WHAT EVERY WINEGROWER SHOULD KNOW:

VIRUSES

Lodi Winegrape Commission

THE AMERICAN VINEYARD FOUNDATION

The American Vineyard Foundation is a California corporation organized in 1978 by the American Society of Enology and Viticulture as a vehicle to raise funds for research in viticulture and enology. Basic and applied research has made the American grape and wine industry the world's leader. The American Vineyard Foundation provides a unique opportunity to unify the industry through an industry-wide research effort to maintain this progress.

avf.org

CDFA PD/GWSS BOARD

The CDFA Pierce's Disease and Glassy-Winged Sharpshooter (PD/GWSS) Board is composed of 14 representatives (eight winegrape producers and six producer-processors) from the California winegrape industry, plus one member from the public. It provides recommendations on the use of funds collected under the PD/GWSS winegrape assessment, a statewide value-based assessment that is paid annually by California's winegrape producers. The PD/GWSS Board's primary focus is on research that will lead to solutions to Pierce's Disease, but it also funds research and outreach on other pests and diseases which are designated by the Board as posing serious threats to California winegrapes.

pdgwss.net

THE LODI WINEGRAPE COMMISSION

In 1991, local growers gathered together and voted to fund the Lodi Winegrape Commission through a self-imposed winegrape tax. The Commission proudly represents 750 growers farming over 100,000 acres of winegrapes. Their mission is to empower all Lodi Crush District 11 winegrowers and serve their common interests to enhance the profitability of winegrape production through promotion, research, and education.

lodigrowers.com • lodiwine.com • lodirules.org

WHAT EVERY WINEGROWER SHOULD KNOW: VIRUSES

Prepared for
Winegrowers in
Lodi and Beyond

Stephanie Bolton, PhD

Funding Provided by
American Vineyard Foundation
CDFA PD/GWSS Board
Lodi Winegrape Commission

Lodi Winegrape Commission 2020
Lodi, California

THE REASON FOR THIS BOOK

The California grapevine virus situation is beyond any quarantines. Viruses – especially leafroll and red blotch – are everywhere. The California Department of Food and Agriculture (CDFA) has a voluntary Grapevine Registration & Certification Program for nurseries in place and UC Davis' Foundation Plant Services (FPS) is providing nurseries with thoroughly screened and accurately tested rootstock and scion source material. Many nurseries are going above and beyond the requirements of the CDFA certification program by implementing vector control and extra virus testing. Still, vectors and viruses are spreading rapidly.

We grow over 100 grape varieties and have many different types of vineyards in Lodi – from highly mechanized, high production vineyards to historic, sought-after vineyards. As creators of the LODI RULES sustainable winegrowing program, we want to ensure the longevity of our farming operations. We see viruses as a BIG threat to this goal.

Here's what you, the grower, can do to help. Make sure that you plan ahead and order CDFA-certified planting material that has undergone virus testing *before* planting, and manage for viruses and their vectors proactively and purposefully (just like with other diseases). Talk with your neighbors and learn together.

In Lodi, we're finding that more and more vineyards are becoming infested with vine mealybugs, which are a very efficient vector of leafroll viruses and vitiviruses. Once a population of vine mealybugs enters a vineyard, it is extremely difficult to eradicate.

Virus infections are hurting our growers financially with lost revenue and management costs, since viruses can inhibit ripening, decrease yield, and lower a vineyard's lifespan. To help Lodi remain profitable and competitive in terms of winegrape quality, the Lodi Winegrape Commission created research focus groups to study our local vine mealybug and virus situations. Two teams were formed in 2017 – the Lodi Mealybug Biocontrol Research Focus Group and the Lodi Grapevine Virus Research Focus Group. Both teams were comprised of growers, viticulturists, pest control advisors, extension personnel, and scientists. Funded partially by the American Vineyard Foundation and the CDFA PD/GWSS Board, these groups met monthly for years to seek feasible, practical solutions both in the short- and the long-term which can be shared with growers in a relatable language.

Our Lodi grower motto is John F. Kennedy's famous quote, "A rising tide lifts all boats." **We want to help our fellow growers understand the need for action when it comes to mealybugs and viruses, and to know what they can be doing to help protect their vineyard investments.** By thoroughly studying these topics via journal articles and textbooks, educational field trips, talking with experts from around the world, and understanding our local situation, we are able to bring our growers the most current and useful information available.

When we all learn together, we can better work together and find solutions faster. This strategy is working for us as we have experienced a big paradigm shift in the industry. Our growers are learning more about viruses and taking action, and our statewide industry is working more cooperatively and communicating better than ever when it comes to viruses.

We hope you find the material in this book valuable and understandable. We're here to help – check out the Grapevine Virus Resources section of our website (lodigrowers.com/growereducation/viruses) and sign up for our grapevine virus email list-serve (email stephanie@lodiwine.com) to stay informed as we continue this journey.

Thanks for helping us protect our grapevines.

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…guess what topic we are tackling next? **ROOTSTOCKS**.

CONTENTS

1 GRAPEVINE VIRUS BASICS

Grapevine viruses pose a severe threat to the sustainability of California viticulture. Unfortunately, there is little faith in virus prevention at any level. Growers are losing contract dollars as wineries reject grape loads due to virus-induced ripening problems.

Understandably, many California growers are in a state of shock, denial, or anger about viruses. They thought that they were buying certified virus-*free* material from nurseries. (Read why there is no such thing as certified virus-free material on page 20). They are throwing the kitchen sink at some vineyards when the Brix won't go above 22 degrees and their contract is for 24. We've heard all sorts of dangerous myths about viruses from the mouths of industry leaders – including "rootstocks don't get viruses" and "mealybugs won't develop resistance to certain insecticides."

7 STAGES OF VIRUS-INDUCED GRIEF

SHOCK	Initial paralysis at seeing red leaves or Brix that won't budge.
DENIAL	Thinking that you don't have to learn about mealybugs and viruses (*your* red leaves are beautiful).
ANGER	Pointing fingers at neighbors, nurseries, and the State of California.
BARGAINING	Trying to convince winemakers that a little virus improves winegrape quality.
DEPRESSION	Realizing the potential cost of ignoring your virus problem.
TESTING	Testing your grapevines for viruses and trying out new management practices.
ACCEPTANCE	Taking responsibility for mealybugs and viruses on your farm and doing what you can to reduce their spread.

The 7 Stages of Virus-Induced Grief, which the Lodi Grapevine Virus Research Focus Group members each jumped around in to some degree. Adapted from a modified version of Elisabeth Kübler-Ross's original grief stage model (1969).

The good news is that there are virus management strategies which growers can implement right now in the short-term, which can be taught through real-world, hands-on integrated outreach from a team of growers, extension personnel, pest control advisors, and scientists. With the right communication, a long-term cooperative virus strategy can save the California industry from devastating future losses.

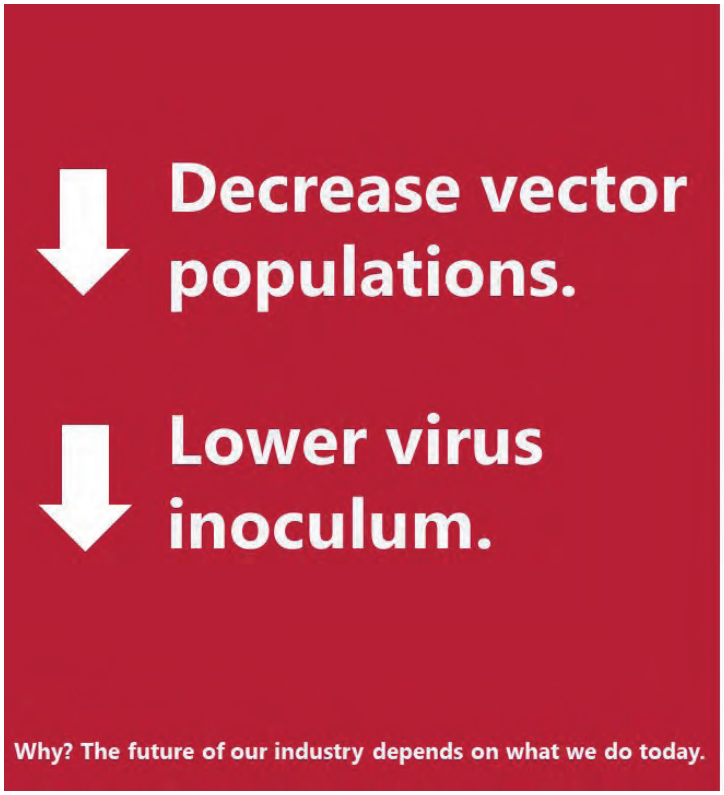
Grapevines are host to many viruses, with some viruses possibly improving quality and others causing disease. **Leafroll 3 virus is considered to be the most economically devastating virus disease of grapevines worldwide.** In California, we are primarily concerned with leafroll, red blotch, and fanleaf virus, although we've started paying closer attention to vitiviruses now that we're seeing vineyard patches collapse. In Lodi, fanleaf virus is manageable thanks to O39-16 rootstock. At this time in our region, most of the red blotch virus issue can be addressed by pulling out infected vineyards over time and replanting with CDFA-certified virus-tested material.

Leafroll virus, on the other hand, is a nightmare for many growers due to our extremely prolific and efficient insect vector, the vine mealybug, which has multiple generations per growing season, blows in the wind, hides under bark, and lives underground on roots. Invasive vine mealybugs can infect grapevines with leafroll virus faster than insecticides can kill them, and to complicate matters, we have protective ants farming the mealybugs for their honeydew.

This photo of neighboring vineyards clearly shows leafroll 3 virus spreading from an older Zinfandel block (bottom left) to a newly planted block with the help of vine mealybugs. The two vineyards are approximately 15 feet apart. Photo by Aaron Lange.

Unlike bacteria or fungi, viruses are not actually alive. They require a host organism to reproduce. At the time of printing and in the foreseeable future, there is no cure for virus-infected grapevines. Neither red blotch nor leafroll viruses are mechanically transmitted. This means that these viruses cannot be spread by pruning unless an infected insect vector (or carrier) travels on the equipment or workers and then feeds on another grapevine.

Due to great expansion of winegrape acres in California, for disease purposes, one could say that many regions have areas of a monoculture. **In these areas, insects and viruses can spread like wildfire.** In nearly all instances, growers cannot see a mealybug infestation nor a virus infection at the moment it occurs. It may take a few years for vine mealybug populations to grow to an observable amount. Likewise, vines may be infected with red blotch or leafroll virus for several years before a grower notices one of the tell-tale symptoms (if the symptoms show up at all): inability of grapes to ripen, decreased quality, or red leaves (in red grape varieties only).



Without a cure and with the threat of spread, the most effective way for a region to reduce the negative impacts of leafroll and red blotch viruses is to remove (or rogue) infected grapevines (which are a source of virus – called inoculum) over time and to encourage the use of CDFA-certified virus-tested planting material. In the case of leafroll virus, mealybug vector populations must also be reduced as much as possible.

TEAMWORK REQUIRED

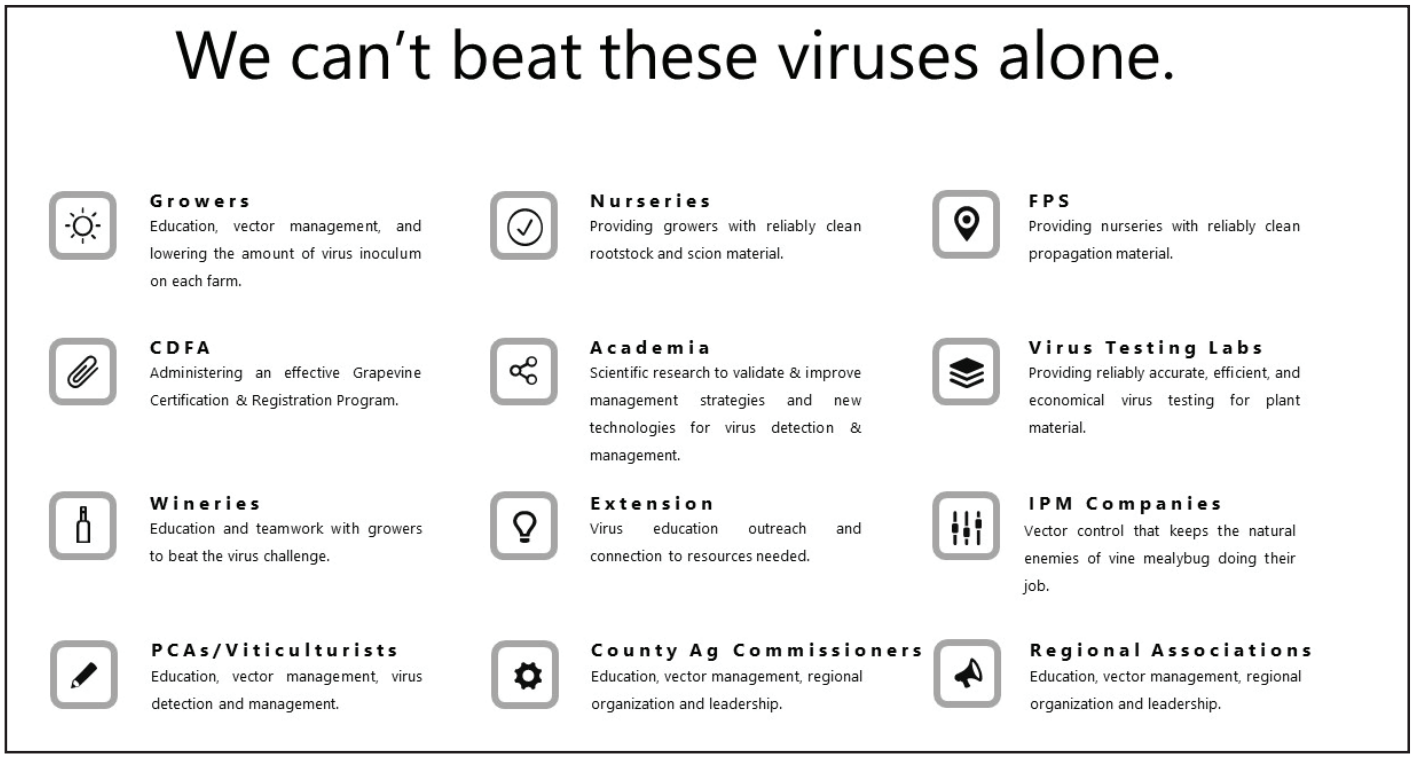
Our Lodi Virus Focus Group is a team of growers, pest control advisors, scientists, nurseries, viticulturists, and extension personnel who are lucky enough to also have Prof. Gerhard Pietersen (Stellenbosch University, South Africa) and Dr. Marc Fuchs (Cornell University) as experts willing to give us advice and support. Collectively, we influence hundreds of thousands of acres in California and beyond. It helps that these people have a financially vested interest in finding virus management solutions, and that they are willing to work towards a greater good for everyone. It's taken us a few years to wrap our heads around what is going on with viruses, and through a lot of outreach we've seen our colleagues begin to understand why it is important to invest time in learning about viruses and then taking the action and spending the money required to manage for them.

Teamwork and neighbor-to-neighbor education is critical to reduce devastating virus infections in California. Many growers do not understand how much money viruses are costing them, or the risk they are putting themselves and their neighbors at when they have mealybug infestations and leafroll virus infections. **The first critical step in our virus outreach project has been to help growers understand why they need to care enough to learn about viruses and their management.**

Over 200 people gathered in Stockton on April 4, 2019, to learn about mealybug and virus management at a meeting hosted by the Lodi Winegrape Commission. Presentations from this day were recorded and are available online at lodigrowers.com/growereducation/viruses.

One of the initial shocks we discovered (and that we are still getting over) is that no one organization is in charge of the California grapevine virus crisis. No wonder there are huge communication gaps. We'll be petitioning for a statewide coordinated research and outreach effort around mealybugs and viruses, similar to the CDFA's Pierce's Disease initiative.

We quickly realized that it's going to take a lot of teamwork and help from the growers, nurseries, FPS, the CDFA, academia, virus testing labs, wineries, extension, IPM companies, pest control advisors and viticulturists, county Ag Commissioners, and regional associations. **We need to stop pointing fingers and realize that we all contribute to the problem and to the solution, and then decide what action each of us can take so that we can move forward together.**



What can you do to help with the grapevine virus challenge?

THE SNEAKY COST OF VIRUSES

Another shock was just how much a virus-infected vineyard can really cost. Economics, the third pillar of sustainability, are important to consider for every issue. We already knew that viruses were costing growers money in the form of decreasing yield and quality, not being able to ripen grapes enough to satisfy a contract, the extra mealybug management that needs to be done now that we know about leafroll virus, virus testing, rogueing a vineyard and the added work that comes with managing replants, and having to pull a vineyard out sooner than expected – even before a planted vineyard becomes profitable. However, it wasn't until we sat down and crunched the numbers that we really understood just how much money everyone is losing here.

One of our Virus Focus Group members was personally testing his CDFA-certified nursery orders for viruses well before most of California. He calculated his losses in one vineyard where they unknowingly planted 70 acres of leafroll-infected Malbec in 2012. **He had thought that the cost was in the thousands of dollars, but when he sat down and really added everything up for our case study, the total came to a shocking 2.5 million dollars.** The vineyard was six years old and just coming into full production. The estimated cost includes removal, planting new vines, vine-training, and loss of revenue for three years. For the rest of the story, see "Case Study: Replanting Following a Leafroll-Infected Vineyard" on page 97.

Not all viruses are spread around in the same way. It's really important for growers to understand the basic differences between the main economically important viruses, shown in the simple chart here.

"A vineyard infected with grapevine red blotch virus is often, not always, slow to ripen. The virus interferes with the normal metabolic processes to a greater or lesser extent depending on resources available to the vines. At harvest fruit quality can range from good enough to absolutely unremarkable. Removing flower clusters at bloom or dropping fruit later in the season makes no difference in the end."

—RHONDA J. SMITH, VITICULTURE FARM ADVISOR, UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION

To learn more: read the article by Rhonda Smith, Monica Cooper, M Anderson, and Mysore Sudarshana called "Grapevine Red Blotch Disease effects on yield and fruit composition" available online at cesonoma.ucanr.edu/files/211414.pdf.

VIRUS COMPARISON CHART

VIRUS NAME:	FANLEAF (GFLV)	LEAFROLL (GLRaV)	RED BLOTCH (GRBV)	VITIVIRUSES (GVA, GVB,...)
What happens to the vineyard?	Decreased yield Deformed & yellow leaves Irregular, double-tipped shoots Poor fruit color & quality Shot berries Vine decline	Decreased lifespan Decreased yield Delayed budbreak Lower Brix Poor fruit color & quality Red leaves in Fall (red varieties only) Vine decline	Decreased lifespan Lower Brix, up to 6° Poor fruit quality Red leaves in Fall (red varieties only)	Possible sudden vine collapse on some rootstocks when there is a co-infection with leafroll virus Rugose wood disease (stem pitting, corky bark, differing diameters between rootstock and scion)
How can this disease spread?	Dagger nematodes Planting material Top-working/bud grafting	Mealybugs and scale insects (which can move by wind, birds, equipment, vehicles, & people) Planting material Top-working/bud grafting	Three-cornered alfalfa hoppers (TCAH) and other possible unknown vectors Planting material Top-working/bud grafting	Mealybugs and scale insects (which can move by wind, birds, equipment, vehicles, & people) Planting material Top-working/bud grafting
Watch out for:	Infected rootstock Sauvignon blanc may mask a fanleaf disease	Ants protect mealybugs from natural enemies and help them move in the vineyard Infected vineyards upwind of your block Mealybugs survive on roots, so if you rip out a leafroll-infected vineyard treat the area for mealybugs and remove as much root material as possible before replanting – or rotate crops The efficiency & widespread populations of the vine mealybug vector	Wild or backyard grapevines which can be a sneaky source of virus for the vectors to carry into your vineyard (some people think that this is how red blotch got into a Foundation Plant Services vineyard)	Ants protect mealybugs from natural enemies and help them move in the vineyard Infected vineyards upwind of your block The efficiency & widespread populations of the vine mealybug vector The sudden vine collapse, especially in white varieties where a grower may not notice a leafroll virus infection
Types:	Fanleaf virus	GLRaV-1, GLRaV-2, GLRaV-2 strain RG, GLRaV-3, GLRaV-4, GLRaV 4-car, GLRaV-4 strain 5, GLRaV-4 strain 6, GLRaV-4 strain 9, GLRaV-4 strain De, GLRaV-4 strain Pr, GLRaV-7 (leafroll 3 virus is the most economically important type worldwide)	Red blotch virus	Grapevine virus A (GVA), grapevine virus B (GVB), grapevine virus D (GVD), grapevine virus E (GVE), grapevine virus F (GVF), and more (GVA appears to be the most common type in California)

"Being aware of the detrimental impacts of leafroll and red blotch is part of the solution. Acting diligently to reduce or eliminate the virus inoculum in diseased vineyards is helping you remain the best stewards of a sustainable viticulture."

—MARC FUCHS, PHD, CORNELL UNIVERSITY

2 NURSERY ORDERING 101: VIRUSES

PLAN AHEAD FOR CDFA-CERTIFIED MATERIAL

> "The foundation of a good vineyard is the grapevine planting material with which it is established."
>
> **—JIM WOLPERT & ANDY WALKER**

WHAT TO DO:

- First, carefully select the best rootstock and grape variety for your location (see resources on page 18 if you need help choosing a rootstock). Giving a nursery more lead time for your order means more options for purchasing the cleanest planting material available (which may be CDFA-certified, 2010 Protocol virus-tested).

HOW FAR AHEAD SHOULD WE PLAN? Nurseries don't need quite as much lead time as a popular daycare, so that's good. Logistically, nurseries need time to create enough CDFA-certified material for your needs. If you want to use dormant benchgrafts or green vines, give a nursery at least 18 months. Always check with your nursery to see what their specific lead times are. Even more lead time is necessary if the nursery needs to source new material from FPS (Foundation Plant Services) and establish a mother or increase block.

WHY IS IT WORTH IT? Basically, you don't want to risk having to pull out an entire vineyard block within 4-5 years of planting. Isn't that a good enough reason?!

RESOURCES

Drs. Jim Wolpert and Andy Walker wrote a great article called "Ordering Grapevine Cuttings and Plants from Nurseries" in 2014.

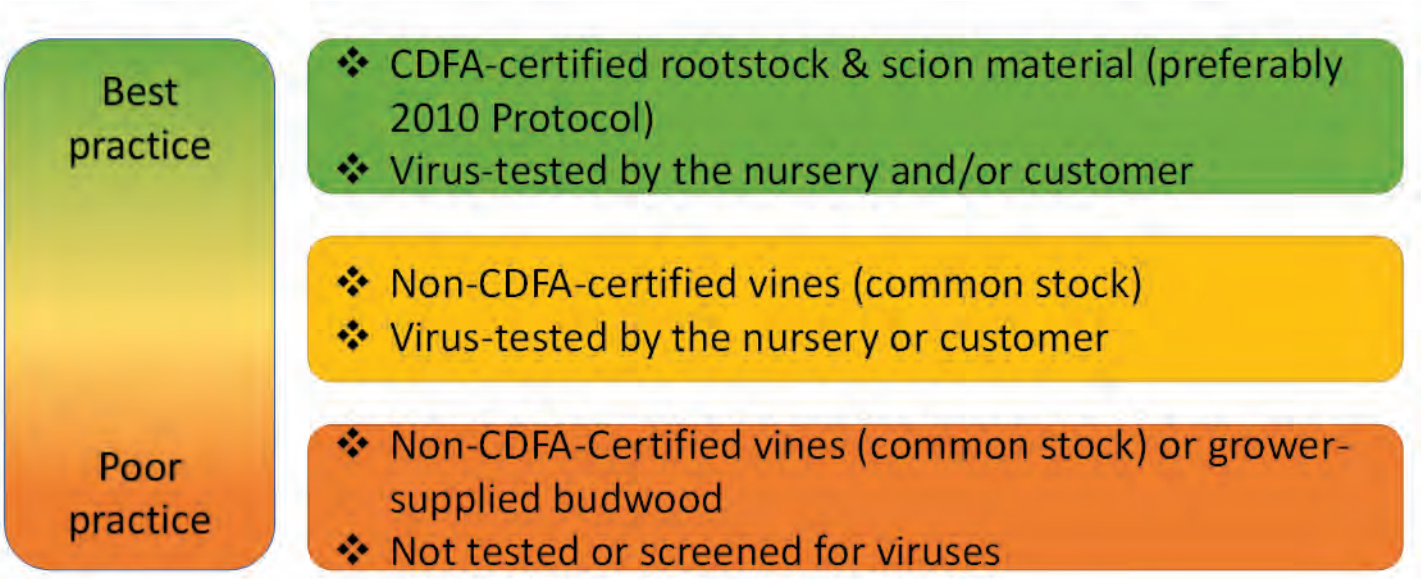
Stan Grant (Progressive Viticulture) wrote a very useful article on how to choose a rootstock for Lodi growers based upon years of viticultural experience, which includes a decision-making chart: "Selecting a Rootstock for a Winegrape Vineyard." Lodi Growers Viticulture Coffee Shop Blog. October 7, 2016.

lodigrowers.com/selecting-a-rootstock-for-a-winegrape-vineyard/

Dr. James Stamp wrote an excellent article about ordering grapevines in the November 2017 issue of *Wine Business Monthly*: "Grapevine Nursery Stock: Observations from Recent Production Cycles."

winebusiness.com/wbm/?go=getArticle&dataId=191691

Dr. Judit Monis wrote a great article about planting a healthy vineyard in the November-December 2017 issue of *The Grapevine Magazine*: "Guidelines for Planting a Healthy Vineyard."



A chart showing some options available for planting material as of 2020.

WHAT TO DO & SAY TO ORDER CDFA-CERTIFIED MATERIAL

STEP ONE: Choose a nursery that pays to be part of the voluntary CDFA Grapevine Registration & Certification Program.

Nurseries participating in the voluntary CDFA "Clean Grapevine Program" undergo certain measures and testing to help prevent virus infection in their certified blocks. The list of participating nurseries can be found online here: cdfa.ca.gov/plant/pe/nsc/nursery/grapevine.html. If a nursery is included on the CDFA Clean Grapevine Program list, it does *not* mean that all of their vines are in the program.

cdfa.ca.gov | 1220 N Street, Sacramento CA 95814 | 916.654.0435

STEP TWO: Ask the nursery for CDFA-certified vines – BOTH rootstock & scion.

