Integrated Pest and Pollinator Management for California Wine Grapes

Flowering habitat in vineyards will support predatory insects such as lady beetles (center) and can play an important role in managing winegrape pests such as vine mealybug and leafhoppers. (Photos: Xerces Society.)

Integrated Pest and Pollinator Management, or IPPM, is a strategic framework for managing pests while protecting pollinators. As its name implies, IPPM takes the core principles and practices of Integrated Pest Management (IPM) and adds specific considerations and strategies for protecting pollinators. The foundations of IPPM include conservation biological control, scouting and monitoring, identifying evidence-based treatment thresholds, and practicing non-chemical management strategies to reduce reliance on and use of pesticides.

The first of these, conservation biological control, 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 service 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 some pest populations below damaging thresholds without the use of chemical intervention. This ecological approach to pest management seeks to integrate beneficial insects back into crop systems for natural pest control. This strategy is based upon ongoing research that demonstrates a link between the conservation of natural habitat and reduced pest problems on farms. For example, a recent Xerces study in California cropping systems, funded by the U.S. Department of Agriculture Natural Resources Conservation Service, found that on-farm habitat areas such as cover crops and hedgerows supported twenty-five times as many beneficial insects as control sites without such habitat features. The estimated value of pest control by wild natural enemies of crop pests is \$4.5–\$12 billion annually for crops in the United States, and \$100 billion worldwide.

Developing and implementing a robust scouting or monitoring protocol in combination with evidence-based treatment thresholds is also critical to IPPM. This practice ensures that treatment decisions are based on insect population or disease infection levels in real time. When combined with identified treatment thresholds, scouting provides the data

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necessary to make informed decisions. Such thresholds are sometimes defined internally by a vineyard manager, but there are also thresholds for specific pests or diseases that have been developed by pest management specialists and adopted broadly. Both scenarios are included in this document, as are sample monitoring protocols and thresholds for common vineyard pests in California.

Non-chemical pest management practices that disrupt pest and disease life cycles and prevent pests from reaching treatment thresholds are an integral part of IPPM. These practices could include cultural practices such as good vineyard sanitation, culling diseased or insect-infested plants, or planting resistant varieties. It could also include adopting practices such as habitat to support natural enemies of crop pests or utilizing mating disruption. Appendix B includes a list of examples of non-chemical pest management practices for wine grape pests.

This document includes information on assessment and non-chemical management of some of the most common pests in California vineyards. For each pest, we identify recommended monitoring protocols, decision support and economic treatment thresholds, and non-chemical management strategies. These protocols and treatments can help reduce the use of chemical pesticides, and, if adopted, can help growers meet the standards for Bee Better Certified (BBC; beebettercertified.org).

A primary source for information contained in this document is the University of California Statewide Integrated Pest Management Program (ipm.ucanr.edu). For each pest, other reliable sources are included as applicable. The protocols, thresholds and management strategies outlined below, when applied appropriately, meet the BBC certification standards for reduced pesticide risks to bees and other pollinators. The pests addressed in this document have been identified as some of the most problematic in several major wine grape growing regions of California, but this list is by no means exhaustive.

About this Publication

- The information in this publication is organized by pest or pathogen.
    1. Powdery mildew (*Erysiphe necator*)
    2. Vine mealybug (*Planococcus ficus*)
    3. Leafhoppers (various species)
    4. Botrytis bunch rot (*Botrytis cinerea*)
    5. Spider mites (various species)
- References and further resources for each pest are listed at the end of the relevant section. There are also a number of appendices containing additional information.
- Growers may use this information to inform their scouting and monitoring protocol, action treatment threshold, and non-chemical management strategies, as well as to help develop their Pesticide Risk Mitigation Plan (PRMP).

1 Powdery Mildew *(Erysiphe necator)*

Powdery mildew (*Erysiphe necator*) is a major contributor to yield and quality loss in California wine grapes, and is the primary driver for fungicide use in this cropping system across the state. Powdery mildew infects upper and lower leaf surfaces and can colonize the entire surface of developing berries. The fungus overwinters as mycelia inside dormant buds or as chasmothecia (spore producing fruiting bodies), typically the main source of overwintering inoculum.

Heavy fungicide use for powdery mildew and other diseases can negatively impact beneficial insect activity in vineyards. About 90% of California grape acreage is treated with sulfur each year, with millions of pounds applied annually by both conventional and organic growers. Typical management for powdery mildew involves applying fungicides multiple times per year from bud break to when berries reach ~12 Brix to control inoculum and subsequent infection. Organic growers rely on biological fungicides and sulfur, while conventional growers will also typically apply demethylation inhibitor (DMI) fungicides, strobilurins, and quinolines in their fungicide rotation. Some of these fungicides may have direct toxic impacts on pollinators, while others may interact with other stressors to reduce pollinator health. Certain fungicides can synergize the toxicity of some insecticides, increasing the toxicity of the insecticides to bees and other beneficial insects. For example, DMI fungicides, which include the azole fungicides, have been found to synergize the toxicity of pyrethroid and some neonicotinoid insecticides to bees (May et al. 2019).

Scouting and Monitoring

On warm winter and spring days when moisture is abundant, ascospores are released from fruiting bodies (chasmothecia) that have overwintered. The ascopores stick to leaves, germinating on the underside. Infection occurs when the wetness period is followed by 10–13 hours of leaf wetness and temperatures remain between 50° and 80°F.

The University of California Statewide Integrated Pest Management Program (UC IPM 2015) recommends monitoring 7–10 days after this initial infection for the presence of powdery mildew by (1) collecting 10–15 basal leaves from approximately 20 vines at random and (2) examining the undersurface for powdery mildew spores. If lesions are found, then monitor disease development by using the powdery mildew risk assessment index (see next section).

Decision Support and Treatment Threshold

To determine if and when treatment is necessary, use the risk assessment index (RAI) described on the University of California IPM program's web page, Grape Pest Management Guidelines: Powdery Mildew (UC IPM 2015). The RAI is based on the Gubler-Thomas model, and uses the relationship between temperature, humidity, and ascospore release to predict initial disease onset. Once infection has occurred, the model switches to a disease risk assessment phase based on ambient temperature (temperature influences the reproductive rate of the pathogen) and recommends spray intervals and material choice, based on the index value.

- RAI values by geographic area can be viewed on a daily basis at https://www2.ipm.ucanr.edu/weather/grape-powdery-mildew-risk-assessment-index/.
- Treatment may be discontinued for wine grapes when fruit reaches 12 Brix.

Monitor temperatures in your own vineyard and calculate the RAI using the rules presented in the UC IPM powdery mildew guidelines (https://www2.ipm.ucanr.edu/agriculture/grape/powdery-mildew/), or use weather equipment that has the index included in its software. Using localized on-farm weather monitoring improves the precision of fungicide applications for powdery mildew, and can potentially reduce the number of treatments over the growing season. Regular scouting for mildew can also help stretch treatment intervals if disease pressure is low.

On the next page is a sample powdery mildew monitoring protocol that incorporates the RAI and the use of sulfur, the chemical product most commonly utilized to manage the disease. The recommended spray interval is based on the risk index (predicted disease pressure), but the timing will vary depending on the type of fungicide applied. The UC IPM powdery mildew guidelines (see link above) include recommendations for resistance management. It is followed by a sample powdery mildew monitoring record template, based on the RAI.

Sample Powdery Mildew Monitoring Protocol (incorporating Risk Assessment Index and use of sulfur)

Crop	Pest / Disease	Sulfur Application Action Threshold	Threshold Source	Monitoring Start Date	Monitoring End Date	Monitoring Frequency
Wine grapes	Powdery mildew	Points System: 0–30 points (low disease pressure) = spray @ 14–21-day interval 40–50 points = spray @10–17-day interval 60 or above = spray @ 7-day interval	UC IPM Grape Powdery Mildew Model ("Gubler-Thomas model"). Use on-farm data loggers to record and track weather	Post bud break, 55°F + 100% humidity	Veraison (softening and coloration of berries)	Daily (weather data). Once mildew spotted: weekly scouting

Sample Powdery Mildew Monitoring Form

Powdery Mildew Monitoring Form

Farm name:

Location (if relevant):

Crop: Winegrapes

Date	Temperature	Risk Assessment Index (# points)*	Recommendations

* as per Gubler-Thomas model

Non-Chemical Management Strategies

To reduce inoculum levels in existing vineyards, consider implementing the following strategies:

- Improve airflow through the canopy to reduce humidity and increase exposure to UV light. Techniques include shoot positioning, foliage trimming, and manual or mechanical removal of leaves from around bunches (DEPI 2010).
- Remove leaves around the clusters at berry set (as done for *Botrytis* control). This can result in 50% disease control (UC IPM 2015). Exposing the clusters early in the growing season by removing four to six basal leaves on every cane causes the cuticle of the fruit to thicken, which helps to resist mildew infections (McGourty 2008). Leaf removal also improves airflow, sunlight, and spray penetration around the cluster, all of which improve disease control.
- Avoid overwatering and overfertilizing. Excessive water and nitrogen both result in lush, soft growth, which is very susceptible to powdery mildew. Overwatering also contributes to higher humidity levels, which may promote powdery mildew development. High nitrogen status increases the susceptibility of vine leaves to powdery mildew, an effect that is more pronounced when combined with low UV light levels (DEPI 2010).
- Monitor damp areas of the vineyard and prevent standing water (Whitted, n.d.).
- Remove flag shoots early in the season. This reduces the impact of powdery mildew by helping to minimize early spore production. Monitor the vineyard closely from budburst onwards, particularly during the third to fifth weeks after budburst. Any flag shoots that are detected should be cut off (DEPI 2010).

When planning new vineyard blocks, consider the following strategies:

- Plant a less-susceptible variety (e.g., Petite Sirah, Zinfandel, Semillon, or White Riesling). Hybrid and transgenic varieties of grapes resistant to powdery mildew are also under development (Fuller et al 2014) and could significantly reduce fungicide inputs for this disease, but non-vinifera varieties can pose labeling challenges for wine producers.
- Face row ends into the prevailing wind to help reduce humidity levels within vine canopies by increasing air movement around the vines (DEPI 2010).

Additional Recommendations:

- Sulfur dust is toxic to some important beneficial insects and mites, and it may encourage damaging populations of spider mites (McGourty 2008). Sulfur dust is also susceptible to off-site movement by wind. Wettable powder formulations can reduce drift and off-site movement of sulfur relative to dust, and may be less toxic to beneficial insects and mites than dust formulations (Zhang et al. 2012).
- For all pesticide applications, calibrate nozzles on your sprayer to ensure that you are applying the appropriate amount at the correct rate. Adjust droplet size, angle, and airflow to improve crop coverage and reduce off-site drift (Schilder 2014).
- If applying fungicides for powdery mildew or other diseases within 3 days of an insecticide application, check for potential synergism of toxicity between fungicide and insecticide classes using the Bee Precaution Pesticide Ratings tool (UC IPM 2018).

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2 Vine Mealybug (*Planococcus ficus*)

The vine mealybug (*Planococcus ficus*) is a major pest in vineyards throughout California, and can be present year-round on vines depending on the region. Vine mealybugs feed on phloem, piercing the trunk, canes, and berry clusters and causing economic losses for vineyards from physical damage, fouling fruit and leaves with honeydew, and from vectoring grapevine leafroll-associated viruses.

The vine mealybug tends to overwinter on root systems in regions with sandy soils, but in the North Coast, due to the region's heavier soils, will overwinter as nymphs under the bark of grapevines. Coastal regions may only have two to three generations of vine mealybug per year, compared to five to seven in the southern San Joaquin Valley, which sees outbreaks earlier in the year than other California regions. Biological control varies by region.

Vine mealybugs are one of the key pests in California wine grape production that can trigger use of insecticides highly toxic to bees and other beneficial insects. Conventional management for vine mealybugs typically involves one to three insecticide treatments per year, depending on pest densities. Common treatments include a bloom application of a systemic insecticide, an early or late-spring application of an insect growth regulator (IGR), a pre-harvest application of a systemic insecticide or insect growth regulator, and/or a post-harvest insecticide application. IGRs can pose risk to larval pollinators upon ingestion, and systemic insecticides commonly used for vine mealybug management, such as neonicotinoids and spirotetramat, are highly toxic to bees upon contact or ingestion.

Guide to Seasonal Monitoring and Resources for Vine Mealybug

Season	Monitoring Location	Looking for:	Resources
Winter (dormant through budbreak)	Lower crown, creases in the trunk, on the roots in areas with sandy soils	All life stages	UC IPM Grape—Delayed-Dormant / Budbreak Monitoring Form (See resources at end of section.)
Spring (after budbreak)	Crown and trunk, cordons, canes, basal leaves	Adult females and crawlers moving up the vine	UC IPM Grape—Insect and Spider Mite Monitoring Form (See resources at end of section.)
Summer (especially after veraison)	Clusters and all plant parts (trunk, cordons, canes, basal leaves). Look for ants and honeydew to see where VMB may be present.	All life stages	UC IPM Grape—Insect and Spider Mite Monitoring Form (See resources at end of section.)

Scouting and Monitoring

Monitor for vine mealybug (VMB) by doing searches on the roots, trunk, cordon, leaves, and clusters. Detailed monitoring procedures on the vines—where to look, what to look for, and frequency of monitoring—vary as the season progresses. Male and female VMB look quite different: males are winged and very tiny, while females are larger and wingless. Adult females are the easiest to monitor and identify on vines, but can be difficult to distinguish from other mealybug species without a hand lens. The most obvious distinguishing feature is that while other mealybug species have long "tails" (caudal filaments), the vine mealybug only has short, uniform filaments around the outside of its body that do not look like tails.

- More information on identifying VMB can be found at http://ipm.ucanr.edu/PMG/C302/mt302bpmealybug.html.

Pheromone traps can also be used to determine the presence of male mealybugs throughout the season, and are most effective when placed in the vineyard early in the spring and monitored regularly (by April 1 in the southern San Joaquin Valley, by May in areas further north, and by June in the North and Central Coast region). Follow the pheromone trapping recommendations from UC IPM (2019a).

Vine mealybug is cryptic and may be confused with fungus, so identification must be done under a microscope or with expert support.

- Video supports are available in English and Spanish on the website of Napa County UCCE at http://cenapa.ucanr.edu/Napa_County_Programs/Viticulture/Vine_Mealybug/.
- There is a bilingual adult female VMB identification poster available for the field is available at https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=20899.
- A male VMB identification sheet for use with a microscope is available at https://cesonoma.ucanr.edu/files/27218.pdf.
  - If males are found, locate infestations with visual scouting.

Monitoring for VMB can begin during bloom or when temperatures reach 65°F and above. Once a week, select 20 random vines in each block of the vineyard to scout for mealybugs. This protocol can be combined with scouting for leafhoppers and mites. For the best estimate of pest distribution, monitor fewer vines in more locations (e.g., divide the block into quadrants and scout five vines per quadrant; each scouted vine should be a few vines in from the end of the row). Be sure to include any areas where these pests have been detected in the past.

- This monitoring protocol can be used with the UC IPM Grape—Insect and Spider Mite Monitoring Form, available at http://ipm.ucanr.edu/PMG/C302/grape-leafhoprmite.pdf.

Observing ant activity can help locate vine mealybugs, as Argentine and gray ants tend VMB in order to harvest honeydew from the mealybugs and leaves. Honeydew may also be an indication of VMB presence, as VMB produce more honeydew than other species of mealybugs that may be present in vineyards. During summer, look for honeydew exudates on the clusters, trunk, and cordons. These exudates will resemble melted candle wax; if the infestation is severe, basal leaves will appear shiny and sticky.

