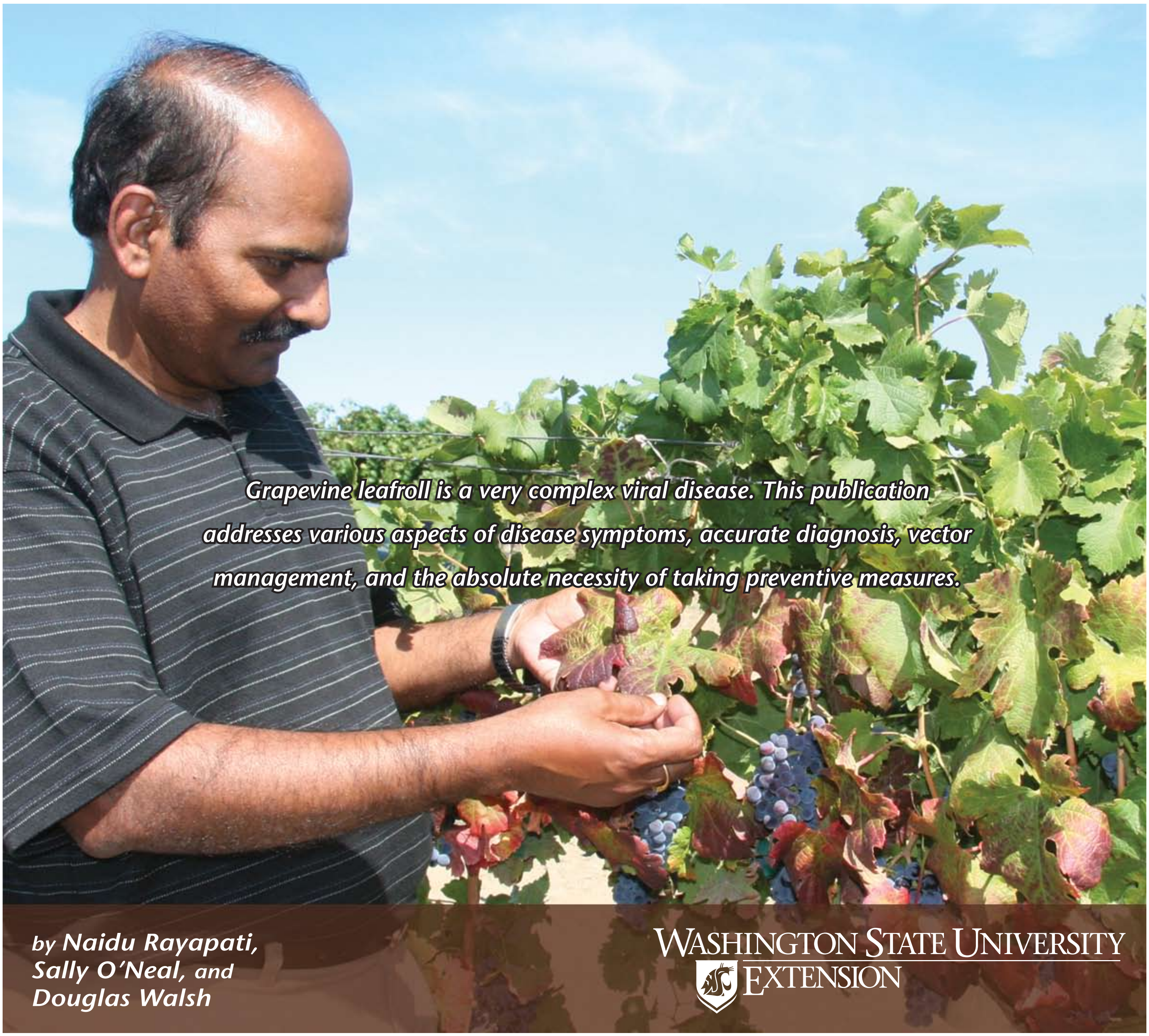
EB2027E

grapevine leafroll disease

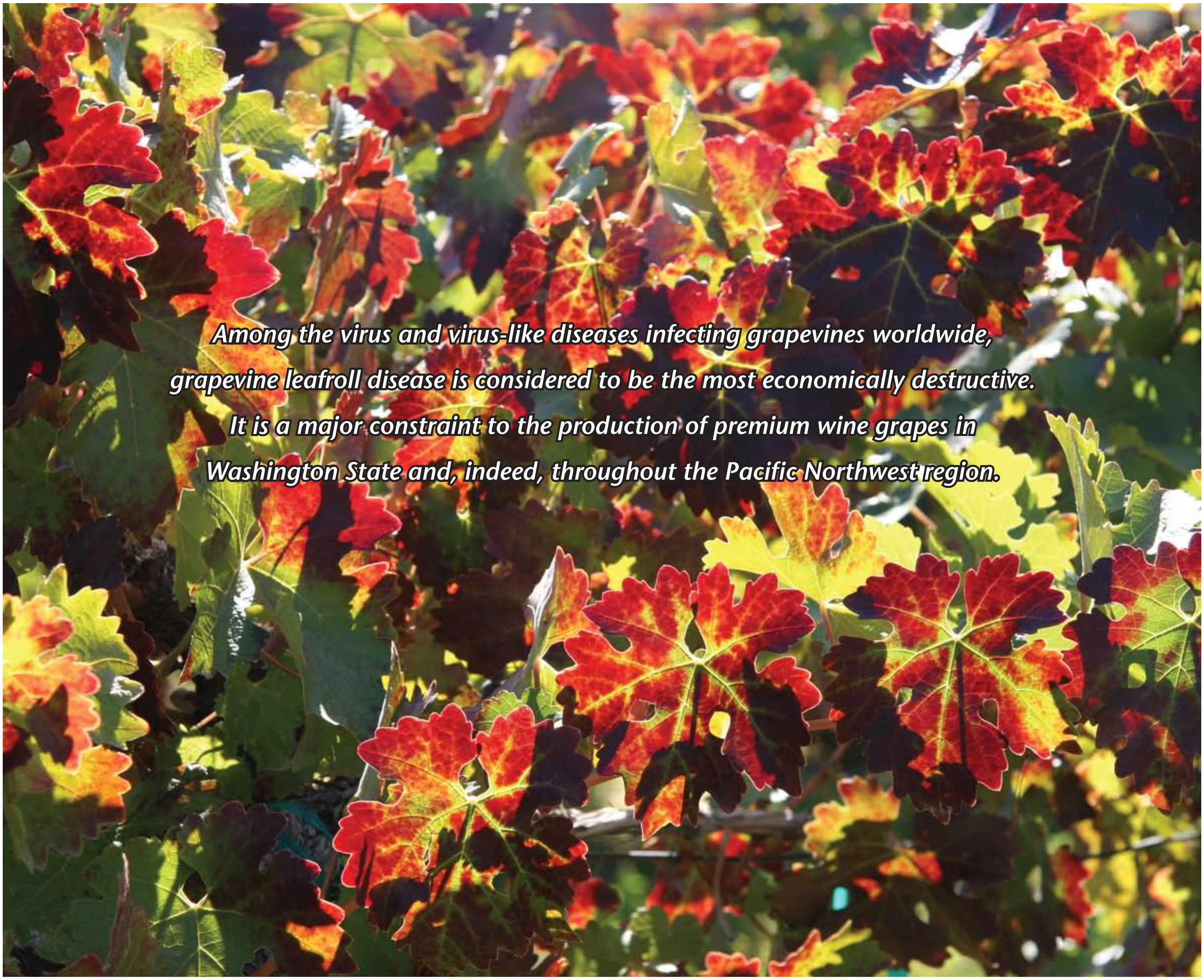
PREVENTION DIAGNOSIS ASSESSMENT MANAGEMENT