At this time, there is NO such thing as guaranteed "virus-free" planting material available to growers. For most nurseries, the top quality, cleanest material will be called "CDFA-certified" "2010 Protocol" "virus-tested" vines. "2010 Protocol" refers to rigorous testing and microshoot tip culture of the foundation stock at the FPS level. Although a vine sold as CDFA-certified is *required* to be comprised of both certifiable rootstock and scion, there have been reports of nurseries not complying with this provision. There is also some confusion around CDFA-certified vine screening for red blotch virus. For these reasons, it is safest to confirm that both the scion and rootstock are CDFA-certified, and that the source wood has undergone recent virus testing to include red blotch.

QUESTIONS TO ASK YOUR NURSERY WHEN PLACING AN ORDER

- Will these vines be CDFA-certified (both rootstock & scion)?
- What virus testing program does the nursery have in place, and does it apply to the vines I am buying?
- May I have a copy of the most recent virus tests (especially leafroll, red blotch, and fanleaf) for all source wood?
- Will the vines be hot water dipped for mealybugs? If not, what method(s) of mealybug & vector control are being used?
- What is your vine replacement policy if vines are delivered with virus vectors (vine mealybugs) or viruses?

WHAT IS A CDFA-CERTIFIED GRAPEVINE?

This will sound confusing, but **CDFA-certified does not mean "virus-free"** nor does it mean that every individual vine that comes off the truck has been tested for viruses and other diseases. Nursery certifications are never guarantees.

A CDFA-certified grapevine is one that is built using propagation materials that can be traced back to vines of each selection maintained at the University of California, Davis by a program called Foundation Plant Services (FPS). FPS intensively tests and monitors the vines in their foundation blocks for a long list of targeted pathogens (economically important viruses, phytoplasma, and Pierce's Disease) and provides propagation material for nurseries to use. For detailed information, see the CDFA's "Registration and Certification of Grapevines" document, 3 CCR 3024-3024.8, 4603, available online at cdfa.ca.gov.

CDFA participating nurseries source plant material from FPS and plant it in vineyards called "increase blocks" or "mother blocks." If the mother blocks are to be certified by the CDFA, the vines from FPS are established on land that hasn't been planted to non-certified grapevines for at least 10 years. These CDFA-certified increase blocks are visually inspected annually by the state of California for disease, and once every five years, the CDFA collects random samples from these mother blocks to test against a smaller set of common and economically important grapevine viruses, including leafroll 3, red blotch, and fanleaf viruses. This testing is NOT sufficient to guarantee 100% cleanliness in the mother stock, but does provide an objective, third-party inspection. Please note that visual inspections by the CDFA are not necessarily conducted at the optimum time for symptoms to appear, and that symptoms are not always apparent for virus-infected vines (especially white varieties and rootstocks).

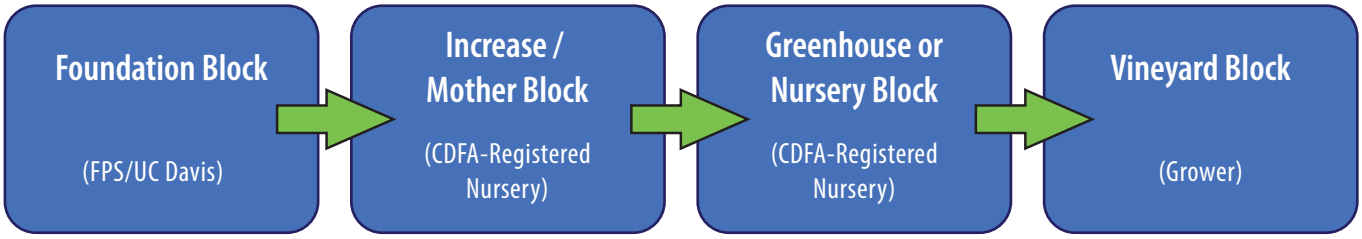
Viruses tested for by the CDFA at the nursery level in certified primary and secondary increase blocks, at least once every 5 years:

Grapevine fanleaf virus
Tomato ringspot virus
Grapevine leafroll-associated viruses
Grapevine red blotch virus

Virus testing requirements from the Registration and Certification of Grapevines document, 3 CCR 3024-3024.8, 4603; available online at cdfa.ca.gov.

For more details, visit cdfa.ca.gov *and search "grapevine certification"*

CDFA participating nurseries can then take propagation material from these CDFA-certified increase blocks to make vines that are available for customers to purchase. The CDFA-certified propagation material is grown in a certified greenhouse (for potted vines) or in a certified nursery block (for bare-root vines). CDFA-certified potted vines must be planted in non-soil media, and certified nursery blocks must have been fallow for at least one season prior to planting for bare-root vines. By regulation, nursery blocks used to grow bare-root vines are also either heavily inspected for nematodes, or they are fumigated prior to planting according to parameters set by the state. Nurseries maintain traceability records for CDFA-certified vines back to the foundation vines at FPS.



LIMITATIONS OF THE CDFA GRAPEVINE REGISTRATION & CERTIFICATION PROGRAM

The CDFA program is not a disease-free guarantee, nor was it ever meant to be

The CDFA Grapevine Registration & Certification Program (est. 1956) does not test for or regulate many important vine pathogens, including Crown gall bacteria, Pierce's Disease, or any fungal pathogens. Even with the major viruses covered by the program, the testing conducted by the CDFA is not sufficient to offer guarantees of cleanliness.

The following disclaimer is associated with CDFA-certified stock:

> *"The Department is not responsible for diseases, genetic disorders, off-types, failure of performance, mislabeling, or otherwise, in connection with the program. In any event, Department liability is limited to the cost or purchase price of the plants, plant parts, or plant material involved. No grower, nursery, dealer, government official or other person is authorized to give any express or implied warranty, or to accept any financial responsibility on behalf of the Department regarding the program, except as provided in 3 California Code of Regulations sections 3000-3033.5, 3044-3049.5, and 3069."*

It is also important to understand that the CDFA certification program is strictly voluntary. Nurseries can choose to opt out of the program entirely, or if they participate, a nursery is permitted to grow both certified and non-certified vines (sometimes called "common stock"). Additionally, although pests like mealybugs are included in the regulations, the inspections and control measures may be insufficient to provide reasonable assurances that vines will not be delivered with a pest infestation. This is why we recommend a close inspection of vines for vectors and quality in the "Taking Responsibility" section on page 25.

Even though it's not a perfect system (but what is?), ordering CDFA-certified rootstock and scion material **greatly** lowers your risk of purchasing planting material infected with viruses. Viruses and their vectors are quite sneaky and difficult to eliminate in any environment despite the best efforts of the CDFA, FPS, nurseries, and growers, so it is wise to test or confirm testing of nursery source material for viruses before propagation, and to also test a random sample of vines before shipment – being sure to test the rootstock and the scion portions of the vines.

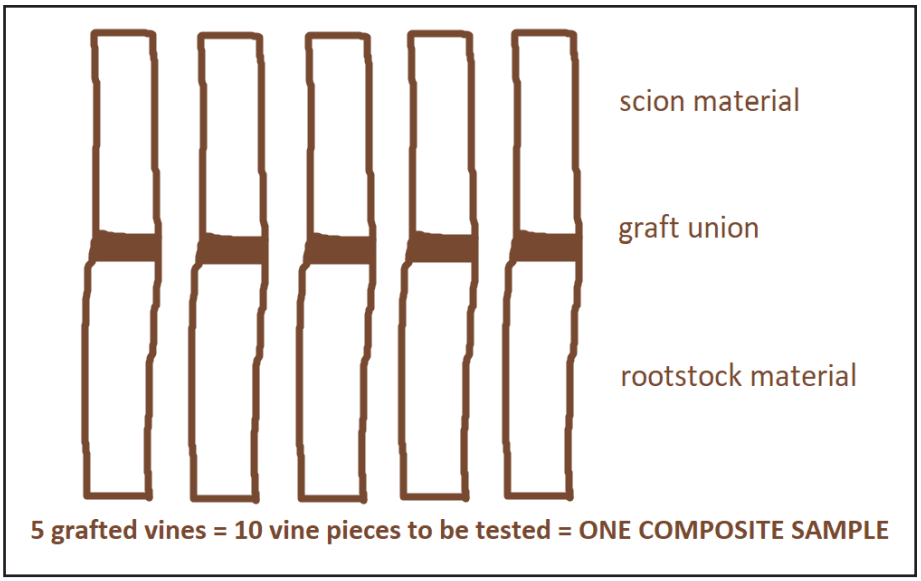
EXTRA TESTING BY GROWERS

As a bonus step, schedule a visit with your nursery to collect samples of the source wood before propagation (best practice) or finished vines for your order to get them tested for viruses, or arrange with your nursery to conduct this extra testing for a fee.

Virus-infected vectors are naturally present in California and virus symptoms are difficult to identify visually, especially in rootstock and white varieties, so a recent full panel virus test on any source wood before propagation is wise. Testing a smaller number of vines at this point in the process is much cheaper than testing an entire block of vines later, when a problem is suspected. A vineyard is a HUGE investment and extra virus testing *before propagation* is one way to help lower your risk for financial losses later. Some nurseries will even allow you to choose your source wood from their increase blocks, and if that is the case, then visiting the nursery in the Fall when symptoms are apparent (for red varieties only, since rootstocks and white varieties don't show the typical red leaf symptom) is a wise choice.

If you have already placed an order and did not test the source wood before propagation, you can test a random sample of vines (being sure to test portions of BOTH the rootstock and scion) at the nursery before shipment.

A vineyard is a HUGE investment and extra virus testing *before propagation* is one way to help lower your risk for financial losses later.



REAL-WORLD EXAMPLE: Pictured here is a bundle of dormant grafted vines which was pulled for virus testing in January 2019. The grower spoke with his chosen laboratory, who said that they can accurately test up to five of these grafted pieces in one composite sample if the grower wanted both the scion and the rootstock material tested, which he did. The grower chose, at random, one vine from a bundle, selecting five different bundles per nursery bin from his order to spot check for viruses (one composite sample per bin). Without taking apart the bundle, he used clippers to snip out a section of the vine which includes a portion of the scion and a portion of the rootstock. Since viruses are not transmissible by cutting, the grower did not need to sanitize his clippers between cuttings. He did, however, need a pair of warm gloves because this task is a cold one!

At this point in the ordering process, the grower is spot-checking the vines. The number of vines he is able to test depends upon his budget. He wisely placed one of the extra nursery labeling tags from each bin into the Ziploc bag with the samples. The outside of the Ziploc bag was labeled with the nursery name, his company name, and the bin's lot information. Each composite sample/bin had a separate Ziploc bag. The laboratory he used for these samples charged a setup fee of $36 plus $179 to test for several leafroll viruses, red blotch virus, fanleaf virus, and two vitiviruses per composite sample. For six bins, the cost totaled $1,290.

The grower is also performing a quality check: checking the strength of the graft union, peeling wax, looking for pests, and examining root color and firmness. If he found any vines which were of poor quality, he alerted his nursery representative. The grower has already spoken with the nursery, before the order was placed, about what would happen if the vines were to test positive for leafroll or red blotch viruses.

HOW TO STAY INFORMED & ORGANIZED

WHAT TO DO:

- Know the vocabulary and questions to ask to order CDFA-certified, recently virus-tested grapevines (page 19).
- Know the basics about the main economically important viruses, plus their vectors (page 15).
- Ask your nursery when the mother material/source wood was last tested for diseases (including viruses) and get a copy of those results. If you've taken the extra step to test the source wood and a random sample of new vines yourself (rootstock and scion), well done!
- Get the lot information from your nursery for each order and keep detailed records of what vines you have planted in each block, with planting dates. This information is found on the label tags attached to the vines. Keep records for replants too!
- Keep all of these virus testing and nursery lot records in the special pages at the back of this book if that makes it easier for you.

WHY IS IT WORTH IT? Farming gets busier every day and it's hard to remember all the details – which means we need to write them down. If another farmer has a virus issue from the same nursery, you may be able to check and see if it's from the same lot as your vines. When it comes to virus management, knowledge is power. You have a much better shot at successfully managing for viruses if you start with tested material and if you know the basics of the viruses you are up against.

REAL-WORLD EXAMPLE: Jim planted CDFA-certified Cabernet Sauvignon in 2014 and is starting to see some red blotch virus show up, which he verified by testing. He has records showing that the mother wood for both the rootstock and scion was tested for red blotch in 2013 and he has the nursery tracking details for his vines, so he can call the nursery and the Ag Commissioner to see if anyone else has seen a problem with the same material. If the problem is with the mother wood, he's helping other farmers who may have grapevines or be purchasing grapevines from that source wood. If no one else reported a problem, he can investigate whether or not a vector is bringing the virus infection into his vineyard.

TAKING RESPONSIBILITY

WHAT TO DO:

- *Before* planting, confirm that virus-tested material was used for propagation and possibly test a random sample of the vines (rootstock and scion portions) yourself – see page 22.
- *Check the label.* The label will often provide good information as to the increase block sources, grafting dates, CDFA-certification status of rootstock and scion material, etc.
- When the plants arrive, carefully inspect them for mealybugs/vectors (examining at least 2-3 pots per flat and peeling back any graft coverings like wax) and general health.
- Know the history of your site. If there was a vineyard planted there before, there could be live leafroll-infected root pieces with mealybugs underground and you should take measures to remove as many roots and mealybugs from the soil as economically possible before planting. If you plant over a previous leafroll infection, you'll want to select the new rootstock carefully (avoid leafroll-sensitive rootstocks).
- Carefully scout the new vineyard annually for viruses, rogueing infected vines in the Winter when the soil is wet to remove the most roots.

Ants tending mealybugs in two-year-old Sauvignon blanc.

WHY IS IT WORTH IT? Extra time up front testing, inspecting, and choosing the best site can save you from having to pull out an entire vineyard that isn't making sugar and cannot meet the winery contract – which we are seeing happen as early as the first year of planting.

REAL-WORLD EXAMPLES: At least three nurseries have confirmed cases in California where mealybugs entered vineyard sites on planting material. Once mealybugs enter a vineyard, especially in large numbers, it is almost impossible to eradicate them from a block due to their high rate of reproduction; with 200-800 eggs per female and up to 7-8 generations per year. Vine mealybugs can vector leafroll virus extremely efficiently. Even at lower populations where they are not affecting fruit quality directly, they may still be spreading leafroll virus. Watch out!!

There is recent, local evidence suggesting that even if you purchase the cleanest vines in the world, if they're planted in a site that previously had leafroll virus and mealybugs or next to an infected vineyard, then those vines can become infected with leafroll virus very quickly (see "Case Study: Replanting Following a Leafroll-Infected Vineyard" on page 97).

Viable root remnants 5 months after a vineyard rip-out despite extensive efforts to kill and remove as many roots as possible. Note from Kyle Brown, who took the photos: "Here are some pics I took in the field. The roots are alive and well so if they have leafroll virus, it would be easy for mealybugs to jump from these roots to a new vine that we are about to re-plant. Scary…" These root remnants tested positive for leafroll 3 virus.

RELATIONSHIP BUILDING

WHAT TO DO:

- Establish good communication with your nursery and neighbors. Responsible nurseries and responsible growers are open to talk about viruses and the preventative measures they have in place to block and minimize their spread.
- If you receive a nursery shipment with vine mealybugs, notify your local Ag Commissioner's office.
- Talk with your vineyard management companies to ensure they move equipment and people from LESS mealybug-infested/ younger vineyards to MORE mealybug-infested/older vineyards during a day's work whenever possible. You do the same!

WHY IS IT WORTH IT? Grapevine viruses are a threat to the entire wine industry in California and we all need to work together on this challenge.

A colony of vine mealybugs in various life stages as seen with a 15x hand lens. It's easy to see how these tiny sticky insects could travel in the wind and on equipment – spreading leafroll virus and vitiviruses around an entire region before anyone even notices. Photo by Stephanie Bolton.

GROWER Q&A.

Question: What if I spend the time, the money, and the energy needed to learn about viruses and manage them, and then my neighbors don't? Will what I do even matter if everyone around me ignores the problem?

Answer: Any farmer – actually, any property, even a homesite – with just one virus-infected grapevine is potentially spreading the virus disease to other vineyards, because they are providing a source of virus for insect or nematode vectors. Then, birds and animals may carry the insect vectors, or people may unknowingly propagate infected budwood to another vineyard. What you do to lower the populations of mealybugs and to decrease the amount of virus in your vineyards ABSOLUTELY matters because it helps your region and the state of California lower the amount of vectors and virus inoculum, reducing the overall spread of viruses.

It is undeniably in your best interest to talk with your neighbors about viruses and mealybugs so that you can all save time and money in the long run. The only way we're going to solve the virus issue is with community- and state-wide efforts, starting with education – one of the main focuses of the Lodi Winegrape Commission, CAWG, FPS, and many other groups.

RESOURCE

Drs. Jim Wolpert and Andy Walker wrote a great article called "Common Miscommunication Problems between Grape Growers and Nursery Plant Suppliers" in 2012.

A special thanks to Paul Verdegaal, MS, Brad Kroeker, Nick Podsakoff, Dustin Hooper, Tia Russell, Chris Storm, Kamyar Aram, PhD, Charlie Starr IV, Norm Peters, Kyle Brown, Karen Suslow, MS, Deborah Golino, PhD, Maher Al Rwahnih, PhD, James Stamp, PhD, and Judit Monis, PhD, for reviewing this Chapter on Nursery Ordering.

3 MEALYBUG MANAGEMENT

THE BASICS

Invasive vine mealybugs (*Planococcus ficus*) have been rapidly spreading around California vineyards for over two decades. Unfortunately, our state is way past any opportunity for a quarantine with this pest. Vine mealybugs first entered California in the Coachella Valley in the early 1990s (Godfrey et al 2003), likely smuggled in suitcase material from another country. This is why it is so important to bring in new planting material the legal way…it may not be as exciting of a story, but there is a reason why we have those laws – it's to protect us all. Think about how much money that one mistake by one sneaky person has cost us all in terms of mealybug sprays, biocontrol, leafroll virus infections, etc. It's pretty unbelievable if you think about it, right?!

Vine mealybugs probably entered Crush District 11 Lodi around 2002. At that time, growers assumed that the vine mealybugs were a virulent population of grape mealybug. It took about a decade for Lodi to learn how to manage vine mealybug, and we're still learning today. Once we realized how efficient of a leafroll virus vector the vine mealybug is – just one vine mealybug can infect a vine in less than 15 minutes! (Krüger et al 2015) – and how devastating leafroll virus infections can be, it became clear that even small populations of vine mealybugs in a vineyard were now unacceptable.

> "We have to consider the risk of virus infection from neighboring blocks and vineyards when deciding whether to plant a new vineyard. We've seen new plantings become infected with leafroll virus within months of being established, not because the virus came in on the nursery material but because the vineyard next door has a virus infection."
>
> **—CHRIS STORM, MS, VINO FARMS**

Trunks may secretly harbor thousands of mealybugs. Do you see all of the cottony white egg sacs, each containing between 200-800 eggs? This photo was taken in the Fall of 2018 at a vineyard in the Borden Ranch – Lodi AVA.

Today, we are on a mission to decrease the numbers and spread of vine mealybugs, and at the same time to lower virus inoculum (or source points) in our vineyards. Mealybugs exist in almost every vineyard in Lodi right now, and it's going to take a huge effort to stop their spread. It's imperative to keep lowering the numbers and spread of mealybugs in our region so that we can also reduce the negative, costly impacts of leafroll virus infections. Learning about how mealybugs are spread and what you can do to prevent further distribution is a crucial step to protect our vineyards! What you choose to do in your vineyard or in the vineyards you manage really does matter for the rest of us.

The Lodi Mealybug Biocontrol Research Focus Group formulated the following simple strategy for our region:

STEP ONE: Don't kill the good insects. It was concluded that our first and most crucial step towards increasing mealybug biocontrol in Crush District 11 was to encourage growers through education to stop killing the beneficial insects with their spray programs. We still have a sizeable number of growers unknowingly using spray applications which harm the beneficial insects.

STEP TWO: Control the ants. Through the experience of an educational field trip to Associate's Insectary in Santa Paula, we learned of the importance of ant control in an effective biocontrol program for vine mealybugs. The role of the ant is to protect and farm vine mealybugs for their honeydew. Ants herd the mealybugs, moving them along the vine throughout the season – including underneath the soil and into the roots, where the grower cannot eradicate them with any current methods. Ants also fend off natural predators and parasites of vine mealybugs. We learned that one main ant species present in Crush District 11 may be the Argentine ant, a very aggressive super organism which we have no effective way to control in the vineyards. Other ant species – both protein feeding and sugar feeding – were also found tending mealybugs during our Mealybug ID Field Day outreach program.

STEP THREE: Use pheromone mating disruption. Finally, we learned that pheromone mating disruption, if the cost can become lower, can be an excellent tool for our region. The mating disruption technique not only decreases levels of mating in a vineyard, but it also attracts beneficial insects to that area.

Be sure to follow the mealybug IPM plan suggested by your trusted pest control advisor, even if you don't think you have vine mealybugs yet. Acting as early as possible is key. Many prominent winegrowing regions in California are considered to be HIGH-RISK areas for vine mealybugs and for the viruses they transmit – especially leafroll viruses and also vitiviruses. In reality, all regions are at risk because mealybugs, leafroll virus, and vitiviruses are prevalent throughout the state of California. Your IPM strategy should include a rotation of modes of action and biocontrol. Vine mealybugs have several natural parasites and predators. Always check your planned spray program against our "Don't Kill the Good Insects" beneficial insect risk chart, found on page 122.

Why is the vine mealybug such an awful pest to have in California?

Vine mealybugs have between 5-7 generations per growing season in Crush District 11 Lodi. The females lay between 200-800 eggs. Put together, this means that a handful of mealybugs present on a vine in April can become trillions of mealybugs or more by October, if unchecked by natural enemies or other pest control tactics. All life stages can be found on all parts of the vine throughout the year. Vine mealybugs very efficiently vector leafroll viruses and vitiviruses. Freedom rootstock, a Lodi favorite, happens to be very sensitive/susceptible to leafroll virus. Argentine ants, an invasive pest themselves whose single super-colony extends from Mexico to Northern California (*California Agriculture* 2002), farm vine mealybugs. At the moment, we have no effective method to control the ants.

VINE MEALYBUGS
BY THE NUMBERS

BY: THE LODI WINEGRAPE COMMISSION

In the LODI AVA, our vine mealybugs have 5-7 generations per growing season.
On average, the females lay 300 eggs each, with about half of those eggs being female.

1ST GENERATION

1 female +
1 male mealybug

2ND GENERATION

1 female x 300 eggs
= 300 mealybugs
150 females

3RD GENERATION

150 females x 300 eggs
= 45,000 mealybugs
22,500 females

4TH GENERATION

22,500 females x 300 eggs
= 6,750,000 mealybugs
3,375,000 females

5TH GENERATION

3,375,000 females x 300 eggs
= 1,012,500,000 mealybugs
506,250,000 females

6TH GENERATION

506,250,000 females x 300 eggs
= 151,875,000,000 mealybugs
75,937,500,000 females

7TH GENERATION

by the 7th generation, those 2 original mealybugs are now
75,937,500,000 females x **300** eggs =

22,781,250,000,000 mealybugs
which then overwinter under the bark and in the roots – helped by ants – until the Spring

Hard-working ants tending their vine mealybug colony on a grapevine. Photo by Charlie Starr IV.

This photo shows a patch of dead and dying grapevines exhibiting what is called the "sudden vine collapse." Mealybugs likely play a role in this collapse. Studies are in progress, but it is looking like a combination of a virus-sensitive rootstock, a leafroll virus, a vitivirus, and another stress leads to vine death. Mealybugs vector, or spread, both leafroll virus and vitiviruses. See page 105 for the full story. Photo taken in Summer 2019 by Stephanie Bolton.

SCOUTING FOR VINE MEALYBUGS

If you can, teach everyone entering your vineyard how to look for vine mealybugs with a hands-on lesson in the vines. Lodi grower Brandon Sywassink has his crew leaders include mealybug ID training with safety talks, and he says that he has had workers find mealybugs before scouts! Vine mealybugs are easy to identify but difficult to find unless their numbers are incredibly high. A population can appear to explode almost overnight, so it's very important to be on the hunt constantly. Scouting works best when you show people a photo of what they are looking for immediately before entering the vineyard, so that the image is imprinted on their retina.

See the included Vine Mealybug Scouting Card in the back.

Mealybugs naturally hide underneath the bark, where they are protected from enemies and insecticide sprays. Mealybugs are also found on the roots, on the trunk, at the graft union, on the cordons, on the shoots, on the leaves (especially the underside), on petioles, and in grape clusters. They'll overwinter mostly on the trunk of the vine and in the roots, and then move up the vine and onto any green tissue during the growing season. By harvest time, they are throughout the canopy. When temperatures cool and green tissue senesces, mealybugs will move back down the vine to overwinter, sometimes with the help of ants.

Tips from local growers & pest control advisors on how to find mealybugs in your vineyard:

- Look for **ants**, who will be tending the mealybugs, or the ants' excavated dirt at the base of trunks
- Look for **black sooty mold** on the grape clusters, cordons, and leaves during the growing season and on the wood in the dormant season
- Look for **white cottony clumps under the bark**, which are the egg sacs (use a hand lens to view the eggs)
- Look for a **dripping waxy substance** in the canopy, on the bark, or attached to the underside of the cordons
- Look for **wet trunks**
- Look for **partially-dead or yellowing leaves** in the late Summer – turn the leaves over and you may find a mealybug feeding near the veins
- Look around any **connecting point** – the petiole to the cordon, the shoot to the arm, the graft union, the crotch, etc.

Chris Storm, Viticulturist, and Matt Kassis, PCA, look for mealybugs during a Lodi Winegrape Commission Mealybug ID Field Day in August 2017. Chris and Matt were both part of the Lodi Mealybug Biocontrol Research Focus Group. Photo by Stephanie Bolton.

Notice the white mealybug residue around the petiole junction. If you look closely you will also see ants crawling on the petiole. Photo by Stephanie Bolton.

The adult female vine mealybug (the one you'll be scouting for, since the males take flight) is distinguishable from other mealybugs because it does not have any long tails; rather, it has short, white, hair-like filaments coming out of its oval-shaped body. These filaments look like they might be legs, but the legs are actually hidden underneath the body.

This photo shows a live female vine mealybug found in a Lodi vineyard, viewed under a microscope. It's actually really interesting to look at mealybugs under a microscope. A simple hand lens works well too. Photo by Stephanie Bolton.

This photo, also taken from a microscope's viewpoint, shows a female vine mealybug who has been flipped over. You can see her little yellow legs reaching for something to hold onto, as she was unable to flip over on her own. Her cottony egg sac, stuck to her body, holds hundreds of tiny yellow eggs. Female vine mealybugs die shortly after giving birth. Leafroll virus is not transmissible from mother to egg – mealybugs acquire the virus from infected vine material by feeding on phloem tissue. Photo by Stephanie Bolton.