Consider monitoring for the presence of beneficial natural enemies and also for mealybug mummies, the remains of dead VMB that indicate the activity of parasitoids in the vineyard. Specifically, mealybugs can be parasitized by *Anagyrus pseudococci*, a solitary wasp. Using a hand lens, observe mealybugs for signs of parasitism such as exit holes or desiccated adult mealybugs. Also monitor for the presence of the mealybug destroyer (*Cryptolaemus* sp.), a type of lady beetle that is a voracious predator of VMB.

In addition to monitoring established vines, any incoming nursery stock for new plantings should be inspected upon arrival before planting.

Training vineyard crews to notice and report VMB at different life stages across the season can be very helpful for quick responses to hot spots (Grandperrin 2022).

Decision Support and Treatment Threshold

The level of treatment varies greatly depending on the region, type of grape, and harvest date. Wine grapes can tolerate low levels of vine mealybug. Decisions about the level of mealybug control need to be made on a vineyard-by-vineyard basis.

Vine mealybug scouting can occur in conjunction with monitoring for other arthropods. UC IPM (2019a) provides integrated directions for scouting and treatment thresholds on forms customized by plant growth stage (see table above with links to forms for dormant / budbreak scouting and weekly scouting after bloom).

Non-Chemical Management Strategies

- Mealybugs are often tended by honeydew-seeking ants (*Linepithema* and *Formica* spp.), so managing ant populations can significantly reduce mealybug infestations. Tilling the soil for weed control can disturb ant nesting and reduce their populations. Planting a cover crop of common vetch, which has abundant nectar supplies, may help attract these pest-tending ants away from grapevines, leaving mealybugs and scale insects exposed to parasitic wasps and predators (UC IPM 2019b). For chemical control, spot applications of baits at the entrance of ant nests is the most targeted approach.
- Sanitation of shoes, clothing, and equipment is an important practice, since the wingless female and nymphal mealybugs are unable to fly, but may be carried by humans and equipment. Remove any soil, debris, or insects from shoes with a stiff-bristled brush when leaving the infested block(s) prior to entering a non-infested block. Equipment should be thoroughly cleaned of soil, plant debris, and insects by the best available means, such as steam-sanitization or with a hot water and detergent solution sprayed with a high-pressure power washer. Cleaning should occur before equipment is moved from any infested block(s) to any non-infested block. All vegetative material and debris (such as vine prunings) resulting from any cultural practices performed within an infested block should remain within the block (Clark, n.d.).
- Mating disruption is an option, and is most effective when applied over at least 10 acres. Greater success has been achieved in northern California, where there are fewer generations of vine mealybug per year (UC IPM 2019a). Field trials with high-density pheromone dispensers achieved significant reductions in VMB damage at medium to high density of pheromone emitters (175+ emitters per acre) and demonstrated reductions in grapevine leafroll-associated viruses in vineyards (Kurtural 2014). Where coordination with neighbors is possible, area-wide management with mating disruption may be achieved across multiple small vineyards (Hogg et al. 2021). Mating disruption can be paired with targeted insecticide applications to increase control of VMB while reducing

overall insecticide inputs.

- An imported parasitoid wasp, *Anagyrus pseudococci*, is the dominant natural enemy of vine mealybug throughout the state and can be highly effective for late season mealybug control; *A. pseudococci* is only active after early May, so it does not provide good early season control. This wasp species is also most effective for control of exposed mealybugs, as it does not effectively forage under the vine bark or in the roots where mealybugs overwinter (Daane et al. 2008).
- Several lady beetles, such as the mealybug destroyer (*Cryptolaemus montrouzieri*) and those in the genus *Hyperaspis*, attack vine mealybug eggs and crawlers. Larvae of predaceous midges (family Cecidomyiidae) feed on mealybug eggs. Daane et al. (2008) note numerous resident natural enemies for various mealybug species, including lacewings (family Chrysopidae) and minute pirate bugs (*Orius* spp.). Many existing natural enemies present were originally imported for use in control of other mealybug species (most of which are also exotic).
- Reduce cluster infestation by pruning vines to prevent clusters hanging directly on the cordon.
- In areas where mealybugs overwinter exclusively on the roots, band application of Tanglefoot onto duct tape that has been wrapped around the trunk may help slow crawler movement up the vine in the spring (UC IPM 2019a).
- To reduce contamination, cover all pomace piles with clear plastic for several weeks, and avoid creating piles that consist predominately of stems (Clark, n.d.; Daane et al. 2008).
- If only a portion of the vineyard is affected, start any management practice such as pruning or harvest in blocks that have no known virus or mealybug infestation to avoid cross-contamination (Hansen 2009).
- If establishing new blocks, keep in mind the date of maturity. According to Daane et al. 2008, early maturing varieties are much less likely to experience serious fruit damage than late-maturing varieties because mealybug populations tend to increase with each new generation.

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Available at http://ipm.ucanr.edu/PMG/C302/grape-spurmonitor.pdf.

UC IPM Grape—Insect and Spider Mite Monitoring Form (for leafhoppers, spider mites, and mealybugs, as well as leafhopper egg parasitism and mite predators).
Available at http://ipm.ucanr.edu/PMG/C302/grape-leafhoprmite.pdf.

3 Leafhoppers (various species)

Leafhoppers (Hemiptera: Cicadellidae) lay their eggs in grape leaf tissues and feed on foliage as nymphs and adults. Feeding by leafhopper nymphs and adults causes stippling of grape leaves which can reduce vine productivity and ultimately affect crop yield and fruit quality, and less shoot growth the following season (UC IPM 2019). However, low levels of leafhoppers can often be tolerated in vineyards and leafhopper populations can be effectively managed by natural enemies.

Several leafhopper species are present in California wine-growing areas; certain species of leafhopper are more strongly associated with particular regions and may include:

1. Virginia creeper leafhopper (*Erythroneura ziczac*)
2. Western grape leafhopper (*Erythroneura elegantula*)
3. Variegated leafhopper (*Erythroneura variabilis*)

The information compiled here is relevant to all three leafhoppers present in wine-grape growing areas.

Treatment thresholds for leafhoppers vary by species, generation, region, and level of parasitization by parasitic wasps (*Anagrus* spp.). If leafhoppers reach damaging levels, common treatments in conventional wine grapes include an insect growth regulator (e.g., buprofezin) or a foliar or soil application of a neonicotinoid. Organic wine producers may apply the insect growth regulator azadirachtin, the contact insecticide pyrethrin, the barrier treatment of kaolin clay, or insecticidal soap or narrow range oil for small infestations. Insect growth regulators can pose risk to larval pollinators upon ingestion, and neonicotinoids are highly toxic to a variety of beneficial insects upon contact or ingestion. Pyrethrin is also highly toxic to bees and some other beneficial insects upon contact.

Scouting and Monitoring

Begin sampling for leafhoppers 2–4 weeks after budbreak, or whenever nymphs first appear, and continue to sample every 7–10 days until leaf-fall or harvest. Randomly select 20 vines in each block of the vineyard, each at least a few vines in from the end of the row. If blocks vary greatly in size, make sure that vine sampling is representative across block acreages. Locate and count nymphs on the underside of leaves as described below. Record counts by species on a monitoring form as follows:

- **First-generation nymphs**—On each vine, choose one leaf at the third or fourth node up from the basal node.
- **Second- and third-generation nymphs**—Choose young but fully expanded leaves in middle of canes.
- Check the leaves for red, parasitized eggs or eggs with emergence holes.

Continue monitoring weekly until harvest. Starting at bloom, combine leafhopper monitoring with monitoring for spider mites and mealybugs.

Decision Support and Treatment Threshold

According to UC IPM (2019), healthy vines can tolerate fairly high populations without harm, and predators and parasites may be able to maintain leafhopper populations below tolerance levels. However, in coastal regions and the Central Valley, grape leafhopper populations may occasionally reach damaging levels and require treatment. Economic control by egg parasites may be less likely for populations of the variegated and Virginia creeper leafhoppers than for the grape leafhopper.

- For the first generation, treatment is not necessary if 20 or fewer nymphs per leaf are found. If parasitized eggs are present, avoid treatments unless leafhopper numbers are significantly above 20 nymphs per leaf.
- For the second and third generation, treat if there are 15–20 or more nymphs per leaf. Coastal vineyards with low incidence of parasitism and small canopies may have a threshold of 10 or more nymphs per leaf.

UC IPM (2019) recommends delaying any chemical control of leafhopper until the second (summer) brood to allow for egg parasitism to reduce populations. If treatment thresholds are exceeded in the first generation, wait until more than half the nymphs are in the third instar; this allows sufficient time for most eggs to have hatched.

Non-Chemical Management Strategies

- Remove basal leaves or lateral shoots during berry set and the 2-week period following (before the first generation of adult leafhoppers emerge), as recommended for Botrytis bunch rot management, will normally reduce peak leafhopper populations during the season by 30–50% (UC IPM 2019).
- Increase and maintain habitat for a range of natural enemies, including spiders, green lacewings (*Chrysopa* spp.), minute pirate bugs (*Orius* spp.), lady beetles (*Hippodamia* spp.), black hunter thrips (*Haplothrips* spp.), and predaceous mites, which help to provide control of leafhopper populations. The predaceous mite *Anystis agilis* is an important predator of first instar nymphs especially in the North Coast (UC IPM 2019). While some sources suggest maintaining vegetative cover in rows and alleyways can increase adult leafhopper populations in vineyards, a study in a North Coast organic vineyard found that maintaining flowering cover crops between rows increased predator and parasite populations and kept leafhopper densities low on adjacent vines (Nicholls et al. 2000; Altieri et al. 2005).
- The egg parasites *Anagrus erythroneurae* and *A. daanei* are the most common *Anagrus* spp. parasitoid wasps found in California vineyards during part of the season. These wasps may be more abundant in vineyards that are adjacent to prune, plum, and almond orchards, and near riparian areas where other leafhopper species, which overwinter in the egg stage, reside. These non-vineyard pest species of leafhopper could serve as alternate hosts for the beneficial *Anagrus* parasitoids, thus restored riparian areas adjacent to vineyards could be of special value. *Anagrus* activity coupled with basal leaf removal may preclude the need for insecticide treatment, even when leafhoppers exceed the treatment thresholds (UC IPM 2019).
- The predaceous mite, *Anystis agilis*, is an important predator of first instar nymphs especially in the North Coast region. Although growers have experimented with releases of lacewings as leafhopper predators, control of economic populations has not been achieved in university field trials (UC IPM 2019).
- Weed removal in vineyards and surrounding areas before vines start to grow in spring can reduce adult leafhopper populations that might disperse to new grape foliage (UC IPM 2019).

Additional Considerations

According to UC IPM (2019), sulfur sprays applied for fungal control may be toxic to *Anagrus* spp. wasps.

References and Resources

Altieri, M. A., L. Ponti, and C. I. Nicholls. 2005. Manipulating vineyard biodiversity for improved insect pest management: case studies from northern California. *International Journal of Biodiversity Science & Management* 1(4):191–203.

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4 Botrytis Bunch Rot (*Botrytis cinerea*)

Botrytis bunch rot is a pathogen that occurs on a wide range of native and cultivated plants. In vineyards, *Botrytis* can cause tissue damage to vine leaves or stems as well as infecting fruit.

This pathogen is most prevalent in seasons and regions with prolonged warm, moist conditions caused by frequent spring rains. The *Botrytis* fungus overwinters in berry mummies on the ground or left hanging on the vine and in canes. After rain or irrigation, the sclerotia germinate and produce spores that are moved by air currents or splashing rain (UC IPM 2016). Symptoms of the disease include early shoot blight and browning / wilting of individual berries in clusters.

Removal of basal leaves can significantly reduce the incidence and severity of disease. Conventional management typically includes fungicide applications before rainfall at bloom and / or after veraison. Many of the fungicides recommended for use by UC IPM, including pyrimidines (e.g., cyprodinil) and demethylation inhibitors, may synergize the toxicity of insecticides applied for vineyard pests around the same time.

Scouting and Monitoring

During rapid shoot growth look for flagging (wilting) shoots or shoot tips. In almost all cases, infection occurs in the axils of leaf or inflorescence junctions with the main shoot; look for a lesion there. The infection results from water pooling in these crotches and remaining for a long duration, with a lesion at the node of the shoot. Flagging may be due to branch and twig borer, Botrytis bunch rot, or powdery mildew. Cut flagging shoots between the flaccid areas and the adjacent area with normal turgor. Brown discoloration on the cut surface is evidence of *Botrytis* (Bettiga & Gubler, n.d.; UC IPM 2016). From bloom to veraison, inspect leaves and shoots for signs of *Botrytis*. Also, inspect at harvest.

Decision Support and Treatment Threshold

The UC IPM Pest Management Guidelines do not specify a treatment threshold for *Botrytis* infection. Risk is weather-dependent, and cultural practices that reduce canopy density can influence pressure. Leaf removal (see below) may preclude the need for fungicides altogether if wet weather does not occur during bloom or late in the season (UC IPM 2016). Apply sprays only when environmental conditions conducive to the growth of the fungus are forecast. Fungicide applications before rain are more effective in reducing *Botrytis* infections than those applied after rain (Bettiga & Gubler, n.d.).

UC IPM describes two disease risk models for Botrytis (http://ipm.ucanr.edu/DISEASE/DATABASE/grapebotrytis.html). Model 1 (Broome et al. 1995) utilizes temperature and leaf wetness duration input variables, together with some additional considerations, and an output "Infection Index Value" which ranges from 0 to 1.0. Under this model, UC IPM reports that a typical threshold before applying a fungicide is 0.5 or greater, but that the threshold may be adjusted up or down depending on various factors such as the vineyard history with *Botrytis*, wine grape variety, and degree of fruit maturity.

The second model described at the UC IPM site uses the same input variables, but this model was not validated in the field and an action threshold is not presented.

Non-Chemical Management Strategies

- Remove clusters from vines at pruning to prevent inoculum from overwintering. Place removed clusters into the row middles where they can be incorporated into the soil. (Bettiga and Gubler, n.d.)
- Manage canopy density to increase air movement and lower humidity. Strategies include leaf removal around clusters, shoot positioning and thinning, sterile shoot removal, and lateral shoot removal.
- Removing basal leaves and lateral shoots immediately after berry set can result in significantly reduced incidence and severity of disease. When conducted immediately after fruit set, this practice can also physically shake off some of the floral debris that can be infected with *Botrytis*, reducing this source of inoculum. Leaf removal should be done on the side of the canopy that receives morning sun (east or north side) to reduce fruit damage from sunburn. In warmer areas, do not remove excessive numbers of leaves. Removing leaves immediately after fruit set (rather than after fruit begins to develop) allows berries to acclimate to the sunlight and develop a thicker cuticle that helps prevent sunburn as well as *Botrytis* infection (UC IPM 2016; Bettiga and Gubler, n.d.).
- Avoid unnecessary irrigation or nitrogen fertilization that promotes excessive canopy growth.
- As possible, prevent any physical damage to the fruit from birds, insects, or even previous powdery mildew infections, which may serve as an entry would for *Botrytis* infections (McGourty 2008).
- Resistant cultivars include: Cabernet Sauvignon, Merlot, Muscat of Alexandria, Rubired, and Ruby Cabernet (Bettiga and Gubler, n.d.).
- Thinning the crop so that grape clusters are not touching each other is recommended if favorable disease conditions are likely to occur (McGourty 2008).
- Promote cluster drying when preharvest rains occur (Bettiga and Gubler, n.d.).
- During bloom time, run an empty air blast sprayer or other blower to remove debris from the flowers (McGourty 2008).
- For three-wire California sprawl-type trellis systems, if wet weather is expected, cut canes just before harvest to improve air circulation for lower humidity in the canopy microclimate (McGourty 2008).
- Avoid irrigation that leads to free water on the vines and fruit for more than 15 hours, as well as excessive irrigation that can lead to dense canopy growth (Bettiga and Gubler, n.d.).
- Consider mulching or using green manures, which have been found to improve breakdown of overwintering mycelium in vineyards in Australia (Jacometti et al. 2010).

