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Grape Phylloxera

Biology and Management in the Pacific Northwest

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Oregon State University | Extension Service

Contents

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Chapter 1

The Biology of Grape Phylloxera

Name
Daktulosphaira vitifoliae (Fitch)
Synonyms
Daktulosphaira vitifolii Shimer
Viteus vitifolii Shimer
Peritymbia (Phylloxera) vitifolii per C.B. vastatrix (Planchon)
P. pervastratrix (Börner)
Phylloxera vitifoliae (Fitch)

Grape phylloxera, *Daktulosphaira vitifoliae* (Fitch) (Homoptera: Phylloxeridae), is an aphidlike insect that feeds aggressively on grape roots. Phylloxera is native to the eastern and southeastern United States, where native American grape species coevolved with the insect.

The American grape species *Vitis rupestris*, *V. berlandieri,* and *V. riparia* are resistant to phylloxera. In contrast, the American grape species *V. labrusca*, *V. aestivalis,* and *V. vulpina* are susceptible to phylloxera. European winegrapes, *V. vinifera,* are the most susceptible.

There is no way to eradicate phylloxera from an infested vineyard. It will eventually kill susceptible grapevines. The only way to manage an infestation in the long term is to replant the vineyard to vines grafted to a resistant rootstock (see Chapter 6).

History

Phylloxera was first found on grape roots in California in the 1850s. In 1860, the pest was introduced to France on American *Vitis* species vines, which had been imported for use in grapevine breeding programs due to their resistance to powdery mildew. By 1900, two-thirds of all *Vitis vinifera* vineyards in Europe had been destroyed. Since then, phylloxera has spread to most grape-growing areas of the world, including New Zealand, Australia, South Africa, South America, Canada, and the United States.

Phylloxera has been in the Pacific Northwest for decades. It was first discovered in Oregon in 1955; however, it was not identified in commercial vineyards until 1990. In 1988, phylloxera was positively identified at eight sites in Washington, one of which was a *V. vinifera* vineyard. Phylloxera is now distributed throughout every major grape-producing region in Oregon, with the exception of Umatilla County, which is part of the Walla Walla American Viticultural Area (AVA).

For more information on the devastation caused by phylloxera throughout the history of grape production, see *Phylloxera: How Wine Was Saved for the World*, by Christy Campbell (see page 23).

Life cycle

The full life cycle of phylloxera involves migration from the roots to the leaves and then back to the roots (Figure 1). The life cycle includes both sexual and parthenogenetic (without mating) reproduction.

In the full life cycle, phylloxera can take four forms, although not all of these forms have been identified in Oregon or the Pacific Northwest:

- Wingless, root-feeding form (radicoles)
- Winged form (alates)
- Wingless sexual form
- Wingless, leaf-galling form (gallicoles)

On *V. vinifera* grape cultivars, phylloxera normally infests only the underground parts of the plant and undergoes an incomplete cycle of seasonal development. The leaf-feeding, gall-producing form is not present. In susceptible American *Vitis* species, the full life cycle occurs, including the leaf-feeding, gall-producing form.

The ability of phylloxera to form the leaf-gall-producing form probably depends both on the strain of phylloxera and the grape species. Phylloxera strains found in California and most major viticulture areas do not produce leaf-feeding gallicoles. In contrast, phylloxera strains found in the eastern United States generally cause leaf galling on American grape species (e.g., Concord) or on interspecific hybrid cultivars that have American *Vitis* in their genotype (e.g., French-American hybrids such as Marechal Foch).

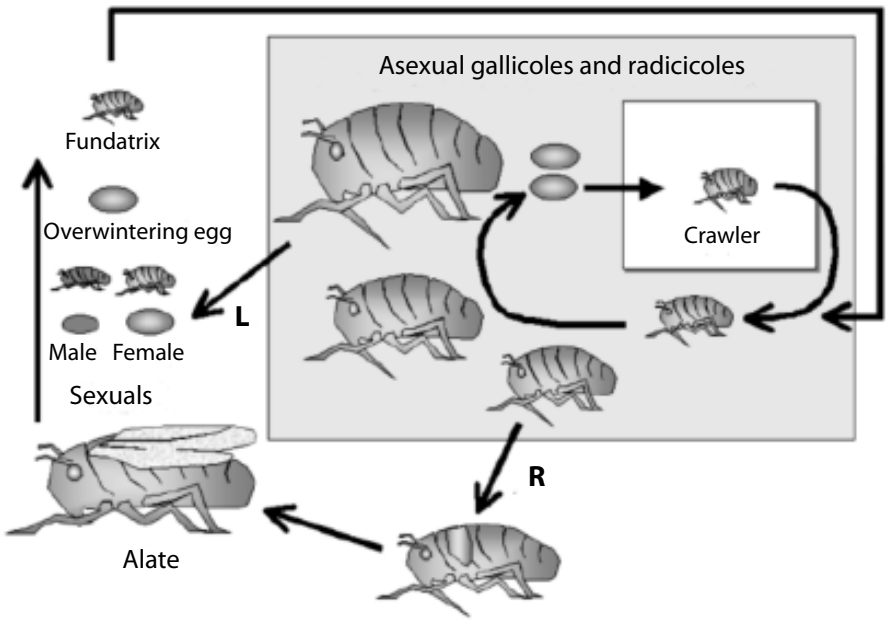

Figure 1. The complete life cycle of phylloxera. L = leaf infestation. R = Root infestation. In the Pacific Northwest, infestation occurs primarily on vine roots. The fundatrix hatches from eggs that had overwintered and can start new development of phylloxera colonies. Image reproduced with permission from Granett et al. 2001.

Phylloxera strains from Australia and the eastern United States have also shown galling on *V. vinifera*.

Root-galling phylloxera

The **wingless, root-feeding form** (***radicole***) is found year-round on vine roots of infected vineyards. Radicoles overwinter in an inactive stage (***hibernant***) or as first- or second-instar nymphs. They begin feeding on the roots as soon as root growth is initiated in the spring. The rate of development depends on vine sap flow, grape root growth, vine phenology, and numerous environmental factors, including humidity, soil temperature (45 to 65°F), and air temperature.

During the summer, larvae (known as crawlers) develop into adult females within 2 weeks. Throughout the summer, these females lay up to 400 eggs parthenogenetically in bundles on the roots. Eggs hatch within 10 days, producing new crawlers.

