DEPARTMENT OF NATURAL RESOURCES

Minnesota DNR Oak Wilt Guide

By the Minnesota DNR Forest Health Unit, April 2022

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Introduction

This document provides guidance from the DNR forest health team on oak wilt management and instructions on management tactics. It is for professional foresters, land managers, and rural landowners with some technical knowledge of forest management.

Oak wilt is a deadly disease that affects all species of oaks (*Quercus*) found in Minnesota. It is caused by a nonnative, invasive fungus (*Bretziella fagacearum*, formerly *Ceratocystis fagacearum*). Oak wilt was confirmed in five Minnesota counties as early as 1944. As of 2021, we estimate oak wilt is present over the southern 40 percent of the range of red oak in Minnesota.

While the oak wilt pathogen can infect all species of oak, those in the red oak group (leaves with pointed tips) die two to four months after infection. Trees in the white oak group (leaves with rounded leaf tips) die more slowly from oak wilt. Bur oaks (*Quercus macrocarpa*) die between one and seven years after infection, while white oaks (*Quercus alba*) die from one to more than 20 years after infection. Some white oaks can recover from oak wilt. At this time, the relative susceptibility of swamp white oak (*Quercus bicolor*) in Minnesota is not well understood. Presumably, it is similar to that of white oak. Symptoms of oak wilt are shown in Appendix 1.

In forests with sandy soils, flatter terrain, and where the majority of tree species are red or bur oaks, oak wilt commonly kills oaks in patches more than 1 acre in size. If left uncontrolled in a forest dominated by oaks, oak wilt eventually kills oaks in gaps for other species to exploit, such as buckthorn and maple species (Dube et al. 2020).

Oak wilt spreads naturally in two ways: above ground by sap beetles that deposit spores on fresh wounds, and below ground through roots of different trees that have grown together, called root grafts. Sap-feeding beetles typically fly less than 0.5 miles from an infected oak to a fresh wound. Wounds are susceptible to infection for up to five days. Oaks usually graft roots with the same species, although different oak species will graft roots occasionally.

Humans play an important role in moving oak wilt long distances by transporting freshly cut firewood and logs from infected trees. Firewood labeled MDA Heat Treatment Certified cannot produce oak wilt spores and is safe to move within Minnesota.

Location of oak wilt in Minnesota

The Minnesota DNR forest health staff updates the map of oak wilt confirmations annually. We divide Minnesota into high- and low-risk zones. High-risk areas for oak wilt infection are within 20 miles of confirmed oak wilt (see Figure 1). If a controlled oak wilt spot is free of oak wilt for five years and we are aware of its status, we remove it from the map if it is at the edge of the higher risk zone.

Reporting and confirming oak wilt

If you see oak wilt symptoms (Appendix 1) outside or near the edges of the high-risk zone, take photos, record the location, and report it using the Great Lakes Early Detection Network app or the EDDMapS website. If you do not have access to the app or internet, report the information to your local DNR forester. Reporting oak wilt outside or near the edges of its current range (see Figure 1) is the crucial first step in stopping its spread.

If you would like to confirm oak wilt, you can submit actively wilting branch samples to the University of Minnesota Plant Disease Clinic for analysis. For an accurate analysis, it is important to follow the clinic's sampling instructions. If branches are too high to reach, collect small wedges from trunks in the autumn, and sample from at least two sides of the trunk. Keep samples cool, and ship for next-day delivery. It is best to ship samples earlier in the week to avoid samples sitting over the weekend. False negative sample results are not unusual, particularly from red oak trunk samples and samples from infected bur and white oaks. Confirm infection prior to any control efforts.

Prevention

Preventing oak wilt is crucial to reducing its spread, especially in the high-risk zone (see Figure 1). Above-ground oak wilt infection can generally be prevented by not wounding oaks from April through July when (1) oaks are most susceptible to infection, (2) the oak wilt pathogen is commonly producing spores, and (3) the two sap beetle species most responsible for carrying spores are abundant.

The highest risk period for above-ground oak wilt infection is in May and June. A rule of thumb is that risk for infection starts when daily highs reach near 60°F for several consecutive days, usually sometime in April. The beginning of this risky period can vary greatly from year to year. The Oak wilt vectors emergence thermal model is a tool to let you know if there is an infection risk for your particular area. The risk starts small from March to early May and gradually climaxes in May or June, after which it declines greatly. A small risk still exists after some point in July for the rest of the growing season; however, there have been few or possibly no observations of oak wilt naturally developing from wounds made after July.

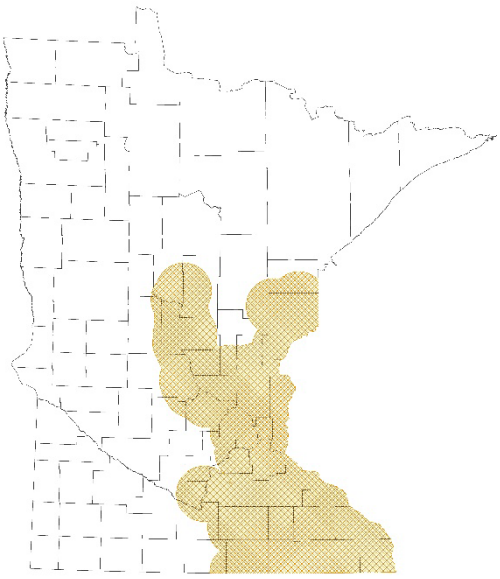


Figure 1. High-risk (tan zone) and low-risk zones (white areas) for oak wilt infection in Minnesota as of 10/02/21.

