptake and cause a wilting syndrome which often results in leaf wilting and drop, and eventually death of the tree.



Oak Wilt Hosts

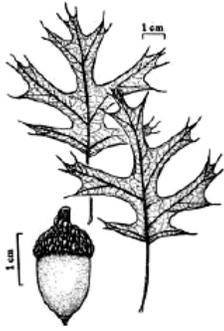
All oaks (*Quercus* spp.) are susceptible to oak wilt to some degree, but some species are affected more than others.

Red oaks, particularly Spanish oak (*Q. buckleyi*), Texas red oak (*Q. texana*), Shumard oak (*Q. shumardii*), and blackjack oak (*Q. marilandica*), are extremely susceptible and may play a unique role in the establishment of new oak wilt infections.

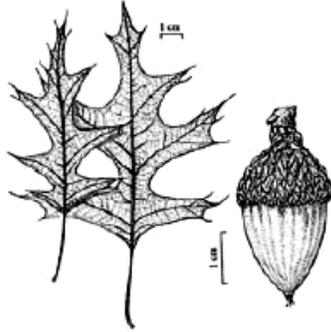
White oaks, including post oak (*Q. stellata*), bur oak (*Q. macrocarpa*), Mexican white oak (*Q. polymorpha*), white shin oak (*Q. sinuata* var. *breviloba*), Durand oak (*Q. sinuata*), Lacey oak (*Q. laceyi*), and chinkapin oak (*Q. muehlenbergii*), are somewhat resistant to the fungus and some rarely die from oak wilt.

Live oaks (*Q. virginiana* and *Q. fusiformis*) are intermediate in susceptibility to oak wilt, but are most seriously affected due to their tendency to grow from root sprouts and form vast interconnected root systems that allow movement (or spread) of the fungus between adjacent trees.

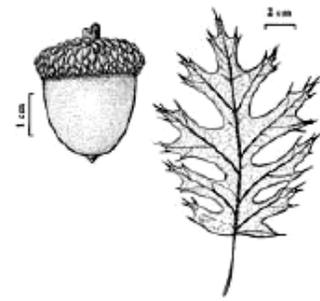
<p>Oaks can be organized into three main groups, based on leaf shape: red oaks, white oaks, and live oaks. Trees in the red oak group have fan-shaped leaves with sharply pointed tips; those in the white oak group have fan-shaped leaves with rounded or blunt tips; and trees in the live oak group have oval leaves with rounded tips.</p>	<p>Red Oaks</p>  <p>Bristled, pointed lobes</p>
	<p>White Oaks</p>  <p>Rounded lobes</p>
	<p>Live Oaks</p> 



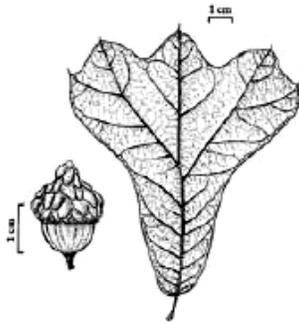
Spanish Oak



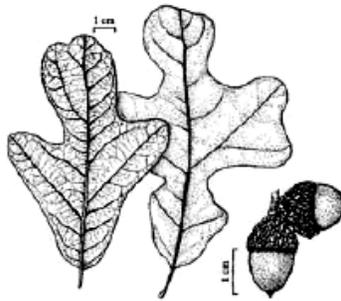
Texas Red Oak



Shumard Oak



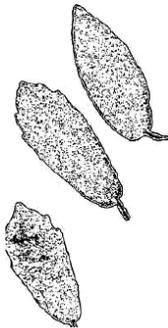
Blackjack Oak



Post Oak



Bur Oak



Mexican White Oak



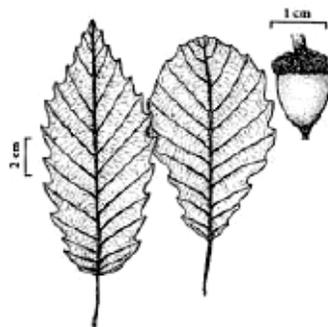
White Shin Oak



Durand Oak



Lacey Oak



Chinkapin Oak



Live Oak

Throughout the range of oak wilt in the United States, red oaks are the most important hosts, but susceptibility varies somewhat by species. Mortality in red oaks can occur within 3 weeks after infection by the oak wilt pathogen under some circumstances. Recovery from oak wilt infections in red oaks can occur, but is very rare.