Crawlers are mobile, but they leave the root where they hatched only if a high phylloxera population has created feeding competition or when a vine is near death. In this case, they travel on the soil surface or through cracks in the soil to infest new roots. They also can climb the vine and be blown by the wind for considerable distances.

Crawlers are most numerous in late summer to early fall when temperatures are optimal for reproduction. Adults, eggs, and crawlers are easiest to detect by digging up grape roots at this time or later in the season (see Chapter 3). The risk of spreading the insect is also greatest at this time (see Chapter 2).

Most larvae that hatch in the fall enter the overwintering stage (hibernant) soon after hatching and become brown and inactive. Alternatively, they may overwinter as first- or second-instar nymphs on nodules or galls on vine roots.

During late summer, some crawlers may develop into winged nymphs, called ***alates***. The reasons for alate formation are not fully understood, but it may be a response to crowding pressure (high populations on the roots) or to high soil temperatures. This form lives only a few days. During this time, it flies and deposits two to six eggs on woody areas of the grapevine such as the trunk. These eggs hatch, producing the **wingless sexual form**. Eggs differ in size, and the larger ones produce females.

The wingless sexual forms develop without feeding, since they lack functional mouthparts. Following four molts, they are mature and mate. Fertilized females then lay a single egg in bark cracks or crevices. This egg survives the winter and may hatch in spring. Although it was previously believed that this egg gives rise to the leaf-galling form in the spring (see below), research now suggests that this is not the case (Granett et al. 2005).

Leaf-galling phylloxera

In addition to the radicole life cycle described above, phylloxera can live out another stage of its life cycle on leaves. This form is the ***gallicole*** and is generally observed on American *Vitis* species (not on *Vitis vinifera*). Gallicoles hatch in the spring (as early as bud break) from eggs that were laid in the soil by the final generation of gallicoles the previous fall (Granett et al. 2005). The resulting gallicole emerges from the soil and migrates to young leaf tissues, where it feeds and forms a gall to house its eggs. A gall proliferates to the underside of the leaf but opens to the top of the leaf. About 400 to 600 eggs are laid parthenogenetically inside each gall.

Figure 2. Phylloxera female (center) and eggs found on vine roots of an Oregon vineyard.

After hatching, crawlers leave the gall and move to the soil or begin new leaf galls. There may be four to six generations of gallicoles per growing season. Individuals of the final generation drop to the ground, burrow into the soil to a depth of 4 feet, and infest the roots. The eggs they lay in the soil will hatch the following spring, restarting the cycle.

On many American grape species, the foliar life cycle is predominant, and the root form is secondary (Downie et al. 2000). This galling, if severe, reduces the photosynthetic ability of the vine, but it generally is not of major concern unless there are large numbers of galls per leaf. Up to 20 galls per leaf have resulted in decreased photosynthesis and berry development of Seyval grapes (McLeod 1990).

Gallicoles occur on the American grape species *V. labrusca* and *V. aestivalis*. They have not been found on *V. riparia*. Also, they have not been observed in rootstock vineyards in Oregon or California.

Identification

The root-infesting form of phylloxera (***radicole***) is found year-round on roots. Adult radicoles are difficult to detect because of their extremely small size: 0.7 to 1 millimeter (1⁄30 to 1⁄25 inch) long and 0.4 to 0.6 millimeter wide.

On fresh, vigorous roots, immature radicoles vary from pale green, yellowish-green, or olive green to light brown. On weakened roots, immature radicoles are brown or orange. Adults (Figure 2) become brown or purplish-brown, no matter what kind of roots they have fed on.

Eggs are found on the roots throughout the summer (Figure 2)

and are yellow. Newly deposited eggs are lemon yellow and oval (0.5 to 0.7 mm long and about half as wide).

Injury

Phylloxera damages *Vitis vinifera* grapevines by feeding on roots, eliciting gall formation. Feeding generally occurs on the tips of the rootlets, resulting in the formation of yellowish-brown, hook-shaped swellings or galls known as nodosities (Figure 3). These galls may engulf the insect's body. In most cases, the swelling stops rootlet growth, and the infested portion of the root eventually dies.

Feeding on larger roots causes rounded swellings (tuberosities), which give the root a warty appearance. The tuberosities may also decay, further weakening the vine.

It is believed that phylloxera inject toxic saliva or gut contents —amino acids and/or waste products—into the root during feeding, thus inducing gall formation. Alternatively, the feeding process may stimulate the plant to release hormones, such as auxin, that initiate the gall.

Root injuries impair absorption of nutrients and water, causing a decline in vine vigor and productivity. Secondary fungal infections and subsequent feeding by other insects and mites also hasten decomposition of roots.

Above-ground symptoms are an indirect result of root damage. Symptoms are visible as low-vigor canopy growth and overall vine decline over several seasons. Foliage is lighter green than normal foliage. Often, infested vines drop their leaves earlier than healthy vines, or the foliage yellows more quickly.

The severity of above-ground symptoms depends partly on the variety, age, and vigor of the vine; soil nutrient and water status; and site drainage.

Damage pattern

Above-ground symptoms usually appear first as declining shoot growth and reduced fruit set in a small, oval area in the vineyard (Figure 4). However, if phylloxera were brought in on own-rooted (ungrafted) planting material, the entire vineyard block may be weakened.

As the phylloxera spread, the weak areas increase in size, with a progression of weaker vines toward the center of the area. Other areas of infestation may also appear in the same vineyard.

It may take 2 to 5 years from the time of initial infestation for symptoms to appear, depending on vine vigor, method of infestation, and location of the planting. In warm areas such as California, phylloxera can have four or five generations per season, and vineyards may decline quickly (in as few as 3 to 5 years). Oregon likely has only two or three generations of phylloxera per season, which

Figure 3. Root galls (nodosities) form at the end of young roots due to phylloxera feeding.

Figure 4. Phylloxera infestation spreading through an Oregon vineyard. Notice the oval pattern of affected vines.

may contribute to the observed slower rate of vine decline and phylloxera spread.