During forestry operations

If an oak stand is in the high-risk zone, and if oaks are a desired future stand component, avoid any activities that could wound living oak trees, including harvesting, cutting firebreaks, and working on trails and roads in or next to the stand from April 1–July 15.

> *DNR foresters: use the appropriate timber sale specification found in the Timber Sale Module to restrict harvesting from April 1–July 15 unless with written permission.*

Examples of exceptions for harvesting in the high-risk period and in the high-risk zone:

- Harvests with no reserve oaks and no oaks directly bordering the timber sale.
- Harvests in a cover type where oak is a minor component and where reserve oaks are widely spaced. In these situations, try to
    - retain a buffer of non-oak trees surrounding residual oaks to protect them from harvest damage.
    - space residual oaks 200 feet or more apart.
    - leave no residual oaks within 200 feet of the stand boundary if adjacent stands are oak forests.
    - encourage loggers to fell trees along the edge of the harvest into the stand to avoid damage to adjacent oak trees.
    - avoid felling trees or skidding near residual oaks within the harvest zone.
- Harvests in oak stands heavily infected with oak wilt, as long as harvesting and moving logs will not damage oaks in adjacent forests.

In areas along the northern edge of the oak wilt range in Minnesota, monitor residual oaks between one and 2 months after April through mid-July harvests and rapidly control oak wilt if it develops in residuals (see Rapid treatment of an isolated wilting oak, page 10). *Contact a DNR regional forest health specialist if you detect oak wilt in these areas.*

Avoid moving diseased oak wood April 1–July 15. Process diseased logs shipped to mills before April 1. Ideally, mill managers would keep diseased logs separate to ensure they are properly handled before April 1. Wood chips, bark slabs, and debarked logs will not produce spores and do not need to be separated from other products.

On recreational, construction, or residential sites

Prevent oak wilt by not pruning or damaging living oaks throughout the state from April through July in yards or recreational settings (e.g., campgrounds). If you must prune or accidentally wound an oak, immediately apply pruning paint, water-based paint, or shellac to the pruning cut or wound. This step very effectively prevents oak wilt infection. Dead branches can be removed anytime during the year without risk of oak wilt infection, but caution should be taken not to cut into living tissue from April through July.

Avoid felling oaks from April through July in the high-risk area. If they must be cut down, apply pruning paint or shellac immediately to the bark and to the last three annual growth rings of the stump to protect them and nearby oaks from oak wilt infection (Figure 2). Lot clearing operations, where oak stumps will be ground down or ripped out within weeks of cutting, are low risk for oak wilt as long as oaks surrounding the site are not damaged during tree felling. If oaks surround a lot that is being cleared from April through July, we recommend painting oak stumps around the edge of the lot, as shown in Figure 2, for added protection.

If you plan to remove trees other than oaks from April through July in the high-risk zone, and if they are next to oaks, avoid damaging the oaks next to them. Even a tiny wound can be infected.

If diseased oaks or branches are a hazard to people, prioritize removing the hazard. Immediately paint fresh cuts to avoid oak wilt with a wound dressing paint or shellac.

Figure 2. To prevent oak wilt, paint stumps as seen above immediately after cutting (photograph from Wisconsin DNR).

Prevention with injections of propiconazole

Propiconazole (e.g., Alamo or Propizol) can be injected into healthy red and bur oaks to prevent oak wilt for two years. It is a relatively expensive treatment and generally used on only a few high-value oaks in yard settings.

Propiconazole does not prevent infections through root grafts, so oaks beyond injected trees can still be infected through underground spread. Propiconazole will sustain a healthy oak as long as injections continue every other year, even when it becomes infected through root grafts. If an oak in a yard gets oak wilt, and there are no barriers (e.g., driveways, roads, houses) between it and other oaks, it would be an appropriate time to inject high-value red or bur oaks within 100 feet of the diseased oak. Injecting valuable trees every other year allows them to continue to thrive as long as they remain free from other problems such as twolined chestnut borer, Armillaria root disease, and severe drought. White oaks (*Quercus alba*) can be injected after they show initial symptoms of oak wilt and every other year thereafter to prevent the infection from spreading.

Injections are best done by professional arborists. Find a certified arborist by using the International Society of Arboriculture's Arborist Search. Homeowners can also treat their oaks themselves. Many companies sell injection equipment and fungicides, and online tutorials demonstrate how to inject oaks.

Controlling oak wilt

Controlling oak wilt involves stopping both underground and above-ground spread of the disease. Cutting down dead or wilting oaks almost never stops oak wilt in the woods, since cutting down oaks rarely kills their root systems. If you want to stop oak wilt from spreading to other oaks nearby, you must prioritize underground control before cutting down wilting oaks.