GROWER LESSON LEARNED THE HARD WAY

Never allow your workers to bring vine material with live mealybugs into your office or truck – the risk for spread is too great! One of our Virus Research Focus Group members told us a story of how his vineyard scout brought in a grapevine shoot with what must have been hundreds of mealybugs to his office, trying to get advice on what the insects were. Before he could shout "Get that out of here!!" the mealybugs had crawled all over his office.

All of the mealybug species that we have in Lodi can spread leafroll virus, just not as effectively as the vine mealybug because they don't reproduce as rapidly. In Lodi, we also have the grape mealybug, the obscure mealybug, and possibly others. The grape mealybug is easy to distinguish because if you gently poke its body with something sharp, it will ooze a red-orange liquid. The obscure mealybug has a few long, white filaments or "tails" coming out of one side of its body and does not ooze a colored liquid when poked.

Sometimes it takes peeling back layers of bark to find the mealybugs. Mike Klouda, a viticulturist, found these mealybugs (in various life stages) and the black sooty mold that grows on the honeydew residue underneath several layers of bark in the Mokelumne River – Lodi AVA. Mealybugs were not visible on the outside of the vine and he did not see any before he peeled back the bark. Photo taken in May 2018.

Mealybugs seem to prefer the backside of leaves, near the veins. Sometimes it helps to look for partially dead leaves and turn them over to find the mealybugs. Notice that the mealybug in the bottom center of the photo has been parasitized by an Anagyrus *wasp, noted due to the hole in its body which the white arrow is pointing towards. Photo by Stephanie Bolton.*

It's rare to find a single vine mealybug on top of a leaf. This photo was taken in a Lodi vineyard around harvest time.

MARKING HOTSPOTS

Brett Chandler from Associates Insectary taught a group of us about how in citrus – another crop plagued by mealybugs – the growers mark their mealybug "hotspots" each year. A "hotspot" would be where there are either a lot of mealybugs observed on one single vine, or there exists a cluster of infested vines. The following season, citrus growers closely monitor any marked hotspots and the areas immediately around them. We think that this is a fantastic strategy. You may think that you will remember where all of your mealybug hotspots are without marking them, but let's be honest – we all have a lot on our minds. Give yourself room to remember more important things, like which days the Lodi Airport Café is open.

A vine marked with our custom vine mealybug flagging tape, indicating a mealybug "hotspot." Photo by Stephanie Bolton.

We encourage you to use your awesome new mealybug hotspot flagging tape (included with this book) to mark your hotspots throughout the season, recording these locations by row and vine # in the back of this book, so that you can easily find them the following season. Yes, that's right, this book comes with custom mealybug flagging tape that no one else has because we made it just for you. You're welcome. We have to try and find some sense of fun during this challenge!

After you've marked your vine mealybug hotspots with your new flagging tape (included), you'll want to closely monitor those vines located downwind of any hotspots. Pay attention to the vines which are in the same row as any hotspots too – it's possible for mealybugs to move down the row along with equipment and workers.

BENEFICIAL INSECTS

THE ROLE OF INVERTEBRATES IN PEST MANAGEMENT

by Jessa Kay Cruz
Senior Pollinator Conservation Specialist
The Xerces Society

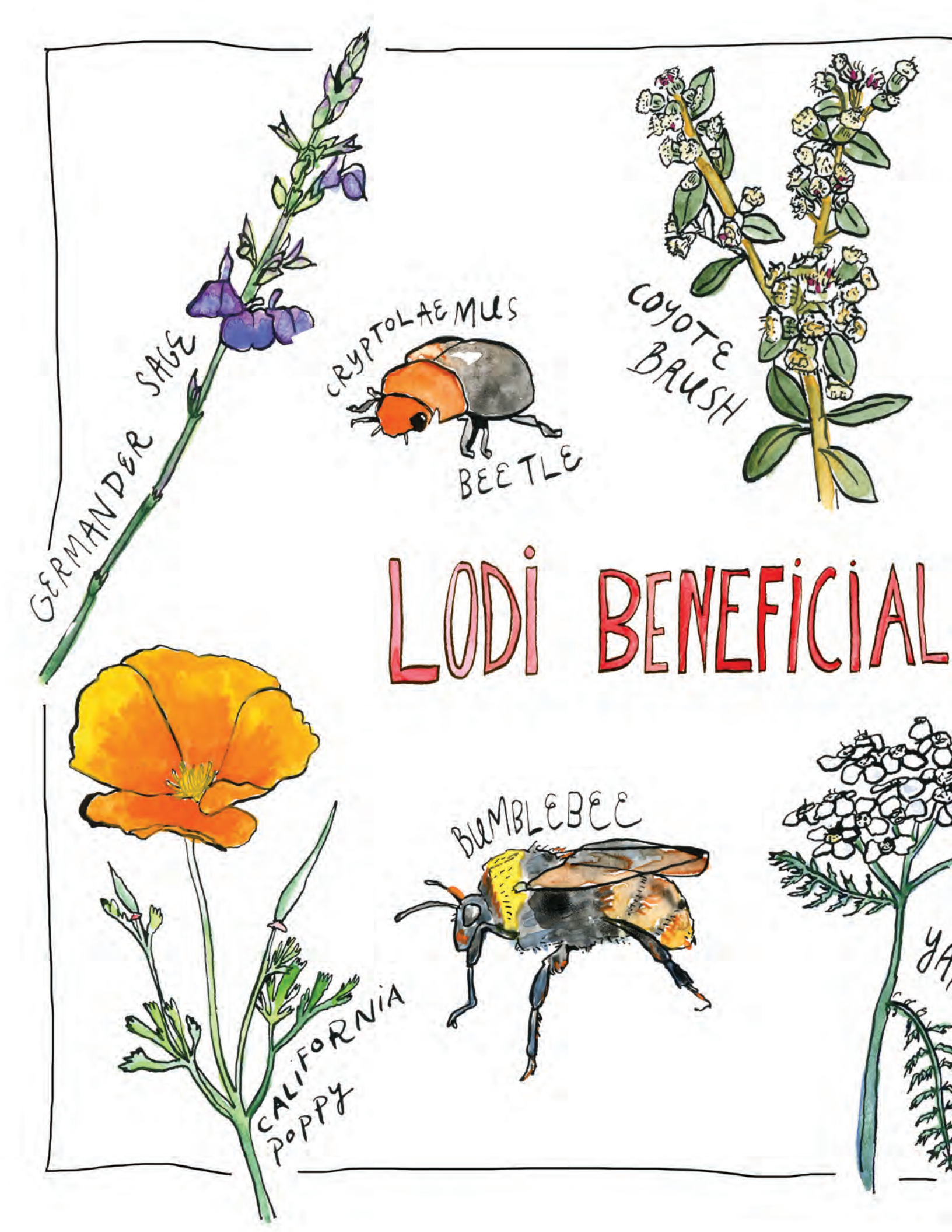
A colorful, flowering cover crop in a KG Vineyard Management LODI RULES certified sustainable vineyard. Photo by Madelyn Kolber.

The vast majority of invertebrates serve vitally important roles in a healthy environment, including pest control, pollination, and providing food for other wildlife. Only a very small number of invertebrates are pests. Yet pesticides rarely distinguish between beneficial invertebrates and those which cause harm, and their use can have a variety of unintended negative consequences. **With the advent of chemical pesticides, the contributions of beneficial insects (those that prey upon or parasitize crop pests) were largely forgotten.** However, pesticides alone have not solved the problem of crop pests – and of course, pesticides can have widespread, harmful impacts.

Ecological pest management focuses on preventive rather than reactive approaches to pest management. By increasing biodiversity and creating habitat for natural enemies, land managers can boost natural pest control services and reduce reliance on pesticides. The restoration of plant diversity in and around crop fields, combined with a variety of cultural, biological, and mechanical pest management practices, can keep pest populations below damaging thresholds without the use of chemical interventions.

Conservation biological control seeks to integrate beneficial insects back into crop systems for natural pest control. This strategy is based upon ongoing research that now demonstrates a link between the conservation of natural habitat and reduced pest problems on farms. For example, in a recent Xerces study in California cropping systems, funded by the Natural Resources Conservation Services, we found 25x the number of beneficial insects in on-farm habitat areas such as cover crops and hedgerows as compared to control sites. Furthermore, **the estimated value of pest control by wild natural enemies of crop pests is $4.5–12 billion annually for US crops, and $100 billion worldwide.**

For more scientifically sound information on the use of beneficial insects in vineyards, including lists of native species for habitat and scouting information, please visit xerces.org.


GERMANDER SAGE
CRYPTOLAEMUS BEETLE
COYOTE BRUSH
LODI BENEFICIAL
BUMBLEBEE
CALIFORNIA POPPY
YA

INSECT PLANTS

LADYBUG

NARROWLEAF MILKWEED

GREEN LACEWING

YELLOW LUPINE

BENEFICIAL INSECT SCOUTING

In addition to scouting for mealybugs, you should also scout your vineyards for any beneficial insects which may be helping you control vine mealybugs and delay resistance to insecticides. In Lodi, we have naturally-occurring populations of the *Anagyrus* wasp and the *Cryptolaemus* beetle (and other beneficial insects). **If you are not finding these parasites and predators, your natural vineyard ecosystem is likely out of balance.** You will want to adjust your spray schedule (see the Beneficial Insect Risk Chart on page 122) to ensure that you are not accidentally killing your beneficials. Also consider supplementing your vineyard with beneficial insects from an insectary (see the Resources section on page 63) until their populations come back to a more natural state. The Lodi Winegrape Commission and a team of five growers were awarded a USDA Western SARE grant in March 2019 to demonstrate state-of-the-art mealybug biocontrol in Lodi. We used pheromone mating disruption, scouting, trapping, and beneficial insect releases to try and reduce mealybug populations across five vineyards. Check out our educational video about the experience on lodigrowers.com/growereducation/viruses.

If you have younger children or grandchildren, the story of these beneficial insects makes for quite an interesting real-world science lesson! In fact, we like to host Family Field Days to teach our children about biocontrol. There are also great videos on YouTube posted by a company called Koppert.

Becca Starr showing off her beetles during a Family Field Day in the Summer of 2018, where we released thousands of Cryptolaemus *beetles donated from Associates Insectary using a parabug drone (you can see the drone's shadow to the right of Becca). It was a blast! Photo by Stephanie Bolton.*

ANAGYRUS WASPS – VINE MEALYBUG PARASITES

The wasp parasitizes the mealybugs by ovipositing an egg inside their bodies. As the wasp egg grows, the mealybug becomes mummified and dies. The wasp egg grows into a larva and chews its way out of the dead mealybug's body. You scout for the wasp by looking for vine mealybug "mummies" which have an exit hole on one end of their body. With good eyesight, you can see the parasitized female vine mealybugs with the naked eye – the hole looks like a large black dot on one end of the mealybug. Some people prefer to use a 15X hand lens to check for parasitism.

A photo showing several mummified mealybugs with exit holes from the Anagyrus *wasp larva which chewed their way out of the mealybugs. Can you spot the ant tending to the live mealybugs in the photo? Several mealybug life stages are apparent here, and you can see how the mealybugs can favor colonization around the petiole-cane attachment point. This photo was taken in a Lodi vineyard in 2017 by Stephanie Bolton.*

An adult Anagyrus *wasp found near a female vine mealybug during a Mealybug ID Workshop in Acampo, California, at Jay Leone's organic vineyard. Photo by Charlie Starr IV.*

Adult Cryptolaemus *beetles on a Lodi grapevine, hunting for their vine mealybug dinner. Photo by Charlie Starr IV.*

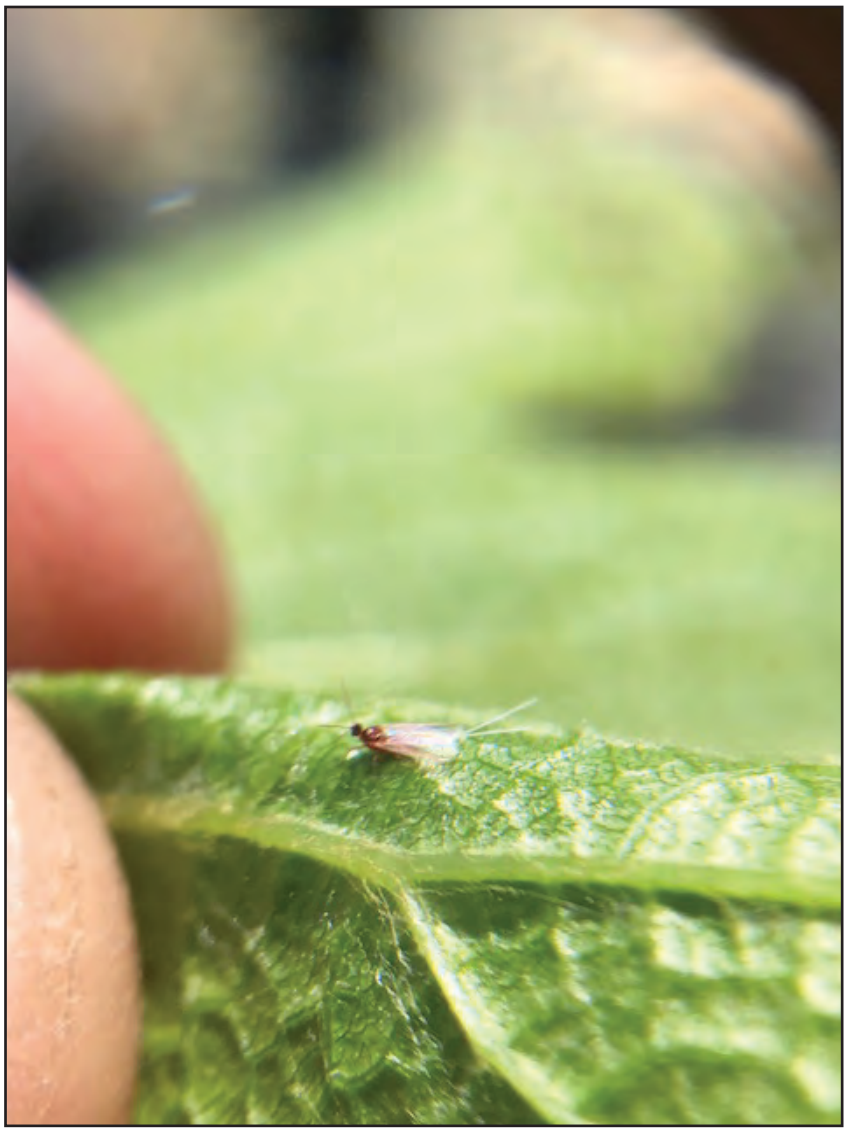
CRYPTOLAEMUS BEETLES – VINE MEALYBUG PREDATORS

The *Cryptolaemus* beetle is so famous for devouring mealybugs that it has the nickname "mealybug destroyer." For the *Cryptolaemus* beetle, we usually find the juvenile near vine mealybugs. The juvenile, in a really amazing feat by mother nature, is naturally disguised as a mealybug. It's like a wolf in sheep's clothing. The adult beetle is found less often, possibly because the adults are attacked by ants. Ants will literally pick up and carry beetles away from a clump of mealybugs.

Juvenile *Cryptolaemus* beetles are approximately the same size and coloring as mealybugs (see page 48). The *Cryptolaemus* beetle juvenile's body is shaggier and the filaments sticking out of its body are longer than that of the female vine mealybug. At Vino Farms they affectionately call the *Crypto* beetle a "Rastafarian mealybug." This disguise works well enough to not get attacked by the protective ants!

TRAPPING FOR VINE MEALYBUGS

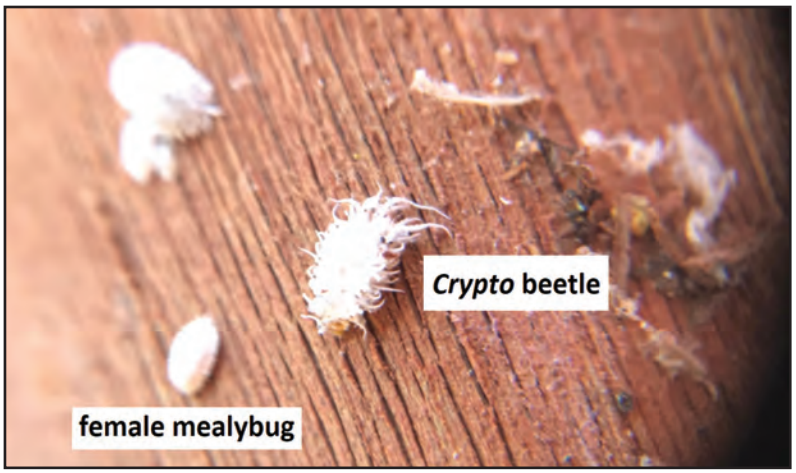
Trapping for vine mealybugs is possible because winged male vine mealybugs are attracted to the scent or pheromone of female vine mealybugs, which has been synthesized into a lure that can be placed in a delta trap for monitoring.



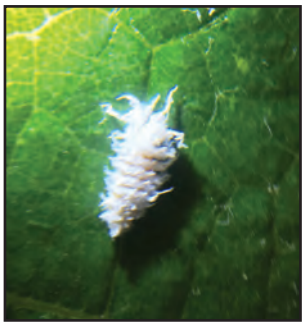
A winged male vine mealybug (the gender found in vine mealybug traps) in April 2019. Photo by Charlie Hamilton.

Trapping is so important that in some other counties like Napa, it is conducted by the Ag Commissioner. In Napa County, they monitor 25 traps per square mile and show the results on an online map. You can find this map online here: countyofnapa.org/1499/Vine-Mealybug.

San Joaquin County will begin trapping for vine mealybugs on a smaller scale in 2020. Ultimately, it is up to each grower to monitor their vineyards for vine mealybugs, and the Lodi Winegrape Commission has resources to help. Suterra (a company which produces mealybug mating disruption products) kindly donates mealybug traps to first-timers at some Lodi grower outreach meetings. There are also instructional materials available from the Lodi Winegrape Commission, along with a microscope that growers may use to check their traps.



A juvenile Cryptolaemus *beetle found near its food: vine mealybugs. Photo by Chris Storm.*



Notice the shaggy-styled body of the Cryptolaemus *beetle – aka the mealybug destroyer.*

Here we pulled back some bark in a Clements Hills – Lodi AVA vineyard late in the season. This vineyard was experiencing collapsing vines in patches, and we suspect that leafroll virus was playing a role in the collapse.

This Cryptolaemus *beetle juvenile was easily found in a Lodi vineyard four weeks after a purposeful release of adult beetles donated by Associates Insectary in 2018. Photo by Stephanie Bolton.*

WHAT LODI GROWERS ARE DOING NOW

Chris Storm, a Viticulturist for Vino Farms who manages vineyards in Lodi and on the coast, now traps for vine mealybugs year-round. Vineyard scouts who work with him collect the traps every week, sometimes saving a few weeks' worth of traps before sitting down to count them all under a microscope. When they collect at least 10 males per trap, they investigate further and apply pheromone mating disruption if needed.

THREE WAYS TO USE VINE MEALYBUG PHEROMONE TRAPS

1. DO I HAVE MEALYBUGS?

Don't think you have vine mealybugs in a vineyard block? Put a trap out and see! With the widespread populations of mealybugs occurring in our region, you would be hard-pressed to find a vineyard without any at all. The highest flight rates occur later in the season, close to harvest.

IMPORTANT NOTE: If your neighbors are using pheromone mating disruption as a tool to help manage mealybugs (which is really smart), your traps may not catch male mealybugs even when they are present. The pheromone confuses the males in your vineyard so they are not attracted to your trap. See #2.

2. START YOUR NEIGHBORHOOD CONVERSATION.

Use your traps to start a conversation about mealybugs and leafroll virus with your neighbors. Ask your neighbors if they will trap and learn along with you as it is in both of your best interests to work together.

3. A DECISION-MAKING TOOL.

Traps can be used as a decision-making tool to know when to begin a pheromone mating disruption program or another treatment. Overwintering mealybugs start coming up from the roots and the base of the trunk in the Spring as temperatures become warmer, slowly moving higher up the vine and into the canopy during the growing season. Between May-June are when the males (the only sex that can fly) start flying around in large numbers.

Traps can also show you how late in the season you have mealybug males flying around, seeking mates. You may be surprised to learn that mating occurs even after harvest, determining mealybug population levels for the next growing season.

Finally, traps can help you monitor mealybug populations over time, from one year to the next, determining how effective your management programs are in different seasonal conditions.

The orange mealybug pheromone trap pictured here is properly placed close to the arms of the grapevine on the wire. Both sides of the trap are folded shut, creating a small and selective hole for flying male mealybugs to enter. The photo was taken on March 30, 2018, in the Clements Hills – Lodi AVA. This grower was getting a head start for the 2018 growing season!

RESOURCE

Dr. Lucia Varela created a great guide to help identify male vine mealybugs: Male Mealybug ID Sheet, UCCE. May 2007.

cesonoma.ucanr.edu/files/27218.pdf

VINEYARD TO VINEYARD SPREAD

NURSERY MATERIAL

Just like growers, nurseries are struggling to exclude vine mealybugs from their increase blocks and greenhouses. Nurseries follow more aggressive mealybug management protocols than the average farmer but remember that mealybugs are prolific in California and difficult to see with the naked eye. Once they are spotted on propagation material it is often already a problem.

2018 planting material delivered with an unwanted and extremely dangerous hitchhiker. Photo by Chris Storm.

Nurseries are at risk for mealybug contamination if:

- there are commercial vineyards within blowing distance/a bird's flight of increase blocks
- budwood from an outside vineyard is entering a nursery greenhouse for propagation
- the nursery is allowing people to enter with contaminated equipment, vehicles, or attire

At the moment, it is recommended that growers inspect all incoming nursery material for mealybugs immediately upon arrival. Depending on which type of plant material you have ordered, look around the graft union (especially under any wax or coating), look on any green tissue, and check the soil around the root zone. Some counties may require that all incoming nursery shipments to their county have the graft union wax peeled away. This is not currently the case in San Joaquin County or Sacramento County, but growers can request it of the nursery on their own. Many nurseries are very accommodating to any practices which may help reduce the spread of vine mealybugs.

Another helpful tool which some nurseries are implementing is the very efficient application of imidacloprid to planting material before it is shipped to the grower. Imidacloprid works systemically after mealybugs feed on grapevine tissue. Thus, imidacloprid applications do not prevent leafroll transmission if mealybugs are present, since mealybugs still feed on the vine. However, a pre-shipment imidacloprid application will kill any feeding mealybugs which may be shipped with the vines and it will help protect what is a very substantial financial investment once the vines are planted and out in the open environment. Speak with your nursery representative to learn about whether they are offering this pre-treatment option.

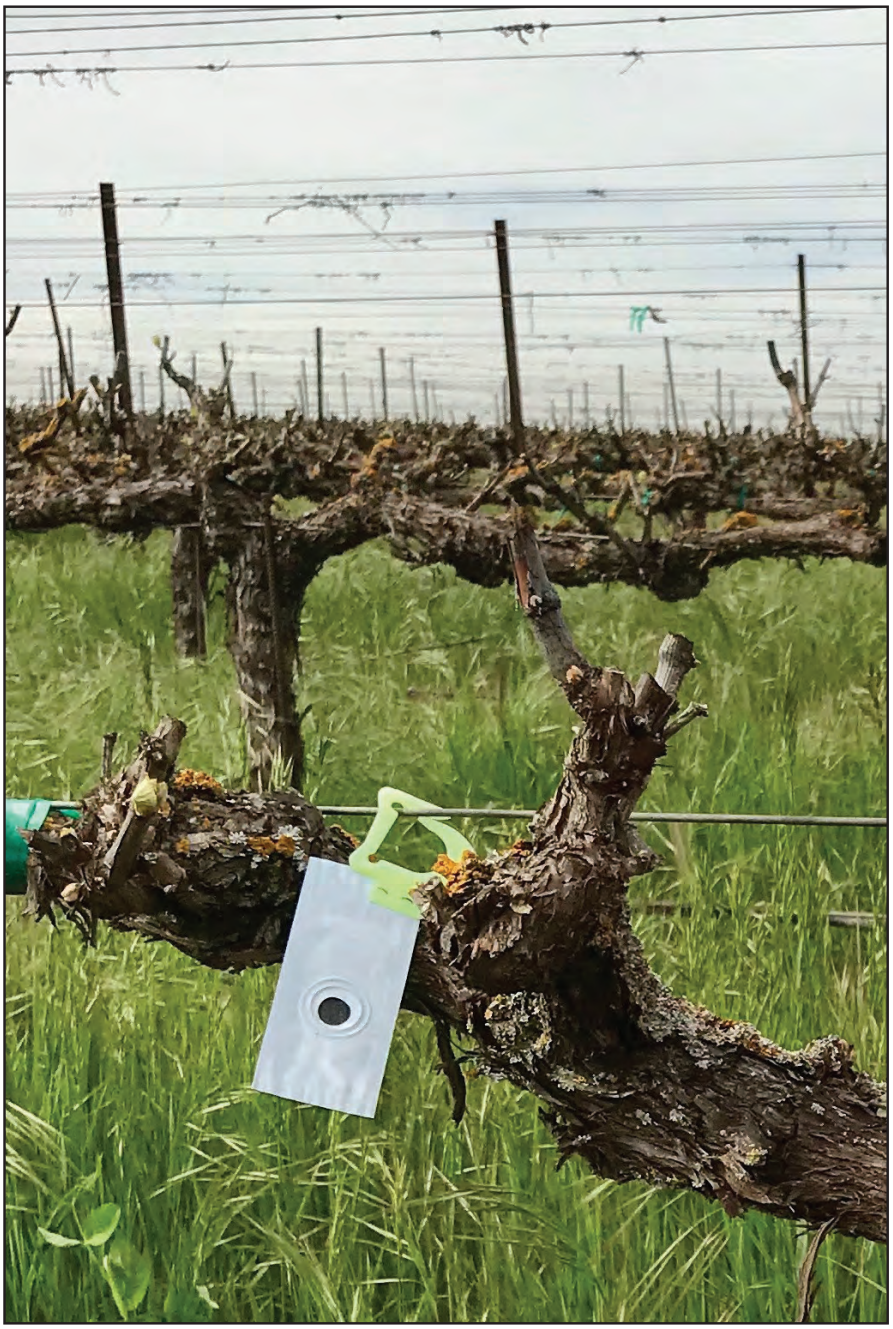
RESOURCE

Drs. Monica Cooper and Lucia Varela created a nice factsheet to help growers learn how to inspect nursery material: Inspecting Green-Growing Vines for Vine Mealybug, UCCE & UC IPM. August 2017.

cenapa.ucanr.edu/newsletters/Vineyard_Views_Newsletter_-_Events70517.pdf

NOTE: Any pre-treatment application is not a guarantee that mealybugs will not be present and begin to feed on vines. It only *helps* prevent leafroll virus infection, it does not prevent outright. It is recommended to monitor newly planted grapevines as soon as they are in the ground for virus infections, starting in year one. If virus infections are found in small percentages, which is common, then rogueing of those infected vines is the best strategy.