Keep in mind that other factors can also cause low vigor and deteriorating vine health:

- **Shallow soil or drought**. Weakened areas will not spread annually unless erosion is occurring, nor will there be a distinct pattern as is observed with phylloxera.
- ***Armillaria* (oak root fungus)**. The weak area is circular and related to an old oak savannah, or an oak growing onsite before vineyard establishment, or oaks currently growing adjacent to the vineyard block.
- **Viruses**. Vines show a general decline of vigor in addition to other symptoms.
- **Nematodes**. Vines are weakened, but symptoms do not necessarily appear in a circular pattern. If nematodes are suspected, take soil samples and submit them to a lab for nematode analysis.
- **Gophers and voles**. Damage to trunks is more random than damage from other causes. There often is evidence of burrows or tracking next to the vine. Physical damage may be visible on the trunk above or just below the soil surface.

Vine sampling (see Chapter 3) can confirm whether phylloxera is the cause of the problem.

Factors affecting infestation

Phylloxera can survive under virtually all climatic conditions tolerated by its host plant. Its development is influenced to a limited degree by temperature, rainfall, and humidity. Waterlogging causes a decline in phylloxera populations.

In California, France, and South Africa, the severity of phylloxera infestions has been shown to be influenced by soil type, with susceptibility to damage decreasing as the proportion of fine and medium sand in the soil increases. Phylloxera does not cause economic damage in soils with a medium to fine sand content of more than 65 percent. Fine-texture soils, such as clay, generally are more favorable for infestation and damage.

Infested vines live longer in fertile, deep, well-drained soils than in shallow soils or soils with poor drainage. Vines growing in heavy, shallow soils succumb to infestation most rapidly. Heavier soils contract and crack when drying, and these openings allow the insect to crawl to and infest root systems.

Vigorous vines in a healthy vineyard do not succumb to phylloxera attack as quickly as weak vines. Differences in vine vigor can be the result of several factors, including climate, cultivar, site differences, and cultural practices (e.g., pruning and training, fertilization, and irrigation).

Chapter 2

Reducing Risk and Slowing Spread of Infestations

- Plant phylloxera-free vines.
- Restrict the movement of soil.
- Adopt sanitation procedures.

The only sure way to prevent phylloxera damage to grapevines is to plant vines grafted to phylloxera-resistant rootstock. Many of the first vineyards planted in Oregon were on their own roots (not grafted) and are now declining in vigor, yield, and health due to phylloxera infestation. If you have a phylloxera-free vineyard of own-rooted *Vitis vinifera*, controlled access and sanitation procedures are required to prevent introducing phylloxera to the vineyard.

Any vineyard can be a source of phylloxera, even if no visible symptoms are present. Phylloxera usually is not diagnosed until several years after its introduction into the vineyard, as populations must increase before vines show symptoms. In addition, phylloxera can live on resistant rootstocks. Although the resistant rootstock can tolerate phylloxera infestations and does not die as a result of phylloxera feeding, it can support populations of phylloxera and serve as a source of new infestations.

Phylloxera has been found to survive on several plant species. It can endure transportation, crushing, destemming, and pressing and can be found in the must (Deretic et al. 2003).

Phylloxera can be spread from vineyard to vineyard on soil or root pieces carried by any form of traffic, including boots, picking totes, vehicle tires, and animals. Infested soil can also be exchanged among vineyards via picking bins at the winery. Prevention primarily means restricting movement of people, equipment, and materials among vineyards and thoroughly cleaning all items that come in contact with vineyard soil. Both vineyards and wineries should implement measures to prevent the movement of potentially infested soils.

Prevention can be a daunting task, as sanitation methods can be impractical and difficult to manage. For this reason, many vineyards eventually succumb to infestation despite prevention efforts. Experience in other viticulture regions has shown that phylloxera will eventually reach

every vineyard in an infested district despite intensive prevention efforts. The fact that phylloxera has spread throughout the world indicates the difficulty of preventing infestation. Nevertheless, the following preventive practices can delay initial infestations and slow their spread once they do occur.

At the vineyard

Plant phylloxera-free vines

Because phylloxera can live on resistant rootstocks, vines grafted to resistant rootstocks can be a source of infestation in your vineyard. Make sure all planting stock is phylloxera-free (see Chapter 7).

Reduce insect movement

The following methods of preventing spread are meant for those vineyards that are currently phylloxera free and are planted to own-rooted *Vitis vinifera* vines or to grafted vines that are not on phylloxera-resistant rootstocks. In this case, the only line of defense, other than replanting, is to make every effort to restrict the movement of people and equipment in and out of the vineyard.

Restricting the movement of soil is most important, as infested soil can be transferred via tractor and truck tires or on bins at harvest. The season of greatest concern is when soil is moist and has the potential to be moved around the vineyard or into other vineyards.

- Begin field work in blocks or vineyards known to be uninfested and move progressively through blocks or vineyards with higher infestation rates.
- Control access to your vineyard. Do not allow entry without your approval.
- Do not share tractors, trucks, trailers, or other field equipment with another vineyard.
- Imprint the name of your vineyard on your picking totes and bins; accept only returned containers with your name.
- Do not share picking totes or bins with other vineyards or wineries.
- Load and unload trucks outside the vineyard on a paved or graveled road. Where possible, load grapes into bins or totes outside the vineyard rows so that the bottoms of the containers do not pick up soil.
- Use bins and totes that minimize the possibility of transporting soil; for example, avoid bins with a waffle pattern on the bottom. Containers should be easy to clean.

Sanitation procedures

- Develop a set of standard sanitation practices for your vineyard, and inform and instruct all workers.
- Establish a sanitation station where people can put on or clean their boots before entering and leaving your vineyard. The station should include "loaner" rubber boots and a tub containing a 10-percent bleach solution to sanitize boots.
- Thoroughly clean trucks that deliver grapes to your vineyard/winery from other vineyards. Cleaning must be done onsite before the truck enters your site. Use a 10-percent bleach solution or hot water with detergent in a pressure washer.
- Thoroughly clean all equipment, totes, and other items before they leave the vineyard and again before they reenter the vineyard. Use a 10-percent bleach solution or hot water with detergent in a pressure washer.

Sanitation practices for workers and equipment can reduce spread but may not prevent spread completely. Phylloxera crawlers can be moved to new areas on equipment or clothing or by wind. Soil is not the only vehicle for movement.

At the winery

The following methods of restriction and sanitation are important for wineries that are adjacent to a phylloxera-free vineyard.