Additional Considerations

- Sorting and culling of damaged fruit should be done at the time of picking and again before the grapes are crushed by running the fruit across a sorting table, if necessary (McGourty 2008).
- If applying fungicides for *Botrytis* or other diseases within 3 days of an insecticide application, check for potential synergism of toxicity between fungicide and insecticide classes using the Bee Precaution Pesticide Ratings tool (UC IPM 2018).

References and Resources

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Available at https://www2.ipm.ucanr.edu/agriculture/grape/botrytis-bunch-rot/.

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5 Spider Mites (various species)

Spider mites can be a significant pest of vineyards, particularly in hotter inland locations. Heavy infestations can cause significant damage to vine leaves. Damage patterns and timing differ by mite species. Multiple sulfur applications for disease control can reduce predator mite populations that play an important role in preventing spider mite outbreaks.

Pacific spider mite (*Tetranychus pacificus*) is the primary pest mite species in the San Joaquin Valley and some coastal California grape-growing areas. The Willamette spider mite (*Eotetranychus willamettei*) causes early season damage in the Salinas Valley and Sierra Foothills production areas. In North Coast vineyards, Willamette spider mite can cause damage in early spring when shoot growth is delayed or later in the season in vines with small canopies.

Biological and cultural controls (e.g., reducing dust in the vineyard) are often adequate for controlling this pest. Chemical controls include a variety of miticides, some of which are highly toxic to bees (e.g., abamectin), as well as organic insecticides such as neem oil, narrow range oil, and insecticidal soaps. Neem oil has insect growth regulator activity that can harm larval pollinators upon contact or ingestion.

Scouting and Monitoring

Monitor for spider mites at least once during the delayed-dormant season and once at bud break, along with other insects, followed by weekly monitoring after bloom. Randomly select 20 vines in each block of the vineyard, each at least a few vines in from the end of the row. If blocks vary greatly in size, make sure that vine sampling is representative across block acreages. Mites are difficult to see, and you will typically notice plant damage before spotting the mites themselves. Use a 10x or 14x magnification hand lens for monitoring mites and mite predators more closely.

For delayed-dormant and budbreak monitoring, choose a spur on the basal portion of a cordon closest to the crown. Look under loose bark on spur tip for orange overwintering form of Pacific or Willamette spider mite.

- Example monitoring form available at http://ipm.ucanr.edu/PMG/C302/grape-spurmonitor.pdf.

Early in the season after bloom, on each of the 20 vines, choose one leaf between the second and fourth nodes. Note on the monitoring form (see below) if mites and mite predators are present (+) or absent (-).

- Example monitoring form available at http://ipm.ucanr.edu/PMG/C302/grape-leafhoprmite.pdf.

Later in the season, monitor the fourth expanded leaf back from the growing tip for the presence (+) or absence (-) of mites and mite predators using a hand lens.

Decision Support and Treatment Threshold

Delayed-dormant and budbreak monitoring do not have a treatment threshold, but are used to identify areas of concern for further monitoring during bloom.

Treatment thresholds are based on the ratio of mite predators to mites monitored on vines after bloom.

- Mite treatments are not necessary if the percent of leaves infested is below 50%.
- Between 50% and 75% infestation, treatment may not be needed if mite predators are frequent (predator–mite ratio = 1:10, up to 1:2).
- At moderate infestation (50–65% infested leaves), treat only if predators are rare (predator–mite ratio = <1:30) and the mite population is increasing rapidly.
- At heavy infestation (>75% leaves infested), treat unless there is a high or rapidly increasing ratio of mite predators to mites. Refer to the table below on treatment guidelines for more specific guidance.

Non-Chemical Management Strategies

- Spider mites thrive in hot, dry, and dusty conditions, including dust from sulfur applications. Take steps to

Treatment Guidelines for Various Combinations of Pacific Spider Mite Injury Levels and Predator–Prey Distribution Ratios in Thompson Seedless Vineyards

Pacific Spider Mite Injury Levels (% of leaves infested)	Predator–Prey Distribution Ratios			
	Rare (<1:30)	Occasional (1:30 to 1:10)	Frequent (1:10 to 1:2)	Numerous (>1:2)
Light (<50%)	Delay treatment to increase predators	Delay treatment	Treatment not likely necessary	Treatment not necessary
Moderate (50-65%)	Treat if population is increasing rapidly	May delay treatment to increase predation	Treatment may not be needed if the predator–prey distribution ratio is increasing rapidly	Treatment not necessary
Heavy (65-75%)	Treat immediately	May delay treatment a few days to take advantage of increasing predation	Treatment may not be needed if predators are becoming numerous	Treatment not necessary if damage is not increasing
Very heavy (>75%)	Treat immediately	Treat immediately	Treat immediately unless predator–prey distribution ratio is increasing very rapidly; carefully evaluate damage	Treatment may not be necessary if population is dropping because of very high (>1:1) predator–prey distribution ratios; carefully evaluate damage

reduce dusty conditions; for example, by maintaining vineyard floor vegetation or applying water to control dust along vineyard roads (UC IPM 2019).

- Many natural enemies, including several species of predatory mites, as well as the sixspotted thrips (*Scolothrips sexmaculatus*), spider mite destroyer lady beetle (*Stethorus picipes*), and generalist predators like minute pirate bugs (*Orius* spp.), bigeyed bugs (*Geocois* spp.), and lacewing larvae, can be highly effective in keeping spider mite populations below damaging levels. Different predaceous mite species present in the same vineyard may offer complementary control of mites on vineyard edges and centers (Prischmann et al. 2002). Avoid use of broad-spectrum insecticide and some fungicide applications—including sulfur—that disrupt biological control (Hanna 1997; UC IPM 2011; UC IPM 2019).

References and Resources

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List of Appendices

A. Bee Better Pesticide Risk Mitigation Plan (Template for Wine Grapes).

B. Sample Non-Chemical Pest Management Strategies for Vineyard Pests.

C. Sample Powdery Mildew Monitoring Form.

D Western US Wine Grapes: Opportunities and Threats for Beneficial Insect Conservation in California, Oregon, and Washington Vineyards.

E. UC IPM Grape—Delayed-Dormant/Budbreak Monitoring Form (for cutworms, mealybugs, ants, spider mites, and scale or thrips).

F. UC IPM Grape—Insect and Spider Mite Monitoring Form (for leafhoppers, spider mites, and mealybugs, as well as leafhopper egg parasitism and mite predators).

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Bee Better Pesticide Risk Mitigation Plan

Client Name

Farm / Ranch Name

Location (county, state)

PREPARED BY:

Name, Title

Organization

Table of Contents

Tables

How to use this plan

This document, the Pesticide Risk Mitigation Plan (PRMP), is intended to guide the completion of the Bee Better Certified Plan ('BBCP'), which must be submitted to Oregon Tilth, the third-party certifier. The information in this document is for internal use, to help farmers meet the pest management requirements for Bee Better Certification.

The sections below review the farm's current practices in relation to the applicable pest and pesticide Production Standards under Bee Better Certified.

Each section is formatted as follows:

BBC Standards

The relevant standard(s) are provided in italics.

Current Practices

This section describes the current farm management practices as applicable to the referenced standards.

Recommendations to Achieve Certification

If the current practices comply with the existing standards, that will be noted in this section. If the current practices are insufficient to achieve compliance with the standards, this section describes actions that should be taken in order to comply.

A. Overview of Farm: Crops and Pests

B. Preventative Non-Pesticide Management

Bee Better Certified emphasizes preventative management to reduce reliance on pesticides through three prongs rooted in traditional Integrated Pest Management:

- ensuring that farms regularly monitor for pests throughout the growing season using standardized procedures;
- ensuring that farms assess pest pressure against pre-defined economic thresholds; ensure that any pesticide use under BBC certification is justified via reference to these thresholds; and
- implementing preventative non-chemical pest management practices to reduce pest pressure.

'Integrated Pest and Pollinator Management for California Winegrapes' contains monitoring protocols, economic thresholds, and non-chemical management strategies for several major winegrape pests in California. This information has been drawn from UC IPM Extension and other credible sources and may be used to satisfy BBC requirements.

1. Pest Monitoring Protocol, Action Thresholds, and Record-keeping

BBC Standards

Standard 2.1.a. Develop a written pest/disease scouting and monitoring protocol and demonstrate that scouting and monitoring occurs regularly throughout the growing season on all certified acreage. [Note that a written scouting/monitoring protocol is only expected for insects, mites, and diseases that are treated or expected to be treated.]

Standard 2.2.a. There must be no unjustified use of pesticides employed against insects, mites, and diseases.

i. *A justified use must be supported by evidence that an economically-damaging pest or disease outbreak exists or has strong potential to exist.*
ii. *Farm-specific scouting and monitoring records can be used to demonstrate an outbreak. Additional documentation (e.g., extension publications, newspaper articles) that supports the severity of the issue may also be submitted.*

iii. *Documentation should provide evidence that an economic threshold has been exceeded. If no threshold is available, provide an expert opinion. Experts may include a certified pest control adviser, accredited crop consultant, extension agent, or other credentialed independent pest management specialist. Advice or recommendations from pesticide or seed company representatives is not considered sufficient evidence to justify pesticide use.*

iv. *Even if use is shown to be justified, growers must follow all other Bee Better Certified pesticide mitigation standards.*

Current Practices

Fill in tables below with current (Table 1a) and planned (Table 1b) monitoring protocols and action thresholds for pests that are treated or expected to be treated. All practices listed in Table 1b should adhere to BBC standards.

Table 1a. Current Monitoring Protocols and Action Thresholds

Crop	Pest/ Disease	Action Threshold	Threshold Source	Monitor Start Date	Monitor End Date	Monitor Frequency

Recommendations to Achieve Certification

Table 1b. Planned Monitoring Protocols and Action Thresholds to meet BBC Standards

Include any new activities or modifications of existing activities that will be adopted to meet standards.

Crop	Pest/ Disease	Action Threshold	Threshold Source	Monitor Start Date	Monitor End Date	Monitor Frequency

Additional Notes: *Explanation of modifications of current protocols or new protocols needed in order to meet BBC standards.*

Written scouting records for all pests outlined in the tables above (both current and new monitoring activities) must be submitted with the BBCP. These records must include: crop, pest, date, # counted or severity (e.g. low/ moderate/high), unit (e.g. per leaf, tree, or row), and whether the observed count triggers an action threshold, if one is available.

Note that the Standards do not require development of a monitoring protocol or action threshold for weeds.

Preventative Non-Chemical Management Practices

BBC Standards

Standard 2.1.d. Implement and maintain at least two (2) preventive non-chemical pest management strategies and one (1) more if fungicides are used during pre-bloom and/or bloom time. Fungicides may only be used on a crop during its pre-bloom or bloom-time if at least one non-chemical pest management strategy is used to directly address the fungal concern prompting the application(s).

i. Select strategies from the Bee Better Certified Non-Pesticide Management Strategies (Appendix J).

ii. Document all approved preventive non-chemical pest management strategies (refer to Appendix J for guidance) using the Non-Pesticide Management Record form

Current and Planned Practices

Fill in tables below with current and planned preventive non-chemical pest management strategies for pests that are treated or expected to be treated. Include any activities will be continued in order to comply with BBC standards and any new activities that will be adopted to meet standards. All practices listed should adhere to BBC standards.

Table 2. Current and Planned Non-chemical Management Strategies

Practice	**Current or Planned? (please note)**	**Description of how practice *is* or *will be* applied (where/when) including area affected (acres)**	**List target pest(s)/disease(s) and describe how practice reduces pest pressure**
Conservation cover (in perennial crop systems, maintain permanent ground covers of native grasses and forbs for weed control			

and natural enemy refuge)			
Beetle banks (establish bunch grasses to promote predatory ground beetles)			
Intercropping (with crops that are attractive or useful to beneficial insects)			
Timing of planting or harvest to avoid pest damage (including choice of crop maturity date)*			
Physical barriers (e.g., floating row covers, fruit bagging)			
Mechanical pest removal (e.g., hand picking, vacuuming, or pure water sprays to remove pests)			
Cultural practices to improve air flow (e.g., plant spacing, row orientation, pruning) *			
Trap cropping (note that flowering trap crops are not permitted to be			

sprayed during bloom)			
Crop rotation *			
Use of resistant varieties (for insect pest and disease control)†*			
Use of cover crops, green manures, and composts (for improved soil fertility)			
Mating disruption (including use of pheromone traps for pest reduction)			
Mulching, hand weeding, mechanical weeding, or grazing (for weed control)			
Mulching plant material (for disease control) *			
Sanitation – removal of debris/infested plant material *			
Sanitation - equipment *			
Eliminate alternate hosts or sites for pests and disease *			
Soil solarization (for nematodes, soil borne			

diseases, or weed seeds)			
Strip cropping (to disrupt pest movement)			
Late water (cranberries) *			
Other (please describe)			
Additional Preventive Practices (Physical, Cultural, Mechanical, or Biological)			

C. Prohibited Pesticide Applications

BBC Standards

2.2.b. During bloom for crops that are visited by or pollinated by insects, do not apply or allow to drift to any flowering plants (including weeds) products containing any pesticide rated as Level I under the Bee Precaution system maintained by the University of California Statewide Agricultural and Natural Resources IPM Program. See Appendix K.

2.2.c. Never apply within three days of one another pesticides that jointly may increase toxicity to bees.

i. *Use the online Bee Precaution pesticide rating tool from University of California Statewide Agricultural & Natural Resources Integrated Pest Management Program to determine if there is potential for a pesticide combination to increase toxicity (synergistic effects, designated by FRAC code) . See Appendix M for instructions.*

2.2.d. Do not use nitroguanidine neonicotinoids (clothianidin, dinotefuran, imidacloprid, and thiamethoxam).

i. *This ban includes the planting of treated seeds.*

2.2.e. Do not use genetically modified crops that express pesticides or are resistant to herbicides.

2.2.f. Do not use conventional soil fumigants (see appendix N).

Current Practices

To protect bees, Bee Better Certified (BBC) prohibits certain pesticide applications. Some applications are prohibited only during bloom. To assess compatibility of current pest management practices, recent Pesticide Use Records (PURs) should be reviewed and summarized in Table 3 (below), using information from Bee Precaution for rating classification for each of the active ingredients listed under PURS.

Table 3: Bee Precaution Analysis for Current Use Pesticides

Trade Name	Active Ingredient	Type (insecticide/ fungicide/ herbicide/ other)	Rating	Potential Synergistic Effects (y/n)	Used to Manage Against

Overview of Table 3: (Current Practices cont)

Neonicotinoids: *list any nitroguanidine neonicotinoids used*

Level 1 Pesticides: *list any Level 1 pesticides used* Please note that Lvl 1 sprays cannot be applied during crop bloom or in flowering temporary habitat areas (remove blooms prior to spraying).

Pesticide combinations that increase toxicity. *list any pesticides used with potential to interact synergistically with other pesticides.* Some pesticides interact, causing larger toxicity together than separately.

Recommendations to achieve certification *describe current pesticide use practices that do not meet certification standards, and / or any restrictions on current use.*

Once certified under Bee Better, continue to avoid all use of the prohibited pesticides, do not use pesticides rated as Level I by Bee Precaution during crop bloom, and do not use chemicals that may increase joint toxicity within three days.

