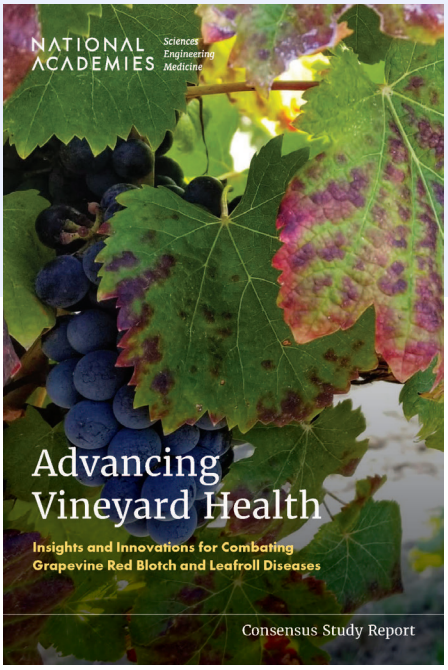
Advancing Vineyard Health



Insights and Innovations for Combating Grapevine Red Blotch and Leafroll Diseases

Grapevine red blotch disease (GRBD) and grapevine leafroll disease (GLD) are growing threats to the California wine and wine grape sector, which contributes $73 billion annually to the state's economy. These viral diseases not only reduce grape yield and the productive lifespan of vineyards but also affect sugars and other aspects of fruit quality that are relevant to wine flavor profiles. Due to the complexity of the processing and aging winemaking involves, it can take years for the full impact of both diseases on the quality of the final product to become apparent.

Several viruses are associated with GLD and are collectively referred to as grapevine leafroll-associated viruses (GLRaVs); of these, the grapevine leafroll-associated virus 3 (GLRaV-3) is considered the primary causal agent of GLD. Mealybugs (family Pseudococcidae) and soft scales (family Coccidae) are demonstrated vectors for GLRaVs. GRBD, caused by the grapevine red blotch virus (GRBV), which is transmitted by treehopper insect vectors (e.g., three-cornered alfalfa hopper), is a more recently identified disease that needs further characterization at the molecular and ecological levels. GLRaVs and GRBV are also transmitted through vegetative propagation.

At the request of the California Department of Food and Agriculture (CDFA), this National Academies of Sciences, Engineering, and Medicine report reviews the current state of GRBD and GLD knowledge and identifies knowledge gaps and key areas where research and actions could help reduce the spread and economic impact of these diseases. The report sets out guidance to improve the management of GRBD and GLD and support future research on grapevine viruses.

CURRENT KNOWLEDGE

GRBD and GLD occur in red or black- and white-fruited grapevine cultivars, but foliar symptoms vary by cultivar, are less pronounced in white-fruited cultivars, and could be confused with nutritional disorders and other maladies. Because the two diseases cannot be reliably distinguished based on visual inspection alone, definitive diagnosis relies on the detection of GRBV and GLRaVs in the laboratory using nucleic acid-based methods (GRBV and GLRaVs) and serological assays (GLRaVs).

KEY KNOWLEDGE GAPS

The committee identified gaps in knowledge about GRBD and GLD and developed recommendations to guide research on the viruses, vectors, and plant hosts, and to advance strategies for disease management. The most significant knowledge gaps are presented here; see Chapter 4 of the report for discussion of all knowledge gaps.

Grapevine Red Blotch Disease

The length of the latency period of GRBD—the interval between when the plant is infected and when it becomes infectious—is currently not well understood but may vary among cultivars and with environmental conditions. Understanding the latency period helps to inform virus testing procedures and elucidate how asymptomatic infections may contribute to virus spread. The report recommends research on latency periods in different cultivars and rootstock-scion combinations, including the time from virus inoculation until vector acquisition, time until symptom expression, and time until the virus is detectable in plant or vector tissues.

Grapevine Leafroll Disease

Several distinct but taxonomically related GLRaVs have been reported in association with GLD—and each of these may also have divergent strains or molecular variants. Questions remain about why GLRaV-3 is predominant among the various GLRaVs, and about the potential disease outcomes of infection with single GLRaV versus mixed infections of different GLRaVs. The report recommends conducting foundational research to understand the factors that may contribute to the spread of GLRaV-3, including interactions with other grapevine viruses.

Disease Diagnostics and Detection

Visual scouting for GRBV- or GLRaV-3-infected vines in vineyards is unreliable due to the variability of symptoms in different wine grape cultivars (see Figures 1 and 2) and because symptoms may not always be expressed clearly and are easily confused with other conditions. This delays disease diagnosis and management efforts, allowing for continued disease spread. There is a need for portable, affordable diagnostic tools that can detect GRBV and GLRaV-3 infections early, and for standardized methods for collecting tissue samples and laboratory testing. The report recommends research to develop new, simple, and affordable high throughput tests for GRBV and GLRaV-3, which could include molecular methods and remote sensing technology, and to optimize sampling methods for accurate estimation of GRBV and GLVaV-3 prevalence.

FIGURE 1 Leaf symptoms of grapevine red blotch virus infection.
NOTES: Among red or black-fruited cultivars, such as Syrah and Pinot noir, foliar symptoms typically appear on older leaves as red blotches that eventually may cover the whole leaf, and the leaf may prematurely senesce (A, B). In white-fruited cultivars, such as Chardonnay, symptoms are less conspicuous, but chlorosis and leaf curling may occur (C).
SOURCE: Marc Fuchs, Cornell University.