Restricted movement

- Restrict all vehicles to paved areas.
- Inspect all vehicles and bins for cleanliness prior to entry.
- Restrict delivery trucks to a sanitation pad.
- Keep picking totes and bins separate for each vineyard.
- Do not share picking totes or bins with other vineyards or wineries.

Sanitation

- Establish a concrete sanitation pad for delivery trucks. Wash down the pad daily during harvest, using a 10-percent bleach solution or hot water with detergent in a pressure washer.
- Require that all vehicles, totes, bins, and other items be cleaned at the originating vineyard prior to delivery.
- Scrub picking totes and bins before returning them to the vineyard.

Chapter 3

Sampling Vines to Confirm Presence of Phylloxera

- Sample roots in late summer.
- Sample around the trunk to a 4-foot depth.
- Look for nodosities, adults, and eggs on roots.
- Use sticky traps to monitor for above-ground forms in late summer.

Grape phylloxera feeding weakens the grapes' root systems, resulting in low-vigor canopy growth and an overall weakened appearance over several seasons. Other factors can cause similar symptoms (see Chapter 1, page 5). Root sampling and monitoring for the pest can confirm whether phylloxera is causing the problem.

Sampling roots for infestation

It is difficult to find grape phylloxera on infested roots in the early stages of an infestation. Therefore, sample roots in suspected weak areas over repeated years. The best time to sample for phylloxera in the Pacific Northwest is when populations are at their peak, from late July through September.

Phylloxera reproduce most successfully on healthy root systems. Dead and weakened vines at the center of infested areas often have very low populations on the roots. When sampling for a suspected phylloxera infestation, take root samples of vines that line the perimeter of the damaged area, choosing vines that show the first signs of decline. Also take samples from vines that look healthy and vigorous. Sample as many suspect vines as possible.

Keep in mind that phylloxera can exist on resistant rootstocks without causing health problems for the vine. Vines growing on resistant rootstocks in close proximity to own-rooted vines should also be sampled.

Collect soil and root material from the upper 4 feet of soil, as most phylloxera are present to this depth. Sample within a 1.5-foot radius around the vine trunk (Figure 5).

For each sampled vine, collect 1 pint to 1 quart of roots and associated soil (soil that is stuck to the roots). Include a portion of a larger root (about 0.5 inch in diameter) as well as feeder roots. Remove roots and associated soil *carefully*, immediately putting them in a sealed container.

Root tips infested with phylloxera are club shaped or hooked (see Figure 3, page 4). Inspect new fleshy growth on fine feeder roots

Figure 5. In late summer, collect soil samples to detect phylloxera infestation. Collect samples to a depth of 4 feet from a 1.5-foot radius around the base of vines. Stunted shoots are evidence of infestation.

for nodosities (small swellings), which are symptoms of phylloxera feeding. Although some nodosities are visible to the naked eye, it is best to examine roots with a 10X hand lens. Nodosities may be yellow, turning brown as the roots get older. After root death, they wither and decay, becoming impossible to detect. Be aware that swellings on feeder roots may also be caused by nematodes; however, to a trained eye such swellings look different than those caused by phylloxera.

Tuberosities (large swellings) often can be seen on older, thicker roots. However, phylloxera often are difficult to detect in advanced stages of an infestation as roots become dry or spongy.

Colonies of phylloxera are most prevalent on larger, thicker roots. Often, phylloxera are found under sloughing bark or in cracks of the root. If colonies contain numerous phylloxera, the colony may appear as yellow spots on the roots. Eggs are smaller than adults, oblong, and yellow (Figure 2, page 3). Both adults and eggs can be detected with a stereoscope or 40X magnification.

Above-ground monitoring

Use sticky tape on trunks and canes to look for the winged and wingless sexual stages of phylloxera in July and August. Two-sided sticky tape can be purchased from most stores and can be easily applied to the circumference of trunks, cordons, or canes. Since movement is from the soil upward, it is best to place the tape near the base of the vine trunk. As the crawlers emerge from the soil and move up the vine, they get caught on the sticky tape. Collect the sticky tape on transparent film such as clear page protectors. Use a 40X magnifier or stereoscope to look for phylloxera. Because of the small size and difficulty in identifying the pest, you may wish to send samples to your local Extension agent or university entomology lab for identification.

On certain susceptible American *Vitis* species, the leaf-feeding form of phylloxera feeds on vine leaves in the summer, producing galls on the undersides of leaves. Phylloxera-produced galls are light green and protrude to the underside of the leaf. They are easily distinguished from the brown or white fuzz produced on the undersides of leaves by erineum mites. However, the leaf-galling form is generally not observed on *V. vinifera* (see Chapter 1). Leaf galls caused by phylloxera have not been reported in Oregon to date.

Identification

Use a dissecting scope or stereoscope to identify the pest (see Chapter 1). If you need help, contact your county office of the OSU Extension Service. Finding *one* phylloxera when sampling is enough to verify an infestation.

Chapter 4

Monitoring the Rate of Phylloxera Spread in the Vineyard

Monitoring options:

- Counting affected vines
- Vigor ratings
- Aerial photography and "normalized difference vegetative index" imaging

Once you know your vineyard is infested, you should monitor the rate of spread and decline in production to estimate how long the vineyard will remain productive. This will help you consider how (or whether) to make the transition to a resistant vineyard (see Chapter 6).

By the time an infestation is confirmed, the insect is likely present in a much wider area than is evident from the above-ground symptoms. The phylloxera may have infested the entire block or vineyard, as it takes a while for populations to build to levels to produce visible stress symptoms.

Monitoring the rate of spread within your vineyard means recording the rate and direction of spread of *above-ground symptoms*—not of the phylloxera themselves. Economically, what matters most is not where the insects are but how long the blocks will remain productive.

The following methods can be used to estimate rate of spread of above-ground symptoms.

Counting affected vines

Infestations often appear as a lens-shaped area of weak vines. The easiest, but least accurate, way to estimate rate of spread is to count the number of vines within each lens. Do this in the fall, just before or after harvest, when symptoms are most apparent.

Annually counting affected vines will give a rough estimate of the economic rate of spread (that is, the rate at which the non- or low-producing area is increasing). Subtract the number of vines affected last year from the number affected in the current year and divide by the number affected last year. This will give you the percent increase. For example, if 50 vines show reduced vigor this year and 20 did last year, calculate the rate of spread as:

$$(50 - 20) \div 20 = 1.5$$

Thus, the rate of spread is 1.5, or 150 percent.