If any pest management decisions are made that have not been assessed in this report please consult standards or Xerces staff to ensure there are no conflicts. If any new active ingredients are planned, review them against BBC Standard 2.2 before applying.

D. Minimizing Off-Site Movement of Pesticides

1. Aerial Applications and Calibration

BBC Standards

Standard 2.3.a.
Aerial pesticide applications are prohibited by the Bee Better Certification. There is an exception for aerial applications of fungicides if:

- *other application methods are not feasible,*
- *the crop is not in bloom,*
- *the fungicide is not prohibited during bloom by Standard 2.2.b, and*
- *a justification and drift prevention plan are prepared and adhered to.*

Aerial applications of fungicides are not allowed within 60 feet of non in-field certified pollinator habitat.

See Production Standards for more detail.

Standard 2.3.b. Calibrate application equipment according to manufacturer specifications at least on an annual basis.

Current Practices

Recommendations to achieve certification

2. Preventing Drift into Pollinator Habitat

BBC Standards

Standard 2.3.c.
Establish a pesticide-free buffer around permanent pollinator habitat.

i. *Spatial buffers in land that is controlled by the certified farming operation should meet the following minimum widths:*
   1) *40 feet for ground-based applications, except airblast.*
   2) *60 feet for airblast and aerial applications.*

   If spatial buffers consist of unsprayed section of crop field then the buffer must be clearly delineated via physical markers and/or GPS polygons.
ii. *Vegetative buffers (drift fences) of species that are not attractive to pollinators may be used instead of spatial buffers, or if spatial buffer distances cannot meet the above requirements.*
   1) *Vegetative buffers should be comprised of densely planted, small-needled evergreen species.*
   2) *Airflow must be maintained within vegetative buffers.*
   3) *Vegetative buffers should be designed to grow above spray release height. Until the buffer is above spray release height any pesticide applications on your property must be in accordance with the drift and runoff precautions on the label in order to minimize potential for movement into permanent pollinator habitat.*
iii. *Minimum width buffers are required within your own property. Where new permanent pollinator habitat is installed on your property a minimum 30-foot buffer must be set aside between the habitat and neighboring farms or land where insecticides are known or suspected to be applied (including insecticide-treated seed).*
   1) *If insecticide application practices on neighboring properties change, spatial buffer requirements around permanent habitat creation on your parcels can be waived, although when feasible, we recommend incorporating a vegetative buffer.*
iv. *Herbicides (except paraquat dichloride) may be applied within buffers.*

Current Practices

Recommendations to achieve certification *include recommendations for existing and planned permanent habitat areas and buffers*

E. Pesticide Use Within Permanent or Temporary Pollinator Habitat

1. Permanent Habitat

BBC Standard

Standard 2.4.a.

Do not use pesticides other than herbicides in designated permanent pollinator habitat.

i. Do not apply herbicides to plants in bloom, including weeds.

ii. Paraquat dichloride may not be used within permanent pollinator habitat.

ii. Use targeted herbicide applications only (e.g., spot spraying rather than blanket applications).

Current Practices

Recommendations to achieve certification *include recommendations for existing and planned permanent habitat*

2. Temporary Habitat

BBC Standard

Standard 2.4.b.

If a justified use must occur where in-field designated temporary habitat is in bloom and the chemical used is rated as Level I under the Bee Precaution system maintained by the University of California IPM Program (see Appendix K) the habitat must be mowed 24 hours prior to the application to disperse pollinators.

i. Herbicide can only be used in designated temporary habitat in a targeted manner to counter weeds of concern.

Current Practices

Recommendations to achieve certification *include recommendations for existing and planned permanent habitat*

F. Record-Keeping

For the final application to Bee Better, we will submit this completed plan and the following additional forms and records to demonstrate your intent to comply with the Bee Better Certified™ Pesticide Risk Mitigation Production Standards. Boxes checked indicate that the requirement has already been met.

All relevant forms can be found in the Document Center on the Bee Better website: http://beebettercertified.org/docs

Check boxes to indicate that these forms and records have been collected and are ready to submit to Oregon Tilth:

☐ Pest scouting and monitoring protocol form

This form should include any activities from Table 1a that will be continued in order to meet the standards, as well as the information in Table 1b. Protocol guidance can be found in Appendix I of the Production Standards.

☐ Pest scouting and monitoring record-keeping form

Submit monitoring form(s) that shows you will follow the protocol outlined above, and keep records of scouting to justify pesticide use for each of your identified pests (except weeds). Templates can be found in Appendix I of the Production Standards.

☐ Non-pesticide management strategy plan

The filled in Table 1b from this plan suffices to meet the requirement. Also see Appendix J of the Production Standards.

☐ Pesticide use records from the past 3 years

OPTIONAL:

☐ Additional evidence that can justify pesticide application

Additional evidence may include information from trusted sources such as professional crop consultants or crop advisors, USDA, Cooperative Extension, etc. Additional evidence should demonstrate that conditions on the farm are conducive to the targeted disease and or pest. Examples of acceptable evidence include scouting and monitoring records, documented damage exceeding pre-determined thresholds, degree day models, moisture and temperate records, or spore counts.

ADDITIONAL RECOMMENDATIONS FOR POLLINATOR PROTECTION (OPTIONAL)

This section describes any additional, **voluntary** management actions (for pest management and/or pesticide mitigation) above and beyond the BBC standards you can take to further protect bees and their habitat as a Bee Better Certified farm. Such actions are not required to achieve or maintain certification.

Scouting and monitoring

If not already part of your protocol, it is helpful to scout not only for insect pests, but also for indication that natural enemies are present.

Pesticide Use

The following measures are recommended, not required.

Appendix B

Sample Non-Chemical Management Strategies for California Grapes

Practice	Description of how practice *is* applied (where/when) including area affected (acres)	Target Pest(s)/Disease(s)
Conservation cover (in perennial crop systems, maintain permanent ground covers of native grasses and forbs for weed control and natural enemy refuge)	Border areas around vineyard are left vegetated, which decreases dust and increases humidity to create unfavorable conditions for pests. Maintains permanent cover of grass and clover between the vines. Areas managed to promote self-sowing and re-seeded as necessary. Reduces dust and increases humidity to create unfavorable conditions. This practice also provides habitat for natural enemies and decreases weed pressure.	Mites Mites, mealybug, leafhoppers, weeds.
Beetle banks (establish bunch grasses to promote predatory ground beetles)	Native bunch grasses are currently planted around the reservoir and other parts of the ranch to support predaceous ground beetles which prey on pest insects.	Vine mealybug, leafhoppers
Timing of planting or harvest to avoid pest damage (including choice of crop maturity date)	Harvest early when mite pressure is high to avoid chemical treatment. Harvest early if Botrytis detected in vineyard to avoid chemical treatment. Late season pruning to reduce danger of fungal infections. Time annual pruning to delay bud break, which decreases pest pressure.	Mites Botrytis Botrytis Powdery Mildew
Physical barriers (e.g., floating row covers, fruit bagging)	Netting over grapes to reduce predation	Birds
Mechanical pest removal (e.g., hand picking, vacuuming, or pure water sprays to remove pests)	Culling infections – hotspot removal of infected plant materials Water sprays to reduce mildew for small areas / hot spots	Powdery mildew, botrytis, vine mealybug Powdery mildew

Appendix B

Cultural practices to improve air flow (e.g., plant spacing, row orientation, pruning)	Leaf-pulling and canopy management throughout growing season throughout entire vineyard, designed to promote airflow around fruit clusters, increase sunlight on fruit, and to decrease humidity. All of this creates a less favorable condition for mildew. Hand pulling of older leaves, which are preferred by the pest Canopy thinning from Mid-May through Mid-July through strategic leaf pulling to improve the efficacy of any spray applications and reduce applications.	Powdery mildew Leafhopper Leafhopper
Use of resistant varieties (for insect pest and disease control)	Resistant rootstock utilized	Nematodes, phylloxera
Use of cover crops, green manures, and composts (for improved soil fertility)	Maintains cover of grass and forbs between the vines. Areas are managed to promote self-sowing and re-seeded as necessary. Provides habitat for natural enemies, creates competition with vines which reduces vine 'lushness' which reduces pest pressure, reduces dust and lowers vineyard temperatures which reduces pest pressure. Reduces weeds which reduces herbicide use.	Vine mealybug, leafhopper, powdery mildew, weeds
Mating disruption (including use of pheromone traps for pest reduction)	Pheromone traps / sprayables to disrupt mating	Vine mealybug
Mulching, hand weeding, mechanical weeding, or grazing (for weed control)	Mows cover crop and leaves as green manure / mulch. Grinds up grape vine prunings and uses them as mulch. Weed whacking and mowing, timed to discourage undesirable vegetation and avoid herbicide use	Weeds Weeds Weeds

Appendix B

	Sheep-grazing or hand-weeding cropped areas to reduce weed pressure and herbicide use.	
Mulching plant material (for disease control)	Mows cover crop and leaves as green manure / mulch. Grinds up grape vine prunings and uses them as mulch.	Mites
Sanitation – removal of debris/infested plant material	Culls (removes) whole vines or infested plant material from vineyard area.	Red blotch, leaf roll, powdery mildew, leafhopper, vine mealybug
Sanitation - equipment	Cleans equipment thoroughly after each use. Insect or disease hotspots are accessed / treated last to avoid contamination.	All
Eliminate alternate hosts or sites for pests and disease *	Removed Himalayan blackberry from riparian area as it can be an alternate host.	Glassy-winged sharp-shooter/ Pierce's disease
Other (please describe)	Manages fertility (keeps levels of N low), which decreases 'lush growth'	Leafhopper, vine mealybug
Other	Regular nutrition sampling of vines to maintain healthy plants Installed owl boxes and raptor perches throughout vineyard to increase natural predation	All Ground squirrels, pocket gophers

Appendix C

Sample Powdery Mildew Monitoring Form

POWDERY MILDEW MONITORING FORM			
Farm Name:			
Location (if relevant):			
Crop: Winegrapes			
Date	**Temperature**	**Risk Assessment Index (# points)***	**Recommendations**

* As per Gubler-Thomas Model

Appendix D

Western US wine grapes: opportunities and threats for beneficial insect conservation in California, Oregon, and Washington vineyards

Emily May
The Xerces Society for Invertebrate Conservation
Written February 2019, updated June 2022

Table of Contents

Executive Summary

This report summarizes opportunities for beneficial insect conservation in Western U.S. wine grape production given the risks of typical pest management practices. The report provides an overview of wine grape management in the major production regions of the Western U.S., including a discussion of primary pests and diseases, typical management activities, and differences by production region. The management summary is followed by a summary of basic conservation practices for beneficial insects and biodiversity in Western wine grapes, including some of the benefits and pitfalls for adoption of these practices in vineyards.

Key Findings

Intensive chemical management for insect pests and fungal diseases in conventional wine grape production in the western U.S. is likely to undermine the quality of habitat for beneficial insects in or near these vineyards. Several emerging insect pests – in particular, a few highly mobile or otherwise difficult to control disease vectors – trigger use of highly toxic insecticides at various times throughout the growing season in many conventional vineyards.

Pest and disease pressure and corresponding pesticide use patterns vary across western U.S. production regions. Fungicides are used heavily in all western grape growing regions for control of powdery mildew, *Botrytis*, and other fungal diseases. Nearly 90% of California's grape acreage is treated with an average of 10 pounds per acre of sulfur each year. Neonicotinoids are also commonly applied for control of mealybugs, leafhoppers, and sharpshooters. Regionally high populations of vine mealybugs and glassy-winged sharpshooters trigger particularly high use of neonicotinoids and organophosphates (mainly chlorpyrifos) in the southern San Joaquin Valley relative to other production regions in California.

However, pest management in wine grapes is not monolithic. There are growers in all western wine grape regions managing vineyards with fewer chemical inputs than the average conventional vineyard. Some production areas have a higher concentration of these growers due to lower regional pest pressure or a local culture of reduced-input farming. These communities of lower-input wine grape growers present the most promising opportunities for establishing high quality habitat for beneficial insects on or near vineyards. In California, pesticide use data by county suggests that the use of highly toxic insecticides in wine grapes is lowest in the Sierra Foothills region. In addition, the Willamette Valley (OR) and North Coast (CA) regions both appear to have communities of growers with minimal chemical intervention and strong interest in environmental sustainability.

Wine grape growers enrolled in existing sustainability certification programs with strong pest management requirements represent the lowest-hanging fruit for improving habitat for beneficial insects in western wine grapes. The certification programs with practice requirements most closely aligned with high-quality habitat conservation work include biodynamic and organic certification (all western states) and Low Input Viticulture and Enology certification (LIVE; Pacific Northwest). While other sustainability certifications in California wine grapes, such as the widely adopted Certified California Sustainable Winegrowing, include some requirements and incentives for reducing pesticide use, these programs generally allow more flexibility in pesticide use practices than the biodynamic, organic, or LIVE programs.

Growing consumer and producer interest in natural wines and soil health initiatives present new opportunities for beneficial insect conservation in vineyards. Natural wine, loosely defined as wine produced with minimal chemical inputs or additives, is a fast-growing sector of the U.S. wine market and production acreage for these minimal-input wines is expanding. In addition, strong grower interest in and government and foundation support for soil health practices have dovetailed to generate substantial momentum around soil health initiatives like California's Healthy Soils Program. Further exploration of these two high-profile production trends, including a careful look at the intersection of beneficial insect conservation with soil health, may provide a gateway to connecting with compatible growers to trial and scale up multi-purpose conservation practices in vineyards.

Threats to beneficial insect conservation in vineyards

A variety of bee-toxic insecticides and fungicides are commonly used in conventional wine grape production in the Western U.S. (Grimalt and Dehouck, 2016). Major insect pests typically managed with moderately to highly bee-toxic insecticides are detailed in the management sections below, but outbreaks of minor pests will also occasionally trigger the use of these insecticides. Heavy use of neonicotinoids, organophosphates, and a cocktail of strobilurin, DMI, and multi-site contact activity fungicides are likely to compromise the quality of habitat enhancements for beneficial insects in many conventionally managed wine grape vineyards.

In California, where pesticide use is tracked by crop and county, over 27 million pounds of active ingredient were applied to wine grape acreage in 2016, the most recent year of available pesticide use data. This represents the second-highest pesticide use (in total pounds of active ingredient applied) for any crop in California, behind only almonds.[1] Wine grape acreage treated with pesticides has steadily increased from the 1990s (Figure 1). Some of this increase is concomitant with increasing acreage planted in wine grapes, while some represents increasing use of pesticides – particularly insecticides and fungicides – on existing wine grape acreage. Per-acre insecticide use for mealybugs, leafhoppers, and Lepidopteran pests continues to increase.

[1] This metric cannot be used to compare pesticide load in grapes to other crops on a per-acre basis. Wine grapes are one of the top California crops in terms of total acreage. Sulfur, a heavy metal fungicide applied to most wine grape acreage, accounts for over 90% of the total pounds of active ingredient used in wine grapes (Zhang et al., 2013).