Underground control includes physically breaking root grafts between oaks or starving out the oak wilt disease in the roots by preemptively killing healthy oaks surrounding diseased oaks. Above-ground control methods prevent spore production or block spore movement from diseased red and bur oaks. If severely wilting or recently killed oaks are cut down in spring, summer, or fall prior to underground control, the oak wilt pathogen can be quickly sucked into the root system of adjacent oaks.

To control underground spread of oak wilt, it is important to understand the possible root grafting distance between oaks and consider how long the oak wilt pathogen has been underground spreading through roots. Oak wilt can survive in roots systems for about five years, slowly spreading to other oaks. Appendix 2 provides a table that estimates the distance in which oak wilt could move between oaks in one year. Trees are more likely to graft roots at greater distances as their size increases, in forests with low tree species diversity, on sandier and shallower soils, and on flatter terrain.

To control the above-ground spread of oak wilt, diseased wood must be properly handled before the following April. See How to properly handle infected wood for details.

If done correctly, oak wilt can be successfully managed on a property-by-property basis throughout Minnesota, but control might not be appropriate in all circumstances. Consult the table on the next page to decide which oak wilt management strategy is most appropriate for your situation. Details on the strategies follow the table.

Find information on financial support programs for oak wilt management on the DNR's oak wilt management webpage.

Prioritize controlling underground spread over above-ground spread if cost is a limiting factor in areas known to have oak wilt. Leaving infected red oaks on site still poses a significant short-term threat to oaks in the vicinity, but underground spread of the disease kills many more oaks overall. If you cannot cut down infected oaks and properly handle their wood, leave them on site through the end of the following July, when they no longer pose a significant risk. However, check if your community has a nuisance-tree ordinance that prohibits leaving diseased oaks standing.

Finally, avoid cutting down oaks when prohibited to protect endangered species, such as the northern long-eared bat. Tree removal within the 150-foot radius roost tree buffer zone for northern long-eared bat protection is *not* prohibited from August 1 through May 31. In cases where oaks cannot be cut down, herbicides can be sprayed onto girdles cut around their trunks to kill them. Details on how to kill spore-producing oaks and healthy oaks can be found pages 10 and 11.

Oak wilt control options

Situation	*Recommended Control Options*
• Oak wilt confirmed in low-risk zone	Please report; control is important
• Oak wilt not abundant • Threatened and endangered plants and buried cultural sites *not* present • Site relatively flat with deep soils; no buried utility lines • Vibratory plows or trenchers available	Vibratory plowing or trenching with cutting to the primary barrier line (p. 9)
• The first two criteria in the above situation apply, but • shallow soils present, or • vibratory plows or trenchers not available, but bulldozers or excavators are	Stump extraction (p. 10)
• Oak wilt pocket and adjacent oaks well beyond grafting distance from other oaks	Host elimination (p. 10)
• A single oak wilted in spring or summer and no other dead oaks nearby	Rapid treatment of an isolated wilting oak* (p. 10)
• Equipment such as vibratory plows or excavators not available, or • Cost is a limiting factor, or • Threatened and endangered plants or buried cultural sites present near oak wilt pockets • Few, small isolated oak wilt pockets, and • No recreational sites or buildings nearby	Frill-girdle and herbicide* (p. 11)
• The first three criteria in the above situation apply, but • Several larger oak wilt pockets, or site has nearby buildings or is a recreational site	Cut-stump, herbicide* (p. 11–12)
• Cost is *the* limiting factor	Slowing above-ground movement (not a control strategy, p. 12)

• Oak wilt is significantly impacting a forest, and landowner
  ○ wishes to capture oak timber value, or
  ○ wishes to restore site to one with more healthy oaks and fewer invasive plants
	Regeneration harvest (p. 12)

• Yard setting and cost not a limiting factor, or • Owner unwilling to sacrifice healthy oaks to ensure control effectiveness	Three alternatives to removing healthy oaks inside the barrier line (p. 13)

• Area already known to have oak wilt, and
  ○ A forest with oaks is not important to landowner, or
  ○ The forest has a diverse make-up of tree species or very steep terrain, allowing for less efficient underground oak wilt movement between oaks
	No control (p. 13)

**Considered an experimental control strategy, but observations indicate the method will provide some control.*

Always follow pesticide label directions. DNR foresters, follow the Division's Pesticide Use Guidelines*.*

Vibratory plowing or trenching with cutting to the primary barrier line

1. Between mid-September and when the ground freezes, sever root grafts around wilted *and* dead oaks, including a buffer ring of healthy oaks (called the primary barrier line). A vibratory plow is the best tool for this, since it disturbs the site the least, but trenchers can also cut root grafts. A 5-foot vibratory plow blade must be used for effective control. In hilly terrain or on loamy or clayey soils, include a buffer of all healthy oaks next to the wilting and dead oaks. On sandy soils and relatively flat terrain, include at least the two closest rings of oaks around wilting oaks. See Appendix 2 for a guide on buffer size.
2. Next, remove healthy oaks, including saplings, within the barrier line, since they are likely to die from oak wilt in the next few years. This removal is called "cutting to the line" and is illustrated below. If cutting to the line is unacceptable, see Three alternatives to removing healthy oaks inside the barrier line.
3. Within a few hours after cutting down healthy oaks within the barrier line, apply herbicide to stumps and root collars according to label directions. Typically, the outer 2 inches of stump surface are sprayed with herbicide (Figure 4). Herbicides that could be applied to stumps include triclopyr (e.g., Garlon), imazapyr (e.g., Arsenal, Stalker), and glyphosate (e.g., Roundup Pro, Razor Pro). Herbicides applied to stumps may lessen the chances of roots re-grafting across the barrier line. Always follow pesticide label directions.
4. Lastly, remove diseased oaks to stop above-ground movement of the disease. It is crucial to remove diseased oaks *after* root graft severing. Properly handle infected wood before April.