Many growers are also protecting the young vines from mealybugs immediately upon planting with a plume of pheromone mating disruption. Hang tag dispensers produced by Suterra are hung at a rate of 200-250 per acre, and mealybug trapping and scouting are performed throughout the growing season (some growers monitor year-round). A second mating disruption product in the form of a twist tie is currently being developed by Pacific Biocontrol. For more information on mating disruption, contact your pest control advisor.

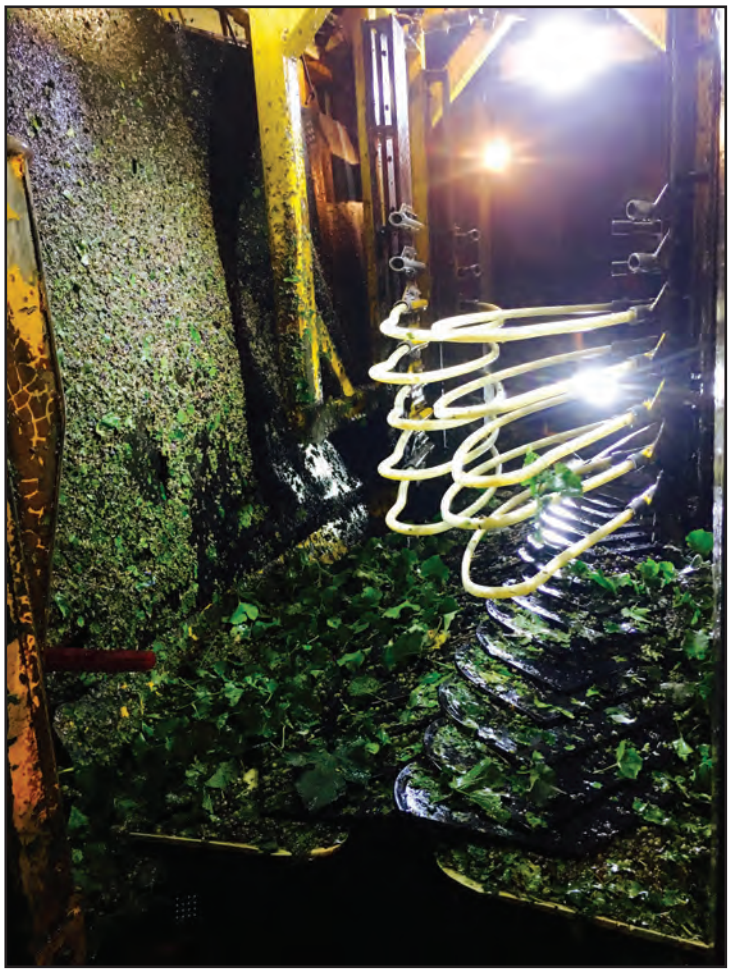


A vine mealybug mating disruption tag hanging in a Lodi vineyard.

EQUIPMENT & WORKERS

Mealybugs are tiny and they secrete a honey-like substance as they feed which is very sticky, making it easy to unknowingly spread colonies of them with equipment and workers from vineyard to vineyard. In Lodi, it is not common to wash and sanitize farm equipment between vineyards during the day, so growers and vineyard managers should always schedule the day's work to move from the newer/less infested vineyards to the older/more infested vineyards. A thorough wash of equipment at the end of the day, being sure to physically remove any plant material from the crevices of the equipment, is crucial.

Mealybugs are present in vineyards year-round, so they can be moved at any time of the year, but you should be especially cautious between the months of April and November when egg sacs and crawlers are present.



A mechanical harvester covered in sticky grape juice, leaves, and vine material. Are there any vine mealybugs hitching a ride too? Photo by Stephanie Bolton.

This photo should scare every California winegrower into action. Look closely to see the mealybugs on new growth. Photo taken in April 2019 by Kyle Brown.

Any equipment or worker is a potential mealybug transporter.

Be especially aware of:

- Mechanical leaf removal equipment
- Mechanical harvesters
- Tires and the under-belly of trucks and cars
- Any equipment or attire that is working in the canopy of the grapevine

If you are in control of scheduling your vineyard work, it is wise to take a few extra minutes to protect your younger vineyards. For those growers who use a vineyard management company, request to be the first stop of the day or pay a little extra to get a wash before any equipment enters your vineyard. These small steps can save you millions of dollars in the long run if they prevent leafroll virus infections.

Remember that irrigators, pest control advisors, and harvest scouts are also moving from vineyard to vineyard throughout the growing season. **Have an honest conversation with anyone entering your vineyard about ways they can protect your financial investment from leafroll-vectoring mealybugs – this may include car washes, shoe changes, and scheduling, and it starts with education on why this is so important.**

RESOURCES

The USDA NRCS (Natural Resources Conservation Service) has two programs – EQIP and CSP – which offer financial assistance for planting hedgerows and windbreaks. The CDFA Healthy Soils Program does too. The Xerces Society offers great resources on choosing hedgerow plants.

nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/

cdfa.ca.gov/oefi/healthysoils/

xerces.org

WIND

In Lodi we love our Delta breezes. They cool us down in the Summer and make us happy when it's 106^0 in Sacramento and only 94^0 in Lodi. They enhance the quality of our winegrapes by providing necessary aeration in the vine canopy.

Unfortunately, Delta breezes are potentially scattering vine mealybugs all over Crush District 11.

Vine mealybug eggs and crawlers are so small and lightweight that they can be blown in the wind – either on their own or along with leaves and other vine material. After sucking a leaf dry by feeding on the phloem, it's quite easy for the mealybug to hitch a ride on the dead leaf as it falls to the ground and then blows into a neighbor's vineyard.

Every grower knows which way the wind blows, so pay close attention to this wind direction when scouting for any mealybug issues. Be aware of any wind coming into your property from neighboring vineyards and

monitor those edge rows for mealybugs and/or leafroll virus more closely than the rest of the block.

In some Lodi vineyards, windbreaks consisting of tall, thick trees or shrubs are planted on the edges of the vineyard to prevent mealybug transmission. This is not a common practice in Lodi but if you were already thinking of planting along a vineyard edge for other purposes, consider trees which would offer some protection from prevailing winds and the mealybugs which may be hitching a ride.

BIRDS

Growers have observed mealybug hotspots underneath power lines and trees, where birds like to hang out. It is possible for birds to drop grape and vine material, which may contain mealybugs, from a neighbor's vineyard into your vineyard.

Pay special attention to the vines underneath power lines when scouting and consider preventive control in these areas. This would be a wise place to put a few mealybug traps.

A mother and baby killdeer in a Lodi AVA vineyard. Photo by Chris Cotta.

Harvest morning in Lodi. Photo by Randy Caparoso.

POMACE

Vine mealybugs can survive the crushing and destemming processes at the winery, ending up as unwelcome pomace hitchhikers. Some wineries choose to return their pomace to the vineyard. Today, most vineyard managers don't allow pomace to enter the vineyard without a kill-step to remove any contaminants such as mealybugs.

If pomace comes from a vineyard known to contain vine mealybugs and there is any question about the effectiveness of the kill-step, it would be wise to dispose of that pomace in another manner, away from any vineyards.

VINE TO VINE SPREAD

Male mealybugs have wings and can fly whereas the female mealybugs cannot fly. Luckily for us, the males are not strong flyers and their flight ability doesn't contribute significantly to vine mealybug spread. Still, mealybugs can travel from vine to vine on their own. Spread from an infested vine to neighboring vines occurs more easily during the Summer and Fall where canopies overlap or where vigorous shoots drape onto the neighboring vines.

Mario Salinas, a vineyard scout, was out checking on the grapevines when he became fascinated by the vine mealybugs and ants. He watched closely as the ants carried mouthfuls of vine mealybug eggs along the drip irrigation line, off to start a new "mealybug farm" on an adjacent vine, capturing this great photo.

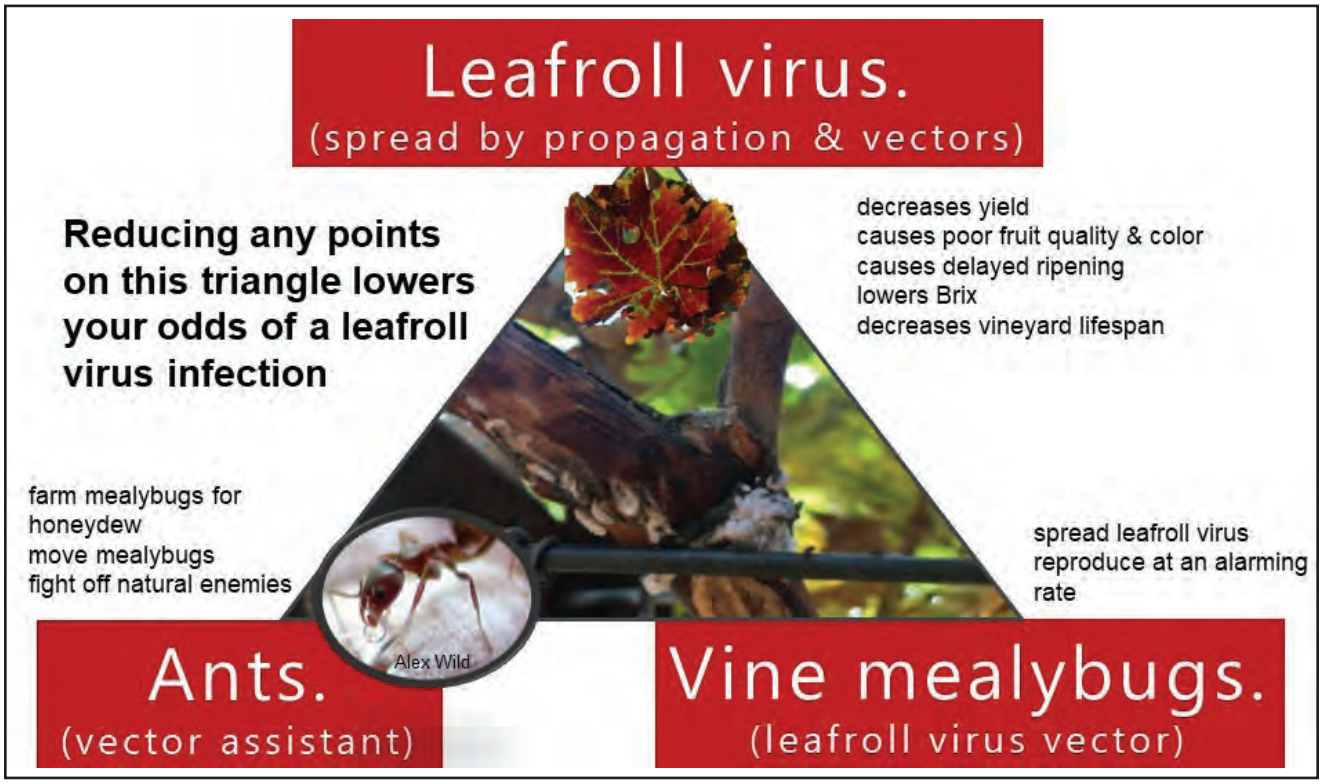
An ant tending to its vine mealybugs. Photo by Charlie Starr IV.

ANTS – THE OTHER FARMER ON YOUR RANCH

Did you think that you were the only farmer on your ranch? Think again! Ants are farming vine mealybugs too. The ants tend the mealybugs, fight off their natural enemies such as the *Anagyrus* wasp and the *Cryptolaemus* beetle, and help the mealybugs move up and down a grapevine throughout the season. Looking for ants on a grapevine is an important part of mealybug scouting – usually where you see ants there are also mealybugs. One day when you have some extra time, grab a hand lens and your camera and watch this ant-mealybug interaction. It is pretty incredible to see. Better yet, grab the kids or grandkids and show them biology in action!

Sugar-feeding ants, such as the Argentine ant, find it advantageous for their ant colony to introduce collections of mealybug crawlers to new vines. In this manner, the ant colony expands its source of food – the golden honeydew secreted by vine mealybugs.

We don't have an effective, efficient sugar-feeding ant control method for larger vineyards at the moment. Ant bait stations work but are labor-intensive because they require a lot of stations to be effective, plus they must be maintained. There are some experimental products that work to control ants but these are inefficient to produce and distribute around most commercial vineyards. Several growers in Lodi, eager for ant control to reduce mealybugs and leafroll virus risk, are experimenting in their vineyards and are willing to share the results. Stay tuned!



Paul Precissi (PCA) helped the Virus Focus Group come up with this triangle explaining the interaction between leafroll virus, ants, and vine mealybugs. The ant photo in the bottom left by Alex Wild was used with permission and can be found in: "Liquid baits control Argentine ants sustainably in coastal vineyards." Cooper, M, Daane, K, Nelson, EH, Varela, L, Battany, M, Tsutsui, ND, and MK Rust. California Agriculture. 62(4):177-183. Published October 1, 2008. doi.org/10.3733/ca.v062n04p177

UNDERGROUND ROOTS

It is currently impossible to remove 100% of grapevine roots when pulling out a vineyard, and we do not have a way to entirely kill all of the grapevines (including the roots) before a vineyard removal. Therefore, root remnants may still be alive underground for several years where a vineyard was ripped out. Mealybugs can feed on roots, making it possible to have underground mealybug colonies surviving after a vineyard has been removed. These mealybugs may then move onto newly planted grapevines.

Remember learning about the importance of crop rotation in elementary school? It's still a smart move today. When you decide to forego crop rotation and your plans are to plant a new vineyard on top of where an existing vineyard occurred, you should first check what's going on underground. In addition to soil testing and nematode sampling, you'll want to dig up some root pieces and have them tested for leafroll virus and vitiviruses (grapevine virus A, B, etc.). Viruses can exist in these root remnants for long periods of time. Even a two-year fallowing period, where the farmer removes all volunteer grapevines, is not enough to eradicate leafroll virus from the underground root remnants. Our leafroll virus expert consultant, Prof. Gerhard Pietersen, told us that in South Africa they've dug up 4-5-year-old root pieces which tested positive for leafroll 3 virus.

A fallow field following a leafroll virus rip-out. It is very important to remove volunteer grapevines during any fallowing period and also in the early years of the new vineyard, post-planting.

SOURCES CITED

Godfrey, K, Ball, J, Gonzalez, D, and E Reeves. 2003. "Biology of the vine mealybug in vineyards in the Coachella Valley, California." *Southwestern Entomologist*. 28(3): 183-196.

Krüger, K, Saccaggi, DL, van der Merwe, M, and GGF Kasdorf. 2015. "Transmission of Grapevine Leafroll-associated Virus 3 (GLRaV-3): Acquisition, inoculation and retention by the mealybugs *Planococcus ficus* and *Pseudococcus longispinus* (hemiptera: Pseudococcidae)." *South African Journal of Enology and Viticulture*. 36(2): 223-230.

journals.ac.za/index.php/sajev/article/view/955/292

2002. "California a supercolony of Argentine ants." *California Agriculture*. 56(1):4-5.

calag.ucanr.edu/archive/?type=pdf&article=ca.v056n01p4c

MEALYBUG RESOURCES

If you have questions about vine mealybug spread and management, attend the Lodi Winegrape Commission's CD11 LODI IPM Network Breakfast Meetings held on the first Tuesday morning of every month, usually at Burgundy Hall, Lodi Grape Festival Grounds, 8-9:30am. More information is available at lodigrowers.com.

Please be advised that because much is learned about vine mealybugs every day, not all of the following resources are up-to-date, but they still contain great information.

Kris Godfrey, David Haviland, Jeffrey Erwin, Kent Daane, and Walt Bentley wrote an excellent article filled with great photos and an explanation of vine mealybug biology – plus it is a simple read: "Vine Mealybug: What You Should Know." 2005. UC-ANR Publication 8152.

anrcatalog.ucanr.edu/pdf/8152.pdf

UC-IPM Online Guidelines – Grape – Vine Mealybug. Last updated 4/19.

ipm.ucanr.edu/PMG/r302301911.html

Photo by Kevin Hill of Parabug.

South Africa also has the vine mealybug as their primary leafroll virus vector, and Prof. Pietersen is one of our "experts" on the Virus Outreach Grant which provided funding for this book. In other words, he has led the way internationally when it comes to leafroll virus. He has written numerous real-world fact sheets on mealybug and leafroll virus management: Institute for Grape and Wine Sciences Leafroll Online Fact Sheets.

igws.co.za/content/fact-sheets/leafroll (*may be moving to* wine-tech.co.za/knowledge-transfer/topical-issues)

Larry Whitted wrote an easy read with practical information on mealybug biocontrol called "Biological Control of Vine Mealybug." Lodi Growers Viticulture Coffee Shop Blog.

lodigrowers.com/biological-control-of-vine-mealybug/

VINE MEALYBUG MATING DISRUPTION

Pacific Biocontrol *(product in development)*
911 Industrial way, Suite A, Lodi CA 95240
Jeannine Lowrimore | jlowrimore@pacificbiocontrol.com
209.603.9244 | pacificbiocontrol.com

Suterra
20950 NE Talus Pl, Bend OR 97701
Loraine Lee | loraine.lee@suterra.com
925.349.8177 | suterra.com

BENEFICIAL INSECTS

Associates Insectary
PO Box 969, Santa Paula CA 93061
Brett Chandler | info@associatesinsectary.com
Michelle Haase | mhaase@associatesinsectary.com
805.933.1301 | associatesinsectary.com

FAR, Inc.
550 Foothills Pkwy, Corona CA 92882
Joe Barcinas | farinc@att.net
951.371.0120 | far-inc.com

Koppert Biological Systems
Chrissie Davis | cdavis@koppert.com
800.928.8827 | koppertus.com

Parabug (*beneficial insect release by drone, pictured on facing page*)
Salinas, CA
Chandler Bennett | info@parabug.solutions
310.418.8967 | parabug.solutions

The Xerces Society
Jessa Kay Cruz | jessa.kay-cruz@xerces.org
855.232.6639 | xerces.org

University *of* California
Dr. Kent Daane
Vine Mealybug Expert
Kearney Agricultural Research & Education Center
559.646.6522 | kdaane@ucanr.edu

4 VIRUS TESTING

THE TASK IS DAUNTING.

VIRUS TESTING IS EXPENSIVE.

YOU DON'T REALLY KNOW WHAT TO DO OR WHO TO TRUST.

THE RESULTS WILL LIKELY BE DEPRESSING...

WHY TEST FOR VIRUSES?

1. Knowledge is money-saving power when it comes to viruses – once you know what you're dealing with, you can make decisions that may save you lots of money over time.
2. Visual symptoms and ripening delays provide clues that a grapevine is infected with a virus, but they cannot be relied upon alone for detection in California. Testing by a trusted laboratory is crucial for an accurate diagnosis if you think you may have a virus infection.
3. Not all viruses affect a vineyard in the same way – for example, leafroll virus, red blotch virus, fanleaf virus, and vitiviruses (or co-infections of these viruses) each have their own management strategies, mostly due to the way they can spread to healthy vines. It's important for the grower to understand which, if any, viruses they may be dealing with.
4. If your vines are infected with viruses, they are sources of inoculum which could infect healthy vines in your vineyard, in your neighbor's vineyard, and in other vineyards across your region.
5. If only some of your vines or a portion of your vineyard is infected, you can act now to reduce the spread.
6. If you have leafroll virus in your vineyard, there can be a carryover infection into the next vineyard planting on the same ground – something you will want to know in order to determine what to plant in that ground next.
7. Ignoring virus infections for even one year can cost the grower a lot of money due to the fast rate of spread (especially with leafroll virus).
8. Testing new plants before propagation reduces the possibility of planting vines carrying a virus infection.
9. It's crucial to know the virus status of any wood before you plan to top-work a vineyard or provide wood for bench-grafting.

BEFORE YOU TEST FOR VIRUSES

Learn the basic symptoms and means of spread for the main economically important viruses – these will help you know which viruses to test for (see page 15).

If you are testing because you see red leaves in your red grape variety vineyard, eliminate other causes which are cheaper to deal with first.

The spotty red color in these Cabernet leaves is likely due to mites, not a virus.

Grapevine leaves are not normally supposed to turn red in the Fall for most varieties. (Exceptions include: Petite Sirah, Malbec, Carignan, Carmenere, Ruby's Red, Alicante, Teroldego, and possibly others – these may naturally turn red or reddish.)

Although this red is beautiful in color, grapevine leaves naturally turn yellow, orange, and brown. When leaves turn red it is an indication of a problem – usually physical injury of the vine, a nutrient deficiency, or a grapevine virus disease.

NOTE: Vines with viruses may or may not express symptoms such as red leaves. Also, white varieties and rootstocks do not show the red leaf virus symptom.

RED LEAF FLOW CHART *(for red grape varieties only)*

Adapted from the Rutgers University "Red Leaves in the Vineyard: Abiotic and Biotic Causes" Fact-sheet FS1260.

I HAVE RED LEAVES ON AT LEAST A FEW VINES.

PS this is almost everyone in California right now. You are not alone.

EXAMINE TRUNKS, CORDONS, AND PETIOLES FOR DAMAGE.

ex: trellising ties, physical damage from equipment or mites, petiole girdling, trunk disease, crown gall

TEST FOR NUTRIENT DEFICIENCIES.

Potassium (K), Magnesium (Mg), Phosphorous (P)

TEST FOR APPLICABLE VIRUSES.

Especially if your vineyard is at risk for viruses.
ex: there are/were mealybugs present

Both photos are from the same Cabernet Sauvignon vineyard. The vine pictured on the left tested positive for leafroll 3 virus, whereas the vine pictured on the right tested negative (the redness is likely due to mite damage). Photos by Charlie Starr IV.

The red color in this Zinfandel leaf is likely due to petiole girdling. Petiole girdling can be caused by the three-cornered alfalfa hopper which is a presumed vector of red blotch virus. Photo taken in July 2018 by Charlie Starr IV.

Severe mite damage in this Merlot vineyard was masking a leafroll virus infection. Once the mite damage was reduced, the grower and his pest control advisor observed the red leaf symptoms typical of leafroll virus. This vineyard tested positive for leafroll 3 virus and grapevine virus A. Photo by Stephanie Bolton.

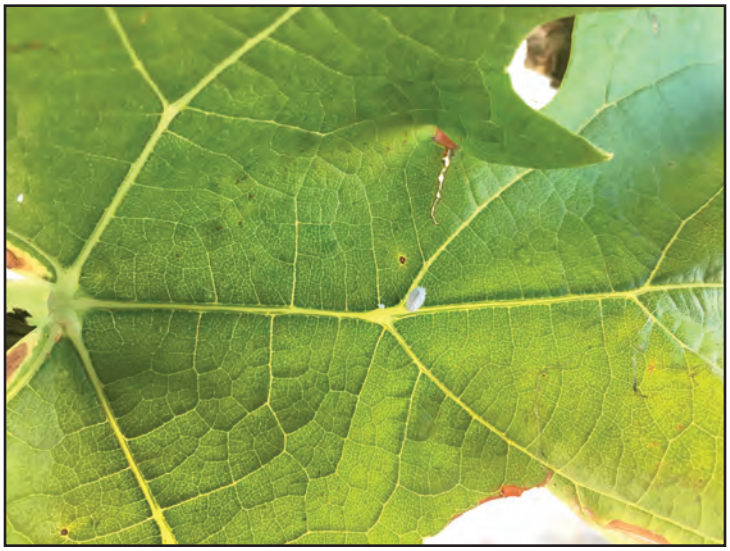
Testing results from high-throughput sequencing (donated by Dr. Maher Al Rwahnih) have revealed a combination of leafroll 3 virus and a vitivirus in these collapsing vines on virus-sensitive rootstock (Freedom). Photo by Stephanie Bolton.

A red leaf symptom in a red blotch virus-infected Cabernet Sauvignon leaf. Photo by Marc Fuchs.

WHICH VIRUSES SHOULD YOU TEST FOR?

The main economic viruses of concern in California at the moment are: leafroll 3 virus, red blotch virus, fanleaf virus, and vitiviruses (GVA, GVB, GVD, and GVF). Some experts believe that growers should also be testing for pinot gris virus, but there is no consistent evidence of an economic impact for this virus.

If you think your vineyard has experienced mealybugs now or in the past, or if your vines are experiencing or are at risk for the sudden vine collapse (see page 105), we recommend testing for leafroll viruses and vitiviruses.



Vine mealybugs vector leafroll viruses and vitiviruses VERY efficiently – it only takes one mealybug to infect a grapevine! Photo by Stephanie Bolton.

WHEN TO TEST FOR VIRUSES

In red grape varieties, Fall is a good time to test for leafroll and red blotch viruses because you can usually see the typical red leaf symptoms. If your plan is to sample red-leafed vines, be sure to flag those vines for testing *before* any machine harvesting.

Research has shown what time of year some viruses are at their peak amount within the grapevine, making that the best time to test as they will be easiest to detect. For fanleaf virus, this is Springtime, whereas for leafroll and red blotch viruses, it's best to test in late Fall. However, testing can be done throughout the year, especially if you suspect that any virus infections have been present for a few years already.

You'll typically want to collect samples on a Monday, Tuesday, or Wednesday in order to give yourself enough time to deliver or ship them overnight to the lab with a weekday arrival date.

COMMERCIAL VIRUS TESTING LABORATORIES

Agri-Analysis LLC
950 W Chiles Rd, Davis CA 95618 (sample delivery)
PO Box 285, Davis CA 95616 (mailing address)
Dr. Alan Wei | info@agri-analysis.com
800.506.9852 | agri-analysis.com

AL & L Crop Solutions
7769 N Meridian Rd, Vacaville CA 95688
Dr. Anna-Liisa Fabritius | info@allcropsolutions.com
530.387.3270 | allcropsolutions.com

California Seed and Plant (CSP)
3556 Sankey Rd, Pleasant Grove CA 95668
Dr. Parm Randhawa | parm.randhawa@csplabs.com
Sukhi Pannu | sukhi.pannu@csplabs.com
916.655.1581 | csplabs.com

eurofins US | EBDI Laboratories
7240 Holsclaw Rd, Gilroy CA 95020
Dr. Raquel Salati | raquelsalati@eurofinsUS.com
408.846.9964 | eurofins.com/biodiagnostics

Sunburst Plant Disease Clinic Inc.
677 E Olive Ave, Turlock CA 95380
Dr. Bhanu Donda | bdonda@sunburstpdcinc.com
Dr. Sam Livingston | slivingston@sunburstpdcinc.com
209.667.4442 | sunburstpdcinc.com

Wonderful Laboratories
449 N Zerker Rd, Shafter CA 93263
Dr. Tefera Mekuria | tefera.mekuria@wonderful.com
661.772.8048 | wonderfulnurseries.com

Be sure to speak with the labs on the telephone to understand which virus tests are available, their sampling requirements, the cost of testing, and how/where to ship the samples.