Appendix D

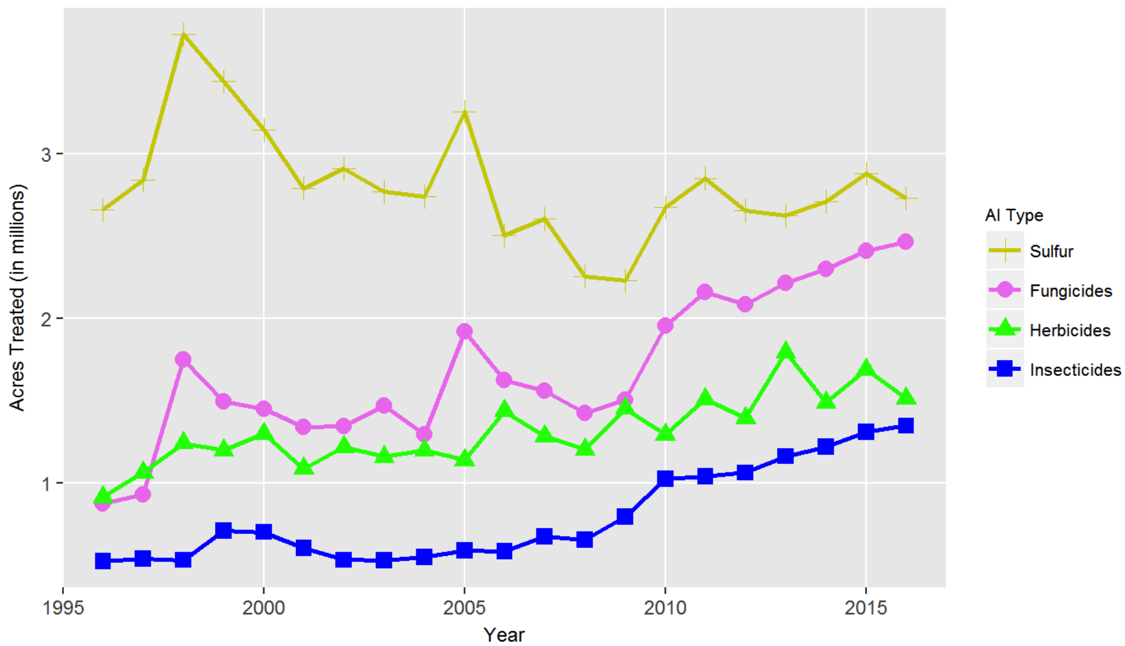

Figure 1. Acres of California wine grapes treated by all AIs in the major types of pesticides from 1996 to 2016. Figure from [California Department of Pesticide Regulation](). Data are available at ftp://transfer.cdpr.ca.gov/pub/outgoing/pur/data/.

Highly mobile disease vectors with a wide range of alternate hosts, such as sharpshooters and leafhoppers, present particular challenges for integration of pest management practices with beneficial insect conservation. Many vineyards apply highly toxic insecticides at the vineyard edge[2] to keep disease vectors out of vineyard blocks, presenting drift concerns for adjacent natural habitat. In coastal California, growers may manage riparian habitat to replace or remove natural vegetation that supports blue-green sharpshooters. The ability to succeed with beneficial insect habitat in a particular vineyard may depend on relatively low pressure from major pests in the local environment and the individual grower's commitment to and personal value placed on habitat conservation.

Vine mealybugs are one of the key pests that triggers use of highly toxic insecticides. Chlorpyrifos is sometimes used before budbreak and after harvest for these insects, while imidacloprid is commonly applied during warmer weather between budbreak and harvest. Both of these insecticides are most heavily used in Central Valley wine grape production, particularly the central and southern San Joaquin Valley, according to 2016 pesticide use data from the CA Department of Pesticide Regulation. North Coast vineyards tend to rely more heavily on pyrethroids for insect pest control, as the more clay-rich soils and limited irrigation in the region reduce uptake of neonicotinoids and other systemic insecticides. Use of highly toxic insecticides (neonicotinoids, organophosphates, pyrethroids, and carbamates)

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[2] It is possible some vineyards apply insecticides to adjacent weedy vegetation, as was anecdotally the case for alternate host vegetation for spotted-wing drosophila in Michigan blueberries, though this is illegal.

appears to be lowest in the Sierra Foothills wine grape acreage relative to Central Valley, Central Coast, and North Coast production areas in California.

Soil fumigation for grape phylloxera is common when replanting vineyards, but use patterns vary by region. In California, the North Coast had a lower proportion of total acres fumigated between 2001-2016 than the other major California grape growing regions, and significantly less than the southern San Joaquin or Central Coast regions (Downie, 2018).

Heavy fungicide use for downy and powdery mildew, *Botrytis* bunch rot, and *Phomopsis* cane and leaf spot is likely to negatively impact beneficial insect activity in vineyards. Powdery mildew drives multiple fungicide applications per year, including multi-site contact activity and DMI fungicides with risk of direct or synergistic toxicity to bees. Both conventional and organic growers apply millions of pounds of sulfur for powdery mildew in California wine grapes each year; sulfur accounts for over half of the total amount of active ingredient by pounds applied per year in wine grapes. About 90% of California's grape acreage (including table and raisin grapes) is treated with sulfur each year. Applications from bud break through bloom are common, especially in wet years.

Table grape and raisin production: lower thresholds, higher pesticide use

Table grapes and raisins are mainly produced in the southern San Joaquin Valley in flat vineyards. In general, these production systems do not appear to be a good opportunity for beneficial insect conservation in or near vineyard blocks. Table and raisin grape growers in the southern San Joaquin Valley tend to favor scorched-earth management/clean cultivation between rows. In addition, table grapes have low thresholds for action for some pests that are not a concern in wine grapes; for example, there is zero tolerance for black widow spiders (Bentley, 2009) and no allowance for mealybugs in the cluster, whereas wine grapes can tolerate low levels of mealybugs and do not treat for spiders. Pesticide use is likely to pose a greater risk to beneficial insects in conventional table grape production than in many wine grape production areas.

Conservation opportunities in Western US wine grapes

Natural wine: growing consumer demand for minimal-intervention wine production

While conventional vineyards applying neonicotinoids, organophosphates, and a cocktail of fungicides annually may be a challenging fit for high-quality habitat work, there are small pockets of sustainable production in California winemaking. The most notable hot spot for organic, biodynamic, and otherwise minimal-intervention producers is in Sonoma County. Many growers in this area have fostered a farming culture centered on environmental stewardship for decades.

In addition, in the past five years there has been an explosion of interest in 'natural wine,' loosely defined as wine made with minimal chemical and technological intervention in the vineyard and winemaking process. Wine shops and distributors in the Bay Area, Los Angeles, New York, Chicago, and D.C. cultivated strong consumer demand for artisan wines produced without pesticides in the vineyard or the addition of commercial yeast, tannins or acids, or filtration. Natural wine – a fringe community and farming philosophy in Europe and the US for decades – is now one of the hottest trends in wine production.

An influential producer in the North Coast region is Tony Coturri of Coturri Winery in Glen Ellen, CA, who has been making zero-additive wine in Sonoma County from grapes grown without pesticides since the 1970s. His winery has served as an educational hub for the minimal-intervention farming and winemaking philosophy, and many natural winemakers from across California apprenticed with Tony before founding their own wineries. His son Nic now runs Sonoma Mountain Winery. Other natural winemakers in Sonoma Valley, such as Côte des Cailloux and Caleb Leisure Wines, partner with Coturri Winery to process their wines.

Other notable natural winemakers include Donkey & Goat Winery in Berkeley, which does not grow its own grapes but works with organic and biodynamic producers in Napa County, Mendocino County, and the Sierra Foothills; Old World Winery (Russian River Valley, Sonoma County); Sky Vineyards (Napa Valley); La Clarine Farm (Sierra Foothills); and several long-standing organic and biodynamic vineyards and wineries in the small Willow Creek AVA in Humboldt County, CA.

Natural wine producers typically do not participate in conventional grower groups/industry associations – though they may apply for organic or biodynamic certification – and most information transfer is farmer-to-farmer. Many travel to Old World production areas (France, Italy) to learn and incorporate centuries-old production methods. The growing number of small-batch artisan winemakers represents an increasing acreage of vineyards with little to no chemical intervention, potentially a great opportunity for high-quality habitat work. What remains unclear is a) how willing and interested these growers will be in adopting production methods perceived as new or risky, and b) how to identify the subset of natural wine producers that may be most willing to adopt habitat enhancements for beneficial insects.

Intersection of soil health and biodiversity conservation

There is strong interest among wine grape growers in management practices that benefit soil health (e.g. reduce erosion, increase water holding capacity, improve soil nutrient availability, and increase soil organic matter/sequester carbon). Some of these practices have co-benefits for beneficial insects; for example, reduction of tillage and increases in resident vegetation or cover cropping in vineyard rows may improve conditions for soil-dwelling bees and other soil invertebrates.

With funding from the proceeds of California's greenhouse gas cap-and-trade program, the California Healthy Soils Program (HSP) Incentives Program provides financial assistance to farmers for implementation of conservation management practices that improve soil health, sequester carbon and reduce greenhouse gas emissions. Eligible practices include but are not limited to: cover cropping, no-till, reduced-till, mulching, compost application, and conservation plantings. This program has also funded research partnerships between universities and farmers to expand understanding of management practices that sequester carbon.

The North Coast Soil Hub is a partnership between Resource Conservation Districts, USDA NRCS field offices, University of California Cooperative Extension, Santa Rosa Junior College educators, industry organizations and associations, and farmers to build farmer-to-farmer information transfer and discussion networks around soil health practices. The program, which is coordinated by the Mendocino, Napa County, Sonoma, and Gold Ridge County RCDs, is currently conducting trials and demonstrations of conservation tillage for soil health and carbon sequestration in North Coast vineyards.

In addition to these programs, there are some large-scale producers, such as the Kendall-Jackson Family Winery in Sonoma County, that are currently investing heavily in research and demonstration trials of soil health practices.

Sustainable wine growing: existing certification programs

There are several existing sustainability certification programs for vineyards and wineries in the western U.S. The most widely adopted of these is the ground-to-bottle Certified California Sustainable Winegrowing certification administered by the California Sustainable Winegrowing Alliance. Not all certification programs are created equal in terms of beneficial insect protection; several are based on wide-ranging checklists of sustainability practices from vineyard management to winery business practices, allowing more flexibility on specific pest management requirements. However, existing programs with solid pest management requirements may be a good channel for locating growers interested in conservation practices for beneficial insects and vineyards where habitat could be placed with fewer concerns about pesticide risk. See *Appendix I: Table of Certification Programs* for more information on existing certification programs, including age, location, number of participants, and a description of standards.

California

In California, agroecological partnerships have emerged as semi-privatized extension initiatives. The California winegrape industry has invested time, money, and effort in agroecological partnerships to reduce agricultural pollution while enhancing the market value of their wine by branding it as ''sustainable" (Cullen et al. 2008).

The first major winegrowing sustainability program originated in Lodi, CA, in the Central Valley. The Lodi-Woodbridge Winegrape Commission developed a handbook of sustainability practices in the late 90s that evolved into the **Lodi Rules** and associated certification.

The Lodi sustainability program was followed by the founding of the California Sustainable Winegrowing Alliance (CSWA) in the early 2000s, a partnership between the Wine Institute and California Association of Winegrape Growers. CSWA created a **Sustainable Winegrowing Program** built around a similar workbook of sustainability practices from ground to bottle. This sustainability program and associated certification have seen widespread adoption among California winegrowers, beginning with a suite of large, influential growers. It is the largest sustainability certification program for California wine grapes, representing 25% of the total California acreage of wine grape production. For current lists of certified wineries and vineyards, see here. There are incentives for reducing use of highly toxic pesticides under this program, but the wide-ranging checklist of sustainability practices from ground to bottle allows growers the flexibility to apply high-toxicity pesticides such as chlorpyrifos if other sustainable vineyard management or business practices are adopted.

In the Central Coast region, the Central Coast Vineyard Team certifies vineyards under their **Sustainability in Practice** (SIP) program. This program has expanded out of state to Michigan grape growers.

A smaller set of California growers are **certified organic** (California Certified Organic Farmers) or **biodynamic** (Demeter USA). Both of these types of growers tend to incorporate cover cropping, compost additions, and other floor management practices that benefit soil health and insect populations. However, while some organic growers are highly reliant on sulfur and other organic fungicides, many biodynamic wine grape growers are fully pesticide-free. Both organic and biodynamic vineyards present opportunities for expansion of high-quality habitat for beneficial insects.

Pacific Northwest (Oregon, Washington, Idaho)

The main winegrowing sustainability certification in the Pacific Northwest is the **Low Input Viticulture and Enology (LIVE)** certification program, which partnered with **Salmon-Safe** to offer dual certification for growers that follow LIVE standards. LIVE certified vineyards implement a variety of habitat and pesticide measures to support biodiversity.

Walla Walla Vinea Sustainable Trust is a smaller certification program for eastern WA/OR and Idaho growers. The standards were adapted from LIVE standards to better fit the irrigation practices of the drier production regions east of the mountains.

There are certified **organic** and/or **biodynamic** wine grape producers in all regions of Oregon (Murray and DeFrancesco, 2016). Though acreage of biodynamic production remains low relative to LIVE certified acreage, there are a growing number of biodynamic producers in Oregon, particularly in the Willamette Valley. This is a promising region and set of growers for beneficial insect conservation.

Overview of Western grape management

Regions

California, which accounts for nearly 90% of US wine production, has three main wine grape growing regions: the Central Valley, Central Coast, and the North Coast, with smaller production areas in the South Coast and Sierra Foothills (Figure 2). Each of these regions contains at least one American Viticultural Area (AVA), or geographically distinct wine production area designated by the Alcohol and Tobacco Tax and Trade Bureau of the U.S. Department of the Treasury. The Central Valley is California's largest grape production region, accounting for nearly 75% of California wine grape production by volume. However, production value is higher in the North Coast and Central Coast regions.

Oregon has four main grape production regions: the Willamette Valley, Southern Oregon (including the Umpqua and Rogue Valley AVAs), Mid-Columbia Valley, and the Walla Walla Valley (Figure 2), as well as a smaller production area in the Snake River Valley in Eastern Oregon. Several of these regions overlap into production regions in Washington State and Idaho. The Willamette Valley is the dominant production area and contains the majority of the grape acreage and wineries in the state. About two-thirds of this grape acreage is planted with Pinor Noir varieties.

Washington State is the second-largest wine producing state behind California. Nearly all of Washington State wine grape production is located in the eastern half of the state in the Columbia, Yakima, and Walla Walla Valleys, with some isolated acreage in Puget Sound (Figure 2). Wine production has increased significantly over the past two decades in both Oregon and Washington, with the number of wineries in these states more than tripling since 2005.