All species in the white oak group are moderately resistant to oak wilt, but if infected, trees can be killed over a period of one to several years. Resistance in white oaks appears to be related to characteristics of physiology and morphology. Upon wounding, infection, or as a part of the natural aging process, white oaks tend to form minute plugs called *tyloses* in their sapwood vessels. These plugs make the wood of white oaks impermeable to water, and also appear to prevent the fungus from moving throughout the vascular system of the tree. Post oak tends to be the most resistant of the group while bur oak is the most sensitive

Texas live oak (*Q. virginiana*) is moderately susceptible to the disease, but because of its tendency to form large, root-connected clones through which the disease can spread, it is also considered to be an important host.

Oak Wilt Biology

Oak wilt is induced when the asexual spores of the *Ceratocystis fagacearum* fungus are transported rapidly through the stem in the transpiration stream of the outermost annual ring. As a defense reaction, materials called tyloses are formed in the vessels which in turn disrupt the water-conducting system. After the death of the tree or branch, the fungus penetrates deeper into the sapwood and also out into the bark. The fungus overwinters as mycelium (a mass of filamentous strands) on the cambium in living infested trees and as fungal spore mats on dead trees. In Texas, spore mats are formed mostly on red oaks, and very rarely on live oak. For this reason, the red oaks are important for establishing new infection centers. Mat formation occurs at any time during the year, but is most common in winter and spring when the weather is cooler and wetter. Red oak infections in late spring and summer usually do not give rise to fungal mats due to high temperatures and low soil moisture conditions. Fungal mats can be found by looking for inconspicuous narrow cracks in the bark of dying red oaks leading to hollow areas between the bark and wood. They often have a distinctive odor similar to fermenting fruit. Fungal mats can be exposed for inspection by chopping away the loose bark. The dispersal of the fungus is by spores which are carried by certain insects. Spread via root grafts can also occur.



Bark section showing spore mat on both surfaces



Bark split caused by fungal mat pressure

Source: USFS

Oak Wilt Spread

Oak Wilt is spread in two ways: overland infections and root graft infections (local spread).

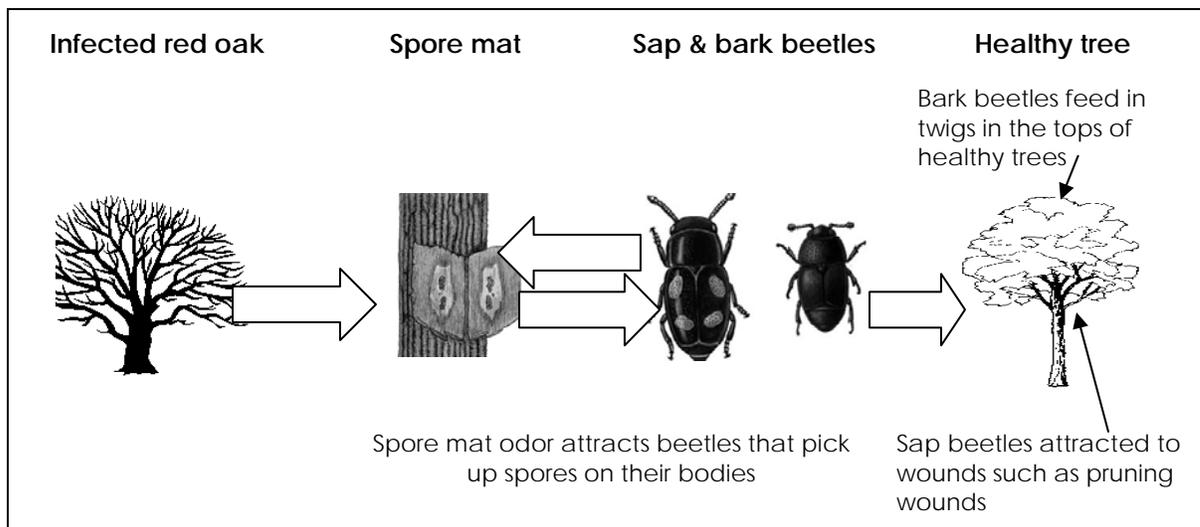
Overland Infections

Most overland infections are initiated by fungal spores transported on the bodies of sap feeding and wood boring insects. Man can also be an important vector for transporting the disease through the movement of wood (such as firewood) from infected red oaks to other locations.