Grapevine leafroll is a very complex viral disease. This publication addresses various aspects of disease symptoms, accurate diagnosis, vector management, and the absolute necessity of taking preventive measures.

by ***Naidu Rayapati, Sally O'Neal,*** *and* ***Douglas Walsh***

WASHINGTON STATE UNIVERSITY EXTENSION



This publication and the research behind it was supported, in part, with an Extension Issue-focused Team internal competitive grant funded in part from the Agriculture Program in WSU Extension and the Agricultural Research Center in the College of Agricultural, Human, and Natural Resource Sciences, Washington State University. The authors also acknowledge the Northwest Center for Small Fruits Research, the Washington State Department of Agriculture, the WSU New Faculty Seed Grant Program, the Washington State Commission on Pesticide Registration, and industry members of the Wine Advisory Committee of the Washington Wine Commission for their support of research presented in this project. We are grateful to Ken Eastwell, Pete Jacoby, Rick Hamman, and Frank Zalom for their valuable editorial assistance.

Download this WSU Extension publication free of charge at http://pubs.wsu.edu (search for EB2027E), http://ipm.wsu.edu/small/sf.html, or http://winegrapes.wsu.edu/virology/.

GLD in WA vineyards

GLD is a stealthy foe. It is difficult to recognize. Symptoms express differently among various cultivars and they don't show up until the growing season is well underway. Sometimes there are no visual symptoms at all. Making matters worse, other conditions may result in symptoms that mimic GLD.

Wine grapevines *Vitis vinifera* L. are susceptible to a broad range of plant viruses—nearly sixty among twenty different genera. That's more than any other perennial fruit crop. Among the virus and virus-like diseases infecting grapevines worldwide, grapevine leafroll disease (GLD) is considered to be the most economically destructive. It accounts for an estimated 60% of yield losses due to virus diseases in grape production worldwide.

The *Crop Profile for Wine Grapes in Washington (MISC0371E),* published in 2003 (http://wsprs.wsu.edu/CropProfiles.html), estimated that GLD affected just under 10% of the state's wine and juice grape acreage, but GLD incidence seems to be increasing across the state in recent years. Today, GLD is considered a major constraint to the production of premium wine grapes in Washington State. This publication presents the latest research findings and recommendations regarding GLD directed toward the wine grape growers and certified nurseries of Washington State.

symptoms

GLD is a very complex disease. Because the expression of symptoms is highly variable among cultivars, it is very difficult to identify GLD based on visual indications alone. In general, symptoms are more dramatic in red-fruited *V. vinifera* cultivars than in white-fruited cultivars. Infected vines typically exhibit no symptoms until late July or early August, as the crop moves toward veraison. One of the early visual signs of GLD in red-fruited cultivars is the appearance of red and reddish-purple discolorations in the interveinal areas of mature leaves near the basal part of the shoots. As summer progresses, the symptoms extend upward to other leaves and the foliar discolorations expand and coalesce to form a reddish-purple color within the interveinal areas of the leaf; a narrow strip of leaf tissue remains green on either side of the main veins. So by the later part of the season (August-October), a typical infection in a red-fruited cultivar will consist of green veins and reddish interveinal areas. In the advanced stages, the margins of infected leaves roll downward, expressing the symptom that gives the disease its common name.

GLD symptoms vary within and among vineyards due to several factors including the variety, age of the vineyard, stage of infection, complex of virus(es) present, viticultural practices, and environmental conditions. Symptoms also vary based on the year and the part of the plant. Foliar symptoms tend to be more pronounced during cooler growing seasons and on the shaded side of the vine.

White-fruited cultivars express GLD symptoms differently if at all. In some cultivars like Chardonnay, infected leaves may show general yellowing or chlorotic mottling toward the end of the season and, in some cases, leaf margins may roll downward toward the end of the season. Other white cultivars may show no visual signs of infection.




GLD expresses in a variety of ways depending upon cultivar and time during the growing season. From top: Cabernet vines earlier in the season, Chardonnay vines earlier in the season, Cabernet vines later in the season, Chardonnay vines later in the season.

American Vitis species and French-American hybrid varieties *(Vitis labrusca* L. 'Niagara,' *Vitis* x *labruscana* L.H. Bailey 'Concord' and 'Catawba,' *V. labrusca* x *V. riparia* Michx. 'Elvira') have been shown to harbor the virus, but they likewise exhibit no visual symptoms. Therefore an infected Concord vineyard could be adjacent to an infected red wine grape vineyard and the former would likely appear healthy while the latter could exhibit typical GLD symptoms. Because of the lack of visual symptoms in juice grapes, GLD has received little attention from the juice grape and nursery industries. Concord remains the most widely planted variety in Washington State, yet the prevalence and economic impact of GLD in these and other juice grapes is unknown. The result is that sanitation practices are less rigorous in the propagation of Concord grapes, which may play a role in the epidemiology of GLD in wine grapes since wine grapes and juice grapes are often grown in proximity to each other in Washington State.