Appendix D

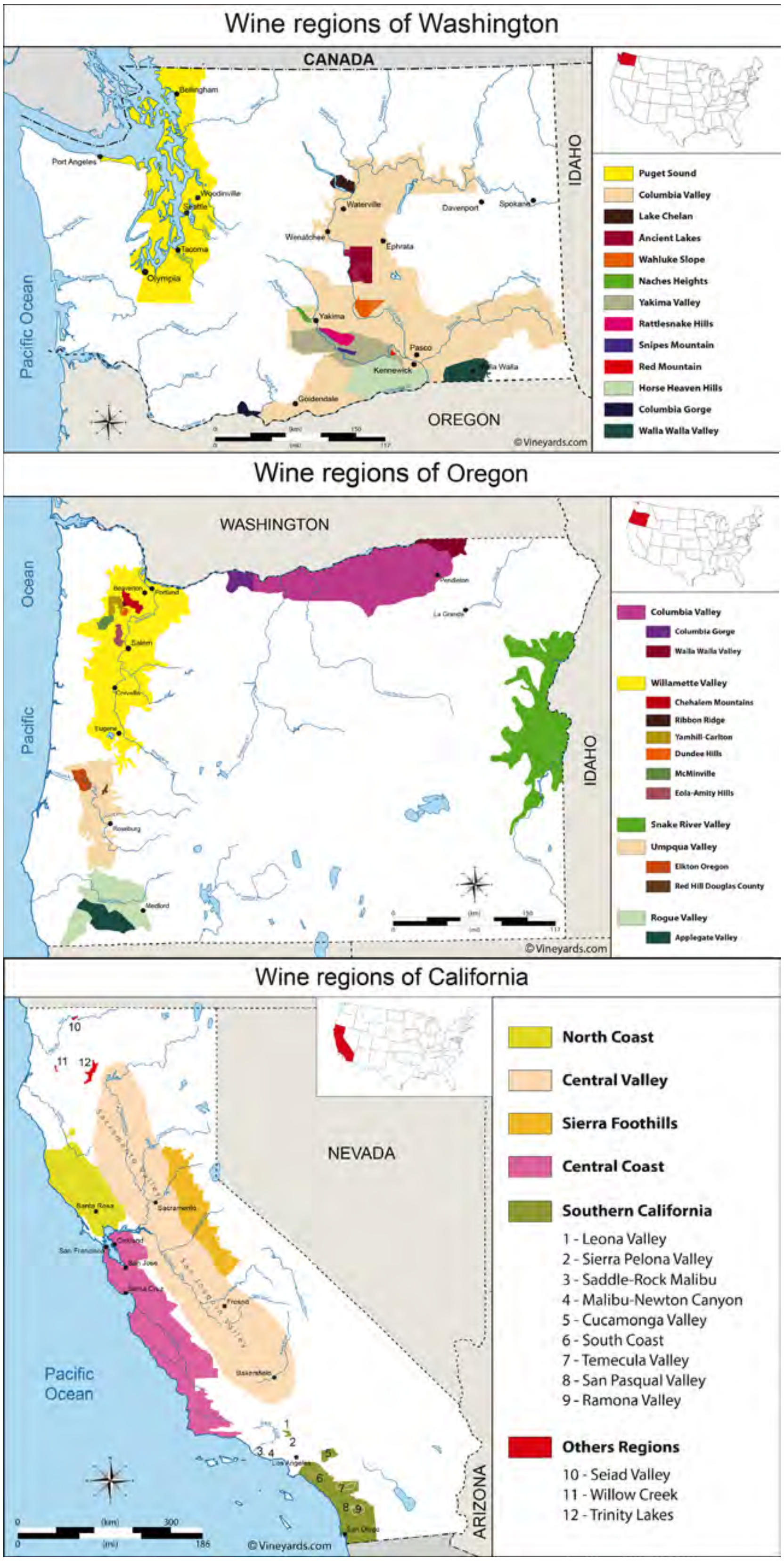
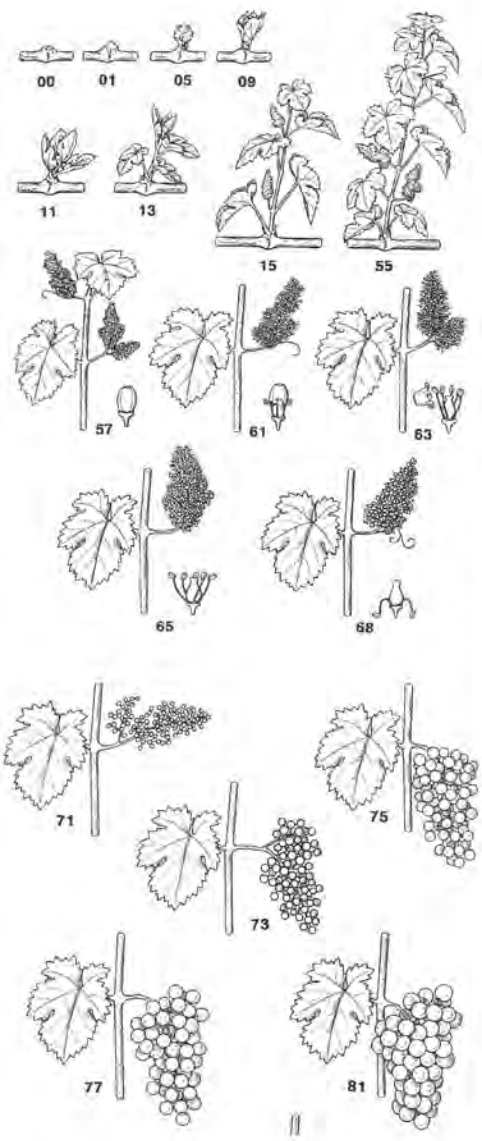


Figure 2. Wine production regions in Washington State (top), Oregon (middle), and California (bottom). Maps © Vineyard Products, LLC (2019).

Appendix D

Phenology

Wine grape management is categorized by stage of grape development (Figure 3), which differs considerably in annual timing depending on the region; for example, the delayed-dormant phase ranges from December to January in southern California, February to March in North Coast vineyards, and March to April in some Washington State regions.



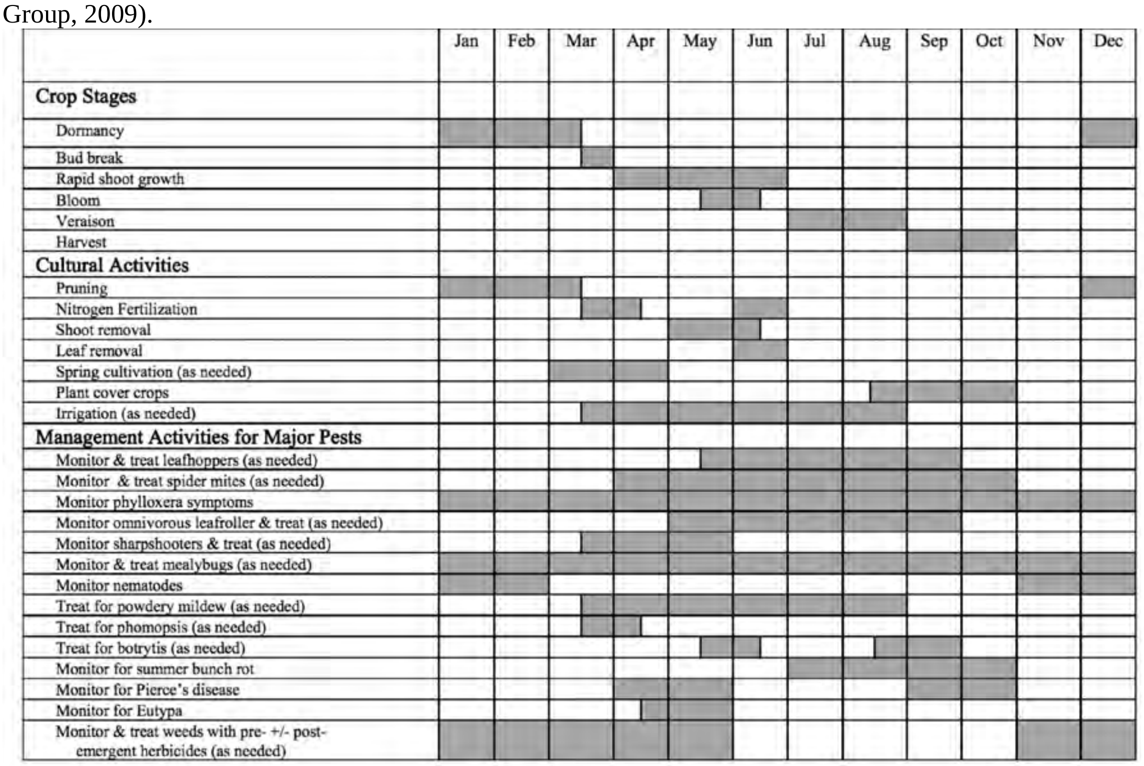
Principal growth Stage	Code	Description
0: Bud Development	00	Dormant: winter buds pointed or rounded and bud scales closed, depending on cultivar
	01	Buds beginning to swell
	03	End of bud-swell. Buds swollen but not green.
	05	"Wooly bud": brown wool visible on bud
	07	Beginning of bud-break: green shoot tips just visible
	08	Bud-break: green shoot tips clearly visible.
1: Leaf Development	11	First leaf unfolded away from shoot
	12	Second leaf unfolded
	13	Three leaves unfolded
	1_	Stages continue with additional leaves unfolded
5: Inflorescence Emerges	53	Inflorescence clearly visible
	55	Inflorescence swelling: flowers pressed together
	57	Flowers separate; inflorescence developed
6: Flowering	61	10% caps fallen
	65	50% caps fallen
	68	80% caps fallen
7: Fruit Development	71	Fruit set: fruit begins to form, flower remains lost
	73	BB-sized berries
	75	Pea-sized berries
	77	Berries begin to touch in cluster
	79	Bunch closure; berries touching
8: Berry Ripening	81	Ripening begins (véraison): berries begin to color
	85	Softening of berries
	89	Berries ripe, harvest

Figure 3. Principal vine growth stage scheme for grapes, adapted from Phenological Growth Stages and BBCH-Identification Key of Grapevine in BBCH Monograph, Meier 1997. (Lorenz et al., 1994)

According to the pest management strategic plans for California, Oregon, and Washington, most Western wine grape growers use the basic framework of integrated pest management (e.g. scouting, monitoring, and thresholds) to manage pests, diseases, and weeds.

Pruning and weed control occur primarily during the dormant season. Some pests and diseases may also be managed through cultural practices or chemical controls applied when the vines are dormant. From the delayed dormant growth phase through post-harvest, growers are actively monitoring and treating for pests and diseases, managing vineyard floor vegetation, and irrigating as needed.

Table 1: Management activities and phenology for California wine grapes generalized across regions. From the Pest Management Strategic Plan for Winegrape Production in California (California Winegrape Work Group, 2009).



Irrigation

Irrigation practices differ significantly by region and can influence control of insect pests, diseases, and weeds. Most California vineyards have some form of irrigation. Some vineyards in coastal California regions are able to farm without irrigation ('dry farming'). Typical California irrigation rates average 4 inches of water per acre in North Coast vineyards, 6 to 8 acre-inches in Central Coast vineyards, and 18 to 30 acre-inches in the Central Valley (California Sustainable Winegrowing Alliance, 2016).

In Oregon, Willamette Valley vineyards are typically non-irrigated after establishment, but other Oregon and most Washington State growing regions use a mix of drip and overhead irrigation for frost control as well as in-season water needs. Many grape acres in Southern Oregon are served by irrigation districts, which generally do not run water from October until April or May. The timing of water availability can have a major influence on management practices in these vineyards (Murray and DeFrancesco, 2016).

Major Insect Pests

Pseudococcus mealybugs

Three species of *Pseudococcus* mealybugs (grape, obscure, and longtailed) are primary pests of Western vineyards. The species are more or less common in different regions: in California, grape and obscure mealybugs are the primary species of concern in North Coast and San Joaquin Valley vineyards; obscure and longtailed are more common in Central Coast vineyards; and longtailed mealybugs are the common species of concern in the Coachella Valley.

Mealybugs feed on all parts of the plant and present multiple routes for damage to grapevines: they can contaminate clusters, transmit viruses, and introduce sooty molds and rots that develop on the thick honeydew that mealybugs deposit along the vines. All three of these species of mealybugs can transmit the economically devastating grapevine leafroll-associated viruses (GLRaVs), which reduce grape yield and quality in infected vines (Golino et al. 2002). Mealybug infestations are often associated with ants, which tend mealybugs for honeydew. Ant tending significantly increases mealybug populations and decreases parasitism by biological control agents (Daane et al. 2007).

Beneficial insects, including a variety of predators and parasites, provide decent control of *Pseudococcus* mealybugs in vineyards with adequate habitat and low to moderate pest pressure, but high densities of mealybugs – especially when tended by ants – can prompt chemical intervention. Typical management includes a delayed-dormant, early spring, and/or summer application of buprofezin (an insect growth regulator), and a late spring application of a neonicotinoid (typically soil-applied).

Vine mealybugs

The invasive vine mealybug (*Planococcus ficus*) is a primary pest in all California grape production regions, but the species is not currently established in Oregon or Washington State production regions. Like the *Pseudococcus* mealybugs, this species is a confirmed vector for grapevine leafroll disease.

Typical annual management for vine mealybugs is one to three insecticide treatments depending on pest densities. The choice of insecticide may depend on what other pests the vineyard is managing at that time during the season, but common treatments include a delayed-dormant application of chlorpyrifos, a bloom and/or pre-harvest application of a neonicotinoid, an early or late spring application of an insect growth regulator, and/or a post-harvest application of chlorpyrifos or spirotetramat. Note that while most California vineyards do not apply chlorpyrifos or other organophosphates as part of their typical annual management, these are often reserved for high-level outbreaks of mealybugs or sharpshooters (California Winegrape Work Group, 2009).

Mating disruption has shown mixed results and may be most useful in vineyards with low mealybug pressure (Walton et al. 2006; Cocco et al. 2014).

The vine mealybug exhibits different ecological traits by region, which can influence the efficacy of control methods; for example, while they overwinter on root systems in the sandy soils of most CA regions, the heavier soils of North Coast vineyards drive vine mealybugs to overwinter as nymphs under the bark of grapevines in this region. Coastal regions only have two to three generations of vine mealybug per year, compared to five to seven in the southern San Joaquin Valley, which sees outbreaks earlier in the year than other California regions.

Classic biological control releases of the parasitoid wasp *Anagyrus pseudococci* have led to high late-season parasitism of vine mealybugs (up to 90%) in the San Joaquin region, but little early to mid-season control. Other biological control agents include the “mealybug destroyer” (*Cryptòlaemus montrouzieri*), a lady beetle imported from Australia in 1891 for mealybug control. This beetle is well established in the coastal regions of California. Effective predators include other lady beetles, lacewings, midges, and minute pirate bugs (Daane et al. 2008).

Sharpshooters

Sharpshooters are among the major pests of California wine grapes due to their function as vectors of the economically devastating Pierce’s disease. A variety of sharpshooters transmit the disease-causing bacterium *Xylella fastidiosa*, which lives and reproduces in grapevine xylem, eventually killing the vine due to xylem blockages. There is no cure for Pierce’s disease once a vineyard is infected, though research is ongoing into bacteriophage cocktails and other possible therapeutic strategies (Kyrkou et al. 2018), and transgenic resistant rootstock has been developed to prevent disease in new vineyard plantings (Dandekar et al. 2019). Pierce’s disease has not been reported north of California, likely because the climate is too cold for the pathogen to survive.

The blue-green sharpshooter (*Graphocephala atropunctata*) is the most important vector in coastal areas. Its primary habitat is riparian areas, and riparian vegetation management is one of the main control strategies for coastal vineyards. The green sharpshooter (*Draeculacephala minerva*) and the red-headed sharpshooter (*Carneocephala fulgida*) are also present in coastal areas but are more important as vectors of this disease in the Central Valley.

The glassy-winged sharpshooter (*Homalodisca vitripennis*) was accidentally introduced to southern California in the 1990s. This large leafhopper, native to the southeastern US, is highly mobile and an active vector of the disease-causing bacterium *Xylella fastidiosa* in several crops, including grapes, almond, and citrus.

Unlike the blue-green sharpshooter, which tends to be restricted to riparian habitats, the glassy-winged sharpshooter lives in many habitats, including agricultural crops, urban landscapes, native woodlands, and riparian vegetation. It has hundreds of alternate hosts, including a wide variety of woody and herbaceous plants including citrus, eucalyptus, sunflower, hibiscus, xylosma, and cottonwood, among many others (Wistrom et al. 2010). Because of its diversity of alternate hosts and importance as a disease vector, sharpshooters are likely to be a source of grower resistance to natural vegetation, including hedgerows and riparian strips, near vineyards.

The threshold for insecticide treatments for glassy-winged sharpshooter is simply their presence –a grower will treat a vineyard if a single sharpshooter is spotted during monitoring. There is also a low threshold for blue-green sharpshooters in coastal vineyards (1 per vine or 7 per sticky trap). Typical pesticide applications include a contact insecticide for overwintering adults applied to the vineyard edge and an early-season systemic insecticide (neonicotinoid) application for nymphs.