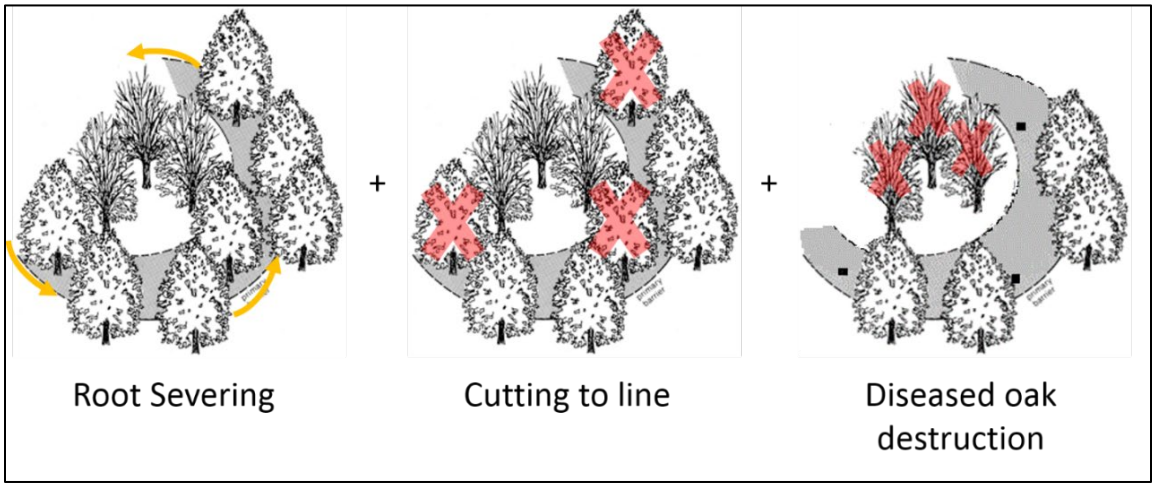


Figure 3. Root-severing followed by felling healthy oaks within the sever line and destroying diseased oaks has stopped oak wilt about 90% of the time (original line drawing from Juzwik et al. 2016).

Stump extraction

1. In late autumn after trees have gone dormant, cut down a buffer ring of healthy oaks around wilted and dead oaks. On loamy or clayey soils, the buffer of healthy oaks should include all healthy oaks next to wilting oaks *and* dead oaks. On sandy or shallow soils, include at least the two closest rings of oaks around wilting oaks. See Appendix 2 for a guide on buffer size.
2. Remove stumps from the cut buffer trees before April. If in the woods, stumps can be put back in their holes upside down.
3. Lastly, remove diseased oaks. Control success increases if diseased oak stumps are removed too. Properly handle diseased wood before April.

Host elimination

1. This control technique assumes oaks in and around an oak wilt pocket are isolated from other oaks (by at least 100 feet) and are surrounded by a forest composed of other tree species that are not oaks. Simply cut down *all* heathy oaks around the dead and diseased oaks.
2. Next, cut down the diseased oak(s).
3. Properly handle diseased wood before the following April.

Rapid treatment of an isolated wilting oak

No research has been published on this strategy. It is considered experimental and potentially risky. Michigan DNR, Manistee National Forest, and Menominee Tribal Enterprises have used this strategy where isolated oaks were clearly infected above-ground and not through root graft disease spread. Preliminary control effectiveness in Wisconsin trials exceeded 80 percent. Tactics A and B are more likely to work if they are done to oaks that were infected in the crown and at the earliest stages of wilt.

A. Rapid felling of an oak in early stages of wilt: (Only employ this tactic if an isolated wilting oak still has a modest portion of healthy green leaves. Otherwise use tactic C.) If an isolated wilting oak is found, cut it down immediately. This goes against conventional wisdom, but in theory, it should work if the tree was infected in the upper crown and wilt has just begun. For oaks felled in August or later, properly handle diseased wood before the following April.
B. Rapid girdling of an oak in early stages of wilt: (Only employ this tactic if an isolated wilting oak still has a modest portion of healthy green leaves. Otherwise use tactic C.) If an isolated wilting oak is found from June through early September, girdle the trunk twice and apply herbicide to the girdles and root collar from July to October 1 (the earlier the treatment, the more effective it may be). Girdling can create hazardous trees, so mark the area as hazardous with appropriate flagging or warnings. This tactic may not be appropriate in places with high recreational traffic. See detailed instructions for girdling under the Frill-girdle and herbicide method on page 11. If you need to remove the hazardous oak, cut it down in the late autumn or winter. Diseased oaks girdled and treated in July and August will produce few, if any, spore mats in spring and could be left on site. For trees treated after August, properly handle diseased wood before the following April.
C. Rapid stump extraction of a wilted oak: If an isolated oak is found that is mostly wilted, cut the tree down between October 15 and December 31 and remove the stump. If in the woods, the stump can be put back in its hole, upside down. Properly handle diseased wood before the following April.