HOW TO TEST FOR VIRUSES: A STEP-BY-STEP PRACTICAL GUIDE

STEP ONE: Decide upon your reason for testing.

Decide why you are testing, since this reason will dictate your sampling plan.

- Do you think your entire vineyard may be infected?
- Is it a new or old planting?
- Are you trying to find new infected vines to remove (rogue) before the virus spreads?
- Are you trying to determine what percentage of the vineyard block is infected?
- Are you worried that a neighboring vineyard's mealybugs and viruses are spreading into your vineyard?
- Do you have a ripening problem?
- Do you have mealybugs and want to know if your vines have been exposed to leafroll virus and/or vitiviruses?
- Do you have a red grape variety vineyard and are seeing red leaves in the Fall?
- Are you sampling dormant canes (both rootstock and scion) at the nursery before placing your final order?

A grower tested this vine for viruses after seeing the typical red leaf symptom. It was positive for leafroll 3 virus. Photo by Charlie Starr IV.

STEP TWO: Pick a lab.

Choose a laboratory that meets your needs for testing, turnaround time, customer service, sample delivery, and budget. Review lab websites and call potential labs to make sure they are a good fit for your needs. Ask around for recommendations. Discuss your reason for testing with the lab.

STEP THREE: Write up a sampling plan.

Along with your chosen laboratory, develop a sampling plan based on the reason(s) for testing and your budget. This written sampling plan should include:

- How many total vines will be sampled
- Exactly which vines are to be sampled (vineyard block, row # and vine # OR symptomatic vines plus random healthy vines to use as a baseline comparison)
- How/if you will be compositing the samples
- Which vine parts are getting sampled (petioles, canes, etc.)
- How many pieces per vine need to be collected (for example, one cane from each side of the vine)
- How the vines will be marked and recorded
- Where the laboratory wants the samples delivered or shipped (confirm an address – some of the lab websites and Sample Submission Forms have confusing information)
- How the lab prefers the samples delivered or shipped (within 1 day of collection, a preferred shipping carrier, etc.)
- The total number of samples to be submitted
- Which virus(es) you want to test for

NOTE: Every sampling plan should include testing healthy vines as a baseline comparison. Think about it: if you only test symptomatic vines (those with red leaves, for example) you may miss a much larger infection occurrence as many vines may not show symptoms.

STEP FOUR: Collect samples.

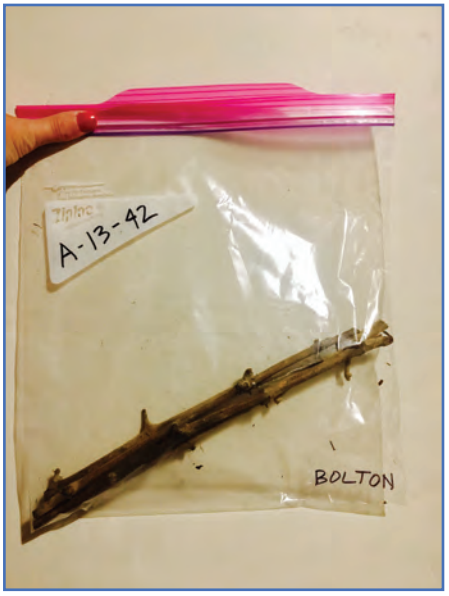
PRO TIP: Collecting samples is much easier with two people – one person to clip the canes, and another person with good handwriting to record the information and keep the samples organized.

MATERIALS NEEDED:

- gallon Ziploc bags
- a cooler (depending on the time of year, you may or may not need a cold pack too – if using a cold pack or ice, throw a towel or some newspaper on top of the cold pack or ice because you aren't supposed to let the plant material freeze)

- a Sharpie
- the lab's Sample Submission Form (downloaded and printed from their website)
- a clipboard with pen and paper
- pruning shears/clippers
- something to carry the Ziploc bags with samples (a tote bag or a 5-gallon bucket works well)
- something to mark the vines you are sampling
- if planning on shipping the samples overnight, you need a cold mailer such as a Styrofoam cooler with ice packs large enough to hold all of your samples and a box that the cooler can fit in

Before starting the sample collection, fill out the lab's Sample Submission Form as much as you can.



Label a set of Ziploc bags with a Sharpie. Vine pieces will go directly into these labeled bags as you collect them, placing one sample into one Ziploc bag. You will need to give each sample/Ziploc bag a code which will match what you *legibly* write on the Sample Submission Form. We recommend a letter to indicate the vineyard block, a row number, and a vine number like this:

Sample A – 13 – 42
(vineyard block A, row 13, vine #42).

It's also good practice to write your last name on the bottom right of each Ziploc bag.

Whoever collects the samples will need to understand how to use your labeling code. If your rows are not numbered already, be specific about where the samplers need to start counting the rows (for example, start on the Northwest corner with row #1 and count up as you move South). With vines, be specific as to how they should count the vine number (for example, count West to East with any missing vines as a number). Give the samplers a map of the vineyard (you can print a satellite image of your vineyard from Google if you do not have a map of your own).

We recommend sampling woody canes, as there is less risk for contamination (versus petioles). You can use one pair of clippers without sanitizing them in between vines and you do not need to wear gloves. The cane pieces should be about 8 inches long and will fit nicely inside gallon Ziploc bags. When you place them in the bag, do your best not to let the cut ends of the canes touch the outside of the bag or your hands. Place the Ziploc bags containing your samples into the cooler periodically as you go along.

Mark the vines which you are sampling with paint on the bottom half of the trunk, flagging tape, or a zip tie on the dripline. Make a note of how you mark them in your records.

It's a good idea to take photos of some of the vines being sampled for your records (at least one possibly infected vine and one healthy looking vine). ***PRO TIP:*** If you turn on the location recording on your smartphone and take a close up picture of the vine, the approximate GPS position of the vine will be stored with the photo.

This unhealthy vine was tested for viruses & fungal pathogens in February 2019. The vine was marked with white flagging tape and this picture, which included the samples in the Ziploc bag, ensured that we had a record of the sample ID & the diseased vine. Photo by Stephanie Bolton.

Once all samples are collected, finish filling out the lab's Sample Submission Form and make a copy for your records. Add in any special instructions, such as composite sampling. If you have any questions, it's best to call the laboratory for assistance.

Prepare your shipping materials or plan to deliver the samples in a cooler to the laboratory. If shipping, overnight the samples in a cold mailer such as a Styrofoam cooler with ice packs. Keep in mind that the last overnight pick-up may be as early as 3pm for some shipping stores. Enclose the Sample Submission Form with the samples such that it won't get wet from any cold pack condensation.

Deliver or ship your samples to the lab as soon as possible (within 2-3 days). Samples degrade in a few days and need to be refrigerated until they are received by the lab. You may refrigerate the samples for 1-2 days before shipping, but it is recommended to submit the samples on the day of collection.

HOW TO REDUCE TESTING COSTS

SET-UP FEE. There is a set-up fee associated with virus testing, so submitting more samples at one time is usually cheaper than submitting the same number of total samples multiple times.

COMPOSITE SAMPLING. Composite sampling will save most growers money. Some labs allow you to composite up to 10 cane pieces into one sample for testing, allowing the testing of 5 vines (at 2 canes per vine) in one sample. If you want to composite samples to save money but also want to know which individual vines are positive, some labs will test a composite first and then, only if there is a positive, will go back and test the samples individually (this needs to be part of the sampling plan discussed with the lab as each vine's wood needs to be labeled separately and delivered in its own Ziploc bag). Your lab will be able to instruct you on the composite method that will work best for you. Make sure that you write any special composite instructions on the Sample Submission Form.

SPOT TESTING OF SYMPTOMATIC VINES. If you have a large, red grape variety vineyard (50+ acres) and there are many vines showing virus symptoms, but only a small percentage (<10%) appears infected, it may be worthwhile to spot test symptomatic vines. In this case, the point of testing would be to train your eye (or the eyes of a few employees) to be able to detect a virus infection *in this particular vineyard* so that you could mark the vines for removal that Winter. Remember to test several random healthy-looking vines too. You will not want to composite vines in this instance, but rather test individual vines. Be sure to take photos and mark the vines carefully to use for training purposes. Once you have dialed in what a virus-infected vine looks like *for that vineyard at that time*, you can mark the symptomatic vines for removal.

NOTE: If leafroll 3 virus is discovered it may be worthwhile at this time to do a second virus-testing pass, checking the vines adjacent to the infected vines within the row for leafroll 3 virus. Then you would be able to get a more accurate estimate of the percent infection across the vineyard and you could decide whether or not to remove the vines adjacent to the symptomatic vines.

Prof. Gerhard Pietersen of South Africa – our leafroll virus expert – provided excellent practical advice and hope in his presentation during our 2019 Mealybug & Virus Outreach Meeting, which is available to watch on lodigrowers.com.

GET TESTED WITH A FRIEND OR TWO. It's much easier (and more comforting?) to get tested for anything scary with a friend. Plus, you can help each other figure out how to do it all, sample together (it takes two people), and ship together. You'll pay one set-up fee if you use the same lab and one Sample Submission Form. I bet the lab will even bill each of you individually if you ask and indicate that request on the Sample Submission Form – just like splitting the bill at a restaurant.

Isn't everything just better with some friends around? Pictured here is the book's main author, Stephanie Bolton, in an old Xinomavro vineyard in Greece with her friends Tony Hoare and Dr. Mark Krstic from Australia.

THE FUTURE OF VIRUS TESTING

Testing for grapevine viruses is a constantly changing business – as new viruses and new strains of existing viruses are discovered, laboratory tests must also evolve. Communication between scientists, laboratories, and growers is vital. With sample preparation and virus detection techniques improving over time, hopefully our industry will see the cost of testing reduced in the future. We have great hopes for a very sensitive and highly accurate ancient dog sniffing technology optimized by the work of USDA scientist Dr. Timothy Gottwald to be applied to winegrape viruses with the help of Dr. Neil McRoberts. However, we do not recommend waiting to test your vineyard since virus spread can happen quite rapidly and accurate methods are available now.

WHAT IF YOU HAVE VIRUSES?

- Sorry, that sucks. Welcome to the club – there are a LOT of members all over California.
- If any of your vines are positive for a grapevine virus, you can decide on a management strategy suitable for that particular virus or virus combination. Right now and in the foreseeable future, there is no cure for a vine infected with a grapevine virus.
- Learn more about any viruses which show a positive test result. Check out lodigrowers.com/growereducation/viruses for information and videos on leafroll and red blotch viruses.
- Determine whether the virus(es) are having a negative impact on your profitability, now or in the future.
    - Are you meeting your desired sugar, yield, and quality parameters in those areas of your vineyard which are infected?
    - In practice, some vines have a stronger immune system and less overall stress, and they can produce quality grapes despite a minor virus infection. These vines are generally ancient vines on their own rootstocks with very low yields. More commonly, vines have a weaker immune system and high overall stress, and they struggle to produce quality grapes when infected with a virus.
- Try to determine the percent of your vineyard which is infected. UC Plant Pathologist Dr. Neil McRoberts is developing a tool which will help with this task – the targeted release date is April 2020. In the meantime, if you want more information about sampling or help designing a sampling plan, you can email Dr. McRoberts at nmcroberts@ucdavis.edu. Knowing how much of a vineyard is infected with which virus(es) can help you decide whether it makes more economic sense to remove infected vines or to start planning to remove the entire vineyard.
- When it comes to leafroll, red blotch, and vitiviruses, removing the virus inoculum (by removing or rogueing the entire grapevine) is the most efficient strategy for helping to protect other healthy vines from infection. It is best to remove a grapevine in the Winter after a period of rain so you can remove as many roots as possible. For leafroll and vitiviruses, it's also best to treat the grapevine with a systemic material targeting the vine mealybug before removal (remembering to allow for enough time for the material to be effective). If mealybugs are present in that area, a re-infection from leafroll virus and/or vitivirus particles in the leftover root remnants may occur in replants.
- The USDA Farm Service Agency's Tree Assistance Program (or TAP) has approved red blotch and leafroll virus as natural disasters eligible for financial assistance. Contact your local FSA office or read the section called "Pulling Out a Vineyard? Read This First" on page 82.

Be careful when you re-plant after a leafroll virus infected vineyard.

Customer: Lodi Winegrape Commission

Report:	V0190	Positive Control	+	+	+	+	
Report date:	4/2/2018	Negative Control	-	-	-	-	
Lab ID	Sample ID	Variety	Row	GLRaV-1	GLRaV-2	GLRaV-3	GRBaV	Sample Control
V680-1	R1	Cab Sauv	1-5	-	-	+	-	Confirmed
V680-2	R2	Cab Sauv	1-5	-	-	+	-	Confirmed
V680-3	R3	Cab Sauv	1-5	-	-	+	-	Confirmed
V680-4	R4	Cab Sauv	1-5	-	-	+	-	Confirmed
V680-5	R5	Cab Sauv	1-5	-	-	+	-	Confirmed

Five root remnants from a vineyard that was removed (due to leafroll virus) still test positive for leafroll 3 virus months after the removal. These root pieces can serve as reservoirs of virus infection for the next planting.

If all of this seems overwhelming, that's because it is. But it is also really important, which is why we are offering help. If after reading these tips and talking with a laboratory you need more help – we are here. Call or email Dr. Stephanie Bolton at the Lodi Winegrape Commission: 209.367.4727 or stephanie@lodiwine.com. *This help is not available indefinitely, so act now.*

A special thanks to Matt Frank, Tia Russell, Dr. Marc Fuchs, Prof. Gerhard Pietersen, and Dr. Neil McRoberts for thoughtfully reviewing this Virus Testing Chapter.

5 INFECTED VINE REMOVAL

ROGUEING BASICS

The take home message from our April 2019 MEALYBUG & VIRUS OUTREACH MEETING was to rogue infected vines!

For many years in Lodi, we were focusing on vine mealybug management and ordering virus-tested planting material to manage for viruses. While these practices are extremely important, with the help of our experts (Dr. Kent Daane, Dr. Marc Fuchs, and Prof. Gerhard Pietersen) we learned that the most efficient and effective way to reduce the spread of existing virus infections in our region would be to remove (or rogue) infected grapevines. Then, the vine mealybugs and unknown red blotch vectors have nothing to spread around.

Removing vines seems like it would be simple – you just pull them out of the ground, right? It's actually more complicated as the case study written by Charlie Starr IV on page 85 shows. Plus, there are some guidelines to follow as to when and how you should best rogue.

Removal of old vine Zinfandel in Lodi. Photo taken in December 2019 by Randy Caparoso.

Rogueing has different forms:

- Removing individual, infected vines in a vineyard where there is a lower percentage of infection (depending on the economics of the vineyard and one's confidence in accurate testing, lower may mean anything less than 20-25% infection)
- Removing a section of a vineyard
- Removing an entire vineyard

Luckily, South Africa has some excellent examples of rogueing in commercial vineyards for the rest of the world to learn from. If you are serious about your leafroll virus education, please learn about the exemplary Vergelegan Estate in South Africa – there is a journal article, a video, and excellent information online. South Africa has the same vine mealybug vector as California. However, the country does not have the extra complication of red blotch virus like we do, and they have a greater availability of hand labor.

RESOURCES

Journal Article: Almeida, RPP, Daane, KM, Bell, VA, Blaisdell, GK, Cooper, ML, Herrbach, E, and G Pietersen. 2013. "Ecology and management of grapevine leafroll disease." *Frontiers in Microbiology*. 4: 94 (1-13).

ncbi.nlm.nih.gov/pubmed/23630520

Video: Gerhard Pietersen's presentation in Lodi. 2019. "Grapevine leafroll disease in South Africa: Properties, Epidemiology and Control."

lodigrowers.com/growereducation/viruses/

Online: Institute for Grape and Wine Sciences Leafroll Online Fact Sheets by Prof. Gerhard Pietersen.

igws.co.za/content/fact-sheets/leafroll – will be moving to winetech.co.za/knowledge-transfer/topical-issues

TIPS FOR ROGUEING INFECTED VINES:

- For new plantings in red varieties where symptoms are apparent, start rogueing in year one if possible
- Red leaf symptoms (red varieties only) are best observed in the Fall before harvest – get to know your vineyards and record the best timing for marking your vines
- Remove the vines when the soil is wet to get as many roots out as possible
- Make sure you have a good idea of how much of the vineyard is infected with viruses (and which viruses) so you can make an educated, economically sound decision
- Always verify at least a sample of both healthy and symptomatic vines with accurate testing – red leaf symptoms, which many growers use to visually identify viruses, can have a number of causes (see flow chart on page 67)
- Removing vines every year is wise because virus infections may spread at a rate of up to 2-3x per year – however, it may make better economic sense to replant vines every few years
- Instead of replanting individual vines in a mature vineyard, some growers are extending the arms of neighboring vines to fill the space
- If you are removing entire sections of a vineyard or if you have a large property with many vineyard blocks, remove the upwind grapevines first and leave space between newer and older plantings
- Make sure that your rogueing efforts matter by protecting the replants – consider surrounding mealybug and virus sources and your ability to protect replants
- If pulling out an entire vineyard, consider crop rotation to break up any monocultures (if applicable) and allowing some time for viruses and mealybugs to get reduced in your neighborhood before putting that investment back in the ground
- If the vineyard has mealybugs, treat the vines before removal with an insecticide (imidacloprid is preferred in South Africa and New Zealand), paying close attention to timing so that it is effective and moves to the underground roots
- If replacing an entire vineyard and replanting to grapes, many California growers now choose to use vine mealybug pheromone mating disruption as a tool for protection
- You may qualify for financial assistance from the USDA Farm Service Agency's Tree Assistance Program (see page 82)

This Zinfandel vine is 100 years old. Some vines may be too valuable to remove, even if infected with a virus. Old vines with a well-developed microbiota and low yields also may not feel the detrimental effects of viruses like higher production vines would. In these cases, it is extra important to manage carefully and proactively for insect vectors. Photo by Randy Caparoso.

PULLING OUT A VINEYARD? READ THIS FIRST (USDA TAP)

LEAFROLL VIRUS APPROVED AS A NATURAL DISASTER ELIGIBLE FOR USDA TAP FINANCIAL ASSISTANCE

We have good news to share with California winegrape growers. If you've attended any of the Lodi Winegrape Commission's virus outreach meetings in the last few years (or read any of our emails sent via the new grapevine virus email list-serve) you probably know that we are big fans of the USDA's Farm Service Agency Tree Assistance Program.

After over a year of appeals and correspondence with helpful local FSA staff, we are happy to announce that the California State FSA has approved leafroll virus as an eligible natural disaster covered under the Tree Assistance Program.

The Tree Assistance Program, or TAP for short, provides financial assistance to eligible growers experiencing a natural disaster using funds from the Farm Bill. Grapevine red blotch virus was approved as an eligible plant disease in 2015. In October 2018, Dr. Alan Wei (who has experience working with growers to test vineyards for red blotch virus as part of an FSA application) spread the word that the Farm Service Agency may be willing to consider leafroll virus too.

Days later, Dr. Stephanie Bolton was in Turlock speaking about – you guessed it – mealybugs and viruses at the Tree & Vine Expo. She mentioned the Tree Assistance Program in the talk and a very nice couple, Connie Burk and Gordon Armstrong, came up to her afterwards. After a conversation about their bad luck with leafroll virus and this new information about TAP, they decided to apply. These growers understood that it would be a great deal of effort and time to go through the application process, and that they would have to appeal rejection decisions since leafroll was not currently approved. They also knew that their perseverance may not only help themselves but also other growers in the future.

Meanwhile, the growers and Dr. Bolton wondered if the TAP financial assistance was even worth the effort of applying. What if a payout meant only $50 per acre? They were finally able to talk with a grower who had used the program for red blotch virus. He told us, "It's definitely worth it!" Richard Lauchland, a gentleman who farms both in Lodi and in Paso Robles, found out about TAP from one of his Paso neighbors. Richard encouraged other growers to apply at a Lodi IPM Network Breakfast Meeting on December 3rd, 2019. Growers may apply for up to 1,000 acres per year and recoup 65% of certain removal and replanting costs.

To learn more about TAP, check out their website (found easily by searching Google for "USDA FSA TAP") or contact your local FSA office.

We believe that this approval of leafroll virus is a crucial step in assisting farmers affected by leafroll virus, which can spread rapidly in areas with vine mealybugs and can decrease winegrape quality, lower yield, inhibit ripening, decrease a vineyard's lifespan, and – as we have recently learned – contribute to the mystery/sudden vine collapse. This approval is also a critical step in reducing the amount of leafroll virus inoculum (or particles capable of infecting healthy grapevines) across the state.

Well done, FSA! A big thanks to Connie and Gordon who put in the effort to help us all.

Vine removal in the Jahant – Lodi AVA. Photo taken in November 2018 by Randy Caparoso.

For San Joaquin County, here is the FSA contact information:

Joanne Gomez | Program Technician
U.S. Department of Agriculture | Farm Service Agency
Alameda/Calaveras/Contra Costa/San Joaquin County Office
7585 S Longe St Suite 100, Stockton CA 95206
209.337.2124 | eFax 844.206.7012

joanne.gomez@usda.gov

ELIGIBILITY (from the October 2019 TAP Fact Sheet):

To qualify for TAP, eligible orchardists and nursery tree growers must:

- Have suffered a qualifying tree, bush or vine loss in excess of 15% mortality for the stand (adjusted for normal mortality) due to an eligible natural disaster;
- Have owned the eligible trees, bushes and vines when the natural disaster occurred, but eligible growers are not required to own the land on which owned eligible trees, bushes and vines are planted;

and

- Replace eligible trees, bushes and vines within 12 months from the date the TAP application is approved. (An extension of up to 12 additional months may be possible.)

Additionally, a person or legal entity is ineligible for payment under TAP if the adjusted gross income (AGI) of the person or legal entity for the relevant tax years exceeds $900,000.

Photo by Randy Caparoso.

TIPS FOR APPLYING TO TAP FOR FINANCIAL ASSISTANCE:

- Before you schedule your vineyard removal, read through all of the information and understand the time frames and eligibility requirements.
- Next, schedule an in-person meeting with your local FSA office. This is the type of thing that is best done in person. (***BONUS:*** Once you are familiar with your local office, you will be ready to apply for other types of financial assistance such as the NRSC EQIP which offers financial assistance for conservation practices.)
- You have to be willing to follow the steps of the program but your patience and paperwork can really pay off – literally.
- You cannot start any removal activities until you receive notice from FSA that your environmental review has been approved, the loss adjustor has completed the initial field inspection, and you receive notice from FSA that your TAP application was approved.
- A claim of loss due to leafroll or red blotch virus must be verified through testing performed at a commercial laboratory, and a minimum of 10 symptomatic vines must be tested from each block claimed to be infected. A list of commercial virus testing labs is attached.
- In today's grape market and with the nature of leafroll virus/mealybugs, you may want to consider good old crop rotation. There are options to still get financial assistance if you switch from grapevines to an FSA approved crop (contact your local office to find out what those crops are).
- Replanting only a section of a vineyard qualifies if the entire vineyard exceeds more than 18% mortality (or percent affected by red blotch or leafroll virus) – this may be the case for some farmers experiencing the sudden vine collapse.

This California-based article on TAP financial assistance was written for educational purposes only. Contact your local USDA FSA office for the most current information, eligibility requirements, and funding availability for TAP.

A special thanks to Joanne Gomez, Program Technician, USDA FSA – Stockton, California, for reviewing this section.

6 CASE STUDY: SCOUTING, MAPPING, AND ROGUEING VINES

by Charlie Starr IV
Independent Pest Control Advisor and LODI RULES Sustainable Grower

WHY MAP THE VIRUS INCIDENCE IN A VINEYARD?

- To help the grower estimate the number of infected vines
- To show the spatial distribution of disease
- To ultimately evaluate the management costs and profitability of the vineyard

HOW WE APPROACH SCOUTING & MAPPING IN RED GRAPE VARIETIES

TIMING: Visual symptoms on red varieties can manifest at different times based upon the year's conditions and the grape variety. The best time to scout and map is in the late Summer or early Fall BEFORE the field has been harvested. Once a field has been harvested, especially by machine, it makes visual identification of red leaf symptoms very difficult and may lead to healthy vines being misidentified and removed.

STEP ONE: We train an entire crew of up to 12 people to visually identify virus symptoms and distinguish the differences between viruses and other issues such as insect damage, nutrient deficiencies, vertebrate pest damage, machine damage, etc. A crew member walks down each vineyard row (looking at the side facing into the sun, which helps to illuminate any red color) and uses flagging tape to mark any vine with visual red leaf virus symptoms.

We're Still Learning... The color of the flagging tape should be easily identifiable. We have learned to avoid any shades of green and use a different color tape each year. We place the tape so it can be clearly seen when passing by on an ATV. Thought needs to be given to harvesters, berm sweepers, pre-pruners, and all other machines that contact the vine and can knock off the tape before the vine is to be rogued in the Winter. In South Africa, they use spray paint to mark the vines which we should probably try.

STEP TWO: (*Completed as soon as possible after step 1.*) Using an ATV, we drive down each row that has a marked vine and record the location of the vine with a GPS unit. There are several options ranging from a handheld GPS to more sophisticated GPS units. Even a smartphone can be used; the key is finding the option that works best for you.

We're Still Learning… We learned that this step has value beyond getting the GPS recording of the location. The person performing step 2 should be trained as good as or better than the scouting crew which previously walked the field. This is because the person on the ATV can find symptomatic vines that did not get marked, plus he or she can give each flagged vine a second look to determine if the marked vine indeed looks like a virus infection. If it is determined that a vine should not have been flagged, the tape is removed and the GPS coordinates are not recorded. Another thought moving forward is to have each person scouting and marking vines to write their initials on their flagging tape. Then, when the ATV driver audits the vines and determines that a vine should not be marked, we have a way of identifying any scouts who may need more education on correctly identifying visual virus symptoms.