Because of the fungal mats that form beneath the bark of certain diseased trees, red oaks appear to play a key role in the establishment of new infection centers. Oak wilt spore mats emit a strong fruity or wine-like odor that attracts many different species of sap beetles. As they feed on or tunnel through the spore mats, the beetles often accumulate fungal spores on the surface of their bodies. The fungus may then be transmitted by these small beetles as they emerge from mats and visit fresh wounds on

healthy trees, both red oaks and live oaks. Sap beetles are attracted to sap exudations from freshly cut logs, stumps and wounds. Fungal mats are most commonly formed on standing trees, but they also can develop on logs, stumps, and fresh firewood cut from diseased red oaks.

Another group of insects, oak bark beetles, can also carry spores of the oak wilt pathogen and help to create new infection centers. These beetles acquire spores of the fungus while feeding on infected branches, and subsequently transmit them when feeding on healthy trees. While sap beetles are attracted to sap from fresh wounds, bark beetles, on the other hand, visit healthy oaks and feed on the buds and in the twig crotches in the tops of healthy trees. There they make twig cavities where they feed and transmit the fungus.



Local Spread

Most new tree infections occur as a result of the fungus moving from an infected tree to a nearby healthy tree through connected root systems (root grafts). The roots of trees in each oak group commonly graft to roots of other trees in the same group, forming a continuous underground network. Oaks within 50-100 feet of one another often will have a common root system due to root grafting. Root grafts do not commonly occur between trees of different species groups, although exceptions do occur. Usually a mix of species in a given location will retard local spread and limit the impact of the disease. However, root grafts often do occur between live oaks and red oaks in mixed stands.

The root grafts allow the Oak Wilt fungus in a diseased oak to travel within the water carrying vessels through the root grafts into a healthy oak. When one tree in a group becomes infected and dies, the fungus spreads through the connected root systems, killing more trees and creating an "infection center."

Depending upon soil type and the mix of tree species in a forest or yard, infection of healthy trees through root grafts can occur at some distance (up to 100 feet or more) from an infected tree. Sandy soils are conducive to the formation of widespread root systems, increasing the likelihood of root grafts occurring farther away from a diseased tree. Some oak species, including live oak, often grow in large groups of similar-aged trees that share a common root system. Such situations can lead to rapid expansion of oak wilt centers if even one tree in the group becomes infected. Root graft infections account for approximately 90% of the spread of the disease within an infection center.



Spread through root grafts is more important in live oaks because of their tendency to grow in motts from root sprouts (making all the trees clones) and to develop interconnected root systems. Movement through roots is slower in red oaks and occurs over shorter distances than in live oaks.

Oak Wilt Symptoms

Red Oaks

- **Leaf discoloration** - Oak wilt is usually identified in red oaks by the symptoms of rapid leaf discoloration and wilting. Often the initial symptom is a subtle off-green color shift that may be visible in the upper portion of the tree crown. Shortly after this initial color shift, the leaves begin to wilt from the top of the crown downward. As the disease progresses, individual leaves quickly discolor, taking on a "bronzed" appearance. The discoloration progresses around the margins of the leaf from the tip to the base. Wilting leaves may curl around the midrib and the line between the bronze and green tissues in individual leaves is very distinct.
- 
- Source: USFS
- **Leaf drop** - Leaves are cast rapidly as the infection progresses. Leaves fall in all stages of discoloration. Even entirely green leaves may fall from affected branches. Some affected branches hold green leaves longer than others. Therefore, the crowns of trees with oak wilt are seldom as uniformly brown as those of nondiseased trees that have been poisoned, girdled, or killed by lightning. In dry years, the appearance of trees with oak wilt may be confused with that of trees with drought symptoms.
 - **Quick progression** - These symptoms quickly appear throughout the crown, often within a few weeks, and leaves at the ends of branches are shed. Symptoms progress from the top of the tree downward. Commonly, infected trees are almost entirely defoliated within a few weeks of symptom onset.
 - **Spore mats**
 - **Surrounding red oaks also dying**