Doing this for a few years will give an idea of how quickly the vineyard will succumb to the

infestation. In Oregon, we've seen rates of spread ranging from 150 percent in an older vineyard (from a point-source infestation such as infested dirt on a boot or picking bucket) to 1,000 percent in a 7-year-old vineyard where phylloxera were introduced on the plant material.

Make sure to note any new areas of symptoms separate from the initial finding. New, apparently isolated areas of symptoms often appear when areas with weaker vines succumb to infestations faster than more vigorous areas.

Vigor ratings

This method is a modification of the counting system described above and can be more accurate. The same person should rate vine vigor each year. Document the size of the declining area(s) in your vineyard by counting the number of affected vines. Then give a vigor rating to the vines (for example, 1 = healthy; 2 = mildly stunted or reduced growth; 3 = severely stunted; 4 = dead). The ratings can be added to a hand-held Global Positioning System (GPS) unit to map the vineyard and track the infestation through the years.

A modification of this system is to keep records of pruning weights in vineyard blocks or affected areas. As vine vigor declines due to infestation, pruning weight also should decline. Monitor pruning weight and yield per vine in one or two long, narrow areas (transects) running through an infested area. The data will tell a great deal about the rate of spread of phylloxera and its economic impact.

Aerial photography, NDVI, and GPS

Aerial photography and ***normalized difference vegetative index*** (NDVI) imaging are the most accurate way to evaluate vine decline due to phylloxera. This method can't identify a phylloxera infestation, but it can provide information on variability in vine health across the vineyard. This information can help identify areas for sampling and monitoring.

Many growers find that photographs taken every 2 or 3 years are adequate to detect vineyard problems and phylloxera spread. The photographic resolution and altitude at which the vineyard is photographed will determine the minimum size of weak areas detected (for example, 1 vine or 10).

The NDVI method is superior for detecting changes in vine health and vigor. Healthy vines show up as a bright or dark color; weak and declining areas show up as lighter colors, depending on the color scheme used.

Once weak areas are identified, ground surveys can be taken. GPS units can be used to map the location of infestations in the vineyard and to track spread. Data also can be used in a GIS (geographic information system).

Chapter 5

Managing a Phylloxera-infested Vineyard

- Reduce or eliminate tillage during the growing season.
- Practice good weed and pest management.
- Increase water availability.
- Prevent overcropping.
- Begin considering options for replanting.

Phylloxera infestation in a self-rooted *Vitis vinifera* vineyard will eventually kill the grapevines. The severity of infestation and progression of vine damage can differ among vineyards because of varying site conditions and management practices.

Although the first impulse upon discovering phylloxera in a vineyard may be to remove the visibly damaged vines, this does not eliminate the pest. Symptoms of phylloxera damage take several years to develop, and the infestation is unlikely to be limited to the area where the symptoms or insects have been found.

Removing infested vines actually *increases* the rate of phylloxera spread because it is not feasible to remove the entire root system when pulling vines. Phylloxera living on remaining root pieces will move to healthy vines as their food supply is used up. Thus, it is better to leave infested vines in the ground for as long as they are economically productive, managing them as described below.

Prolonging the productive lifespan of infested vines is one approach to dealing with phylloxera. Another is to slow the spread of infestation within the vineyard by altering management practices. Both approaches should be used. Eventually, however, you will have to decide when to replant with vines grafted to a resistant rootstock (see Chapter 6).

Slowing the spread of infestation in the vineyard

If phylloxera has been found within a vineyard block, take steps to slow its spread to uninfested blocks.

If you use clean cultivation between rows to reduce competition for water, restrict tillage to the period between November and May, when phylloxera populations are at their lowest. Tilling during the growing season will accelerate the spread of phylloxera within the vineyard. Tilled aisles also increase the risk that rain or erosion will move infested soil downhill, and tillage results in more mud on boots and equipment.

No insecticide effectively controls phylloxera infestations in established plantings. Newly registered systemic insecticides

such as spirotetramat have shown some positive results in California and are being trialed in Oregon for efficacy. However, years of additional research will be needed to understand the effect of these products.

Previous research has shown that pesticides may slow the rate of spread of phylloxera. However, in vineyards where above-ground damage is visible, root infections by secondary pathogens may have already caused irreversible damage.

Soil treatments with pesticides show little promise because of the great depths at which phylloxera occur and because chemical penetration is poor in heavier soils.

Prolonging vine lifespan

Infested vines that are otherwise healthy and unstressed are better able to tolerate phylloxera feeding than low-vigor or stressed vines. Therefore, conditions that promote vigor, such as deep, fertile soils and irrigation, may enable infested vines to live longer.

It is important to maintain or improve weed and pest management to prevent these stress factors from contributing to vine decline. To help manage stress, prevent overcropping of phylloxerated vines; crop removal may be required in weak vines.

There are several management practices to manage vine health by reducing competition. Irrigating infested vines to avoid water stress is an important tool for maintaining vigor. If irrigation is not possible, water availability can be increased by maintaining a vegetation-free strip within the vine row with herbicides or in-row cultivation. It is also possible to reduce soil moisture competition by removing between-row cover crops or vegetation. Maintaining a clean, tilled vineyard, however, has several drawbacks, including soil erosion, increased dust in the vineyard (which can exacerbate mite problems), and a tendency to spread phylloxera by tilling, especially during summer when populations increase. An alternative to tilling between rows is to plant a less competitive vegetative cover. A low-growing grass with a shallow, noncompetitive root system, such as sheep fescue, is one option.

Finally, there is some evidence that compost mulches might prolong the life of infested vineyards. Mulches can positively impact vine health by improving soil health and nutrient availability and by supporting soil microbes that may keep diseases from infecting damaged roots (Powell et al. 2007).

Analyzing your options

Eventually, a decision will need to be made as to whether (and when) to replant an infested vineyard with vines grafted to phylloxera-resistant rootstock. Several options are possible:

- Pull out vines after they become unprofitable, and don't replant.
- Replant infested blocks when they become unprofitable to manage.
- Replant the entire vineyard in a scheduled, piecemeal replant program.

A decision to replant an infested vineyard should come only after careful consideration of the vineyard operation and business. The deciding factor should be the profitability of each vineyard block.