Above: GLD symptoms express first at the basal part of the shoots, progressing upward as the summer progresses.
Below: Visual symptoms of GLD are typically more dramatic in red-fruited cultivars (vines at top) than white-fruited.

impacts of GLD

Overall growth and vigor of grapevines and yield of berries are detrimentally impacted by GLD. Infected vines exhibit reduced leaf area and develop weak trunks over time, which translate into decreased vineyard life span and vine productivity. Yield reductions directly attributable to GLD vary, but reductions in the neighborhood of 50% (or more if the disease is severe) are commonly reported on a worldwide basis. In Washington State, estimated yield reductions attributed to GLD typically range between 5 and 10%. Losses can be much greater if the disease is severe. In practical terms, even a small decrease in annual yields due to GLD has a cumulative impact on the long-term viability and profitability of a vineyard.

Quality characteristics are also negatively impacted by the presence of GLD. Berry weight, fruit maturity at harvest, soluble solids (°Brix), pH, and titrable acidity are all negatively impacted by GLD. Leaf discoloration due to lack of chlorophyll diminishes the photosynthetic efficiency of infected leaves resulting in reduced supply of carbohydrates and sugars to the berries and also reduced nutrition to the trunk, which negatively impacts early development the next season. This produces a cascade of physiological events that result in reduced yields due to fewer and smaller bunches, a delay in fruit maturity of 3-4 weeks, uneven fruit size and maturity, lower sugar accumulation in berries, and poor color development of grapes due to lowering the accumulation of anthocyanins. Simply put, growers with severely infected vines may find that the fruit never sweetens, no matter how long they leave it on the vine. Even in the case of white-fruited varieties, where the leaf discoloration and other visual symptoms are less or not present, GLD has been shown to have similar negative impacts.

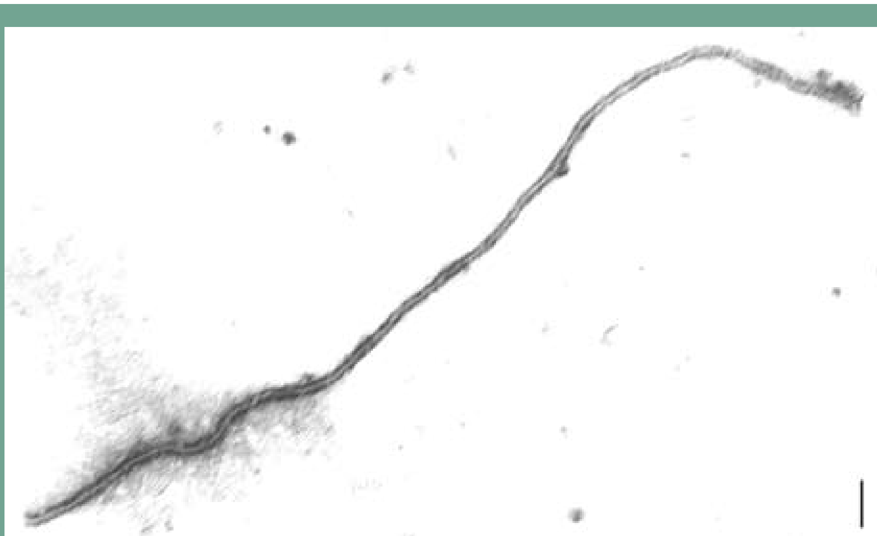
Other impacts of GLD include the fact that infected vines should not be used as a source of propagation materials. Vines compromised by infection are likely to be more susceptible to winter injury, resulting in greater vulnerability to other pathogens including crown gall disease. But the bottom line is that reduced yields and poor quality grapes directly affect Washington State's reputation for high-quality wines and reduce our ability to maintain a competitive edge in domestic and international wine markets.

GLD infection is implicated in a host of quantity and quality issues in a vineyard. The photos below show fruit clusters from GLD-infected (center) and non-GLD-infected grapevines. Left, Chardonnay; right, Cabernet Franc.

viruses associated with GLD

At least nine distinct virus species have so far been documented in red- and white-fruited grapevines showing GLD symptoms. They are called grapevine leafroll-associated viruses (GLRaVs) and are numbered GLRaV-1 through -9 in order of their discovery. They belong to a family of plant viruses called Closteroviridae. GLRaVs are confined to the vascular tissues (mainly phloem). They usually occur in very low quantities and generally are not transmissible from grapevine to grapevine by mechanical inoculations. The only exception is GLRaV-2, which can be transmitted mechanically to herbaceous hosts like *Nicotiana benthamiana*. The virus particles of GLRaVs are filamentous (1400-2200 nm long and 10-12 nm diameter) and highly flexuous. They are morphologically similar to one another when observed under an electron microscope but are serologically distinct. GLRaVs contain a single molecule of linear, single-stranded, positive-sense RNA genome and they show distinct differences in genome organization. As of 2007, the complete genome sequence is available for GLRaV-1, -2, and -3. GLRaV-3 has a large genome of 17,919 nucleotides (nt), followed by GLRaV-1 with 17,647 nt and GLRaV-2 with 16,494 nt. The genomes of other GLRaVs are being sequenced and should be available for public access in the near future. GLRaV-3 has the second largest genome of any known plant virus after *Citrus tristeza* virus (19,296 nt in size), a devastating virus of citrus in the United States and elsewhere. On a worldwide basis, GLRaV-3 remains the most prevalent as well as the most economically destructive among the currently known GLRaVs. GLRaVs show distinct differences in their genome organization and the number and arrangement of genes encoded by these viruses. In addition, they can also occur as divergent molecular variants. GLRaVs and their variants can frequently occur as mixed virus infections in an infected grapevine.

As of 2007, six of the nine GLRaVs (GLRaV-1, -2, -3, -4, -5, and -9) have been found in Washington vineyards. In addition, grapevine rootstock stem lesion-associated virus (GRSLaV), a distinct strain of GLRaV-2 denoted as GLRaV-2-RG, has been detected



Electron micrograph of a GLRaV particle isolated from a leafroll-diseased vine. Note scale bar at lower right for particle size (1 nanometer - nm - equals 1/1,000,000 millimeter). The virus particles of GLRaVs are filamentous and highly flexuous.