Live Oaks

- **Veinal death** - Leaves on diseased live oaks often develop chlorotic (yellow) veins that eventually turn necrotic (brown), a symptom called veinal necrosis.
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- Source: USFS
- **Leaf Drop** - Defoliation may be rapid, and dead leaves with brown veins often can be found under the tree for months after defoliation.
 - **Twig Dieback** - Massive twig dieback progressively spreading throughout the crown.
 - **Varying progression** - Most live oaks defoliate and die over a 1 to 6 month period following initial appearance of symptoms. Some live oaks take longer to die, and a few untreated trees may survive many years in various stages of decline.
 - **Surrounding live oaks also wilting and dying**

White Oaks

- **Leaf discoloration** - Leaves first fade or turn yellow or bronze and begin to wilt. Then leaf tips and margins become brown and necrotic. In some species, veins become necrotic; this is a diagnostic symptom. Discoloration proceeds from the margins to the base, sometimes interrupted by the leaf veins.

- **Leaf drop** –
- **Varying progression** - Symptoms progress inward and downward in the crown, often accompanied by defoliation, until the tree is dead. White oaks usually die slowly, one branch at a time. Whereas in the red oak group the disease may kill the tree in a few weeks, in the white oak group it may take several years. However in bur oak, symptoms are essentially the same as in the red oaks, and the tree may die within one growing season.



Oak wilt diagnoses may be confirmed by isolating the fungus from diseased tissues in the laboratory. Samples can be submitted to: Texas Plant Disease Diagnostic Laboratory, 1500 Research Parkway, Suite A130, Texas A&M University Research Park, College Station, TX 77845. A county extension agent, Texas Forest Service forester, or trained arborist should be consulted for proper collection and submission of samples.

Oak Disorders That Can Be Confused With Oak Wilt

There are several disorders that can affect oaks, many of which can be misdiagnosed as oak wilt. Very few however, cause leaf drop as pronounced as does oak wilt. When this symptom (leaf drop) is added to any of the above, oak wilt can be reliably identified.

Other oak problems include:

- **Insects**

Oak Leafroller – This insect can defoliate red and white oaks. In the spring, the larvae either fold or roll individual leaves, forming an enclosure for protection and rest, when not feeding. This can be confused for an oak wilt symptom in red oaks. Natural enemies of leaf roller caterpillars include birds and parasitic wasps.

Oakleaf Caterpillars – The larvae feeds on all species of oaks, but prefers white oaks. Some infestations can cover several acres. There are two generations: May – June and August – September. The larvae can devour entire leaves except the main vein.

Tent Caterpillars – Growth loss and dieback can occur, but trees are seldom killed by this defoliating insect. The first noticeable signs of attack are sparse crowns and falling frass. Caterpillars often cluster on the lower trunks of infested trees.

Spider Mites - Spider mites are small insect-like bugs that feed on plant juices. They cause small feeding injuries that, when present in high numbers, create a bronze look to the tree.

Boring Insects - Boring Insects can cause a great deal of damage to a tree very quickly as they consume the trees water and food conducting tissue. They are generally most successful against stressed trees. The symptoms of borer attacks are sap spots on the trunks of the tree followed by dieback that starts in the top of the tree. The leaf symptoms are different than oak wilt symptoms in that the leaves remain on the branches.

Twig Pruner – The twig pruner prefers oaks but also attacks other hardwoods. The larvae bore into the stems and cut off or prune twigs, terminals and branches up to 1 inch in diameter. During the summer, fall and winter, pruned twigs (with leaves attached) litter the ground under infested trees. The end of the severed twig presents a smoothly cut surface.

- **Diseases**

Oak Anthracnose - Oak Anthracnose is a fungal disease that affects newly forming leaves in the spring. White oaks are most severely affected. It causes irregular brownish areas on the leaves, most frequently along veins which can give a brownish appearance

on the tree. In severe cases it will cause the entire tree to turn brown. It is rarely fatal and usually occurs as the leaves emerge during cool and wet springs. Healthy oaks can easily withstand this disease and can replace the infected leaves. Less healthy trees can be further weakened.

Leaf Blister - Affected leaves develop blisters on the upper surface. The blisters are round, raised and wrinkled and vary in color from yellow to purple. Most of the affected leaves remain on the tree, and there is little damage.

Hypoxyton Canker - Hypoxyton Canker is a fungal disease that often attacks trees that are weakened. It has very characteristic patchy growths on the trunk and large branches. A symptom is dieback that starts in the top of the tree. Weeping areas will develop on the trunk and branches. The leaf symptoms are different than oak wilt symptoms in that the leaves remain on the branches.