Frill-girdle and herbicide method

This strategy can create hazardous trees. Do not use it near recreation areas, buildings, or in forests used by recreationists. Mark the area as hazardous with appropriate flagging or warnings. No research has been published on this technique, so it is considered experimental. A variety of forest managers in Minnesota and Wisconsin have successfully used this type of control strategy.

1. Mark oaks that wilted or are wilting after August 1. Then mark a buffer of healthy oaks that may be root-grafted to the infected oaks and all previously killed oaks (mark living oaks inside the pocket too, down to 1 inch in diameter). This often includes two rings of the nearest healthy oaks around wilting *and* dead oaks, but may include more. See Appendix 2 for a guide on buffer size.
2. Anytime from August 1 to November 1, make two horizontal girdles with a chainsaw or ax around each marked healthy buffer oak over 4 inches in diameter. Single girdles may be used successfully, but are not as effective. Girdles should reach through the bark and go into the sapwood 1 inch, encircle the entire trunk, and meet end-to-end. Make the highest girdle no more than 18 inches above the ground, and separate the two girdles by roughly 6 inches. Clean wood chips out of girdles and apply herbicide to the girdles and the root collar. Published and unpublished trials have seen the highest success with the triclopyr-based herbicide Garlon. Trials using the picloram and 2,4-D-based herbicide Tordon RTU were not successful in Michigan and Iowa. Oaks between 1 and 4 inches in diameter can be killed with a basal bark herbicide treatment instead of a frill girdle treatment. Always follow pesticide label directions.
3. Cut down dead, girdled oaks before spring to eliminate hazard trees, if needed. Cutting down girdled oaks can be dangerous and ideally is done by an experienced tree feller.
4. Lastly, remove diseased oaks and properly handle infected wood before April.

Cut-stump, herbicide method

No research has been published on this technique, so it is considered experimental. The Minnesota DNR forest health unit is tracking some sites where this technique has recently been used, and Menominee Tribal Enterprises is also evaluating this method.

> *DNR foresters: contact your regional forest health specialist if employing this tactic. It can be incorporated into forestry operations at little cost. The timber permit holder is not responsible for applying herbicide to stumps unless they sign a contract to spray.*

1. In late summer or autumn, cut down a buffer of healthy oaks next to wilted and dead oaks. In all situations, create a wide buffer, including *at least* the two closest rings of oaks around wilting *and* dead oaks. Be sure to cut all healthy oaks regardless of size, even small saplings within and around the oak wilt pocket. See Appendix 2 for a guide on buffer size. In older mortality centers on flat, sandy sites, making an even larger buffer than Appendix 2 suggests will be more successful.
2. Immediately apply an appropriate herbicide to stumps. Typically, the outer 2 inches of stump surface is sprayed with the herbicide as well as the sides of the stump and root flare (Figure 4). Examples of herbicides that may be applied to stumps: triclopyr (Garlon 4 Ultra, Garlon 3a, Remedy Ultra), imazapyr (Arsenal, Stalker), and glyphosate (Roundup Pro, Razor Pro). Always follow pesticide label directions.

3. Lastly, remove diseased oaks to stop above-ground movement of the disease. It is crucial to remove diseased oaks only after grafted oaks are cut down. Properly handle infected wood before April.

Figure 4. Kill stumps and root collars by applying herbicide to the outer 2 inches of stump surface, shown in blue, and the root collar (image from USDA Gen. Tech. Report NRS-96).

Slowing above-ground movement

To slow above-ground movement of oak wilt, cut down diseased oaks in late autumn or winter after all trees have dropped their leaves for the fall. Properly handle infected wood before April. *This technique won't stop the underground spread of oak wilt in most situations.*

Regeneration harvest

If oak wilt is abundant in a forest, it is not realistic to completely eliminate the disease. Sustainably harvest the mature trees while ensuring a younger forest regenerates afterward. It is more beneficial to have an earlier harvest as oak wilt develops in a stand, to maximize oak regeneration from younger vigorous stumps and minimize invasive plants proliferating in oak wilt pockets. The oak wilt pathogen will die out in stumps and root systems eventually. Oak can still be an important part of the new forest. Planted seedlings and those originating from acorns will not get oak wilt through their roots, and many uninfected oak stumps will grow sprouts that will mature into trees. In a regeneration harvest:

- Maintain mature oaks for acorn production that are several hundred feet away from oak wilt mortality centers.
- Consider employing steps in the Stump extraction section, or other control strategies, to discourage underground spread of oak wilt to residual oaks or adjacent forests.
- Maintain mature trees other than oak for seed production and to promote tree species diversity.
- Consider planting different species of oak if they are not present on the site.
- Do not harvest from April through mid-July (see the Prevention during forestry operations section).
- Avoid spreading oak wilt.