Photo by Marc Fuchs, Cornell University.

in Washington. GLRaV-2 and its strains such as GLRaV-2-RG are important because they are documented to cause graft incompatibility and decline under certain scion-rootstock combinations. The data obtained so far indicate that GLRaV-3 is the most common and widespread among the different GLRaVs in Washington vineyards, followed by GLRaV-2 and GLRaV-4. In addition, these six GLRaVs have been found occurring in mixed infections of different combinations in GLD-infected vines of both red- and white-fruited cultivars. GLRaVs also can occur as mixed infections with other groups of viruses. Mixed infections can result in synergistic effects leading to more severe damage to grapevines than infection with a single virus.

The etiology (i.e., cause, origin) of GLD is not yet clearly traced or understood. We call the viruses associated with GLD "grapevine leafroll-associated viruses" because we lack concrete scientific proof that they are the primary causal agents of GLD. It is also not yet clear whether induction of GLD can occur via a single GLRaV infection or requires the presence of mixtures of GLRaVs.

*The **complexity** of these questions presents a challenging **research opportunity** for virologists serving the grape-growing community.*

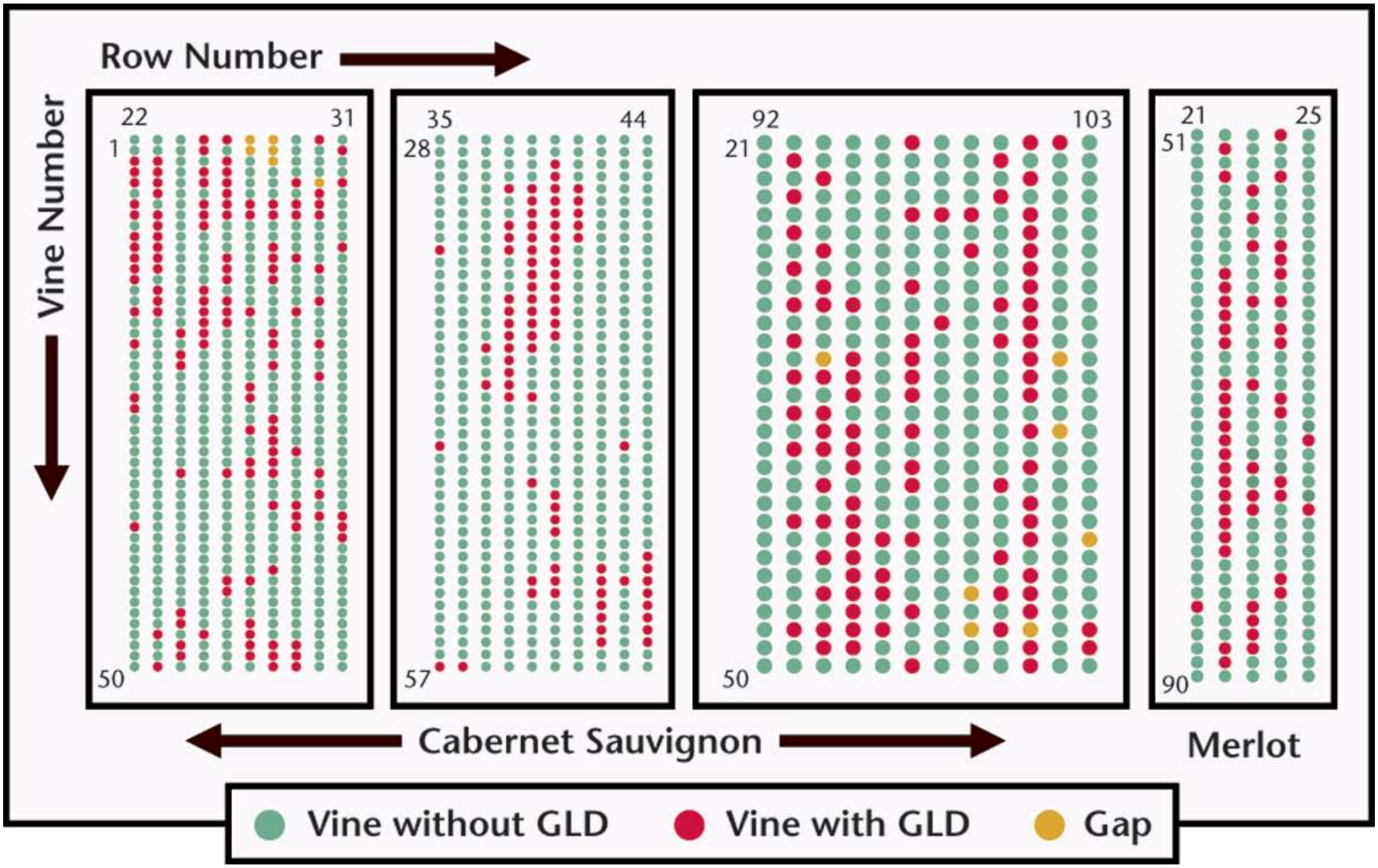
GLD spread

GLD and GLRaVs do not seem to spread from infected to healthy vines by physical contact or through seed. Neither cultivated nor wild species of plants other than grapevines have so far been found as alternative hosts for any of the currently known GLRaVs. The principal means of spreading GLD is the use of infected plant material when establishing new vineyards or replacing vines in an established vineyard.

To reduce the spread of GLRaVs, we must improve virus screening and eliminate the distribution of infected vegetative cuttings. The first step is making sure that any propagation material introduced into a new or established vineyard is virus-free. This applies to vegetative cuttings used in grafting as well as rooted cuttings used for new and replacement plantings. The vast majority of Washington vineyards are self-rooted, therefore grafting is not a widespread concern in our state at this time. Grapevine certification programs that include virus testing are the first line of defense. Vineyard managers need to understand the importance of working with certified nurseries, WSU researchers, or other screening programs that ensure their planting materials are "clean," which is to say free from viruses and other diseases.

Because vegetative cuttings are transient and can tote their virus payload along with them, viruses such as GLD are sometimes called "suitcase" or "Samsonite" viruses.

There are consequences when infected propogation material is introduced into a vineyard. The new planting pictured below shows classic GLD symptoms in the vine on the right.



Graphic above shows the actual spatial distribution of GLD-infected vines in four different blocks representing different cultivars and grown in widely separated geographic regions.