Good record keeping is invaluable when making this important decision. Review records of production, costs, and revenues for past years. Monitor the rate of spread of phylloxera and vine decline to help predict how long the infested block can remain profitable (see Chapter 4).

Also consider the existing features of the vineyard. Replanting provides an opportunity to change some of the features of the production system (e.g., cultivar, clone, spacing, and training system) in order to improve production efficiency, fruit quality, or crop marketability. See Chapter 6 for additional discussion of these and other factors.

If you decide to replant, **use only phylloxera-resistant rootstocks**!

Chapter 6

Replanting Options for Establishing Phylloxera-resistant Vineyards

- Plan ahead.
- Replant blocks with other problems first.
- Use replanting as an opportunity to correct other vineyard limitations.
- Let the ground lie fallow for 5 years if possible.
- Minimize competition with new vines.

Growers with infested vineyards or those wishing to avoid infestation in own-rooted blocks have several options for replanting with phylloxera-resistant, grafted plants. You can wait to replant until a confirmation of phylloxera infestation, or you can replant to resistant rootstocks before an infestation is confirmed. Replant strategies may be different in each situation. This chapter reviews the options and discusses advantages and disadvantages of various strategies.

The primary objective of replanting is to establish a new vineyard that is resistant to phylloxera. When considering replanting options, a related objective is to reduce the costs of the transition. Consider these two objectives together. Do not use a replanting method that will impact the long-term health and viability of the new vineyard. Likewise, carefully weigh the economic realities of the transition to protect the financial health of your business. For more information on establishment costs for vineyards in Oregon, see the following OSU Extension Service enterprise budgets:

- *Vineyard Economics: Establishing and Producing Pinot Noir Wine Grapes in Western Oregon.* 2008. EM 8969-E. http://oregonstate.edu/dept/EconInfo/ent_budget/PDF/EM8969-E.pdf
- *Vineyard Economics: Establishing and Producing Cabernet Sauvignon Wine Grapes in Eastern Oregon.* 2009. EM 8974-E. http://oregonstate.edu/dept/EconInfo/ent_budget/PDF/EM8974-E.pdf

Whatever replant strategy you choose, you will have more flexibility if you plan the replant ahead of time. The more prepared you are, the more likely that replanting will be an opportunity for improvement rather than a desperate rescue of a dying vineyard.

When to replant

All self-rooted *Vitis vinifera* vineyards in Oregon are at risk from phylloxera infestation, and it is possible that all will eventually become infested. However, infestation might take 1 year or 30. This uncertainty is due in part to the size and demographics of the vineyard or winery and of the growing region.

Rates of phylloxera infestation are higher in the Willamette Valley than in other parts of Oregon. This region not only has a critical mass of vineyard acreage, but also larger vineyard and winery operations and more movement of people, equipment, and fruit among vineyards. Grape-growing regions such as the Columbia Gorge and southern Oregon have lower incidences of phylloxera-infested vineyards, and the threat of infestation might not be as strong. Infestation is still possible in these regions, however.

Uninfested vineyards

More replanting options are available if you replant before the vineyard is infested. In this case, replanting can be based on a long-term plan of vineyard replacement and rehabilitation. Decisions are planned rather than dictated by the spread of phylloxera and the pattern of vine decline. This allows you to anticipate the financial implications of replanting and to spread replanting costs over a longer period. Base the order of block removal and replacement on block profitability. Be sure to order plant materials from reputable nurseries well in advance and integrate the replacement process into a larger plan for vineyard rejuvenation and improvement.

Consider replanting vineyard blocks with other design problems first. For example, replanting provides an opportunity to renovate or change trellis systems, change vine and row spacing, change varieties or clones, or add an irrigation system or drainage tile. In addition to conferring phylloxera resistance, rootstocks also can be used to correct problems with excess vigor, water stress, poor fruit set, or vine nutrition.

Replanting profitable blocks before a phylloxera infestation is confirmed is a more difficult decision. Replanting still has advantages, particularly in the long term. A vineyard on resistant rootstock will provide a supply of grapes that will not be compromised by phylloxera, and resistant rootstocks substantially add to a vineyard's resale value.

It is vital to keep reestablishment time to a minimum in any situation, but that objective becomes especially critical with profitable production blocks. In these blocks, the time without fruit production must be kept as short as possible.

Infested vineyards

Because phylloxera eventually will move throughout the vineyard, prepare a replanting schedule for the entire vineyard. Replanting schedules will be dictated by the decline of phylloxera-infested vines (see Chapter 4). Remove or replant blocks with declining production when they no longer are profitable to manage. Start replanting the least profitable blocks, regardless of whether they are the most heavily infested. This will allow you to begin vineyard improvement while providing phylloxera resistance through grafted vines.

Keep in mind that planting resistant rootstocks in an infested site is not insurance against continued spread of phylloxera in own-rooted areas of the vineyard. Many phylloxera-resistant rootstocks will support phylloxera populations and can serve as a reservoir for continued spread.

Remember that the distribution of phylloxera in the vineyard is wider than the area of visibly affected vines, and vines outside a weak spot will continue to decline. Thus, extend the replanted area well beyond the borders of the visible infestation.

Replant infested areas on a row-by-row basis. Replanting in complete rows will reduce management difficulties caused by variations in vine size and age. Replanting apparently healthy, productive blocks can be difficult due to temporary loss of revenue, but it can increase vineyard value as well as future marketability and productivity.

Replanting as an opportunity to improve the vineyard

Evaluate vineyard blocks before making replant decisions. Identify the vineyard's limitations, and determine whether replant strategies offer an opportunity to correct them.

- Is the production system efficient?
- What is the anticipated lifespan of the trellis?
- Could the spacing or trellis system be changed to improve quality or production?
- Should an irrigation system be installed or renovated?
- Are there limiting soil factors such as compaction, nutrient deficiencies, acidity problems, or poor drainage?
- Are pathogenic nematodes or fungi present in the soil?

Many of these factors can be corrected most effectively before planting, when existing plants or trellises do not obstruct access to the entire block.

Replanting options

There are several options for replanting infested vineyards.

- Remove all vines and trellis systems in an infested block, fallow, and replant.
- Remove all vines and replant using the existing trellis structure.
- Interplant vines between existing vines.