Three alternatives to removing healthy oaks inside the barrier line

If you are unwilling to sacrifice healthy oaks inside the primary barrier line, you have three options:

A. Protect healthy oaks within the planned primary barrier line with propiconazole. This step should take place in the summer prior to vibratory plowing or trenching. Propiconazole will not stop disease spread through roots, but it will keep oaks from developing wilt as long as they are injected every other year.
B. Install a secondary barrier line. This replaces steps two and three of vibratory plowing or trenching with cutting to the primary barrier line. Secondary barrier lines often fail, which creates additional control costs and complications, but could save many oaks within the primary barrier line without having to use pesticides. An illustration of secondary barrier lines is seen in the illustration on p. 9 as the inner dashed line. Closely monitor healthy oaks between the primary and secondary barrier lines, and if you see them wilt, fell them in the dormant season and properly handle their wood.
C. Closely monitor healthy oaks within the primary barrier line, and if you see them wilt, fell them in the dormant season and properly handle their wood.

No control

If the goals for a forest do not include having an abundance of healthy red or bur oaks, and if oak wilt is already established in the surrounding landscape, not controlling oak wilt may be appropriate. Likewise, in steep terrain and diverse forests, oak wilt's impact is often relatively small, making disease control unnecessary.

In forests where oaks are abundant, oak wilt will continue to spread from oak to oak, and new infections nearby could start as a result of above-ground spread. Invasive, undesirable vegetation or aggressive native shrubs and trees such as hazel, red maple, boxelder, elm, and cherry may take over in areas impacted by oak wilt (Dube et al. 2020).

Firewood timber sales

If firewood is being salvaged from dead or dying oaks from a forest known to have oak wilt, only remove oaks that have loose bark or no bark. These oaks no longer can transmit oak wilt. Oaks dead for more than one year are also safe to remove. Removal of infected oaks from a stand will not stop underground progression of oak wilt.

How to properly handle infected wood

Consult the table below to determine whether additional action is needed to reduce the risk of spore production in the spring on infected oak trees, oak logs, or oak firewood:

Infected oak description	*Action needed to reduce spring spore risk*
Oak has been dead for more than one year	None (no risk)
White, bur, or swamp white oak	None (risk is very low)
Red oak* that wilted before July 15	None (risk is very low)
Red oak branches or trunks less than 6 inches in diameter	None (risk is low)
Red oak that wilted, but timing of wilt is unknown 1. Cambium is brown on opposite sides of trunk in summer or early autumn (Figure 5) 2. Cambium is white on at least one side of trunk  *Figure 5. Blue arrows point to brown cambium in autumn.*	1. None (risk is very low) 2. See options below (could produce spores in the spring)
Red oak wilted after July 15	See options below (could produce spores in the spring)

** Red oak includes any oak with pointed lobes on leaves: black, northern pin, and northern red oaks.*

If an oak log could produce spores in the spring:

- Avoid moving logs or firewood from April through July 15.
- Avoid moving logs or firewood outside the high-risk zone unless they will be processed or handled properly prior to April.

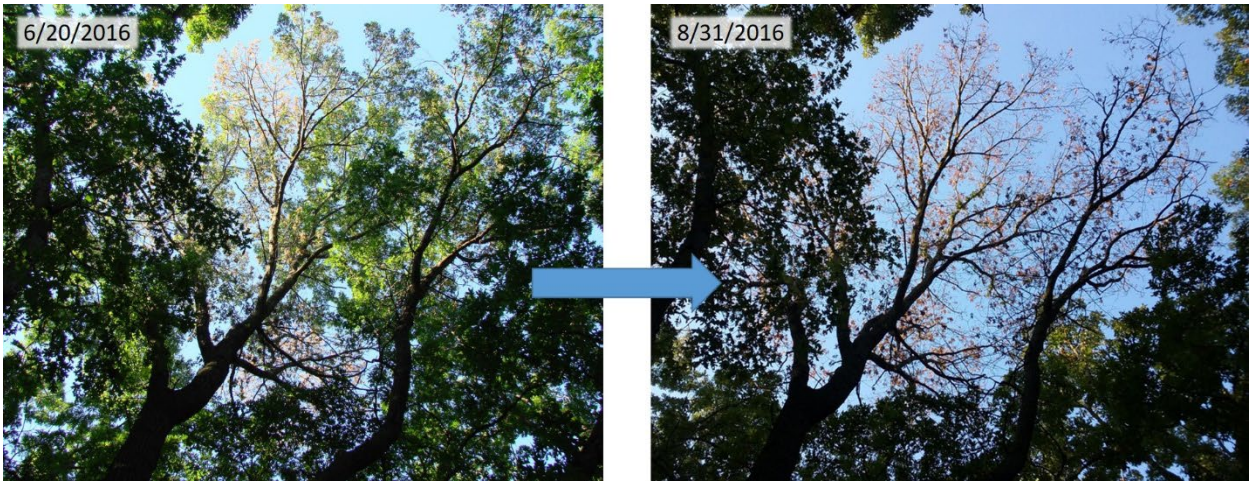
For diseased red oak logs larger than 6 inches in diameter and those that died after July 15:

1. Split into firewood segments no wider than 4 inches and pile loosely before January to allow logs to dry out before spring.
2. Burn, debark, or chip infected logs and branches before April. Chips and bark will not spread infection, so they can be left on site.
3. Kiln-dry or process logs into lumber before April.
4. Tarp diseased wood from April through the end of July. Completely bury edges of the tarp to prevent sap beetles from coming into contact with spores. The tarp should be thick enough to prevent punctures.