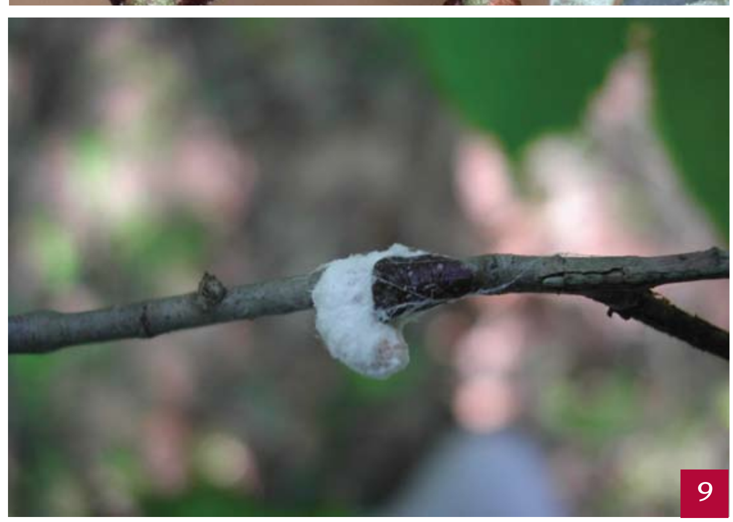
There is also some evidence that GLD can spread within and between fields. We are not precisely certain how or if GLD can spread within a vineyard. Certainly, since grapevines are perennial plants, leaving infected vines in a vineyard could provide a means for infecting other vines through subsequent vegetative cuttings. It is also conceivable that root grafts could occur as vine roots grow together beneath the soil. Finally, there is the possibility that the virus could be field transmitted via arthropod vectors.

In an effort to understand the complexity of field spread, researchers have been studying the spatial distribution of GLD in Washington vineyards. The most common pattern is that GLD-infected vines are clustered along individual rows, which may be an indication of secondary spread between neighboring vines within rows by a slow-moving vector (see graphic above.) Additional potential means of spread could be pruning, harvesting (whether manual or mechanical), implement cross-contamination, and/or root grafting. This type of distribution pattern has been found in different cultivars and also across wine grape-producing countries in Europe, the United States, South Africa, Australia, and New Zealand. In addition, GLD infection has been documented in new vineyards planted near a heavily infected block, further suggesting the possible involvement of insect vectors in the spread of the disease.

So who's the culprit? Both mealybugs (Pseudococcidae) and scale insects (Coccidae) have been implicated in the spread of GLD.

Grape mealybug *(Pseudococcus maritimus* Ehrhorn) is a documented vector for GLRaV-3 under laboratory conditions. The grape mealybug is the predominant mealybug found in Washington vineyards. Other mealybug species have been documented as vectors of GLRaVs in western U.S. vineyards, but these species have not been found in Washington. While grape mealybug has two generations per season, other species such as vine mealybug (*Planococcus ficus*) can have up to nine generations per season, dramatically increasing the number of potential vector insects within a vineyard in a relatively short period of time. Because of this danger, a concerted effort is necessary to prevent the establishment of vine mealybug in Washington State; vine mealybug has been established as a quarantine pest in this state. Other mealybugs implicated in the spread of GLD include *Planococcus citri, Pseudococcus longispinus, P. affinis, P. calceolaria, P. comstocki, P. viburni, Heliococcus bohemicus*, and *Phenacoccus aceris*.

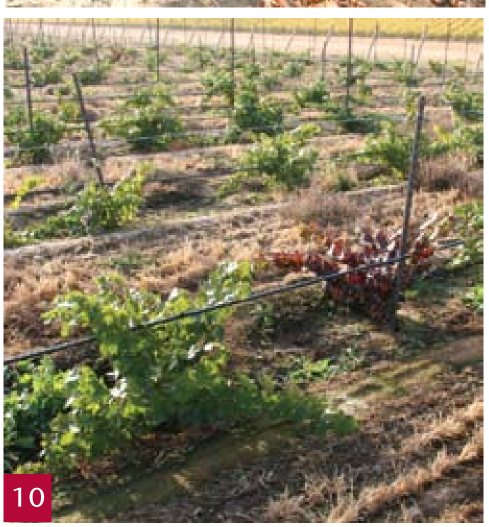
The status of scale insects in Washington vineyards and their ability to act as vectors for GLD is less certain. It has been documented that some scale insects have the ability to spread GLD, specifically GLRaV-1 and -3. European fruit lecanium scale *(Parthenolecanium corni)*, a common nuisance pest in California vineyards, is a suspected vector of GLRaVs and is present in Washington vineyards. The cottony maple scale, *Pulvinaria innumerabilis,* is another reported vector known to occur in Washington. The scale insect *Pulvinaria vitis,* known variously as the wax scale or wooly vine scale, has been reported as a vector of GLRaV-3 in Italy; its presence in Washington is not documented.



Photos, from top: grape mealybug, W. Cranshaw, CSU; citrus mealybug, US National Collection of Scale Insects Photographs Archive, USDA ARS; European fruit lecanium scale, J. Payne, USDA ARS; cottony maple scale, PA-DCNR - Forestry Archives. All photos this page from Bugwood.org.

influence of viticulture practices

GLD infection can be passed from rootstock to scion or vice-versa. Above: Healthy new vineyard. Below: Vineyards planted with infected material.