STEP THREE: Finally, we transfer the data to a computer. We use GIS software to display and analyze the data but several tools are available, ranging from simple options like Google Earth to more robust software like QGIS and ArcGIS.

Charlie Starr IV mapping vines showing leafroll virus symptoms in October 2018. Photo by Stephanie Bolton.

THE CASE FOR SCOUTING, MAPPING, AND ROGUEING FOR VIRUSES AS DEMONSTRATED WITH TWO DIFFERENT VINEYARDS.

FIELD ONE STATS

- 44 acres
- Planted in 2013 on virgin pasture ground
- San Joaquin complex soil
- Adjacent vineyards on the North and East sides
- Pasture on the West and South sides
- Cabernet Sauvignon Clone 7 on Freedom rootstock (CDFA-certified material)
- Vine mealybug was found in 2015 and control methods that included water-run imidacloprid and Movento were started that year

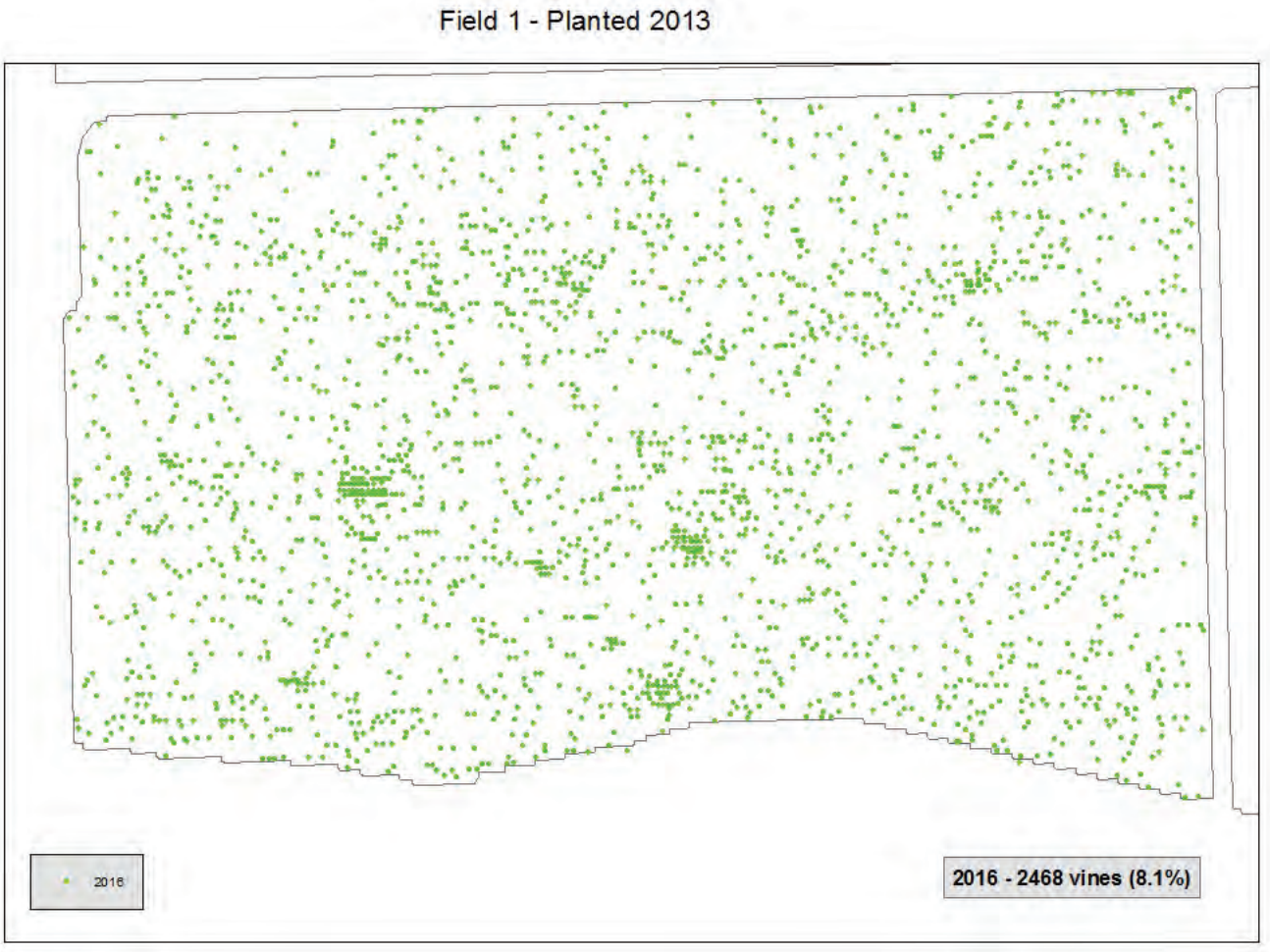
TIMELINE

2015: Virus was first observed and a single vine was tested with results coming back positive for leafroll 3 virus.

The next question was:
How much of this newly planted vineyard has leafroll virus?

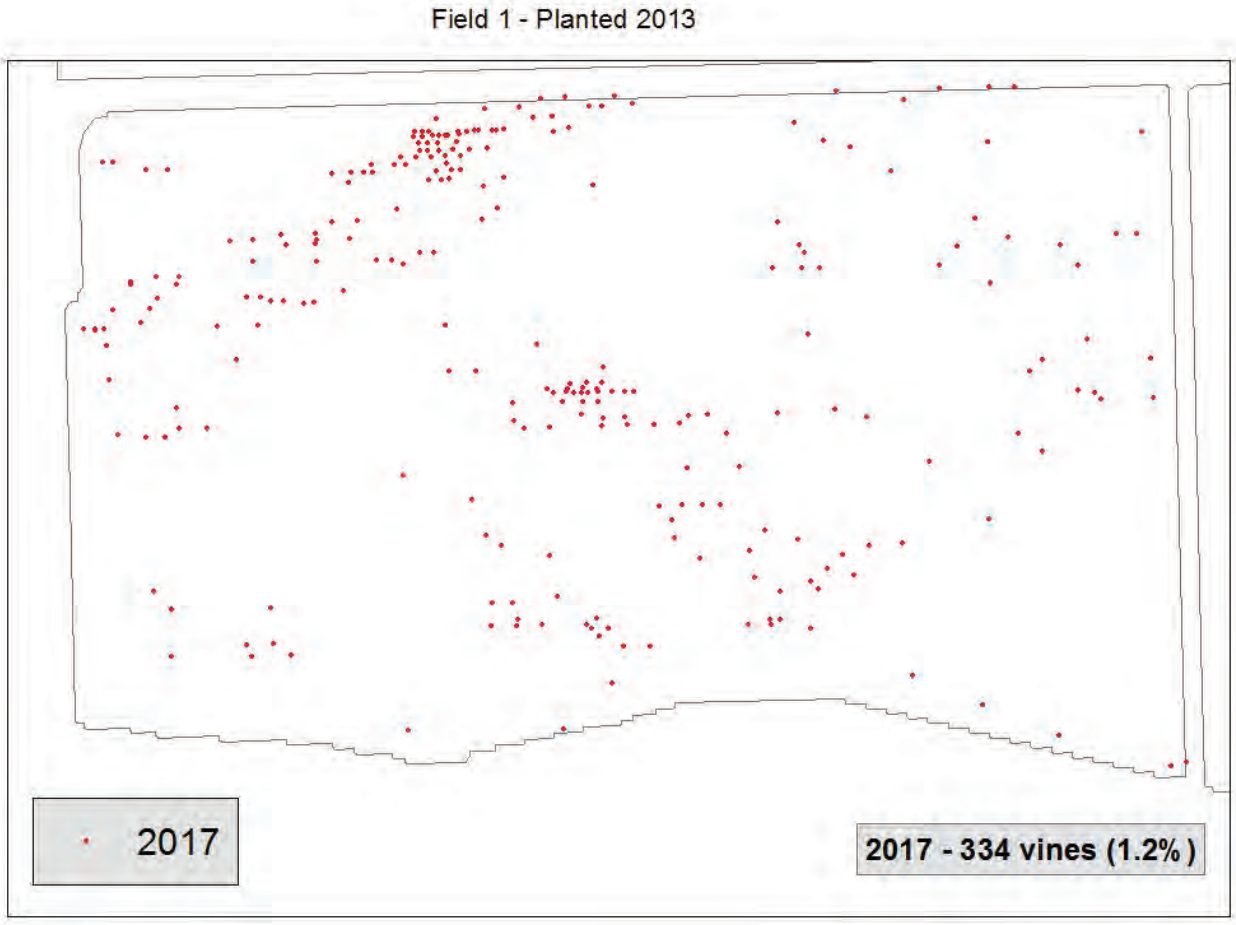
Classic leafroll virus-infected red leaf symptoms on Zinfandel. Photo by Stephanie Bolton.

2016: A visual survey was completed and mapped using GPS.



The 2016 visual survey showed a larger than expected amount of infected vines – totaling 2,468 vines or 8% of the vineyard. To confirm the visual survey, 10 random flagged vines were tested for red blotch and leafroll viruses. 2 of the 10 vines were positive for red blotch virus and the other 8 vines were positive for leafroll 3 virus. Therefore, there was high confidence that the vines which were flagged during the visual survey were indeed infected with virus. All 2,468 flagged vines were rogued (removed) that Winter.

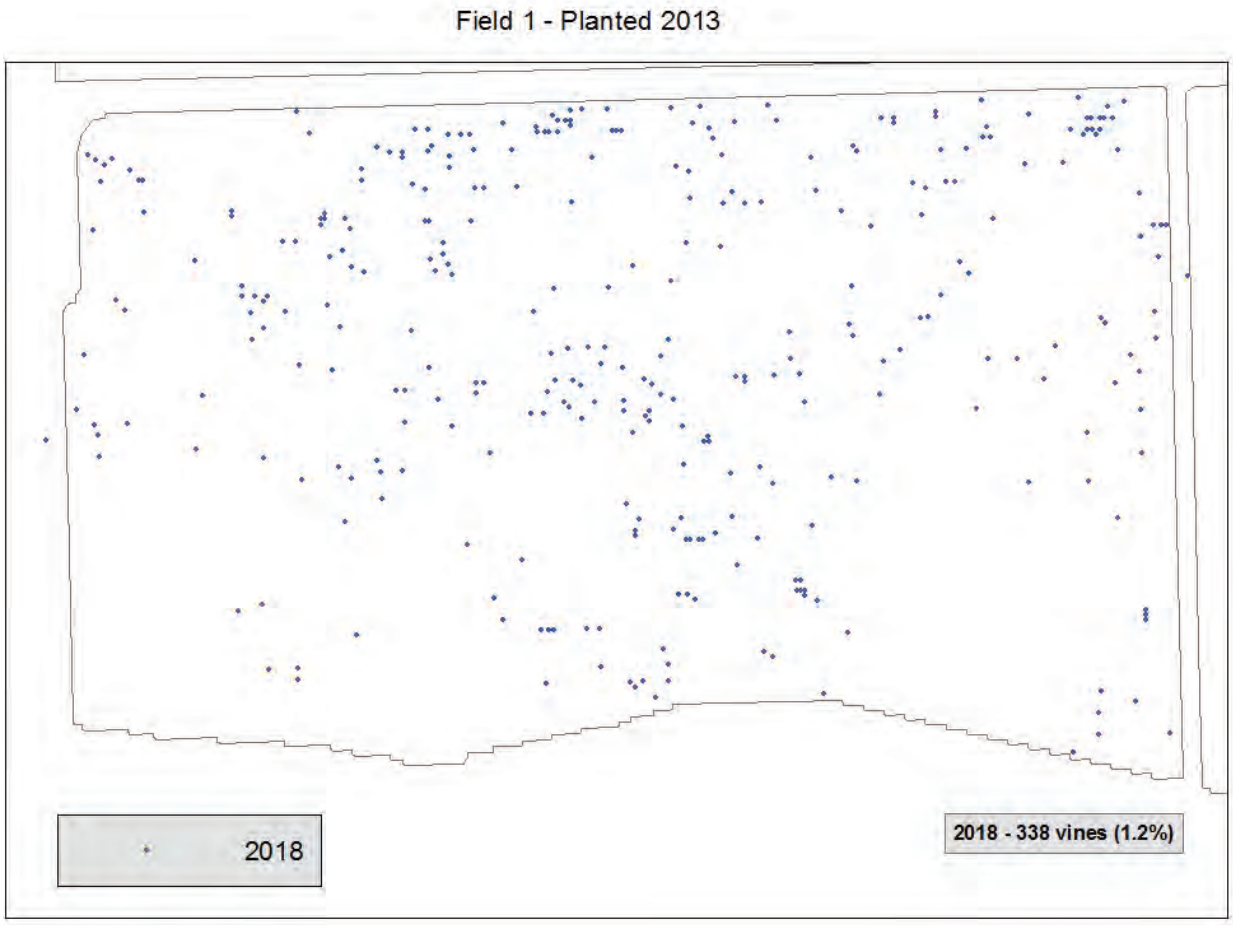
2017: Using the same protocol as in 2016, vines showing red leaf symptoms were flagged and another 10 random flagged vines were tested for red blotch and leafroll virus. All 10 vines tested came back positive for leafroll 3 virus. 334 flagged vines were rogued. Although another 1.2% of the vineyard had to be removed, the dramatic decrease from 8.1% in 2016 to 1.2% in 2017 was encouraging.



"I am very confident that you and your growers will succeed in making good inroads into leafroll control, as the people I met were extremely passionate as well as knowledgeable in this regard, and also appeared to be willing to learn from each other too."

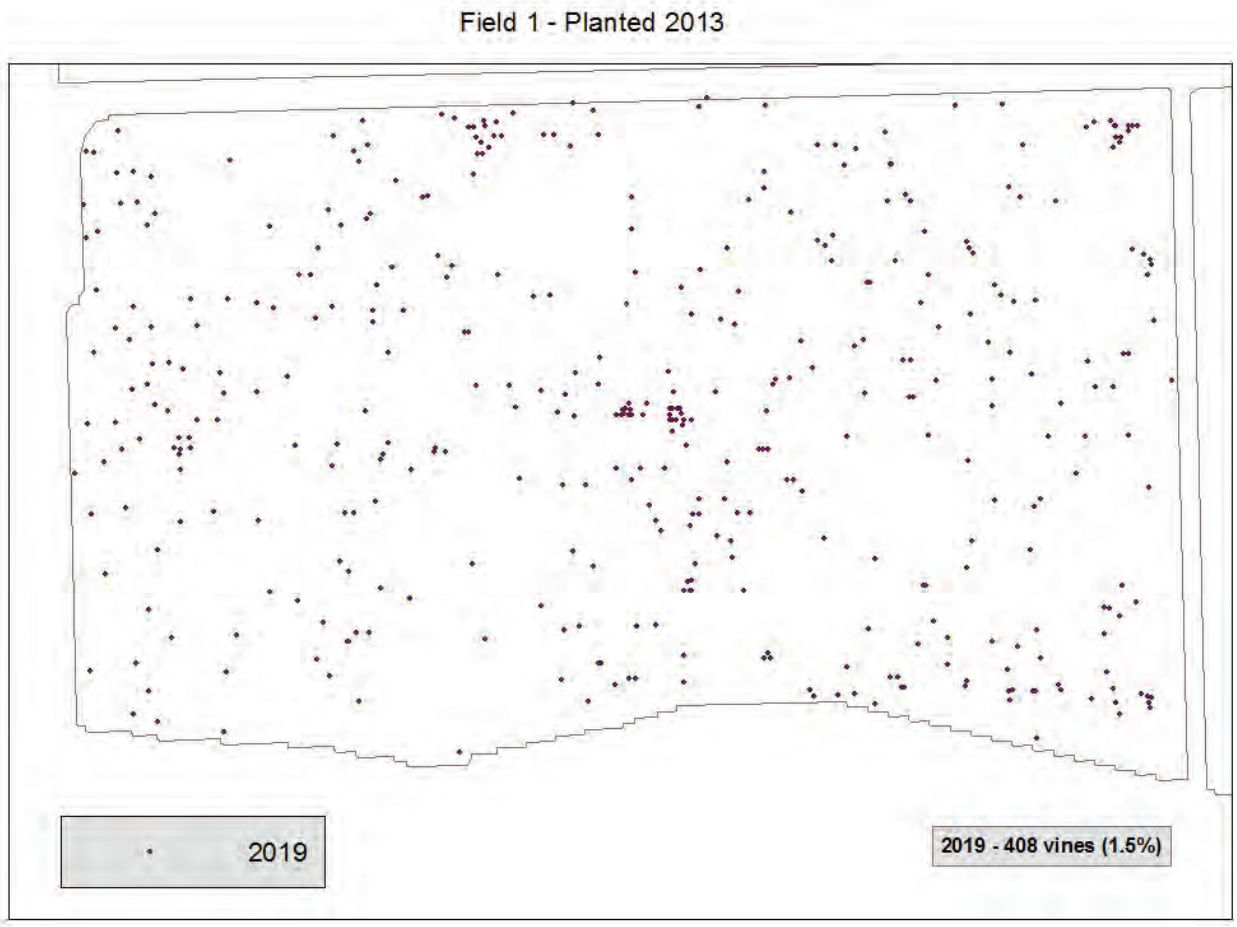
—GERHARD PIETERSEN, PHD, STELLENBOSCH UNIVERSITY, SOUTH AFRICA

2018: Vines showing red leaf symptoms were flagged, a random sample of 10 vines were verified with testing, and all 338 marked vines (1.2%) were rogued.

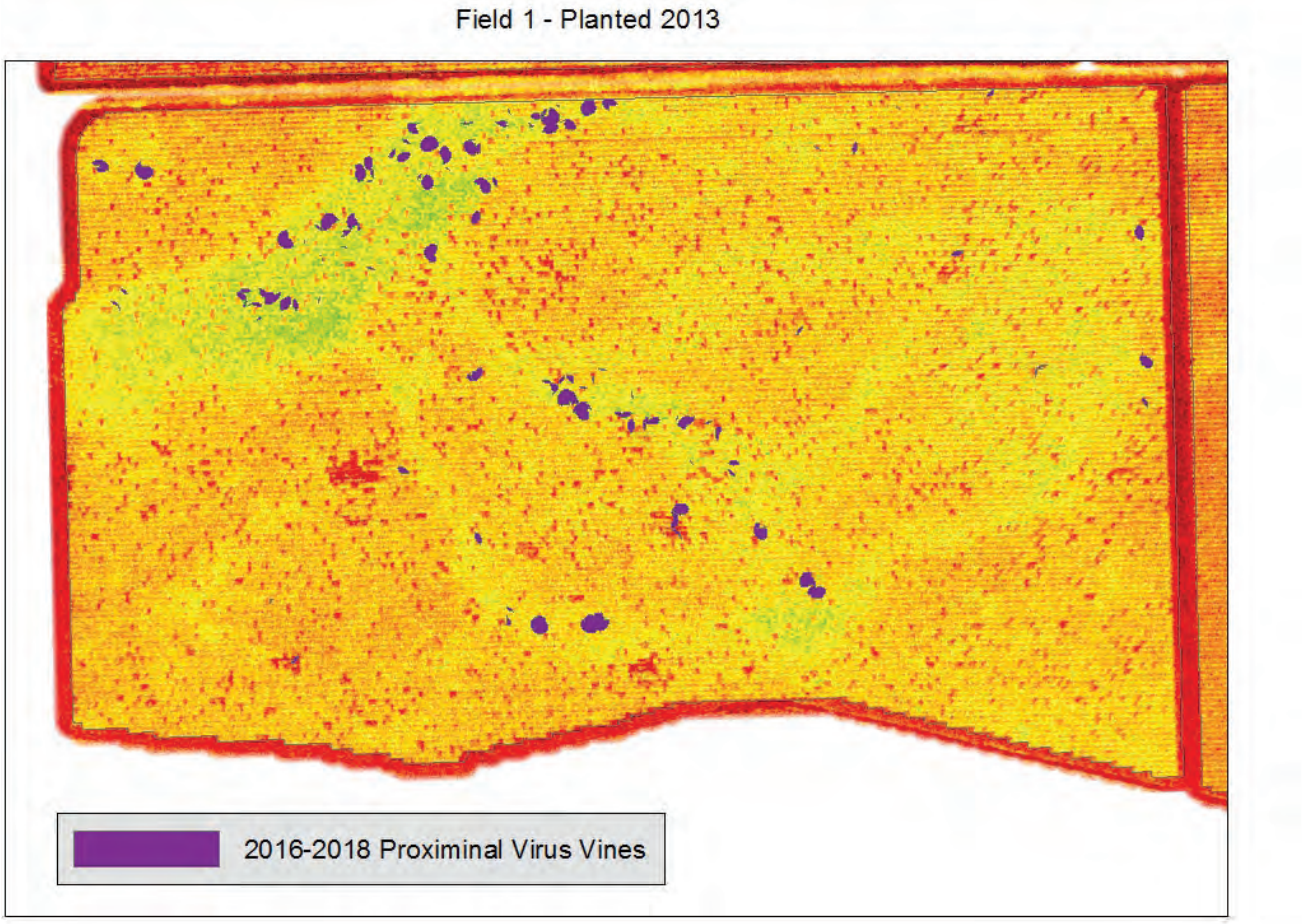


An example of a vine that would be flagged for removal during scouting. Photo by Stephanie Bolton.

2019: Vines showing red leaf symptoms were flagged, a random sample of 10 vines were verified with testing, and all 408 marked vines (1.5%) were rogued.



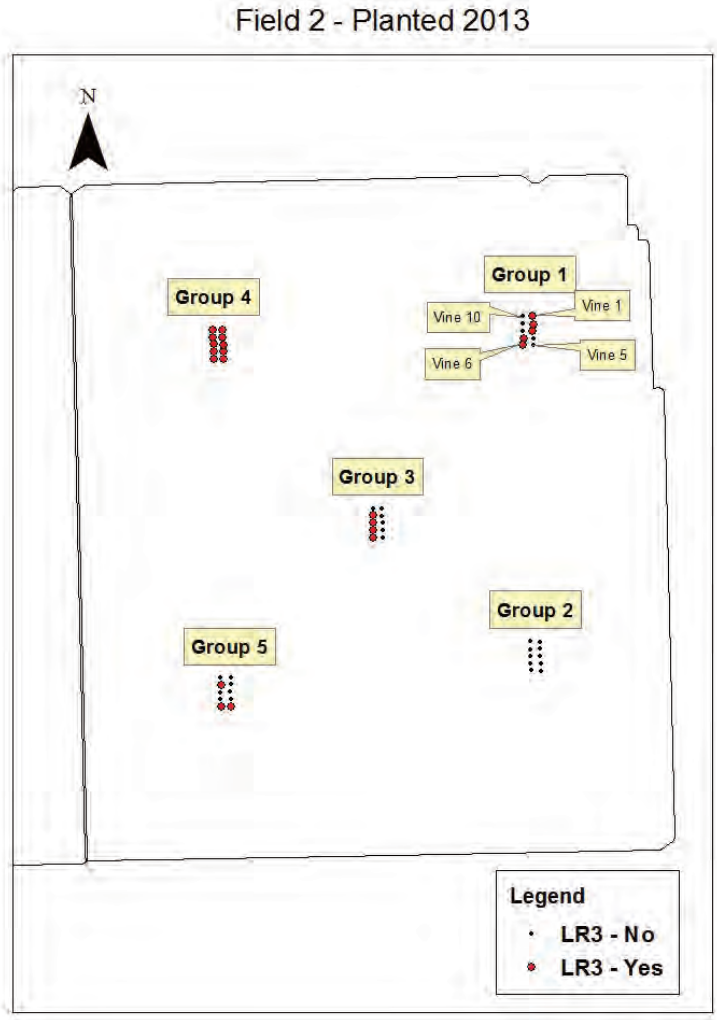
In 2019 we were disappointed that the level of infection had not dropped below 1%, which was the goal from the onset. We are still looking into why this may be the case. Field 2 will show what can happen without rogueing.



The power of mapping: During the analysis of Field 1, we could see where vines were becoming infected in proximity to previously infected and rogued vines – or where secondary (vine to vine) spread was happening. With this geospatial relationship overlaid on an NDVI map, you can clearly see secondary spread occurring in areas of the field that show higher vigor (the yellow/green color).