The most effective method is complete reestablishment of the vineyard and trellis system, but this method is also the most expensive due to the cost of reestablishment and loss of production. Interplanting is the least expensive method initially, but has a greater risk of failure of newly planted vines.

Complete reestablishment

This is the only choice when the existing vineyard has serious limitations. For example:

- Renovation allows deep ripping to loosen hardpans and pull up old vine roots.
- Blocks can lay fallow to reduce pest populations. Plant cover crops to improve soil health and reduce phylloxera and nematode populations.
- Soil treatments such as fumigation and incorporation of phosphorus, potassium, or lime are possible only in the absence of growing plants.
- Changing the trellis system or vine spacing or installing drainage tile also requires a fresh start.

Replanting with the existing trellis

Replant with the existing trellis only if the plan and organization of the vineyard are acceptable and the trellis system will last at least 10 more years. Many of the major vineyard modifications discussed above are not possible if the trellis structure is retained.

Removing old vines may be difficult with the trellis in place. In some cases, large, old vines cannot be removed without damaging the trellis system, so they must be cut off and killed with herbicides. The old root system remains in place, however, and may supply inoculum for viruses, root diseases, and insect infestations. Existing phylloxera populations could increase pressure on the new rootstocks.

Interplanting

The goal of interplanting grafted vines between producing, established vines is to get the new plants into production while the old ones continue to supply revenue. It is possible that a new grafted vineyard could be established with little or no loss of production.

Do not consider interplanting if the existing vineyard has serious limitations that could be corrected by vineyard renovation (e.g., dry farmed, poor trellis system, or wide spacing).

Interplanting has many potential problems.

- It is difficult to remove old plants before planting.
- Removing the old vines can exacerbate problems with nematodes, soil fungi, and high phylloxera populations.
- Interplanting results in competition between new and old vines for water and nutrients, thereby decreasing the rate of development of the new vines.
- Interplanting makes vineyard management more difficult due to variation in vine size and age.

The most serious of these problems is competition from the existing vines. Poor establishment of young plants could result in a nonuniform vineyard with vines

of different ages, various cultivars or clones, and a mix of grafted and own-rooted vines.

If you choose to interplant, the priority must be to establish the new vines. Adjust vineyard management to favor growth of the new vines. Consider the following management practices.

- Irrigate the new plants. If the young vines are not irrigated during establishment, vine failure can be significant.
- Remove or reduce permanent cover crops that compete with young vines. Completely removing the cover crop is not always desirable, however. In some cases, it is important to maintain cover for trafficability and to prevent soil erosion. In this case, competition can be reduced simply by widening the weed-free in-row strip.
- Root-prune the established plants so that there is no significant root competition with the young vines.
- Summer prune the canopy of established plants to increase available light for the new plants.
- Remove phylloxera-infested vines within 2 years, by the time the new planting is being trained to the fruiting wire.

Inarch grafting

Self-rooted vines can be converted to vines with resistant rootstocks by a grafting technique called inarching. This technique involves planting resistant rootstocks next to the trunks of existing vines and grafting them onto the trunk. The goal is to completely replace the root system of the self-rooted plant with the phylloxera-resistant stock.

This technique has been tried in California with mixed results. Some growers were able to change the root system of established vines without losing production. However, this technique has not been reliable in Oregon, where cool, wet weather after grafting often results in graft failure. Furthermore, interplanting rootstock into an established vineyard can be difficult because of competition from vines. In unirrigated vineyards, lack of water during rootstock establishment is a problem. This method is not advised except in small-scale experiments.

Replanting

Removing vines

There are two basic approaches to removing own-rooted vines:

- Use a backhoe to remove vines and as many roots as possible.
- Use herbicides. Apply a systemic herbicide to the cut base of the trunk during the growing season.

Fallow

It is difficult to remove or kill all vine roots in the soil profile. Vine roots that persist in the soil may support populations of phylloxera for years. Phylloxera can weaken young vines, even those on resistant rootstocks, if populations are high. The roots can also serve as inoculum for viruses that had infected the vine, and they can support populations of nematodes, plant-pathogenic fungi, and other insect pests. For this reason, a fallow period after vine removal is suggested to allow populations of phylloxera and other pests to decrease and to allow residual vine roots to decompose.

A fallow period of 5 or 6 years has traditionally been recommended. It is often impractical to wait 5 years to replant, but it is important to recognize potential problems associated with immediate replanting. The fallow period can be shortened to 3 years if the soil is fumigated.

Chapter 7

Buying Winegrape Plants

- Choose phylloxera-resistant rootstocks.
- Choose rootstocks suitable for your location.
- Purchase vines from a reputable nursery.
- Buy certified, virus-free plants if possible.
- If buying vines from out of state, observe quarantine restrictions.
- Ask about nursery treatment of plants to kill phylloxera.

Selecting good plant material is a critical step in establishing a profitable vineyard. Considering vineyard establishment costs and potential longevity, it is important to start with clean plant material. Clean plant material is defined as material that is free of known pest and disease infestation. If possible, obtain certified plant material. Certified plant material refers to vines that have been tested and found to be free of harmful grapevine viruses such as fanleaf or grapevine leaf-roll virus.

Choosing a reputable nursery that sells certified, virus-free plants is an important step in procuring good-quality, true-to-type, disease-free plants. For a list of commercial nurseries, see the National Grape Registry (http://ngr.ucdavis.edu/index.cfm). Consult your local Extension horticulture agent for more information on reputable nurseries in your area.

The most popular rootstock–scion combinations are in great demand. Often, nurseries will not have adequate stock on hand for immediate orders. To ensure availability of plant materials of your choice, place your order at least 1 year in advance.

Choose phylloxera-resistant rootstocks

Although self-rooted (ungrafted) plants are about half the cost of grafted vines, it is not recommended to plant self-rooted vineyards in the Pacific Northwest due to the presence of phylloxera and the potential for infestation in currently uninfested areas. Vines grafted onto a resistant rootstock are the **only** insurance against phylloxera. Grafted plants are well worth the higher cost when compared to the cost of reestablishing a vineyard after infestation.

Grafting, which combines two different varieties or species to form a new plant with the characteristics of the two parents, has been used in both fruit trees and viticulture since ancient times. It has been used to change variety, enhance vigor, or increase tolerance to soil characteristics. Grafting became a common practice in viticulture after the European phylloxera epidemic.