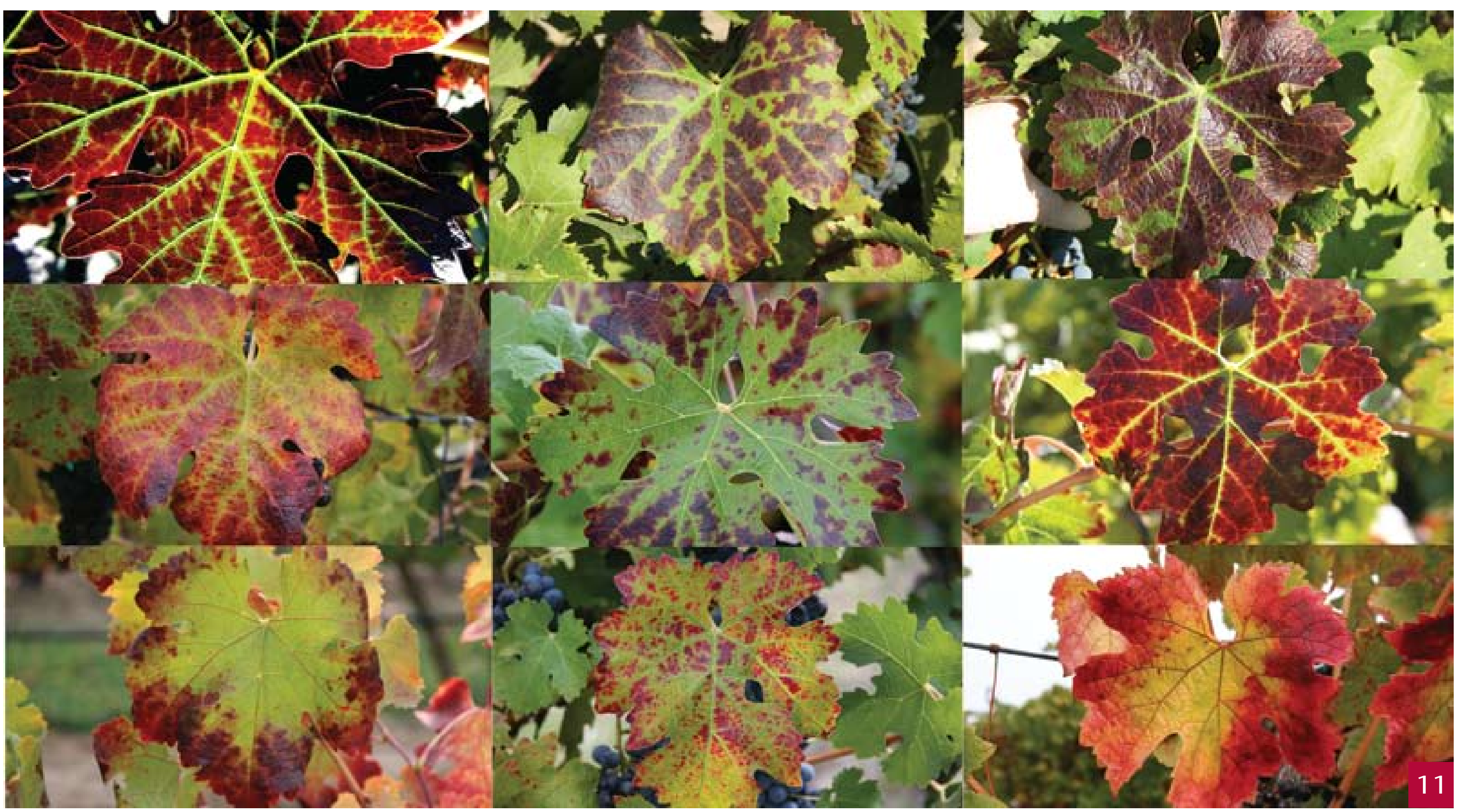
GLRaVs can induce severe symptoms in self-rooted vines and in grafted vines. In grafted vines, the infection can be passed from the rootstock to the grafting material or vice-versa. A scion (i.e., a shoot to be grafted) can carry a latent infection and be asymptomatic until it is grafted onto a rootstock and, conversely, a virus-infected rootstock can pass symptoms on to the grafted material. In fact, sometimes two different viruses are present—one in the scion and one in the rootstock—resulting in mixed and synergistic interactions. Since viruses may be present in either or both scion and rootstock without showing any obvious symptoms it is important to use clean materials in order to prevent disastrous consequences. This is particularly critical in places like western Washington where grapevine cultivars are propagated by grafting onto suitable rootstocks to promote early ripening due to reduced heat units and to gain protection from phylloxera and nematode-borne virus infections. An exacerbation of disease problems due to rootstock-scion interactions has been reported in California and elsewhere following grafting of virus-infected scion varieties onto virus-sensitive rootstocks. There is also mounting evidence in California and Europe that a shift in rootstock planting preferences can result in graft incompatibility causing disorders like young vine decline and rootstock stem lesion necrosis. In these places, GLRaV-1 and -2 and GLRaV-2-RG have been linked to graft incompatibility.

In eastern Washington, wine grapes are self-rooted and true to type. In recent years, some growers in the Columbia Valley have been adapting “top working” or “top grafting” (i.e., grafting of existing vines to more popular varieties) as a means to quickly switch over from an undesirable variety to a popular variety to catch up rapidly with market trends in a relatively short period of time and to avoid costs in establishing new vineyards. Top working can take place among red- or white-fruited cultivars, from red-fruited cultivars to white-fruited cultivars, or vice versa. Growers planning to switch over from an existing cultivar to another cultivar by top working must be aware that presence of virus (either known or latent) in either material can significantly reduce the success rate of top grafting. It has been documented in other viticulture regions that a transition from grapevines on their own roots to grapevines propagated by top working can result in virus-induced disorders like graft incompatibility or the appearance of new diseases if the scion and/or rootstock vines are compromised.

diagnosis

Accurate diagnosis of GLD and the GLRaVs present in an infected vine is the cornerstone in GLD management. While some red-fruited cultivars produce distinct visible symptoms, reliable diagnosis is not possible based on visual symptoms alone. Not only do symptoms vary among the cultivars, the expression of symptoms is influenced by several factors like variety, age of the vine, virus titer (i.e., concentration), time of year, and whether an infected vine contains one or more GLRaVs and their strains. And since GLD symptoms don't show up until late in the season, visual diagnosis is not possible early in the growing season or during the dormant season. Since many growers and nurseries collect wood for propagation during winter season and GLD produces no visual abnormalities on dormant wood, diagnostic methods other than visual observation are necessary to ensure accurate high-quality, virus-free planting material.

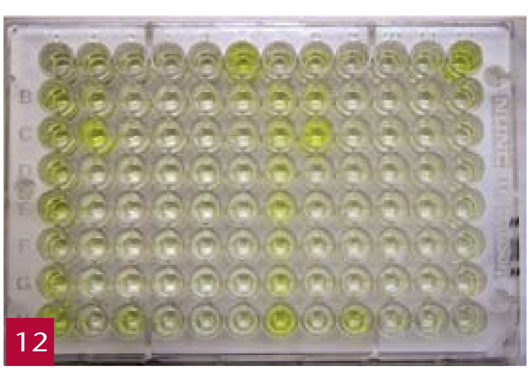
Not only does GLD express symptoms very mildly, if at all, on white cultivars, the expression of symptoms varies significantly among red cultivars, as the photos below show. Reliable diagnosis of GLD cannot be made by observation of visual symptoms alone.