Stem Cankers - Several fungal diseases can cause stem cankers that can be confused with the fungal mats of oak wilt. Most stem cankers form either irregular or concentric calluses on tree trunks or dead branch stubs that cover decaying wood beneath them.

- **Man Caused Problems**

Changes in Soil Grade - Roots of trees grow near the surface of the soil. These "feeder" roots are often in the top few inches of the soil surface. When additional soil is added over the top of tree roots they are, in effect, suffocated. Added soil is often denser and more compacted than the original soil. This prevents the tree from establishing new roots. Ultimately the tree will die from this. Sometimes the decline and death can take many years.

Soil Compaction - Soil compaction results from soil particles being pressed together. This interrupts the free flow of moisture and gas exchange, and inhibits root growth. Trees that are growing in these conditions become inefficient and are less able to breathe. They often begin to slowly decline as they use more energy than they are able to manufacture.

Cut Roots - Roots get cut for various reasons such as during construction, installing utilities, etc. Because most tree roots grow in the top 18 inches of the soil, the cut does not have to be deep to injure the tree. Severe root loss will show up as dehydration – which happens quickly as the tree dries out and wilts. Less severe root loss will show up as crown dieback in future years.

Chemical Injury – Chemical injury can be the result of air pollution, herbicide usage, and other sources. Herbicides can cause blotchy dead areas on leaf surfaces of mature leaves and curling on expanding leaves. Soil activated herbicides can cause dieback. Air pollutants can cause bleached spots or interveinal death.

- **Oak Decline** - Oaks are susceptible to a "decline" syndrome, which is a disease caused by the interaction of several injurious agents working simultaneously. In the case of oak decline these factors can include drought, defoliation, fungi that cause stem cankers or root diseases, and wood-boring beetles. The interaction of these factors may result in the decline and death of oak trees over a local or regional area. Symptoms vary greatly, and differentiating oak decline from oak wilt can be quite difficult. In oak decline, separate infection patterns or centers are not evident. Instead, several oak species may be affected and they are usually widely scattered throughout the stand.

Oak Wilt Prevention

Efforts to prevent oak wilt from getting started in a tree or stand is generally easier than controlling it once an infection occurs. Unfortunately the old adage about keeping trees healthy is only partially true with oak wilt. However preventing injury to trees is an important first measure. Prevention can include:

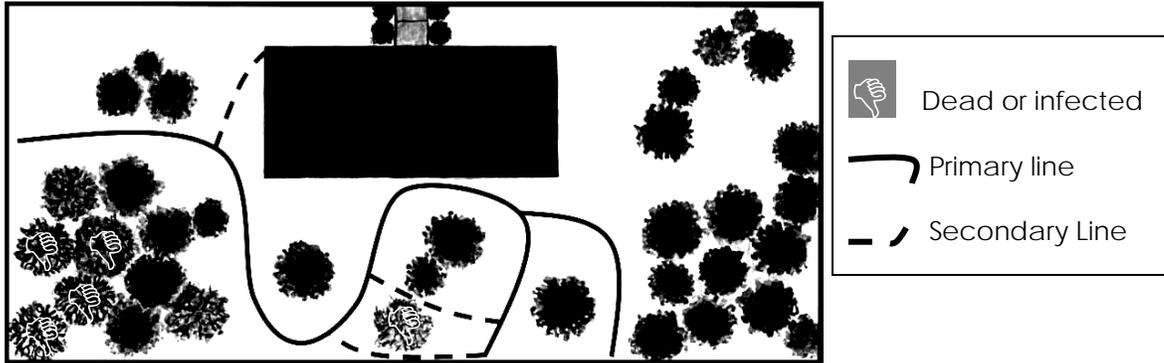
- **Avoid Injuring Healthy Trees** - Trees with fresh wounds outside existing oak wilt centers are visited by beetles transporting spores of the fungus. Because open wounds create avenues for infection, damage to trees from construction, pruning or severe storms may lead to new infection centers. Preventing injury caused by human activity is especially effective in avoiding the establishment of new infection centers. In particular, pruning or construction activities in or near oak woodlots during the susceptible period (late winter, spring and early summer) often results in injury to oak trees that leads to infection. If construction activity or pruning is unavoidable, or if storms injure oak trees during the critical period, the wounds should be treated immediately with a commercial tree paint or wound dressing. Tree paint should be used immediately after trees are wounded, at any time of the year.
- **Be Careful With Firewood** - Firewood cut from tree species that form oak wilt mats can spread the fungus. It is best to purchase wood that has been thoroughly dried for at least one full year (seasoned). Avoid oak wood that appears unseasoned, that may have tight bark, and cut ends which show no cracks or signs of aging. If questions arise about where the trees were cut or the species of tree cut, it is best to cover the wood pile with clear plastic. Make sure the edges are tucked into the soil to prevent insect spread. For trees that die in the early summer, firewood can be safely cut by the fall. As the tree dries, it can no longer support growth of the oak wilt fungus. Also, the oak wilt fungus is not a good competitor with other fungi or bacteria that invade dead wood. Smoke from burning diseased logs does not represent a problem. Heat from the fire kills all spores or beetles that might be present.
- **Create a Buffer Zone** - Oak wilt fungus transmission through root spread between adjoining trees accounts for most of the tree loss in oak wilt centers. Root spread can be stopped by creating a buffer zone between the oak wilt center and healthy trees. A trench should be established 50 - 100 feet from the last symptomatic tree. The distance depends on the size of the infected tree and soil type. For example, a larger buffer would be needed for a large, old red oak growing on porous sandy soil. Using a rock saw, commercial ditching machine or a backhoe, the trench is dug at least 48 inches deep. The trench is immediately filled.
- **Tree Injection With Systemic Fungicide** - Trees within the buffer zone can be treated with a systemic fungicide. It is applied by injecting the fungicide into the root flares. Propiconazole is most effective when applied as a preventive treatment. However, it has been applied after the tree develops symptoms as a therapeutic measure. Trees that are symptomatic have less chance of complete recovery than those that are free of symptoms. Trees with more than 30% canopy loss should not be treated. Alamo® is one such product labeled for use in the control of oak wilt.