5. For areas where oak wilt is common, leave infected trees standing for one year after death, beyond which they can no longer form spore mats. Infected trees add little risk to the general area if oak wilt is common. However, some communities have nuisance tree ordinances that prohibit leaving diseased oaks.

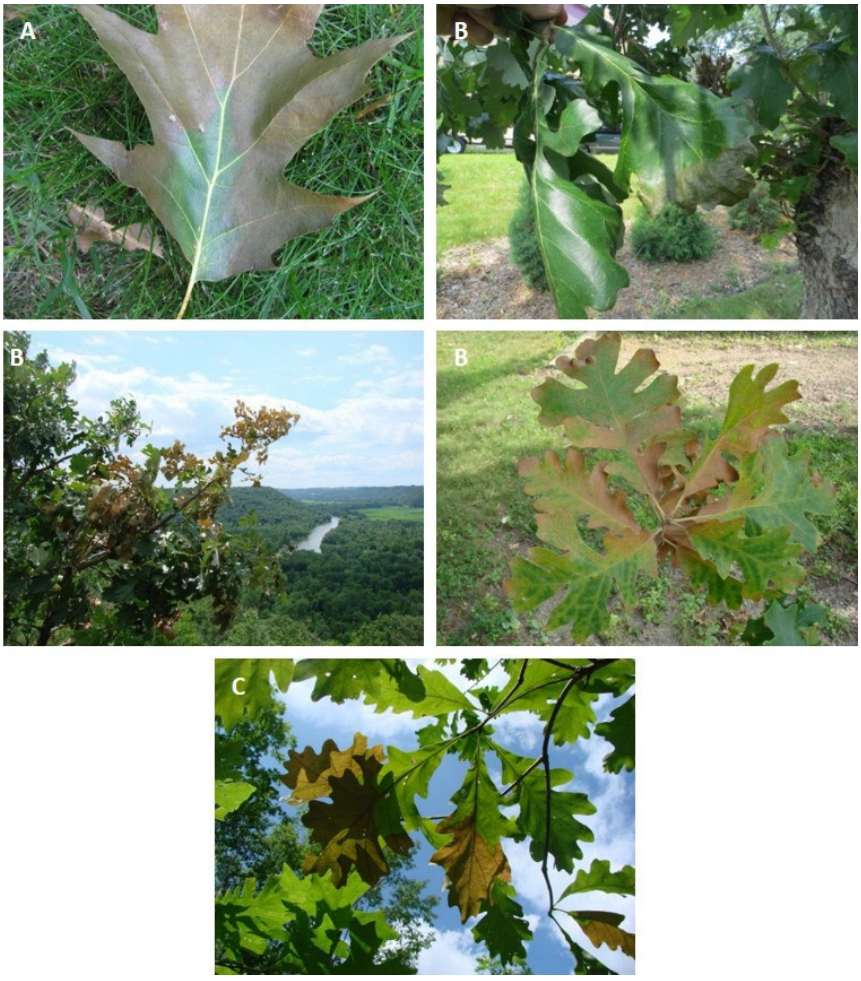
Appendix 1: Photo guide to oak wilt symptoms

Initial wilt symptoms on a red oak. Leaves on outer branches are drab green, bronzed, or wilting.



Red oaks die one to two months after initial symptoms and drop most of their foliage. *Quick and abundant leaf drop in a matter of days after initial leaf symptoms distinguishes oak wilt from other killers such as twolined chestnut borer, Armillaria root disease, and herbicide.* Oaks struck by lightning can lose their leaves quickly but show a lightning scar. If oak wilt starts in early fall, the tree may appear to just be turning fall color. In that case, have a sample analyzed for disease confirmation.

Abundant green, brown, and bronzed leaves under an oak in the growing season signal oak wilt.



Oak wilt leaf symptoms on red oak (A), bur oak (B), and white oak (C).

Oak wilt on a large bur oak affected about 25 percent of its canopy in one summer. *Symptoms start in the outer canopy,* which distinguishes oak wilt from less concerning diseases such as anthracnose, bur oak blight, and shoot blights.

Oak wilt kills neighboring oaks by spreading through connected root systems. Healthy maples surround the dead oaks.


Brown or purple streaking on the wood surface is sometimes visible on actively wilting branches. Streaking must be visible on living branches immediately after bark removal, and is more readily seen on white and bur oaks than on red oaks.

Elliptical pressure pads, formed in the center and on top of flat spore mats, are diagnostic for oak wilt, and form on some diseased red oaks as they are dying or shortly after death. Opposing pads form between bark and wood, causing bark to crack (left). Pads and mats give off a fruity smell, similar to bananas or wine. Pads are light gray when fresh (middle), and quickly rot and turn black (right).


Oak wilt (left) compared to damage from twolined chestnut borer (right). Oak wilt kills red oaks in weeks and causes them to lose most of their leaves. It also can kill stump sprouts. Twolined chestnut borer usually kills oaks in two or more years, killing portions of the canopy each year, and does not kill small saplings. Leaves on oaks infested with twolined chestnut borer turn autumn-orange and hang on branches for much longer.