FIELD TWO STATS

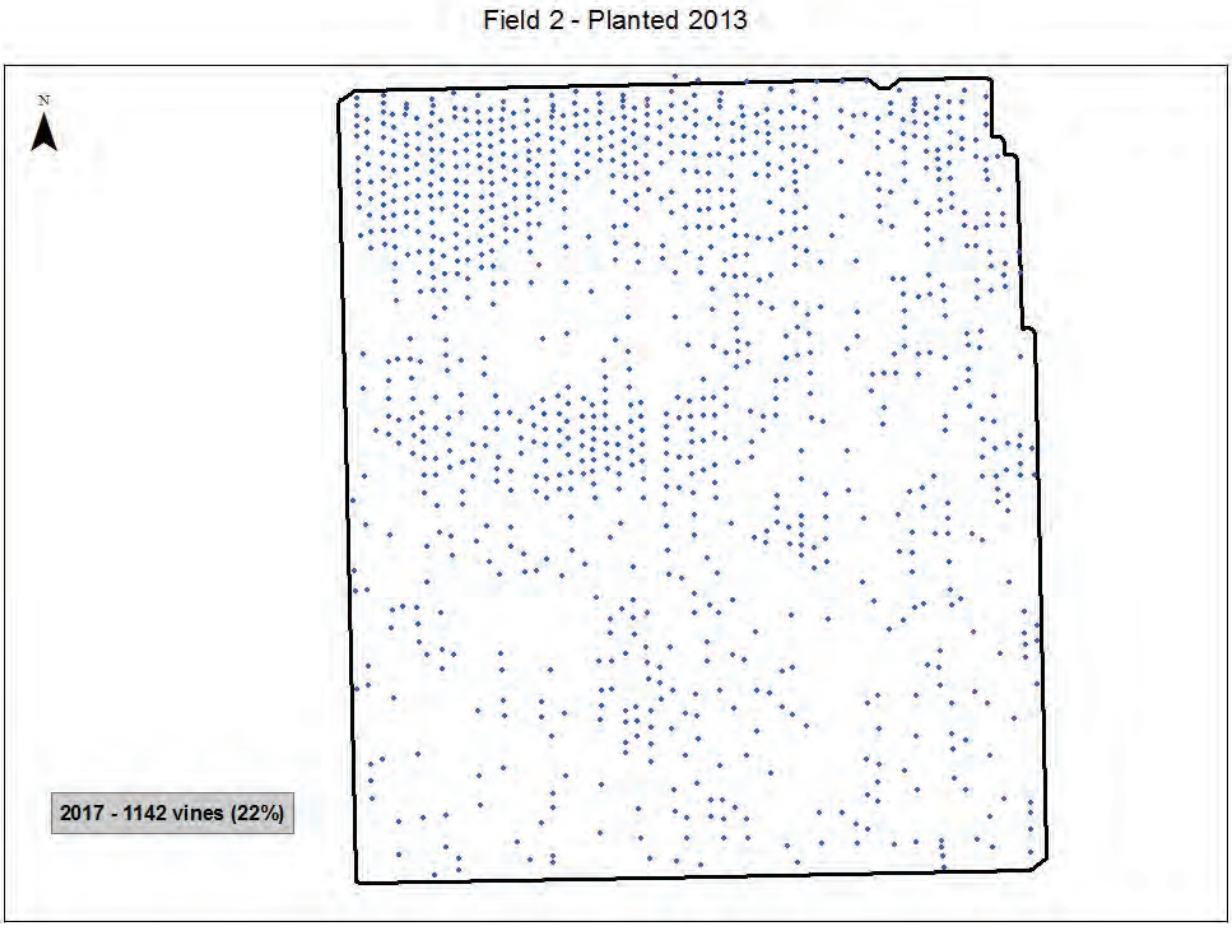
- 8.5 acres
- Planted in 2013 following the removal of a Zinfandel vineyard
- Kingdon fine sandy loam soil
- Surrounded by vineyards with a substantial riparian buffer on the North, East, and West sides (there is an adjacent vineyard to the South)
- Cabernet Sauvignon Clone 7 on O39-16 rootstock (CDFA-certified material)
- A high incidence of vine mealybugs were found in 2015 and control methods that included water-run imidacloprid and Movento were started that year



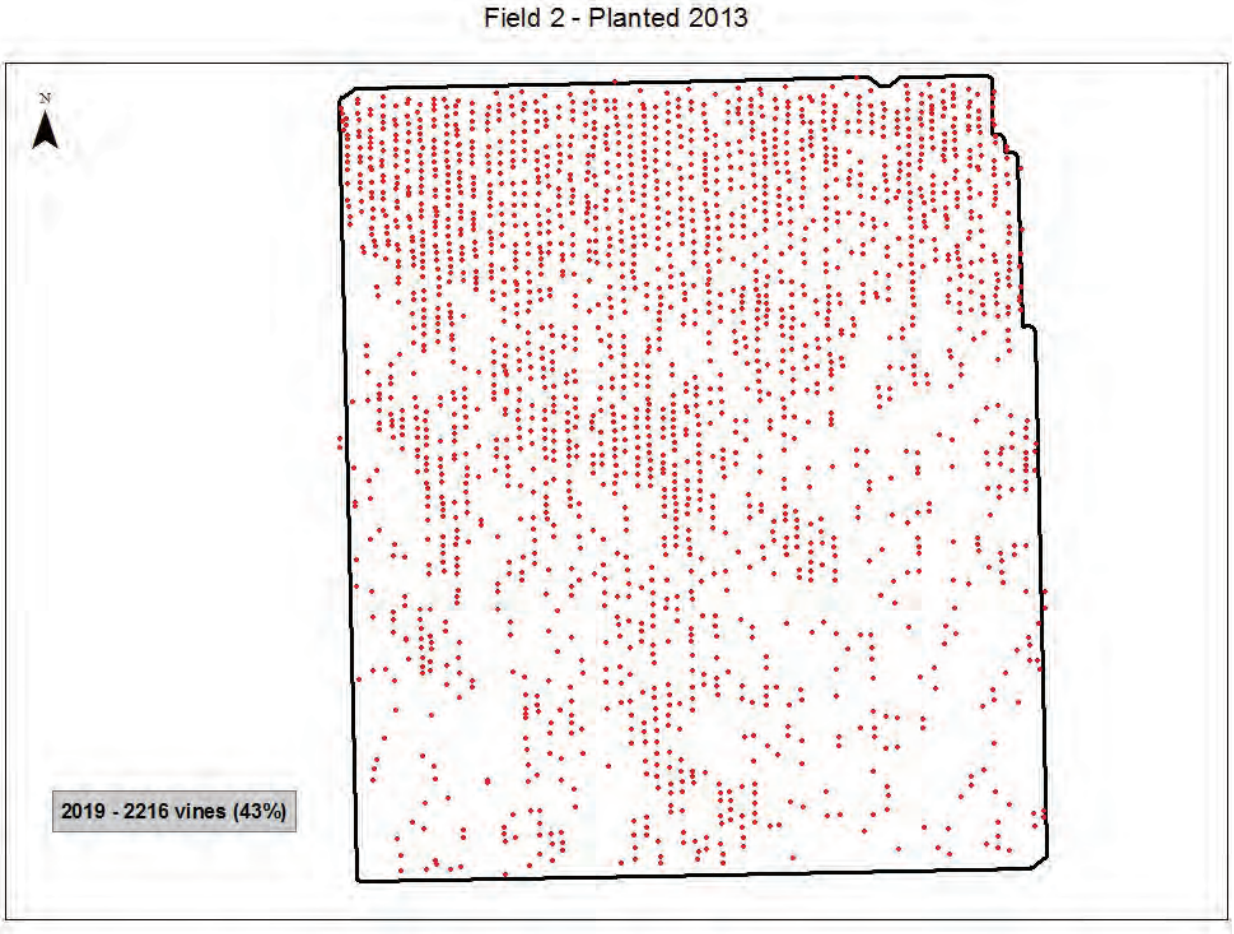
TIMELINE

2016: Visual red-leaf symptoms of leafroll 3 virus were observed at a much higher level than in other vineyards of the same age. Testing each vine for viruses is not economically feasible. To give ourselves an idea of how much virus infection there was, we used a combination of visual assessment and testing. We created 5 groups of vines. Each group had 10 vines, 5 vines in one row and another 5 vines in the adjacent row. Each vine was mapped and visual observations were made and recorded. Then each vine in group 1 was tested for viruses to confirm that the vines with visual symptoms did have leafroll 3 virus and the ones with no symptoms did not. This result then gave us confidence that the other vines in the groups were visually assessed correctly.

2017: Already thinking that we were past a 20% infection threshold, making rogueing not a viable option, we still wanted to map the field to know the level of infection and the spatial distribution. We flagged 1,142 symptomatic vines and mapped the vineyard, but did not spend extra money on further testing at this point since vines would not be removed. 22% of the field was flagged as infected with leafroll 3 virus.



2019: To measure the percent increase in virus infection over time without rogueing, the vineyard was once again scouted, flagged, and mapped showing a 43% infection. This represents a 21% increase from 2017.



We continue to watch this Cabernet Sauvignon vineyard. With the level of infection, wine quality and sugar accumulation problems are becoming a concern which is alarming for a 7-year-old vineyard.

Uneven ripening in Cabernet Sauvignon. Photo taken in October 2018 by Stephanie Bolton.

WHAT WE HAVE LEARNED

Since 2015, we have learned a great deal about viruses and the importance of recognizing the signs of virus and vectors early. By mapping virus-infected vines, we are able to estimate the level of infection and observe any spread over time. By recognizing red leaf symptoms early and taking action, any spread can be minimized.

Over the past several years, we have adopted strategies which we share not as a recommendation of what to do, but of things that should be considered. We are continually learning and the best strategies are constantly changing. The two vineyards described represent just a few examples of the scouting, mapping, and rogueing we've performed in several commercial vineyards.

Currently our best adaptive virus management practices include the following for new plantings:

- Before planting the vineyard, remove as much of the old roots as possible. Each root remnant could be harboring a virus and/or a virus vector.
- Control ants early. Ants are tending to mealybugs and can transfer mealybugs and viruses from old root remnants to the newly planted vines.
- Buy the cleanest planting material that you can find. Talk to your nursery and even inspect and test your order before it arrives.
- Start vine mealybug control as soon as the vines are in the ground.
- Visually inspect red cultivars as early as possible. Mark, test, rogue.
- Continue to mark, test, and rogue until you reach below 1% infection.
- Talk to neighbors about viruses and mealybugs. Your problem is their problem and vice-versa.

7 CASE STUDY: REPLANTING FOLLOWING A LEAFROLL-INFECTED VINEYARD

by Daniel Meyers and Chris Storm
Vino Farms

DEMONSTRATION VINEYARD STATS

- 70 acres (rootstock trial = 1.25 acres)
- Cabernet Sauvignon Clone 7 on O39-16 rootstock
- 11 x 5 spacing
- Planted in 2019
- Borden Ranch AVA
- San Joaquin silt loam soil

DEMONSTRATION VINEYARD HISTORY

The Lodi Grapevine Virus Research Focus Group needed a demonstration vineyard to observe what happens as a grower tries to move from a full leafroll virus infection rip-out to a healthy, replanted vineyard with a low rate of infection over time. Chris Storm had the foresight to also include different rootstocks in a replicated trial in the demonstration vineyard.

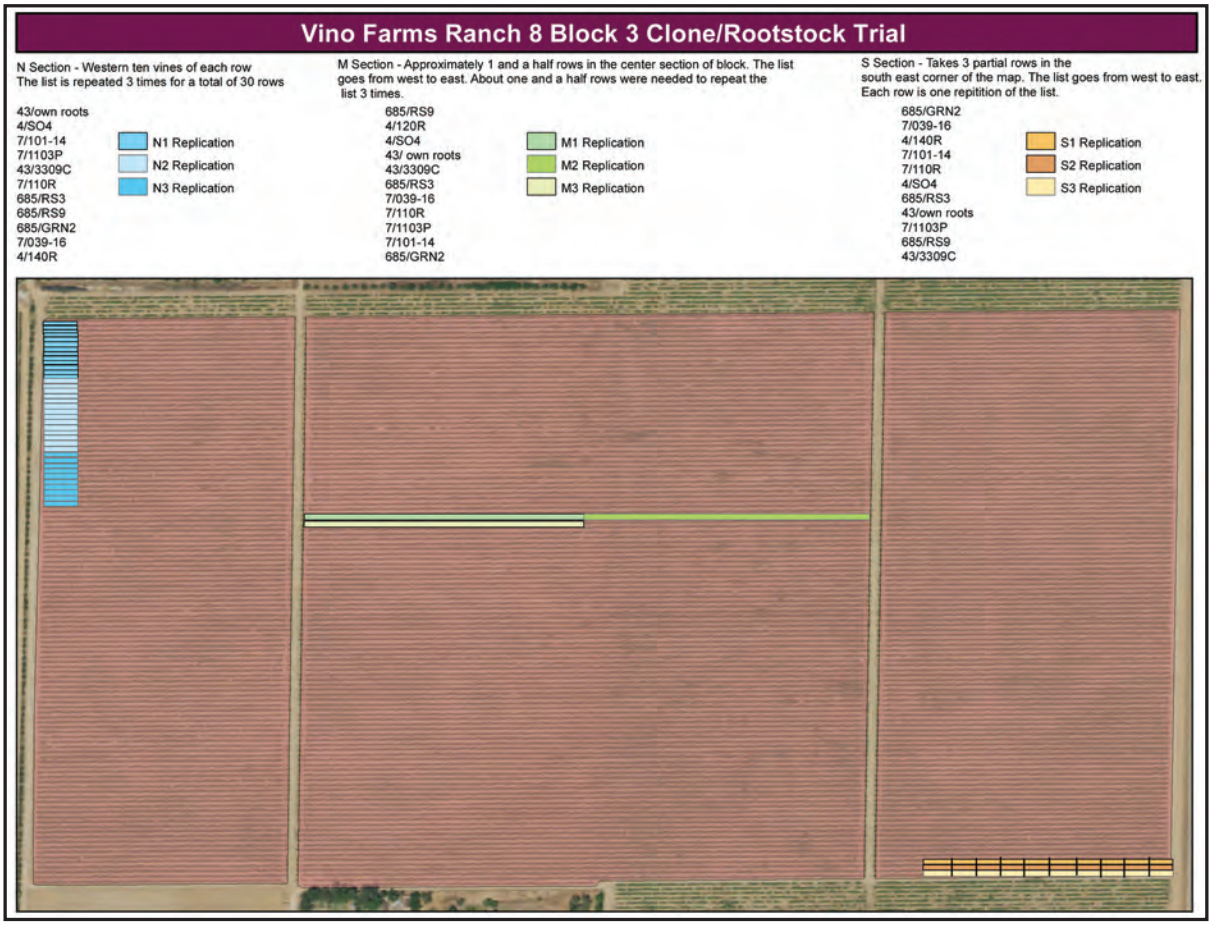
This demonstration vineyard was previously planted to Malbec Clone 9 on 1103 Paulsen in 2012. We noticed the vineyard was showing red leaf symptoms in the Fall of 2014 but assumed the symptoms were nutrient related, which is a common occurrence in young Malbec. It has very bright Fall colors that mask disease symptoms. In 2015, virus testing was conducted showing the presence of leafroll 3 virus.

In subsequent years, the vineyard struggled to ripen and extensive testing showed that over 70% of the vineyard was infected with leafroll 3 virus. With the high leafroll virus infection rate, the block could no longer ripen a crop (even a 2 ton/acre crop) above 21 degrees Brix. The decision was made to remove the vines but to leave the trellising to save some costs during redevelopment. The vines were chain-sawed at the base of the trunk, and any vines attempting to re-grow the following Summer were treated with glyphosate.

After fallowing for an entire year, dormant Cabernet Sauvignon vines (CDFA-certified plus extra grower testing) were planted in early 2019 into the existing trellis system. There are vineyards to the North, South, East, and West of this ranch. We manage the vineyards to the North and South and others manage the vineyards to the East and West.

ROOTSTOCK TRIAL

We wanted to test as many rootstock combinations as possible in order to see if there would be a difference in leafroll 3 virus transmission and susceptibility between different clone and rootstock combinations, especially with natural leafroll and mealybug inoculum present. After seeing sudden vine collapse (page 105) becoming common in blocks planted on Freedom rootstock, we were curious to see if any other rootstocks or clones are more or less susceptible or resistant to the damage caused by the leafroll associated viruses. Wonderful and Duarte Nurseries were willing to supply rootstocks for the trial and Cabernet Sauvignon clones varied based upon availability (see list of clones and rootstocks in map).



The trial consists of three replicates located in three different sections of the overall vineyard block. We named the three replicates N, M, and S sections. The N section is in the Northwest corner of the block, the M section is in the middle of the block, and the S section is in the Southeast corner of the block. In each of the sections (N, M, and S), there are three replicates of each rootstock. Each replicate contains 11 different rootstocks that consist of 10 vines each. That means that there are 90 vines for each of the 11 rootstocks. In total there are 990 individual vines in the trial.

Samples from each vine were tested in October/November for a panel of viruses. In total, 131 vines tested positive for leafroll 3 virus only (13.23% of vines) and 10 vines tested positive for both leafroll 3 virus and the vitivirus grapevine virus A (1% of vines). All rootstock types represented tested positive for leafroll virus.

Only 1 vine tested positive for leafroll 3 virus in the N section and no vines tested positive for a virus in the M section. The S section came back with 130 vines out of 330 testing positive for leafroll 3 virus, and 10 vines testing positive for both leafroll 3 virus and grapevine virus A (a vitivirus). About 42% of the vines in the S section were infected by a virus between January-November 2019.

A trial vine on 1103 Paulsen, planted in January 2019, which tested negative for a virus panel in November 2019. Photo by Daniel Meyers.

A vine on its own roots, planted in January 2019, which tested positive for leafroll 3 virus in November 2019. Photo by Daniel Meyers.

Our assumption had always been that the source of the vine mealybug was the neighboring vineyard to the West and upwind of our vineyard. The results from lab testing quickly disproved that theory. The section with the most leafroll virus was the S section which bordered an adjacent Vino Farms block of 29-year-old Pinot Grigio. The source of the vine mealybug and accompanying leafroll virus and grapevine virus A was our own Pinot Grigio block that had a historic vine mealybug infestation and was experiencing significant sudden vine collapse. We learned that it's a lot easier to blame a neighbor than yourself.

We did not expect the trial vines to become infected with virus from neighboring vineyards so quickly. We plan to continue to monitor the vines in the middle M section for viruses over time in order to observe any potential rootstock sensitivity or resistance towards underground leafroll inoculum.

Vino Farms marks vine mealybug hotspots with the new custom flagging tape. Photo by Daniel Meyers.

8 CASE STUDY: NEIGHBORHOOD COMMUNICATION

by Aaron Lange
LangeTwins Family Vineyards & Winery

After four years of evolving our virus monitoring and management programs to reduce the risks of leafroll 3 virus infection in our own vineyards, our team at LangeTwins recognized that **we were underestimating a critical source of potential infection: the neighborhood.** We had made significant progress in understanding the epidemiology of leafroll virus in the Lodi area, but almost all our efforts to reduce our risk of infection focused on management strategies within our own organization's control: selecting clean nursery stock, performing proper site preparation, scouting new vineyards, and rogueing out infected vines to reduce leafroll source inoculum. However, we were not focusing enough on the virus and vector status of our neighbors' vineyards and how that could compromise a successful long-term leafroll virus management plan.

We removed a vineyard in early 2019 in the Lockeford area with plans to replant with winegrapes in 2020. As a new part of the site preparation work, we added a "neighborhood risk evaluation" phase, where I reached out to the owners of the immediately adjacent vineyards to inquire about their knowledge of leafroll virus and its known vector, the vine mealybug. **This was a very awkward phone call to make: I didn't know how to broach this seemingly taboo topic with a fellow grower without making it sound like I was challenging their farming practices, questioning their viticultural knowledge, or otherwise coming off like a nosey farmer, poking his nose in another person's business.**

I called my neighbor, who owned a small block of red winegrapes upwind from my open field, and respectfully asked if he was familiar with the effects and spread of leafroll virus and its vector. We had a good conversation, and it ended with my neighbor allowing my crew to survey his vineyard for virus symptoms and vectors, as long as I kept the information confidential. (This neighbor has since given me permission to share the story anonymously.)

My neighbor – like many other growers in our region – believed that his vineyard was clean of virus and did not have a major issue with vine mealybugs. In addition, he believed that the vineyard's rootstock of O39-16 made the vines resistant to all viruses. After surveying the vineyard and lab testing to confirm the results, we identified over 500 virus-positive vines and four "hot-spot" areas indicating significant secondary spread (spread due to a vector vs. original plant-material infection).

Virus-carrying vine mealybugs do not respect property lines, and you won't notice their trespassing efforts until you start to see virus symptoms (if they even appear at all). By then, it's too late to protect the vine. Photo by Stephanie Bolton.

After sharing these results with my neighbor, he responded some skepticism but also a sense of "so, now-what?" He explained that he does not wish to rogue out 502 vines of his younger vineyard, which is understandable. However, I explained that there is good evidence that the more virus-positive vines you have in your vineyard (virus inoculum), the faster vine mealybugs will spread the virus. In addition, there is good evidence that leafroll virus has a negative effect on quality and the lifespan of the vine. Finally, vine mealybugs can easily be spread by birds, wind, and machinery – so, the more virus inoculum present in the neighborhood, the more likely vine mealybugs will be virifulous.

Even though I was unsuccessful in convincing my neighbor to rogue out infected vines, he was respectful of my concerns and we agreed to work together this Spring to share information and perhaps coordinate our vine mealybug control strategies. Through having this tough conversation, we were able to share information on how leafroll virus is spread and debunk a prevalent myth in our industry – that O39-16 rootstock makes the vine resistant to leafroll virus, which it is not true.

> "Your mealybugs are your neighbor's mealybugs and your neighbor's mealybugs are your mealybugs, just like your viruses are your neighbor's viruses and your neighbor's viruses are your viruses."
>
> **—KENT DAANE, PHD, UNIVERSITY OF CALIFORNIA**

The ultimate question remains: we can do everything to find cleaner plant material and perform the best site preparation possible, but if there is not a coordinated effort with neighboring vineyard owners to eliminate virus-positive vines and to reduce vine mealybug populations – not just for winegrape quality concerns, but to the lowest levels possible to minimize virus vectoring – is a new vineyard planting in a vulnerable area destined to become infected with leafroll virus and therefore drastically reduce its winegrape quality and profitability as a vineyard investment? I strongly believe this last question, which indicates an existential crisis to our industry, is worthy of breaking through this taboo topic with our neighbors to spur more communication and collaboration to our mutual benefit.

Aaron Lange, the author of this chapter, produced an excellent video showing leafroll virus spread. We are lucky to have passionate growers like Aaron in Lodi, who raise the bar for open communication about mealybugs and viruses. Watch his video at lodigrowers.com/growered-ucation/viruses.

A typical sudden vine collapse site – in the collapsing "patch" are healthy vines, dead vines, recently collapsed vines, collapsing vines, and empty spaces where dead vines were removed. Taken July 2018 in Lodi, California. Photo by Stephanie Bolton.

9 SUDDEN VINE COLLAPSE

Across California, winegrape farmers are observing – much to their dismay – patches of grapevines mysteriously collapsing. Farmers, pest control advisors, extension personnel, and scientists have studied these dying vines extensively in Lodi since around 2010. By 2018, the Lodi Winegrape Commission began to organize this endeavor in the form of case study interviews and consistent vineyard testing. Thanks to the efforts of a team of growers and scientists, we are learning that viruses are likely involved in what we now call the "sudden vine collapse" and we can offer some management recommendations.

THE BEGINNING OF A COLLAPSE

During the growing season, a farmer will begin to notice that there are a few dead vines near each other. Vines die for many reasons – diseases, tractor injury, rot, severe stress, etc. – so the grower is not too alarmed. The grower will either ignore or remove these few vines without really knowing why they died. The same scenario may occur over the next 2-3 years with vines dying and possibly getting removed. By the third or fourth year, these dying vines are now one larger patch of missing, stunted, dying, and dead vines which are much more noticeable and frightening than before. Replants in this area may also begin to collapse. At this point, the grower is concerned about the spread of this dying patch of vines but is not sure what to test for or how to protect the rest of the vineyard. These collapsing patches can be up to acres in size and are viewable simply by looking at the satellite view in Google Maps or Google Earth.

THE HISTORY IN LODI

Charlie Starr and Mark Shimozaki, local independent pest control advisors, and Paul Verdegaal, retired UCCE Farm Advisor, brought in dozens of scientists between 2010-2019 to study collapsing vines in different vineyards. Unfortunately, for many years no one was able to pin down a cause that made sense. Each expert could usually find the pathogen(s) that they study in the collapsing patch of vines, but the pathogen or disease found was inconsistent across vineyard sites, did not match the pattern of spread, or could not be attributed to the death of the grapevines. The only consistencies in the earlier days were that the collapse was typically occurring in mature vineyards (aged 15-20 years) on Freedom rootstock and when tested for common viruses, leafroll virus showed up. Freedom rootstock is very popular in Lodi so it was hard to tell if the rootstock was a causal factor or just a coincidence.

Leafroll virus is known to inhibit ripening, decrease yield, reduce quality, and decline a vineyard's lifespan, but the team did not think that this virus alone could cause a mature vine to collapse. Once the collapse was observed on CDFA-certified virus-tested replants within a patch, the team realized that the age of a vineyard was no longer a causal factor. Grape scion variety also does not seem to be relevant, with collapsing vines occurring in Cabernet Sauvignon, Pinot noir, Chardonnay, and other varieties.

Many, many theories were tested – from *Phylloxera* to esca to *Phytophthora* to lightning strikes. By 2018, the working hypothesis was that a combination of certain rootstocks (including Freedom), leafroll virus, and a third stress (possibly trunk disease, vitiviruses, water stress, etc.) created a disease complex leading to the collapse. Intrigued by the mystery, UC Plant Pathologist Dr. Akif Eskalen (UC Davis Plant Pathologist) joined in the efforts in 2019. The Lodi team was happy to have Akif on board because he was excited to help and more importantly, he was willing to work across scientific disciplines, building upon the work that preceded his involvement.

Two levels of stunted shoot growth, a typical symptom of the mysterious collapse, in July 2018 in a collapsing patch on Freedom rootstock in Lodi, California. Photo by Stephanie Bolton.

SYMPTOMS OF A COLLAPSING PATCH
(based upon observations in Lodi):

- Vines may show stunted shoots, growing to less than half the size of healthy shoots.
- Vines may collapse at any time during the year.
- Many vines push out fruit before they collapse.
- Collapsed vines lack feeder roots (smaller roots closer to the surface).
- The entire vine goes from having green shoots to being completely dried up rather quickly (typically in 2-6 weeks).
- The symptoms look similar to Eutypa dieback, but vine death is more rapid and without cankers.
- In many cases, the graft union in particular appears rotten and when you saw through the trunk at this junction, you can see dark, necrotic tissue.
- The scion tissue directly above the graft union may appear swollen or engorged.
- The patch of collapse tends to spread in the direction of the wind.
- The patch itself appears as a rough circular shape (resembling a soil-borne disease) which can be viewed in Google Maps once it gets large enough.

In this sudden vine collapse example as viewed with Google Earth, the grower started seeing a single vine collapse here and there in 2014 or 2015 in his 23 acre block. He thought maybe it was oak root fungus. Look at the growth of the collapsing patch by May 2017 (right) and the difference from June 2013 (left). There are many examples just like this one. Some growers have seen their collapsing patch grow by 30% over one year.

GETTING CLOSER TO SOLVING THE MYSTERY

With leafroll virus likely involved, the team enlisted the help of Dr. Maher Al Rwahnih (UC Davis Plant Virologist). In July 2019, Akif and Maher, along with Starr and others, took samples of collapsing and healthy vines from four affected vineyards in Lodi which had been monitored for this issue for several years. Rootstock and scion samples were thoroughly tested for fungal and viral pathogens by Akif and Maher, respectively. The Lodi Winegrape Commission helped to fund fungal testing and Maher generously donated highly accurate virus testing (high-throughput sequencing and PCR). Maher tested for leafroll viruses (of which there are several types – designated by numbers such as leafroll 3 virus), vitiviruses (another group of viruses with several types – designated by letters such as grapevine virus A), and even unknown viruses, which can be picked up by the high-throughput sequencing. Maher was familiar with research studies conducted by Dr. Deborah Golino (UC Davis Plant Virologist) where a combination of a leafroll virus and a vitivirus led to vine decline, both at the time of grafting and later on in a vine's life (with infection occurring post-planting).

Every collapsing vine from each of these four vineyards tested positive for both a leafroll virus and a vitivirus. Trunk disease pathogens were isolated from each sample, but not the same ones. So far, multiple case studies from California vineyards have provided evidence to support the current hypothesis that a combination of a leafroll virus-sensitive rootstock, a leafroll virus, a vitivirus, and another stress (possibly trunk pathogens, crop or water stress, etc.) leads to the collapse. Collapse symptoms and positive test results for both a leafroll virus and a vitivirus have been confirmed on Freedom, O39-16, and 101-14 Mtg rootstocks, but there are likely more affected rootstocks. We continue to collect case studies to investigate the potential role of viruses and rootstock types in the collapse disease complex. Thus far, leafroll 3 virus and the vitiviruses grapevine virus A and F appear to be the most common pathogen culprits in the disease complex leading to the collapse.