Oak Wilt Control

Unfortunately, there is little chance to save an oak tree infected by the oak wilt fungus. The only way to maintain healthy trees is through prevention. Early detection and prompt removal of dead or dying trees and breaking root grafts between diseased and healthy trees are essential. Management of oak wilt is easy in theory but not in practice. However it can be done cost-effectively. Steps include:

- **Sanitation** - Infected red oaks that die in late summer or fall should be cut down and burned or buried soon after discovery to prevent insects from transmitting spores from fungal mats that may form on these trees in the fall or following spring. Removing a diseased tree that is still living may actually spread the infection by accelerating the movement of the fungus into adjacent trees that are grafted to it by the roots. In any case, removal of infected trees should also include severing the roots to prevent root-graft transmission of the disease.
- **Severe The Root System** - As described above in the creating a buffer paragraph, severing the roots around an infected tree(s) is a crucial step in protecting healthy trees from transmission of the disease through root grafts. Commercially-available root barriers

may be inserted in the trench to reduce the potential for trench breakouts. Correct placement of the trench is critical for successful protection of uninfected trees. The entire infection center should be encircled with the trench. Because there is a delay between colonization of the root system by the fungus and appearance of symptoms in the crown, all trees with symptoms should be carefully identified first. Then, the trench should be placed 50 to 100 feet beyond these symptomatic trees, even though there may be "healthy" trees at high risk of infection inside the trench. Often two lines are recommended: a primary line outside of apparently healthy trees and a secondary barrier outside of every obviously infected tree. The fungus can be in a tree for 2-3 weeks without leaf symptoms appearing.



Trees within the barrier, including those without symptoms, may be uprooted, cut down and removed, or deadened with herbicide injection to improve the barrier to root transmission. Tree removal should be initiated after trenching, starting with healthy trees adjacent to the trench and gradually working inward to include symptomatic trees. An alternative to removal of healthy trees may be fungicide injection. Contact a trained horticulturalist for assistance with this option.

- **Injection Of Fungicides** - Once a red oak tree becomes infected with oak wilt, there is no chemical treatment that is capable of curing the disease. However, injections of the fungicide propiconazole may extend the life of live oaks and is reported to save white oaks that are not in advanced progression of the disease.

Control of infected sites is the best course of action when the disease is diagnosed. This should include the combination of disrupting root grafts, removing and properly disposing of diseased red oaks (after severing the root grafts) and using propiconazole as a preventive. Contact the Texas Forest Service, Texas Agrilife extension agent, or a trained horticulturalist for assistance and more information.

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