A bur oak suffering from oak wilt (left, in late June) and bur oak blight (right, in early September). Oak wilt kills leaves and branches starting from the outer part of the canopy. Bur oak blight kills leaves (but not branches) starting from the inner and lower part of the canopy.

Appendix 2: How to determine buffer size to control oak wilt

Any tactic used to control the underground spread of oak wilt is costly, so it is important to place the barrier line (or buffer) at the right distance for successful control. This involves sacrificing healthy oaks for the good of the entire forest. The table below shows whether or not a healthy oak near an oak wilt pocket should be included within a buffer. An illustration on how to use the table is in Lake States Woodlands: Oak Wilt Management—what are the options (Cummings Carlson et al. 2010).

In an oak wilt pocket, add the diameter of a diseased oak to the diameter of a healthy oak to calculate their combined diameters at breast height (Combined DBH, left column). Looking at the four right-hand columns, choose the one that applies to your site and use the combined DBH row to see how far oak wilt could spread between the two oaks in one year, *in theory*. If the healthy oak is closer to the diseased oak than that distance, include it within the buffer. Repeat this process for all diseased and dead oaks in the pocket and all healthy oaks around the pocket.

For example, a 13-inch-diameter red oak wilted on a sandy site, and it is next to three other dead oaks that wilted previously. You plan to stop oak wilt with a vibratory plow. You are wondering whether or not a 17-inch-diameter healthy red oak should be included within a vibratory plow line. This 17-inch oak is closest to the 13-inch oak in the disease pocket. First add those two diameters (30 inches of combined DBH). The distance in the table that matches this situation is 58 feet. If the 17-inch healthy oak is 59 feet away from the diseased oak, then the vibratory plow line should go between it and the diseased oak. If it is 58 feet away or closer to the diseased oak, then the vibratory plow line should go around it to include it in the buffer.

We do not recommend using this table in steep terrain, in mixed species forests on heavier soils, or with white and bur oaks. In those cases, if using root severing techniques, place your primary barrier line outside one ring of healthy oaks located next to diseased oaks. For cut-stump herbicide or frill-girdle herbicide techniques, place the barrier line outside two rings of healthy oaks.

Table 1. Suggested buffer distance (feet) away from wilting or dead oaks.

Combined DBH (inches)	Any time the herbicide methods are used	Stump extraction, vibratory plowing, or trenching on sandy soils	Larger pocket on loamy sands, loams, or clays with stump extraction, vibratory plowing, or trenching	Smaller pockets (very few oaks killed in prior years) on loams or clays with stump extraction, vibratory plowing, or trenching
10	26	19	15	11
12	31	23	19	13
14	36	27	22	16
16	41	31	25	18
18	46	35	28	20
20	51	39	31	22
22	56	43	34	25
24	61*	47	37	27
26	66*	50	40	29
28	72*	54	43	31
30	77*	58	46	34
32	82*	62*	49	36
34	87*	66*	53	38
36	92*	70*	56	40
38	97*	74*	59	42
40	102*	78*	62*	45
42	107*	81*	65*	47
44	113*	85*	68*	49
46	118*	89*	71*	51
48	123*	93*	74*	54
50	128*	97*	77*	56
52	133*	101*	80*	58
54	138*	105*	83*	60
56	143*	109*	87*	60
58	148*	113*	90*	60
60	153*	116*	93*	60

Distances in gray that are marked with an asterisk (*) are farther than people have documented oak wilt moving underground in one year. For oak wilt pockets that are *less than one year old*, we do not recommend placing vibratory plow lines or extracting stumps more than 60 feet away from the outermost dead or dying oak. Since oaks killed in prior years exist in most oak wilt pockets, often at the edges of pockets, the potential underground spread from those dead oaks is greater than the one-year spread potential. This is the reason we included distances of underground oak wilt spread that would occur over multiple years.

This table was derived from research done in Michigan, where the probability of underground disease spread within one year was modeled on deep sands and loamy sands in northern pin oak (*Quercus ellipsoidalis*) forests (Bruhn et al. 1991). The model was based on observations of northern pin oaks with maximum combined diameters of 44 inches and a maximum underground spread of oak wilt in one year

of 41 feet. The authors of this research wrote that prior to their research, they observed a maximum annual spread of 60 feet in those forests. The first and second columns represent a 99 and 95 percent confidence interval, respectively, that oaks beyond the specified distance on deep sands avoid underground oak wilt infection for one year. The third column represents a 95 percent confidence interval on loamy sand, and the fourth represents an 80 percent confidence on loamy sand. Research done in Minnesota (J. Juzwik et al. 2010) and Wisconsin (D. Bronson, personal communication March 5, 2020), in which the original Michigan model was analyzed, also influenced this table.

We recommend you measure distances between oaks that wilted in different years in a pocket to give you a better idea of where to place a barrier line for a vibratory plow, trencher, or for the stump extraction method. Keep in mind oak wilt persists in root systems, slowly spreading out each year from a previously killed oak, so grayed values with asterisks are reasonable to use for oaks killed in prior years. Additional research on this topic would improve our understanding of the necessary buffer size for the various control methods.

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