OCTOBER 2019

By October 2019, the team of growers and scientists studying the sudden vine collapse were ready to present their preliminary data to the Lodi wine-growing industry. Thanks to various presentations and a new grapevine virus email list-serve created by the Lodi Grapevine Virus Focus Group, people across California knew that the Lodi Winegrape Commission was actively trying to solve the mystery of the collapse. On October 1, 2019, during harvest, about 140 people showed up at a Lodi breakfast meeting to hear Stephanie, Akif, and Maher talk about the collapse and announce the potential involvement of a combination of a leafroll virus and a vitivirus. The high number of attendees from both near and far (and during harvest!) showed just how widespread and economically devastating the issue had become. Journalist Ted Rieger attended the meeting and wrote an article about the collapse for Wine Business Monthly, which was the #1 read article for 30 days on winebusiness.com (Rieger 2019).

THE DANGEROUS LEAFROLL VIRUS & VITIVIRUS COMBINATION

The Lodi Grapevine Virus Research Focus Group studied fanleaf virus, red blotch virus, and leafroll virus. Most of the members had heard about vitiviruses, but we figured that vitiviruses were one of the many grapevine viruses which existed but that we didn't really have to worry about. We were wrong, and we have Maher to thank for educating us. In combination with a leafroll virus, vitiviruses can actually be quite harmful to grapevines – especially those on leafroll-sensitive rootstocks. Most growers in California have probably never heard of vitiviruses. Vitiviruses are a group of viruses with letter names – grapevine virus A, grapevine virus B, grapevine virus F, etc. Alone, vitivirus infections may cause the rugose wood disease symptoms of stem grooving or corky bark, along with differences in rootstock and scion diameter. Like leafroll viruses, vitiviruses are spread (or vectored) by mealybugs and scale insects. There is research to suggest that together, a co-infection of a leafroll virus and a vitivirus worsens any disease effect on grapevines (Rowhani et al 2018).

Get out your hand lens and search for mealybugs, which spread leafroll virus and vitiviruses. Photo by Stephanie Bolton.

ROOTSTOCKS & VIRUS SENSITIVITY

Thus far, most of the observed collapsing vines have been on Freedom rootstock, with verified symptoms/positive virus test results also discovered on O39-16 and 101-14 Mtg rootstocks. Additionally, the team knows of *unconfirmed* reports of collapse happening on 110R, 1103 Paulsen, Harmony, and others.

In a blog post on lodigrowers.com published on October 7, 2016, Stan Grant (Viticulturist, Progressive Viticulture) warned growers that when it comes to viruses, vines on Freedom, 3309 Courderc, and Kober 5BB rootstocks "commonly display more severe disease symptoms than vines on other rootstocks" (Grant 2016).

From Chapter 13 of the textbook *Grapevine Viruses: Molecular Biology, Diagnostics and Management* (Rowhani et al 2017) and a Cornell handout called "Grape leafroll disease" (Cieniewicz and Fuchs 2015):

- The following rootstocks have shown some level of graft incompatibility with a leafroll virus in the scientific literature: Kober 5BB, 1103 Paulsen, 5C Teleki, 3309 Courderc, 1616 Courderc, 3306 Courderc, 101-14 Mtg, Harmony, and Freedom.
- When both leafroll virus 2 and the vitivirus grapevine virus B were present, the rootstocks Freedom, Harmony, Kober 5BB, and 3309 Courderc experienced virus-induced young vine decline.
- Studies showed graft incompatibility or vine decline when scions infected with leafroll virus 1 and the vitivirus grapevine virus A were grafted onto 3309 Couderc, 101-14 Mtg, Freedom, and 420A Mgt.

The Lodi team is currently reviewing scientific studies from all over the world to have a more comprehensive list of rootstocks which may be a risk factor for this collapse.

IS YOUR VINEYARD AT RISK FOR THE COLLAPSE?

If you have a leafroll virus-sensitive rootstock and your vineyard is in a winegrowing region with mealybugs, leafroll viruses, and vitiviruses present, then you are at risk. Educate yourself. Talk with your pest control advisors and neighbors. Prevention is key, as with any other disease. Both mealybugs and viruses may be present in your vineyard even though you cannot see them nor observe any symptoms (especially in white grape varieties).

COLLAPSING VINE PHYSIOLOGY

The combination of a rootstock that is very sensitive to leafroll virus (such as Freedom) + a leafroll virus + a vitivirus may lead to a sudden vine collapse, which can happen in patches in a vineyard block or a region due to the presence of an efficient and prolific virus vector, the vine mealybug.

The virus and rootstock combination mentioned above is likely the primary cause of this collapse, where:

1. A scion becomes infected with virus(es) in the vineyard.
2. The virus-sensitive rootstock is rejecting the virus-infected scion in an effort to save itself from infection (which is ultimately a terrible move).
3. The movement of starches from the scion to the rootstock is inhibited, causing a buildup of free starch around the graft union and a swelling of tissue above the graft union.
4. The root system becomes starved and feeder roots die off or the vine is unable to produce new feeder roots.
5. The flow of nutrients and water within the vine is severely reduced.
6. The vine struggles to grow, causing a stunting of shoots.
7. A lack of water and nutrient flow leads to apoplexy (sudden death) in a matter of weeks.

A sample of scion (top) and rootstock taken for extensive testing, showing pitting and grooving of the rootstock just below the graft union. Photo by Maher Al Rwahnih.

Once an infected vine is completely dried up and dead, the virus-carrying, hungry vine mealybugs are forced to move to a live vine to obtain a new source of food – potentially exacerbating the spread of viruses and contributing to a collapse.

MANAGEMENT OPTIONS FOR THE COLLAPSE

Now that there exists evidence to support the involvement of leafroll viruses and vitiviruses in the collapse, management options may be offered. The following advice is based upon intense study, via scientific articles and real-world experience, of grapevine viruses and mealybugs, how they spread, and their management. The California winegrape industry is still learning how to best manage for viruses and their vectors. Likewise, there is still a lot to learn about the sudden/mystery vine collapse. The information presented here is intended as sound advice only, in an effort to aide in the ultimate decision-making by the vineyard owner.

If you think you may be experiencing the collapse:

STEP ONE: Test your vineyard – both collapsing and healthy vines.

For more information on virus testing, including a list of commercial laboratories, please see the Virus Testing Chapter on page 65.

Choose a virus testing laboratory that you trust (you may want to send samples to one commercial laboratory plus Foundation Plant Services for extra confirmation when you begin virus testing). We suggest testing two composite samples. For composite sample 1, collect material from at least five non-adjacent collapsing vines in the patch (vines showing symptoms that are still alive). For composite sample 2, collect material from at least five non-adjacent healthy vines in the vineyard block, far away from the collapsing patch (but with similar soil, irrigation, etc.). Most laboratories will allow up to ten cane pieces per composite sample, which would mean one cane from each side of the vine for five vines. Usually when testing for leafroll and vitiviruses it is not necessary to sterilize your pruning shears between samples. However, since we are still studying the collapse, it is recommended to clean your shears between the diseased and healthy samples (or even better, begin your sampling in the healthy part of the vineyard).

Test the samples for:

- Leafroll virus 1, leafroll virus 2, leafroll virus 2RG, and leafroll 3 virus (common leafroll viruses in California)

and

- GVA, GVB, GVD, and GVF (common vitiviruses in California)

Testing in the Fall (before the leaves senesce) is the best time of year to sample for these viruses because their amount within the grapevine is the highest. Plus, if you do have viruses, then the Winter would be a good time of year to remove the infected grapevines because wet soil allows for the greatest removal of root material.

STEP TWO: Remove the co-infected vines.
Although it is painful, the most efficient way to reduce the spread of viruses in the field is to take out the infected vines. By rogueing or pulling out and destroying the vines, you are removing the source point of infection. Each situation should be considered individually and the decision on how many vines to remove is very personal. Any leafroll- or vitivirus-infected vines in a vineyard serve as a potential source of virus which could be transmitted to healthy vines via mealybugs, which are spread by wind, workers, equipment, ants, animals, etc.

How many vines to remove depends upon the virus-status of the rest of the vineyard, the value and marketability of the grapes, the risk to surrounding grapevines and neighboring vineyards, the age of the vineyard, the emotional attachment to the vines, the presence of mealybugs throughout the vineyard, and a grower's financial situation. For nearly all growers, it will be too expensive to test each vine in and around the collapsing patch individually. If part of the vineyard is virus-free (confirmed with testing), growers will likely want to estimate the size of patch to be removed. Keep in mind that vines may be infected although the virus amount is not yet great enough to be detectable by commercial testing. In several cases, the team has found that an entire vineyard is infected with leafroll 3 virus and the collapsing patch is co-infected with leafroll 3 virus and a vitivirus.

Unfortunately, there is no cure for grapevine viruses now or in the foreseeable future. There is, however, financial assistance available to eligible growers who need to remove a vineyard infected with leafroll virus through the USDA Tree Assistance Program (see page 82).

STEP THREE: Reduce the mealybug vectors.
Manage vine mealybugs to the best of your ability (see Chapter 3 on Mealybug Management) – this helps to protect your healthy vines as well as the vines of your neighbors and ultimately your region. Unfortunately, vine mealybugs are very sneaky insects and oftentimes growers do not realize they are in the vineyard until 1-2 years later, after they have infected vines with leafroll and/or vitiviruses.

STEP FOUR: Spread the word.
Due to the high numbers and great expanse of vine mealybugs and leafroll virus in California, there are a lot of vineyards at risk for this sudden vine collapse. Please help to spread the word and educate your friends and neighbors. There are many resources and videos available online at lodigrowers.com/growereducation/viruses.

NOTE: Leafroll virus and vitiviruses are not only spread by mealybugs and scale insects, but they are also spread by planting material (through grafting or top-working). Therefore, grafting new material onto infected rootstock and collecting grafting material from an infected vineyard are highly discouraged.

THE MYSTERY CONTINUES...

Future research hopes to address the following questions:

- If the hypothesized disease complex risk factors (vine mealybugs, leafroll virus, vitiviruses, sensitive rootstocks) have been present for decades, then why are growers observing the collapse now? Wouldn't growers have seen it earlier? Did the recent drought exacerbate the situation? Are there more mealybugs present now or are mealybugs and the viruses they vector distributed further across California than before?
- If the two main diseases in this complex are leafroll viruses and vitiviruses, both spread by mealybugs and scales, then why does the collapsing patch have a circular pattern? Mealybug-vectored diseases usually move down/across vineyard rows with a smaller amount of spread between rows.
- Which leafroll viruses are of concern? Which vitiviruses are of concern?
- Which rootstocks are more or less sensitive to leafroll virus, vitiviruses, and a combination of these viruses?

Growers, researchers, and students collect samples to study the sudden vine collapse. Photo by Stephanie Bolton.

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A special thanks to Charlie Starr IV (Pest Control Advisor and Grower, Lodi CA), Dr. Akif Eskalen (UCCE Plant Pathologist), and Dr. Maher Al Rwahnih (UC Davis Virologist) for reviewing this Chapter on the sudden vine collapse and for all of their efforts to help us understand this disease complex.

10 FUTURE RESEARCH

Thus far, it appears that research on the following topics is much needed and important to Lodi growers:

1. An effective and efficient ant bait for use on large (50+) acre blocks to control ants which tend mealybugs.
2. A prevention strategy for leafroll replants (both individual vines and entire vineyard blocks).
3. The role of viruses in complexes with other biotic and abiotic stresses (including elucidating the sudden vine collapse).
4. Rootstock and scion combinations which are more or less prone to virus disease symptoms.
5. How to determine the percent of a vineyard which is infected with virus in a cost-effective manner.
6. Cost-effective methods of virus testing.

BIFS GRANT ANNOUNCEMENT

A team including the Lodi Winegrape Commission was awarded $1 million under the revamped CDFA BIFS Program

The California Department of Food and Agriculture (CDFA) has awarded funding for a project to be administered through the Office of Pesticide Consultation and Analysis (OPCA) Biologically Integrated Farming Systems (BIFS) grant program.

Project leader Dr. Kent Daane of UC Berkeley and collaborators will receive $1 million in funding for "Refinement and Implementation of an Areawide Program for Vineyard Pathogens and their Insect Vectors." This project will establish two demonstration blocks of at least 1,000-acres each where pheromone disruption tools will be used to control vine mealybug, the insect responsible for vectoring grape leafroll disease. Vines infected with leafroll virus will also be systematically removed to further prevent the spread of this economically devastating disease. Grower outreach will be conducted in collaboration with the Vineyard Team and the Lodi Winegrape Commission to expand the adoption of these low-impact practices in place of chemical insecticides. The project work will be done in the Lodi and Central Coast winegrape regions and take four years to complete.

The goal of the BIFS grant program is to demonstrate and refine integrated pest management (IPM) programs designed to reduce chemical insecticide inputs, especially non-selective, biologically disruptive insecticides with higher risk to human health and the environment. Projects foster farmer-to-farmer information exchange and on-farm demonstrations of IPM practices while allowing growers to maintain yields and quality. Outreach efforts bring together scientists, farmers, and consultants in a collaborative, co-learning environment that enables farmers to learn and adapt farming practices to local conditions.

Detailed information on this program, including the application process and application requirements, is available at: cdfa.ca.gov/oefi/opca/bifs.html.

Chris Storm (center left) and Larry Whitted (center right) man a "Mealybugs & Beneficials" station at an interactive Leafroll Virus Tailgate Talk in October 2018. Photo by Julie Sasak.

"We are excited to collaborate on this project to help grow the science and practice of addressing this critical issue in the industry."

—Kris Beal, Executive Director, Vineyard Team

"The project will be a partnership and collaboration among the vineyard outreach programs of the Lodi Winegrape Commission and the Vineyard Team, farmers, pest control advisors, and University of California research and extension personnel, which make up the Management Team. The overall goal is to develop leafroll virus control strategies that can be extended and utilized long after the project's 4-year term."

—Dr. Kent Daane, Project Leader, UC Berkeley

"It's been 25 years since the first BIFS program grant was awarded to Lodi with the goal of demonstrating practical sustainable farming practices. That original program was the predecessor of Lodi's world-renowned sustainable viticulture program, the Lodi Winegrowers Workbook and the LODI RULES certification program. With the latest BIFS grant award, Lodi is once again taking a leadership role in practical sustainable viticulture with the goal of tackling leafroll viruses, one of our industry's toughest long-term challenges."

—Chris Storm, Viticulturist, Vino Farms

HISTORY OF THE BIFS PROGRAM

(from the BIFS 2019 Request for Proposals document, available online)

The Biologically Integrated Farming System (BIFS) program ran from 1995 to 2010. Projects focused on fostering farmer-to-farmer information exchange and on-farm demonstration of integrated farming practices that promote IPM and biological systems while allowing growers to maintain profitable businesses. Originally a project of Community Alliance with Family Farmers (CAFF), BIFS transitioned to a grant program administered by the University of California (UC) Sustainable Agriculture Research and Education Program (SAREP), based at UC Davis. The program received supplemental funding and cooperation from the California Department of Pesticide Regulation (CDPR) and the US Environmental Protection Agency (EPA). The SAREP BIFS program funded 12 projects in 11 different farming systems.

The adoption of BIFS practices was found to reduce pesticide use, improve soil fertility, decrease erosion and nitrogen leaching, and increase populations of beneficial insects, fishes, birds, and game. For example, BIFS wine grape growers nearly eliminated use of chlorpyrifos and other organophosphate insecticides in the Central Coast. In BIFS apple orchards, organophosphate use was decreased by 33% through the use of pheromone mating disruption. Post-project research found that the 650 growers in the Lodi Winegrape Commission continued to implement BIFS practices after the project ended.

OUTREACH VERSION OF THIS BOOK

We enjoy helping others catch up on their grapevine virus knowledge and have already sent a lot of this material to several US states and other countries. We have a Grapevine Virus Outreach Toolkit available for those of you who are a leader in your region, eager to help others learn about viruses. We are also hopeful that other regions may want to produce their own version of this book, using local stories and photos. Contact Dr. Stephanie Bolton at the Lodi Winegrape Commission for more information – 209.367.4727 or stephanie@lodiwine.com.

We recommend that you arrange a small meeting for you and your neighbors, using this book as a roadmap. It's a good way to educate yourself, your PCA, and the rest of your team.

Charlie Starr IV and Tia Russell, both members of the Lodi Grapevine Virus Research Focus Group, talk to growers about identifying virus symptoms during a 2018 Leafroll Virus Tailgate Talk in Acampo, California.

AN IMPORTANT FIRST STEP IN BIOCONTROL: DON'T KILL THE GOOD INSECTS!

Your **CD11 Mealybug Biocontrol Research Focus Group** has put together this regionally-specific chart, based on the **UC-IPM Relative Toxicities of Insecticides and Miticides Used in Grapes to Natural Enemies and Honey Bees Table**, available online at ipm.ucanr.edu/PMG/r302900111.html, and years of real-world experience.

Help the good insects (beneficials, predators, parasites) help you!
What GOOD insects are we trying to keep ALIVE, anyways?

The ***Anagyrus* wasps**, ***Cryptolaemus* beetles**, and **lacewings** who attack mealybugs.

The **predatory mites**, **six-spotted thrips**, and **minute pirate bugs** who attack mites.

The ***Anagrus* wasps** and **green lacewings** who attack leafhoppers.

The **parasitic wasps** and **flies** who attack caterpillars and omnivorous leafrollers.

Trade Name	Common name	MOA	Good insects stay alive	May reduce good insects	Good insects are killed	Notes
Acramite	bifenazate	20D				
Admire Pro (soil)	imidacloprid	4A				use caution if applying when cover crops or insectary plants are flowering
Altacor	chlorantraniliprole	28				
Altrevin	metaflumizone bait	22B				
Apollo	clofentezine	10A				
Boric Acid	disodium tetraborate	unknown				

Trade Name	Common name	MOA	Good insects stay alive	May reduce Good insects	Good insects are killed	Notes
Bt	*Bacillus thuringiensis*	11A				
Envidor	spirodiclofen	23				
Esteem ant bait (soil)	pyriproxyfen	7C				
Intrepid	methoxyfenozide	18				
Movento	spirotetramat	23				
Nealta	cyflumetofen	25A				
Omni Supreme	narrow range oil	contact				
Onager	hexythiazox	10A				
Surround	kaolin clay	-				
Tango	S-methoprene	7A				

Trade Name	Common name	MOA	Good insects stay alive	May reduce good insects	Good insects are killed	notes
Trilogy	neem oil	multiple				broad spectrum but low toxicity to beneficial insects
Actara (foliar)	thiamethoxam	4A				may cause flare-ups of spider mites
Admire Pro (foliar)	imidacloprid	4A				toxic to bees and parasitic wasps
Agri-Mek	abamectin	6				appears to kill six-spotted thrips; moderate toxicity to predatory mites
Applaud	buprofezin	16				kills lady beetles
Assail (foliar)	acetamiprid	4A				toxic to bees and parasitic wasps
Belay (foliar)	clothianidin	4A				toxic to bees and parasitic wasps
M-Pede	insecticidal soap	dehydration				broad spectrum – moderate toxicity to all insects
Success, Entrust	spinosad	5				may kill predatory thrips, flies, lacewings, and beetles
Venom (foliar)	dinotefuran	4A				toxic to bees and parasitic wasps
Zeal	etoxazole	10B				sterilizes female predatory mites

Trade Name	Common name	MOA	Good insects stay alive	May reduce good insects	Good insects are killed	Notes
Danitol	fenpropathin	3A				broad spectrum toxicity to beneficial insects and predatory mites
Delegate	spinetoram	5				moderate toxicity to beneficial predators and parasites
Fujimite	fenpyroximate	21A				high toxicity to predatory mites
Imidan	phosmet	1B				high toxicity to beneficial insects
Lorsban Advanced	chlorpyrifos	1B				high toxicity to beneficial insects
Malathion	malathion	1B				high toxicity to beneficial insects
Pyganic	pyrethrin	3A				moderate toxicity to beneficial predators and parasites
Pyrenone	pyrethrin/piperonyl butoxide	3A				high toxicity to beneficial insects
Sevin	carbaryl	1A				moderate toxicity to beneficial predators and parasites

For the "**May reduce good insects**" category, you may wish to seek further advice from a trusted professional because the risk to beneficials can be dependent on application, timing, and cover crop use. Remember to rotate chemistries and follow label application instructions carefully to delay resistance development. Using **beneficial insects** for **biocontrol** of other insects/mites is an **IMPORTANT** part of **resistance management** in your vineyard.

This chart is to be used as a guide only and the best thing you can do is to monitor your vineyard for beneficial insects throughout the growing season. Much more research is needed to determine specific effects of products in a vineyard setting. For more information, the Xerces Society has written two helpful books: *Farming with Native Beneficial Insects* (Lee-Mader et al. 2014) and *Beyond the Birds and the Bees: Effects of Neonicotinoid Insecticides on Agriculturally Important Beneficial Invertebrates* (Hopwood et al. 2013).

Please share your personal vineyard experiences with different plant protectants and their effect on beneficial insects! stephanie@lodiwine.com

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The April 2019 meeting of the Virus Focus Group. From bottom left, clockwise: Nick Podsakoff, Aaron Lange, Paul Precissi, Stephanie Bolton, Kamyar Aram, Kyle Brown, Julie Sasak, Charlie Starr IV, Gerhard Pietersen, Tia Russell, and Norm Peters.

LODI GRAPEVINE VIRUS RESEARCH FOCUS GROUP

Stephanie Bolton, PhD
Kyle Brown
Matt Frank
Aaron Lange
Neil McRoberts, PhD
Norm Peters
Nicholas Podsakoff
Paul Precissi
Tia Russell
Charlie Starr IV
Chris Storm, MS
Keith Striegler, PhD
Karen Suslow, MS
Paul Verdegaal, MS

The outreach work and management tips provided in this book build upon decades and decades of research – both in the laboratory and in the field – by scientists, extension personnel, nurseries, laboratories, industry, and growers. Many, many people wrote articles and books which helped us understand viruses. Several people took the time to patiently answer our many questions in person, by telephone, and over emails. The Virus Focus Group would like to especially acknowledge the following people for their excellent and helpful support along this sometimes painful journey towards virus acceptance:

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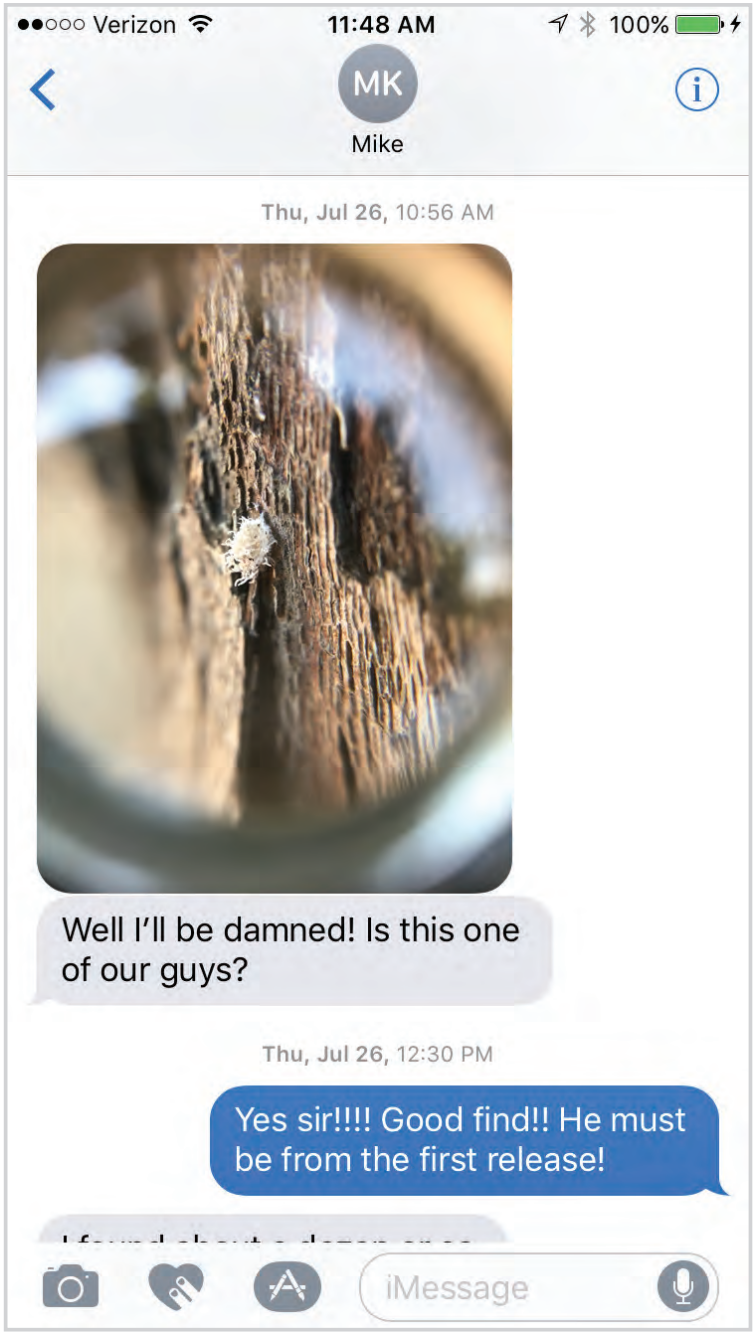
Mark Shimozaki
Rhonda Smith, MS
James Stamp, PhD
Caine Thompson, MBA
Andy Walker, PhD
Alan Wei, PhD
Larry Whitted
Houston Wilson, PhD

We appreciate all of the attendees at our virus outreach events – you are amazing!

Thanks to the Velvet Grill Diner for keeping our coffee cups filled.

We'd also like to thank our friends and families for pretending to be excited about mealybugs and viruses as we showed them "cool" photos and sent countless nerdy text messages. Instead of my Mom calling and asking, "How's the weather?" she now says, "How are the mealybugs?"



Mike Klouda gets excited when he finds a juvenile Cryptolaemus *beetle on a grapevine, after releasing adult beetles earlier. Photo by Stephanie Bolton.*

RECORD KEEPING

because you have a lot going on in that beautiful head of yours

Keep planting records (for traceability), record vine mealybug infestation levels, monitor beneficial insects, write down virus testing results, get your neighbor's phone number…