Area-wide management for glassy-winged sharpshooters was implemented in Riverside County in 2000 to slow the spread of the invasive insect and to reduce pressure on grapes from high abundances of sharpshooters in adjacent citrus. Common chemical treatments included neonicotinoid, organophosphate, carbamate, and pyrethroid insecticides. Heavy use of imidacloprid for sharpshooter control has led to the development of imidacloprid resistance in some sharpshooter populations (Byrne and Toscano, 2006; Esser and Randhawa, 2015).

Leafhoppers

Leafhoppers (Hemiptera: Cicadellidae) lay their eggs in grape leaf tissues and feed on foliage as nymphs and adults. At high densities, leafhopper damage can reduce the photosynthetic capacity of the vine, resulting in delayed fruit ripening, fruit sunburn, and reduced shoot growth the following year. However, healthy vines can generally tolerate relatively high densities of leafhoppers.

Several species of leafhoppers are present in Western grapes, but densities of different species differ by region. Grape leafhoppers are a primary pest in northern Central Valley and North Coast vineyards, and can also pose a problem in warmer interior areas of the Central Coast. Variegated leafhoppers are a primary pest in southern Central Valley and South Coast vineyards. Virginia creeper leafhopper has been occasionally detected in vineyards in northern Sacramento Valley, northern Sierra foothill counties, and in Lake and Mendocino counties. Both grape and Virginia creeper leafhoppers can sometimes reach damaging levels in Oregon and Washington vineyards.

Many natural enemies contribute to management of leafhopper populations, including several species of *Anagrus* parasitic wasps as well as generalist predators such as spiders, lacewings, minute pirate bugs, and predaceous mites and thrips. An area-wide program in Lake and Mendocino counties is working to improve biological control of the Virginia creeper leafhopper through the introduction of an *Anagrus* species from the Sacramento Valley (*Anagrus daanei*). Note that the commonly used sulfur fungicides may be toxic to *Anagrus* spp.

Cultural control can also help keep populations below damaging levels. According to UC IPM, removing basal leaves or lateral shoots during berry set and the 2-week period following (before adult leafhoppers emerge) – also recommended for *Botrytis* bunch rot management – will typically reduce peak leafhopper populations during the season by 30-50%. While some sources suggest maintaining vegetative cover in rows and alleyways can increase adult leafhopper populations in vineyards, a study in a North Coast organic vineyard found that maintaining flowering cover crops between rows increased predator and parasite populations and kept leafhopper densities low on adjacent vines (Nicholls et al. 2000, Altieri et al. 2005).

Leafhoppers are typically monitored from a month after bud break until harvest. Treatment thresholds vary by leafhopper generation and species, region, and level of parasitization by *Anagrus* spp. If leafhoppers reach damaging levels, common treatments include an insect growth regulator (e.g. buprofezin) or a foliar or soil application of a neonicotinoid.

Spider mites

Spider mites feed on grape foliage and cause damage ranging from leaf spotting to necrosis and bronzing. Damage patterns and timing differ by mite species.

Pacific spider mite (*Tetranychus pacificus*) is the primary pest mite species in the San Joaquin Valley and some coastal California grape-growing areas. The early-season Willamette spider mite (*Eotetranychus willamettei*) causes damage in the Salinas Valley, Sierra Foothills, and Willamette Valley production areas. In North Coast vineyards, it can cause damage in early spring when shoot growth is delayed or later in the season in vines with small canopies. In Washington State, the McDaniel spider mite (*Tetranychus mcdaneliis*) and yellow spider mites *(Eotetranychus carpini borealis*) can reach damaging levels.

If populations reach damaging thresholds, typical chemical control is one to two miticide applications (e.g. bifenazate, spirodiclofen, abamectin).

Spider mites thrive in hot, dry, and dusty conditions, including dust from sulfur applications. Multiple sulfur applications for disease control can increase mite populations (James et al. 2002). Vineyard floor vegetation can help reduce dust. Both California and PNW Extension publications recommend applying water to control dust along vineyard roads.

Predatory mites can be highly effective in keeping spider mite populations below damaging levels (Doutt and Nakata, 1965). Like the pest mites, densities of different predatory mite species differ by region; western predatory mites (*Galendromus occidentalis*) are more common in the Central Valley and the predatory mite

Typhlodromus pyri is more common in North Coast and Pacific Northwest vineyards. Different predaceous mite species present in the same vineyard may offer complementary control of mites on vineyard edges and centers (Prischmann et al. 2002). Broad-spectrum insecticide and some fungicide applications – including sulfur – can disrupt biological control by predatory mites (Hanna et al. 1997).

Grape phylloxera

Grape phylloxera (*Daktulosphaira vitifoliae*) feed on grape roots, stunting or killing vines. They are reliably controlled with the use of resistant rootstock, but cultural practices for resistance management (e.g. preventing exposure of resistant rootstock to high levels of phylloxera infestation) include crop residue management, irrigation, and sanitation of infested equipment (Granett et al. 2001).

In colder regions such as the Walla Walla valley, severe winter temperatures make grafting vines to resistant rootstock a risky option (Murray and DeFrancesco, 2016). Some of these grape-growing regions in Oregon and Washington remain free of phylloxera thanks to strict use of clean plant materials and controls on transport of infested materials. Preventing phylloxera from entering or spreading within these areas through surveillance, detection, and quarantine is essential when growers cannot use resistant rootstock for phylloxera control (Benheim et al. 2012).

There are no curative options for an infested own-rooted vineyard. Insecticides will not reverse damage on vines, but growers will sometimes apply them to stem further damage. Increasing soil microflora diversity through cover cropping may help prevent phylloxera damage in infested vineyards. Organic vineyards managed with cover crops and compost additions had lower root necrosis on phylloxera-infested vines than the paired conventionally managed vineyards, likely due to changes in soil microflora that decreased pathogen load around vine roots (Lotter et al. 1999).

Leaf-eating Lepidoptera

Several types of defoliating and webbing Lepidoptera are major pests of Western grapes, including grape leaffolder (*Desmia funeralis*), Western grapeleaf skeletonizer (*Harrisina brillians*), omnivorous leafroller (*Platynota stultana*), orange tortrix (*Argyrotaenia franciscana*), light brown apple moth (*Epiphyas postvittana*) and several species of cutworms.

While the densities and economic impacts of the different species differ by region, they are included together here as monitoring and management are similar and sometimes integrated across these Lepidopteran pests. Treatment for Lepidopteran pests is typically timed before larvae of leaf-rolling species begin to roll leaves, with applications ranging from bloom (especially for omnivorous leafrollers) to bunch closure.

Omnivorous leafroller is a primary pest in both the Central Valley and coastal regions of California. Although it feeds on foliage, flowers, and fruit, the major source of damage from the omnivorous leafroller is typically secondary: its feeding sites allow for entry and development of bunch rots.

Grape leaffolder is a pest in the central and southern San Joaquin Valley with highly fluctuating annual populations. In most years, populations do not reach damaging levels, but during population peaks leaffolders can defoliate entire vineyards.

Western grapeleaf skeletonizer does not occur in all grape production areas. In areas where it does occur, granulosis virus usually keeps populations below economically damaging levels (UC IPM). If the virus is not present in a vineyard where the skeletonizer is present, growers typically treat with a neonicotinoid, diamide, or Lepidoptera-specific insecticide (e.g. Bt or methoxyfenozide).

Orange tortrix can be a major pest in coastal regions of California. Damage from light brown apple moth is also more common in coastal regions.

Cutworms feed on vines in the early part of the season and can damage buds and early shoots. Variegated cutworm (*Peridroma saucia*) is the most common species in the San Joaquin Valley and North Coast, while spotted cutworm (*Amathes c-nigrum*) is predominant in the Central Coast counties (UC IPM). This is typically a minor pest, but can occasionally cause economic damage in localized areas. Though natural enemies generally provide effective control and keep cutworms below damaging thresholds, growers will apply highly toxic insecticides such as carbaryl to combat high densities of cutworms.

Nematodes

Nematodes feed on grape roots, reducing water and nutrient uptake and vine vigor and yield. There are several types of nematodes that cause damage in Western vineyards. Of these, the dagger nematode is generally the highest concern, as it vectors the destructive grapevine fanleaf virus (California Winegrape Work Group, 2009). Cultural practices to exclude nematodes before and during planting are critical, as nematode populations are generally permanent once established in a vineyard. There are resistant rootstocks available, but these may not be resistant to all types of nematodes present in a vineyard (Ferris et al. 2012).

Conventional growers typically apply a soil fumigant such as metam sodium prior to establishing new vineyards. Methyl bromide was the most common fumigant applied pre-planting until its phase out under the Montreal Protocol (Zasada et al. 2010). Post-planting, nematicides such as spirotetramat may be applied throughout the year, but are generally applied during the rapid root growth period in the spring and/or fall (early post harvest).

Minor and Emerging Insect Pests

There are more than a dozen other insect pests that can trigger the use of moderately to highly toxic insecticides when populations spike, as well as several emerging species that may develop into major pests.

Grape thrips (*Drepanothrips reuteri*) and Western flower thrips (*Frankliniella occidentalis*) do not generally cause economic-level damage, but when densities increase beyond economic thresholds, growers will typically treat with spinetoram or a foliar neonicotinoid. These are more important pests during the rapid shoot growth period in North Coast, Oregon, and Washington vineyards than warmer California regions.

Several species of scale can infest Western grapes, including cottony grape scale (*Pulvinaria vitis*) and European fruit lecanium scale (*Parthenolecanium corni*). Like mealybugs, scale produce honeydew that can attract honeydew-seeking ants and provide a substrate for the development of sooty molds and rots. Most scale infestations can be maintained below economic levels by parasitic wasps, except where broad-scale insecticide or heavy fungicide use disrupt biological control or where tending ant populations protect scale insects from parasitization.

A new species of concern for Western vineyards is the three-cornered alfalfa treehopper (*Spissistilus festinus*), the only confirmed vector of the economically devastating red blotch virus (Bahder et al. 2016, Ricketts et al. 2016). This pest has a wide range of alternate hosts, including many legumes (Wistrom et al. 2010). Research into the life history and biology of the three-cornered alfalfa treehopper in different growing regions are ongoing, and there are no current management guidelines for this insect in vineyards, but it may develop into an annually managed major pest as new research emerges on the epidemiology of red blotch.

Pacific Northwest vineyards may be more impacted by the emerging invasive pests spotted wing drosophila (*Drosophila suzukii*) and brown marmorated stink bug (*Halyomorpha halys*) than California vineyards. Grapes are not the preferred host of spotted wing drosophila, but populations may spike in areas with berries already damaged by insects, birds, or *Botrytis* bunch rot. In PNW vineyards, growers may apply highly toxic insecticides to control larvae in fruit from veraison to harvest. Brown marmorated stink bug arrived several years ago and populations remain low in grape production regions, but this pest may build to damaging population levels in the next decade.

Other occasional pests include grasshoppers, whiteflies, other *Drosophila* flies, branch and twig borers, click beetles, false chinch bugs, black vine weevils, Japanese beetles, flea beetles, and grape bud beetles. For more information on these pests, consult the UC IPM Grape Pest Management Center, WSU Extension Grape Insects, or the Pest Management Guide for Wine Grapes in Oregon.

Viruses

Red blotch virus

Grapevine red blotch-associated virus (GRBaV), or red blotch disease, is an economically devastating disease that reduces grape yield and quality in infected vines. It is best controlled through careful selection of clean vineyard stock at planting. There are no curative options for this disease once it is present in a vineyard, so management is limited to preventing spread of the disease and minimizing yield losses. If there are few symptomatic vines (<25%-30% of the vineyard), the current recommendation is to rogue infected vines and replant with clean vines during the dormant season when insect activity is low. Grapevines showing red blotch symptoms can tested by a commercial lab to confirm the presence of GRBaV. Above the threshold of 25-30% infection, however, economic losses may be great enough to justify replanting of the entire vineyard with clean stock. However, the likely continued presence of infested vines in the surrounding landscape presents a challenge for maintaining disease-free vineyards even after replanting.

The only confirmed vector of red blotch virus is the three-cornered alfalfa treehopper (*Spissistilus festinus*), but it is likely that a few other species of treehoppers, leafhoppers, and other sucking insects may also transmit the disease.

Leafroll disease

Like red blotch virus, grapevine leafroll disease has no curative options once it is present in a vineyard and management is limited to preventing spread of the disease and minimizing yield losses. Leafroll affected vines can have yield losses of 30-60%, delayed and uneven ripening of fruit, a reduction in brix and berry color, and an increase in titratable acids (Ricketts et al. 2015). The disease is vectored by mealybugs and scale insects, which can move the disease from block to block even at relatively low densities (Golino et al. 2002).

Pierce's disease

Pierce's disease is caused by the bacterium *Xylella fastidiosa,* which lives and reproduces in grapevine xylem, eventually killing the vine due to xylem blockages. This bacterium causes similar disease symptoms in a wide variety of plant hosts. There is no cure for Pierce's disease once a vineyard is infected, though research is ongoing into possible therapeutic options (Kyrkou et al. 2018, Dandekar et al. 2019). This disease has presented a serious challenge for the US grapevine industry, particularly in areas of California invaded by the glassy-winged sharpshooter, a highly mobile disease vector (Kyrkou et al. 2018).

Fan leaf disease

Grapevine fanleaf degeneration disease, or fanleaf virus, is another disease with no curative options once it is present in the vineyard aside from pulling and replanting diseased vines. Introduction to new vineyards is almost always through plantings of virus-infected nursery stock. Once present in the vineyard, the virus can be transmitted by certain nematodes, and can remain present in the soil/root material for several years after removal of diseased vines. Areas with heavy infestation may need to be fallowed or solarized before replanting. Replanting should occur on nematode-resistant rootstock.

Fungal Diseases

Powdery mildew

Powdery mildew (*Erysiphe necator*) infects upper and lower leaf surfaces and can colonize the entire surface of developing berries. The fungus overwinters as mycelia inside dormant buds or as chasmothecia (spore producing fruiting bodies), the dominant source of overwintering inoculum in most production regions.

Powdery mildew is a major driver of fungicide use in Western grapes, as growers typically apply fungicides multiple times per year from bud break to when berries reach ~12 Brix to control inoculum and subsequent infection. At low to moderate disease pressure, growers will apply a rotation of biological fungicides, sulfur, DMI fungicides, strobilurins, and quinolines. At high pressure, 'soft chemistries' (e.g. biologicals and sulfur) are no longer effective. Basal leaf removal can improve coverage of powdery mildew fungicides on clusters; this leaf removal alone can result in 50% disease control.

Fungicide use for powdery mildew is largely driven by weather; wet years increase disease pressure and subsequent fungicide use but applications can be few to none in very dry years. Like most fungal diseases in grapes, infection and treatment are more common in northern and coastal California and Pacific Northwest regions than in drier Central Valley and South Coast regions.

Downy mildew

Downy mildew (*Plasmopara viticola*) attacks all green parts of grapevines, leading to browning and dessication of infected leaves, shoot tips, and berries (UC IPM). The pathogen is most common in regions where it is warm and wet during shoot growth, and is dispersed by splashing rain and wind. In most regions the fungus survives the winter mainly as oospores in fallen leaves, but may also survive in buds, shoot tips, and persistent leaves in regions with mild winters.

Preventive management consists of effective soil drainage and sanitation of overwintering inoculum, but most vineyards affected by downy mildew are managed with a combination of pre- and post-infection fungicides. Strobilurin, QOI, and multi-site contact activity fungicides (especially copper) are often applied in early spring.