Laliman, the French viticulturist, was the first to suggest grafting susceptible wine varieties to rootstock of resistant American *Vitis* species. The rapid adoption of this practice led to a chaotic period from 1880 to 1930, when nurseries offered a confusing assortment of rootstocks. The use of inappropriate rootstocks caused new problems, particularly lime-induced chlorosis. Extensive research on rootstocks after 1950 revealed that several aspects of scion (the grafted vine) behavior depend on features of the rootstock. These include adaptation to growing conditions, susceptibility to mineral deficiencies or toxicities, tolerance to soilborne pests and diseases, vigor, productivity, and fruit quality. After more than a century of experimenting with rootstocks in Europe and throughout the world, a considerable amount of information on rootstock performance is now available.

There now are many types of grafted rootstocks from which to choose. The choice of a rootstock for a particular location depends on complex interactions among soil type and depth, soil physical and chemical properties, pests, diseases, water availability, and environmental factors. Thus, onsite evaluation is imperative for rootstock selection. For more information on selection of rootstocks for phylloxera resistance and other qualities, see OSU Extension publication *Grapevine Rootstocks for Oregon Vineyards*, EM 8882 (http://extension.oregonstate.edu/catalog/pdf/em/em8882.pdf).

Interspecific hybrid grape cultivars

Some American hybrid grapes are grown in the Pacific Northwest, including cultivars such as Marechal Foch and Baco noir. Many of these hybrid cultivars have both American *Vitis* species and *Vitis vinifera* species in their genetic lineage. Therefore, rootstocks may be required to avoid the susceptibility of these vines to attack by phylloxera over time.

Plant type

Nurseries sell dormant field-grown and greenhouse (green) potted plants. Green plants need to be hardened off before planting and may need more careful irrigation after planting. Check with nurseries for availability and recommendations.

Grade

Dormant, field-grown plants are available in two grades, based mainly on plant size. Check with nurseries for availability and costs for specific cultivars or clones.

Purchasing plant materials out of state

The Oregon Department of Agriculture has a grape quarantine against grape phylloxera. If you plan to purchase plants from nurseries outside Oregon, you must follow these regulations.

Grape plant material imported into Oregon *must* be accompanied by a phytosanitation certificate that certifies the plants are free from any "known disease or infestation." Rooted grape plants may be imported only if they have grown in soilless, sterile media.

For more information and the specific details of the quarantine, contact the Oregon Department of Agriculture, or see the quarantine rules online (http://www.oregon.gov/ODA/PLANT/docs/pdf/quar_grape.pdf).

Purchasing plant materials in Oregon

The above requirements do not apply to plant material purchased in Oregon. Ask the nursery about the health status of vines you purchase and always purchase from a reputable source. For a list of reputable nurseries, contact your local Extension horticulture agent or visit the National Grape Registry Online (http://ngr.ucdavis.edu/index.cfm).

Plants purchased from Oregon grapevine nurseries commonly are field-grown. Nursery inspectors check plants for phylloxera or symptoms of infestation in the winter when plants are dug. However, it is very difficult to find phylloxera, particularly in winter, and no certification or inspection method is without error.

As insurance against phylloxera infestation, some nurseries treat plants with a hot water dip or insecticide to kill phylloxera that may be present. Treated plants may cost more. To be effective, plants must be dipped for 5 minutes at 110°F (to warm the roots) and for 5 minutes at 125°F to kill phylloxera. Research has shown that this treatment eradicates phylloxera without harming dormant plants (Stonerod and Strik 1996).

Conclusion

While phylloxera can be devastating for commercial viticulture, it can be managed with the use of resistant rootstocks.

This publication discusses ways to avoid infestation in phylloxera-free sites. However, it is important to note that phylloxera has been identified in vineyards in nearly all regions of the state, and it is only a matter of time before uninfested vineyards will be infested. This is in part due to the rigorous sanitation requirements needed for prevention and isolation. Only portions of eastern Oregon are believed to be phylloxera free. However, that region likely will eventually succumb to infestation. This has been the case in every area of the world, even with strict sanitation efforts and quarantines.

The only way to avoid phylloxera infestation is to use resistant rootstocks. When planting a new vineyard, plant only vines grafted to phylloxera-resistant rootstocks. For existing own-rooted vineyards, the only line of defense is to replant to vines grafted to phylloxera-resistant rootstocks. When planting or replanting, obtain certified plant material if possible and always purchase from reputable nurseries.

If own-rooted vines in an established vineyard exhibit decreased productivity (yield and canopy growth), thoroughly analyze the vines and the vineyard site. Many factors can result in reduced yield and vine growth, including mite infestation, high nematode populations, drought stress, nutrient deficiencies, virus, or other diseases. Sampling for phylloxera and testing for other problems—for example, soil nutrient status or nematodes—may reveal that a vineyard has more than one problem. Talk to your local OSU Extension faculty or field rep/consultant for more information. By diagnosing as many factors as possible, you can mitigate multiple problems through site renovation, relocation, and selection of appropriate rootstocks.

Phylloxera sampling is discussed in Chapter 3. For assistance in identifying phylloxera samples and assessing management practices, contact the resources listed on page 22.

Local grower resources in commercial viticulture

Local Oregon State University Extension offices throughout the state may be able to assist in phylloxera diagnosis and management. Please contact the following individuals for assistance or more information.

AVA	OSU Extension county office	Extension agent	Phone
Umpqua Valley	Douglas http://extension.oregonstate.edu/douglas/	Steve Renquist	541-672-4461
Southern Oregon*	Jackson/Josephine http://extension.oregonstate.edu/sorec/	Marcus Buchanan Rick Hilton	541-776-7371
Columbia Gorge	Hood River http://extension.oregonstate.edu/hoodriver/	Steve Castagnoli	541-386-3343
Walla Walla	Umatilla, Milton-Freewater http://extension.oregonstate.edu/umatilla/mf/	Clive Kaiser	541-938-5597

**Includes the AVAs of the Umpqua, Rogue, Illinois, and Applegate valleys.*

For specific information on entomology and verification of phylloxera infestation, contact the following.

OSU main campus	Phone
Vaughn Walton, horticultural entomologist http://hort.oregonstate.edu/faculty-staff/walton	541-737-3485
Patty Skinkis, Extension viticulture specialist http://hort.oregonstate.edu/faculty-staff/skinkis	541-737-1411

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