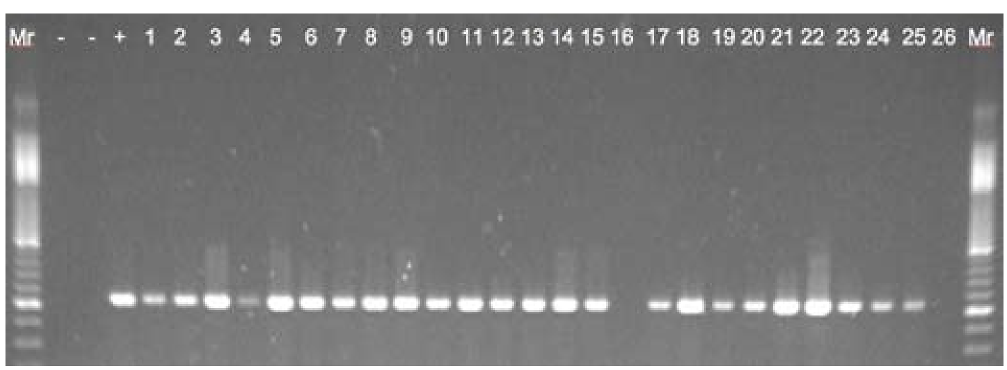


Above: Several conditions mimic GLD symptoms. The top photo shows an injured vine; the two leaf photos show zinc deficiency. Below: Samples testing positive for the virus show up as yellow in an ELISA test. Below right: Results from RT-PCR test indicate presence of GLRaV-3 as shown by white bands. Samples known to be positive (+) and negative (-) for the virus are included in each assay as controls to verify the test results.

Visual diagnosis of GLD is also problematic because several other physiological conditions including nutritional issues (e.g., zinc deficiency), physical damage, or herbicide injury result in discolorations that can mimic GLD symptoms. There are differences, but they can be difficult to spot. GLD symptoms will typically appear on different shoots throughout the vine, generally beginning at the bottom of the plant and progressing upward, while the symptoms caused by physical damage are restricted to the injured portion of the shoot, with all leaves beyond the point of injury showing discoloration. The discoloration caused by physical damage will be apparent over the entire leaf blade. Nutritional deficiency and herbicide damage will express visual symptoms that are temporary and may not occur in the same vine in successive years.

When visual diagnosis is insufficient or inconclusive, alternatives are available. Three methods are commonly used for the diagnosis of GLD and associated GLRaVs, one field-based and two laboratory-based. The field-based method, known as biological or field indexing, is widely accepted but labor-intensive and time-consuming, requiring a large area of land and two to three seasons to obtain results. The laboratory-based methods are enzyme-linked immunosorbent assay (ELISA) and reverse transcription-polymerase chain reaction (RT-PCR), both of which are widely used for routine diagnosis of different GLRaVs. These tests are more versatile, can provide results within days, and a large number of samples can be tested in a relatively short period of time. Although ELISA is both simple and effective, it cannot diagnose all known GLRaVs, as antibodies have not been developed for all of them. In contrast, RT-PCR assays can discriminate each of the known GLRaVs. RT-PCR is also the more sensitive of the two, able to detect viruses at much lower concentrations than ELISA. The major limitation of RT-PCR is that it is more expensive than ELISA. Both ELISA and RT-PCR procedures can be susceptible to genetic variants of the viruses in question.





In addition to the time and labor requirements of biological indexing, it may not be a useful technique if a variant of a particular GLRaV causes latent infection in the indicator host or if the bud wood has no virus, even though the test material contains the virus. But despite the limitations of biological/field indexing, it is still a useful technique for determining the presence of an unknown graft-transmissible disease. It can also be employed to field-verify test results obtained from ELISA and/or RT-PCR. Lab assays have the inherent risk of producing either false positive or false negative results, and ELISA and RT-PCR are no exceptions. Each has the potential to produce false negative results due to low virus titer (i.e., concentration), uneven distribution of virus in the vine, or inhibitory effects of compounds present in tissue extracts. To improve the reliability of the lab assays, samples should be collected from different parts of the vine and at different times of the season, and good laboratory practices with proper internal controls should always be utilized. False positive results are uncommon unless contamination occurs during testing, test samples are mislabeled, or the antibody materials used for testing are of poor quality.

You can't tell by looking! First photo below shows a red cultivar (left) and white cultivar (right); both infected with GLD. Next two photos show how symptoms can differ between two red cultivars (Cabernet Sauvignon on the left, Merlot on the right). Bottom photo shows Cabernet Sauvingnon (left) and Chardonnay (right), both of which tested positive for GLRaV-3.

GLD management

prevention

The following point cannot be overemphasized: GLD is best managed by prevention. Because grapevines are propagated through vegetative cuttings and infected propagation material is largely responsible for the establishment and spread of GLD, the first line of defense occurs whenever a new vineyard is established. New plantings should always use virus-tested grapevines from reliable sources like certified nurseries. Never assume that grapevines without visual symptoms are healthy and never procure planting materials from an unreliable source or take cuttings from an existing vineyard with unknown phytosanitary status. Planting cuttings that have been, or may have been, infected is a risky proposition; planting a particular clone or cultivar that has tested negatively for the presence of GLRaVs as well as other viruses is a good long-term investment toward sustaining profitability in a vineyard. The difference in cost between untested and tested planting material is minimal, especially when considered as a part of the overall expense of establishing a new vineyard, not to mention the long-term cost of dealing with a GLD-infected vineyard. Why cut corners on this crucial step?

Unfortunately, many vineyards in Washington State have been established with non-certified vines and GLD is already present. There are no effective curative measures for eliminating the virus once it is established in a vine—the only recourse is to minimize the impacts of the disease. The focus in this situation is on curbing the spread of the disease and minimizing economic losses.

Is it possible that GLD spreads through contact, such as mechanical or manual pruning or harvesting?