FIGURE 2 Leaf symptoms of grapevine leafroll disease.
NOTE: GLD symptoms, including leaf reddening, on a black-fruited Vitis vinifera cv. Cabernet Sauvignon (left) relative to an adjacent non-symptomatic vine of the same cultivar (right).
SOURCE: Naidu A. Rayapati, Washington State University.

Vectors

Mealybugs and scale insects are recognized as the main vectors of GLRaVs, but knowledge of the full spectrum of potential vectors and their distribution in California may be incomplete. Important characteristics such as abundance, distribution, and life cycle have not been determined for all vectors of GLRaVs, and few transmission assays have been conducted to quantify vector acquisition and inoculation efficiencies. The report recommends support for research on the mechanisms and timing of acquisition, retention, and transmission of all GLRaV vector species, as well as the influence of environmental conditions and host genotype on GLRaV transmission dynamics.

Vector Plant Preference and Behavior Manipulation

A growing body of work shows that virus infection can alter the behavior of the insect vector and the fitness of host plants in ways that promote the acquisition and transmission of the viruses, a concept known as the vector manipulation hypothesis. The report recommends research on virus–vector–host interactions to determine how the different species or varieties of grapevines contribute to virus spread, as well as how GRBV or GLRaV-3 infection of the host can alter vector behavior.

RESEARCH AND ACTIONS THAT MAY YIELD PROMISING MANAGEMENT SOLUTIONS

Improvements in short-term "stopgap" and medium-term measures are needed to sustain the wine grape industry, in addition to pursuing longer-term solutions. These include:

- **Clean Plants:** Encourage the adoption and implementation of higher sanitary standards in registered mother blocks using robust, state-of-the-art, sensitive, and reliable diagnostic methods.
- **Roguing (removing) Infected Vines:** Develop optimal roguing and replanting schemes and facilitate their implementation.
- **Vector Management:** Determine the optimal conditions for the application of systemic insecticides to achieve better mealybug and three-cornered alfalfa hopper control and support research on mating disruption for mealybug control. A greater emphasis on ant management in vineyards could help suppress mealybug populations and increase the impact of biological control strategies.

- **Sanitation:** Determine the most effective and practical farm and worker equipment sanitation measures and harvesting and pruning strategies to minimize the spread of insect vectors.

- **Areawide Pest Management:** Develop areawide GLD and GRBD vector management programs and encourage grower participation in these programs. Longer-term investment in host resistance to the viral agents of disease and even vectors are considered to be important strategies for sustainable management of GLD and GRBD.

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- **Host Plant Resistance:** Support traditional plant breeding and bioengineering approaches for developing grapevine resistance to GLD and GRBD. Multidisciplinary and trans-institutional collaborations could enhance synergies in pursuing bioengineering approaches such as RNAi-mediated resistance and CRISPR/Cas-based genome-editing technologies.

CONSIDERATIONS FOR FUTURE RESEARCH

These future research directions could help develop viable solutions to virus diseases that threaten vineyard health and the sustainability of the California wine grape industry. High-priority considerations are presented here (see Chapter 6 for the full discussion).

Developing Models to Guide Insect Vector and Disease Management

In other cases of plant disease outbreaks, insect vector population models and disease risk models have been valuable tools for stakeholders to understand pest risk, production practices that mitigate risk, and critical windows of time for scouting and management activities. The report recommends research to develop publicly available, regionally relevant insect vector population models and disease risk models that can be used to guide local and areawide management activities for GLD and GRBD.

Engaging a Wider Range of Researchers

Specific funding for early- and mid-career scientists, and to address specific knowledge gaps, may help expand the pool of researchers working on grapevine virus diseases. The report recommends developing additional funding mechanisms to address particular research needs, such as accepting off-cycle proposals for projects that have the potential to dramatically improve GLD and GRBD management.

Longer-Term and Replicated Studies

Longer studies may be needed to accurately describe disease biology and inform recommendations for disease and vector management. Furthermore, supporting collaborative research would allow multiple research teams to address the same research questions to boost the replicability of results. The report recommends that funders consider projects lasting more than 3 years, including studies that advance control recommendations, translational research, and projects that integrate economic and societal impacts, as well as projects that allow for the replication of experiments in different locations and at different timepoints to obtain more robust and reliable insights.

Knowledge Sharing and Collaborative Research

Greater sharing and integration of research findings could be facilitated by the establishment of a dedicated working group and expanded opportunities for researchers to interact and share ideas at in-person meetings. The report says that creating a working group could help to foster collaboration among GLD and GRBD researchers.

Education and Outreach

Successful management of vector-borne diseases does not rely solely on devising strategies to control the pathogen or its vector; it also requires cooperation from growers. Effective educational and outreach strategies to communicate GLD and GRBD management advances could help boost the adoption of new practices. The report sets out recommendations to provide opportunities for researchers to share findings via dedicated websites or virtual town hall events to facilitate interactive discussions among researchers, extension agents, and growers. The report also recommends supporting research on understanding and improving the flow of information

across grower social networks, and on outreach efforts to understand the drivers and barriers to successful adoption of GLD and GBRD management practices.

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FOR MORE INFORMATION

This Consensus Study Report Highlights was prepared by the Board on Agriculture and Natural Resources based on the Consensus Study Report *Advancing Vineyard Health: Insights and Innovations for Combating Grapevine Red Blotch and Leafroll Diseases* (2024).

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