Left: Roguing can sometimes be part of an effective program, but only if vines are completely removed, including roots. Below: The clustering of infected vines could be a result of vine-to-vine spread, perhaps from root grafting, as discussed on page 8. More research is needed on vine-to-vine transmission of GLD.

vine removal

Of the various strategies available, removing and replanting the entire vineyard is the most effective, but this is typically impractical. In the case of a mature vineyard, however, a grower may find that replanting is in fact the best option. After weighing all factors including loss of income during re-establishment, future losses from infection, and spread of infection if no action is taken, this can be the most economical option for a mature vineyard with a substantial GLD infection. If a grower chooses to replace a vineyard, it is critical not only to make sure that virus-tested cuttings are used in the replanting, but also that the entire root system of the infected plants has been removed. If roots remain, suckers can form and grow, which may provide a source of virus inoculum for replanted cuttings.

Roguing or selectively removing infected vines is one of the least cost-effective ways to manage GLD, but can sometimes be part of the strategy when considered on a case-by-case basis. The decision to attempt to selectively remove infected plants depends upon the level of infection, the timing of removal in relation to age of the vineyard, and the benefit-cost ratio of replanting. Generally speaking, roguing and replanting individual vines with virus-tested planting material makes more sense during the formative years of the vineyard and before the infection has become widely established.

One of the things that makes effective roguing so difficult is that, due to the lack of visible expression of symptoms as discussed earlier, it is hard to know which vines are infected. Not only are visual symptoms less apparent in some cultivars, but vines that are infected during the later part of the growing season do not show obvious symptoms for the next season or two. If vines are becoming infected from immediately adjacent vines, as is sometimes the case, a prudent strategy might be removal of the vine known to be infected and one or two vines on either side of it. Roguing will obviously be less effective if the infection is coming from farther away, such as neighboring vineyards.

doing nothing

What if a grower chooses to do nothing? If infected vines are retained in a vineyard, it is likely that they will serve as a potential source for the secondary spread of the virus within a block and a source of infection for neighboring vineyards. A grower with infected vines may need to implement additional control measures, adding to the expense of managing the vineyard and reducing profitability/sustainability.

Some growers apply nutrient supplements to alleviate the symptom expression, but this is not a management technique, as it only masks the chronic underlying problem.

vector management

Grape mealybug is a documented vector for the causal agents of GLD. Mealybugs overwinter as eggs or crawlers in the egg sacs, usually in the bark cracks or under the bark scales on the grapevine trunk and in the arms or laterals. In the spring, crawlers move quickly to new growth to feed. They mature in June, and adults move back to older wood to lay eggs. The second generation of crawlers will move to new growth, including the fruit, where they mature through July and August. In addition to their potential to vector GLD, this second generation may contaminate fruit by production of honeydew, which may further lead to favorable conditions for sooty mold development. Generally speaking, control procedures for grape mealybug are most effective when the insects are in the crawler stage.

Chemigation treatments with chloronicotinyl insecticides are registered for use on grapes. Several products can be effective against mealybugs at any time during the growing season. Irrigation water requirements for adequate distribution of systemic insecticides vary among products. Chemigation of imidacloprid is an effective treatment available for grape mealybug applied mid to late spring when the vineyard soil moisture is being held at or near field capacity. Soil moisture is important in transporting imidacloprid. Chemigation with thiamethoxam and dinotefuran has proven effective in deficit irrigation situations.

If a vineyard is not drip irrigated, foliar treatments can be applied for mealybug control. Foliar sprays of chlorpyrifos are labeled exclusively for dormant or delayed dormant applications and, if utilizing this organophosphate, care should be taken to avoid runoff. Research has demonstrated that foliar sprays of imidacloprid (Provado) are not very effective at controlling grape mealybug infestations. Foliar sprays of thiamethoxam, acetamiprid, and dinotefuran should be directed toward the trunk and main laterals. When applying foliar sprays for this pest, sufficient water and pressure must be used to loosen bark and drive the pesticide into cracks and under loose bark.

Late summer spray applications for grape mealybug control are usually ineffective.

Outbreaks of the European fruit lecanium scale *(Parthenolecanium corni)*, suspected of vectoring viruses in California, have occurred in Washington vineyards in recent years. While their connection to GLD is not conclusively established, these insects can secrete honeydew and make a vineyard unsightly in spots. Because this is unattractive to consumers and winemakers, some growers control scale with delayed dormant applications of oil and approved organophosphates. If neonicotinyls are applied for control of other arthropods, they will also provide incidental control of lecanium scale.

Some growers choose, for a variety of reasons, to fumigate their fields for nematodes before planting grapevines. Nematodes are not vectors of GLRaVs and are probably of little or no significance in the management of GLD. Since nematodes feed on roots and cause feeding damage, however, they may affect vigor and productivity, which could perhaps predispose grapevines to infection by soil-borne pathogens. More information on nematode control programs for grapes can be found in the WSU Extension Publication *Pest Management Guide for Grapes in Washington* (EB0762).

Photos on opposite page and immediately below show mealybug impacts on bark and fruit. Photo at bottom reminds us that, in some cases, pesticides are our friends.

summary

GLD is a threat to the sustainability of the wine industry in Washington State and, indeed, in the Pacific Northwest region. By applying lessons learned from other viticulture regions and using foresight and teamwork, our state's relatively young viticulture industry can be protected. We must all work together to monitor and maintain the sanitary status of our vineyards. One should not assume that GLD is somebody else's problem and sanitation is somebody else's job, since your neighbor's problem will soon become your own as GLD infection spreads. Practical measures like avoiding the planting of infected materials, preventing secondary spread within and among vineyards by controlling vectors, and following guidelines on how to handle infected grapes will go a long way toward decreasing the incidence and spread of GLD in Pacific Northwest vineyards.

You may download copies of this and other publications from WSU Extension Publishing and Printing online at http://pubs.wsu.edu, or call 1-800-723-1763. This publication is also available at WSU's integrated pest management web site, http://ipm.wsu.edu.

Issued by Washington State University Extension and the U.S. Department of Agriculture in furtherance of the Acts of May 8 and June 30, 1914. WSU Extension programs and policies are consistent with federal and state laws and regulations on nondiscrimination regarding race, sex, religion, age, color, creed, national or ethnic origin; physical, mental, or sensory disability; marital status or sexual orientation; and status as a Vietnam-era or disabled veteran. Evidence of noncompliance may be reported through your local Extension office. Trade names have been used to simplify information; no endorsement is intended. Published April 2008. Subject codes 233, 356. EB2027E.

WASHINGTON STATE UNIVERSITY EXTENSION

Use pesticides with care. Apply them only to plants, animals, or sites listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.