Botrytis bunch rot

Botrytis bunch rots are most prevalent in seasons and regions with prolonged warm moist conditions caused by frequent spring rains. The *Botrytis cinerea* fungus overwinters in berry mummies on the ground or left hanging on the vine and in canes. After rain or irrigation the sclerotia germinate and produce spores that are moved by air currents or splashing rain (UC IPM). Symptoms of the disease include early shoot blight and browning/wilting of individual berries in clusters.
The disease is typically managed with a combination of cultural practices to reduce canopy density and improve airflow along with fungicide applications. Mulching or

using green manures may improve breakdown of overwintering mycelium (Jacometti et al. 2010)

Typical fungicides for *Botrytis* include anilinopyrimidine, DMI, and multi-contact activity fungicides, and the most common timing is just before or during bloom to prevent blossom infection. In addition, growers may apply insecticides to control insects feeding on shoots and berries.

Interestingly, some producers of dessert wines manage for (rather than against) *Botrytis* infection, as the "noble rot" intensifies the sweetness of infected grapes and can add flavor complexity to wines. Several North Coast winemakers produce these botrytized wines.

Summer rot

A wide variety of fungal pathogens can infect ripening berries with surface damage or cracks. Berry decay can be severe and lead to colonization by acetic acid bacteria, culminating in 'sour rot' that impacts the quality of wines produced from these clusters. Cultural practices can reduce growth-related or mechanical cracking of berries, but after symptoms of summer rot have emerged, growers will likely apply fungicides – most commonly multi-site contact activity fungicides – to control the spread of pathogens.

Phomopsis cane and leaf spot

Phomopsis cane and leaf spot (*Phomopsis viticola*) infect spurs and canes, appearing first as spots on leaves and later as spots on berries. Infected berries can shrivel and become mummified. Infections generally occur when shoots begin to grow. Spores are released in large quantities from the overwintering pycnidia on diseased canes and spurs (UC IPM).

Growers typically apply lime sulfur over the winter to reduce inoculum and a QoI or multi-site contact activity fungicide before the first rain after bud break. Multiple contact fungicide applications may be used in years with significant rainfall, or growers may apply a systemic fungicide.

Eutypa dieback

Most mature plantings will eventually be infected with some type of fungal trunk disease/dieback caused by *Eutypa lata* and other fungi in the Diatrypaceae family. Preventive practices are effective when adopted in young vineyards. These include delayed pruning, double pruning, and applications of pruning-wound protectant (fungicides, or alternatively boric acid or essential oils). These practices also have some utility in mature vineyards. Post-infection, more labor-intensive sanitation and vine surgery practices can help prolong the productivity of a diseased mature vineyard.

Weeds

Weeds are the major pest challenge during the dormant season. Weeds growing under the vine rows can directly compete with grapevines for water, nutrients, and light. In conventional vineyards, most weeds are controlled with a mix of pre-emergent and post-emergent herbicides. Organic vineyards typically use cultivation/tillage for weed control.

Grape growers are increasingly interested in alternatives to herbicide-driven weed management – but also new herbicides – as several common weed species have developed resistance to the mainstay herbicides glyphosate, glufosinate, and paraquat in Western states.

Vineyard conservation practices

Habitat protection

In grape production areas, biodiversity conservation begins at the vineyard edge: protecting existing native trees, vernal pools, and riparian habitat and maintaining native vegetation around vineyards.

Protecting natural vegetation has benefits for pest control in vineyards. Natural enemies, including lady beetles and parasitoid wasps, are more abundant and associated parasitism rates are higher adjacent to vineyard edges with wooded vegetation (Thomson and Hoffmann, 2009). The benefits of wooded edges extend about 50m into vineyard blocks (Thomson and Hoffmann, 2013).

Habitat enhancement outside vineyard blocks

Hedgerows

Perennial hedgerow plantings can provide habitat for a diversity of beneficial insects and other wildlife. They can serve as windbreaks, reduce erosion and runoff, improve water infiltration, and replace invasive annual weeds with perennial native vegetation. Thrupp et al. (2008) documents several case studies of the wildlife benefits of hedgerows – including for a wide variety of beneficial insects – in North Coast vineyards.

However, careful plant selection is needed to balance wildlife benefits with disease risks to adjacent vineyards. Many plant species can harbor the bacterium that causes Pierce’s disease, serving as reservoirs of the pathogen in the landscape. A variety of common hedgerow plants, including elderberry, mule fat, and California blackberry, are hosts for the blue-green sharpshooter that vectors this disease. Ceanothus can harbor the *Eutypa* fungus, which causes trunk dieback in grapevines.

Insectary strips/meadows

An insectary ‘island’ planted with a mix of flowering herbaceous annuals and perennials (e.g. yarrow, *Penstemon*, *Salvia*) at Benzinger Vineyard in Sonoma County increased the density of beneficial insects (Thrupp et al. 2008). Beneficial insect density declined with distance from the insectary planting. For more on in-row use of flowering cover crops, see the “Vineyard floor management” section below.

Appendix D

Nesting boxes for avian predators

Providing nest boxes for generalist insectivorous bird species (for example, the Western bluebird) may help enhance avian control of caterpillars, sharpshooters, and other insect pests. A study in two organic North Coast vineyards found that avian nest boxes increased predation of larvae in vineyard rows (Jedlicka et al. 2011). However, avian species diversity and community composition is dependent on the availability of riparian habitat – nest boxes only increase the abundance of species that are already present in the landscape (Jedlicka et al. 2014).

Vineyard floor management

Vineyard floors are managed on a spectrum of intensity across different wine production regions. In Oregon, for example, growers typically maintain year-round perennial cover between vineyard rows, but Central Valley vineyards are often managed with clean cultivation and little resident vegetation. Hilly production areas such as the North Coast region in California are more likely to plant cover crops to reduce topsoil erosion during dormant periods.

Cover crops

Cover crops are a relatively inexpensive practice with stacked benefits for the crop and surrounding environment: enhancing soil carbon, increasing soil water retention, reducing the need for fertilizer inputs, and supplying cover and food resources for beneficial insects (McGourty and and Reganold, 2002). Under so-called 'clean cultivation,' wind and water erosion can strip centimeters from the top layers of soil in vulnerable vineyards annually. Cover crops planted between rows can protect soils from erosion during winter rains without negatively impacting vine health or weed control under vines (Baumgartner et al. 2008).

Many cover crop mixes offer a combination of soil health benefits and food resources for beneficial insects. Altieri et al. (2010) trialed a series of flowering annual cover crops planted in vineyard rows to provide season-long flowering resources (buckwheat, phacelia, sweet alyssum, bishop's weed, and wild carrot), finding that where weather allowed for good establishment, pest densities were reduced in cover cropped rows. A typical 'soil builder' mix seeded in October and disked under in March-April in North Coast vineyards consists of bell beans, peas, vetch, oats, and mustard, offering flowering resources and shelter for beneficial insects, nitrogen fixation, and nematode suppression. Planting sweet alyssum every 10-12th row supported high predatory mite populations relative to spider mites in a Sonoma County vineyard (Thrupp et al. 2008).

Cover crops increase soil organic matter, which in turn can affect microbial activity in the rhizosphere. Lotter et al. (1999) found that organic vineyards managed with cover crops and compost additions had lower root necrosis on phylloxera-infested vines than the paired conventionally managed vineyards, likely due to changes in soil microflora that decreased pathogen load around vine roots.

Flowering cover crops in North Coast vineyard rows increased the density of leafhopper predators and parasites, keeping leafhopper densities lower in adjacent vines (Nicholls et al. 2000, Altieri et al. 2005). In the Pacific Northwest, broadleaf cover crops such as clovers planted between rows were found to reduce cutworm feeding on grapevine buds (Olmstead, 2010). In vineyard where mealybugs or scale insects are being tended by honeydew-seeking ants (*Linepithema* and *Formica* spp.), planting a dense nectary-bearing cover crop such as common vetch can help attract these pest-tending ants away from grapevines, leaving mealybugs and scale insects exposed to parasitic wasps and predators.

However, the changes to abiotic and biotic conditions in vineyards introduced by cover crops can alter pest, disease, and moisture dynamics in ways that are not always net positive. In Oregon and Washington, cover crops may encourage populations of moles and gophers (Olmstead, 2010). Careful plant selection will be an important component of habitat work in areas with disease vectors that utilize both herbaceous and woody species as alternate hosts; for example, where the three-cornered alfalfa treehopper (*Spissistilus festinus*) is present, the use of legumes in cover crop mixes may not be advisable, as legumes are a preferred alternate host for this vector of red blotch virus. Developing plant recommendations for cover crop mixes, insectary plantings, and hedgerows that take alternate hosts into account will be important for cultivating grower trust in these practices.

Reducing tillage

In addition to its negative impacts on soil-dwelling arthropods, repeated tillage can reduce soil fertility and increase erosion. Tillage and associated heavy equipment can also lead to root zone compaction and reduced water infiltration.

Vineyards can improve conditions for beneficial insects by maintaining resident vegetation between rows with mowing only (no disking or tilling). A study from the Central Valley found that cover crops and/or no-till practices with resident vegetation can be implemented in an irrigated vineyard without affecting grape productivity in mature vineyards (Steenwerth et al. 2013).

Mulching

Using mulches for weed management in vineyard rows may be able to reduce herbicide inputs with the added benefits of increasing soil water holding capacity, organic matter, and beneficial insect populations.

A study in Australian vineyards found that the addition of straw or compost mulches increased natural enemies – particularly ground beetles, predatory Hymenoptera, and spiders – in vineyard rows (Thomson and Hoffman, 2007). Straw mulches increased earthworm abundance.

Green mulching with subterranean clover increased invertebrate abundance and levels of macronutrients (C, N, K) in Italian vineyard soils (Favretto et al., 1992)

Appendix D

Adoption of IPM/CBC practices

Growers are most willing to adopt new management practices if they learn about them from other growers. According to Cullen et al. (2008), "farmers develop confidence in ecologically informed techniques such as CBC when they observe their fellow growers successfully negotiating the risks of new practices, adapt them to their specific farming system, and observe and improve the performance of the farming system with the help of other farmers trying out new techniques."

Scale-up of conservation practices for beneficial insects in vineyards is likely to be most effective if influential growers adopt and adapt these practices to their specific farming system and region, and can then demonstrate the efficacy and benefits of the practices to other farmers in their communities.

In the wine grapes context, it is important to note that adoption of IPM may not always reduce use or risk from pesticides. Epstein and Bassein (2003) found that temperature-driven models for fungicide applications introduced to improve wine grape IPM recommended more applications than typical use patterns in many California vineyards.

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Grape—Delayed-Dormant/Budbreak Monitoring Form

Supplement to UC IPM Pest Management Guidelines: Grape

UC IPM
www.ipm.ucdavis.edu

Grower/Vineyard: ___________________________________ **Block:** ________________ **Date:** ______________

Comments: ____

Directions:

1. On a warm day (65°F or above), divide the vineyard into quadrants; monitor 5 vines per quadrant. For the best estimate of pest distribution, monitor fewer vines in more locations. Be sure to include those areas, however, where you have noticed pests in the past.
2. For spur monitoring choose a spur on the basal portion of a cordon closest to the crown.
   - **Cutworms:** Examine 5 buds on each of the 20 vines for damage (hollowed buds). If bud damage is present, look for cutworms under bark, on cordons, trunk, and at soil level. Record the number of damaged buds.
   - ***Pseudococcus* mealybugs:** Look for grape mealybug crawlers under loose bark at the spur tip. Along Central Coast, also look for more mature obscure and longtailed mealybugs at the base of spur, under bark.
   - **Vine mealybugs:** Look for nymphs and females under bark at graft union, in old pruning wounds, and below the base of the spur.
   - **Ants:** If you find ants, search more closely for mealybug crawlers or for European fruit lecanium scale.
   - **Mites:** Look under loose bark at spur tip for orange overwintering form.
   - **European fruit lecanium scale:** If ants are found look more closely for the immature scale under loose bark on old wood.
   - **Thrips:** For wine and raisin grapes, monitor for thrips after budbreak by opening shoots or gently tapping buds over white paper.
3. Note presence or absence (+ or -) of cutworm damage, ants, vine mealybugs, *Pseudococcus* mealybugs, European fruit lecanium scale, and thrips. Count and record mites on each vine.

Location	Vine	Cutworm damage (damaged buds)	Obscure, longtail, & grape mealybugs	Vine mealybug	Ants	Spider Mites	European fruit lecanium scale or thrips (in wine and raisin grapes)
1	1						
	2						
	3						
	4						
	5						
2	6						
	7						
	8						
	9						
	10						
3	11						
	12						
	13						
	14						
	15						
4	16						
	17						
	18						
	19						
	20						
Total							
Percent damaged							
Treatment threshold		Don't treat if less than 4% of the buds per location are damaged.	Treat if 1 out of 5 spurs (20%) is infested according to PMG.	Treat if vine mealybug is found according to PMG.	Identify areas of concern for spring monitoring.	Identify areas of concern for bloom monitoring.	Identify areas of concern for spring monitoring

Grape—Insect and Spider Mite Monitoring Form

Supplement to UC IPM Pest Management Guidelines: Table Grape

www.ipm.ucdavis.edu

Directions:

1. Start monitoring weekly for leafhopper nymphs one month after budbreak or when nymphs first appear, and for spider mites after first leaves emerge.
2. Randomly select 20 vines in each block of the vineyard, each at least a few vines in from the end of the row.
3. Sample leafhoppers, spider mites, and mealybugs as outlined below.

Leafhoppers	**Spider mites**	**Mealybugs**
On each of the 20 vines: *First generation nymphs* • Choose one leaf at the 3rd or 4th node up from the basal node. • Count and record the number of nymphs on each leaf. *Second and third generation nymphs* • Choose young, fully expanded leaves in middle of cane. • Note whether you see grape leafhopper nymphs (G), variegated leafhopper nymphs (V), or both (B). *All generations* • Check the leaves for red, parasitized eggs (red or exit holes) • Note their presence (+) or absence (-) on each leaf.	On each of the 20 vines: *Early in the season* • Choose one leaf between the 2nd and 4th nodes. • Use a 10X or 14X hand lens and look for mites and mite predators. • Note if mites and mite predators are present (+) or absent (-). *Later in the season* • Choose the fourth expanded leaf back from the growing tip. • Use a 10X or 14X hand lens and look for mites and mite predators. • Note if mites and mite predators are present (+) or absent (-) on the monitoring form.	On each of the 20 vines: *Early in the season* • Inspect basal leaves for grape, obscure, and longtail mealybugs. • Inspect under the bark of trunks for vine mealybug. *Later in the season (in table grape)* • Inspect all plant parts for mealybugs. • Record with a check any vine that is infested.
Record your results on the table on page 2 of this form.		

Treatment guidelines for various combinations of Pacific mite injury levels and predator-prey distribution ratios in Thompson Seedless vineyards.				
	Predator-prey distribution ratios			
Pacific mite injury levels (percent of leaves infested)	**Rare** (<1:30)	**Occasional** (1:30 to 1:10)	**Frequent** (1:10 to 1:2)	**Numerous** (>1:2)
Light (<50%)	Delay treatment to increase predators	Delay treatment	Treatment not likely necessary	Treatment not necessary
Moderate (50 to 65%)	Treat if population is increasing rapidly	May delay treatment to increase predation	Treatment may not be needed if the predator-prey distribution ratio is increasing rapidly	Treatment not needed
Heavy (65 to 75%)	Treat immediately	May delay treatment a few days to take advantage of increasing predation	Treatment may not be needed if predators are becoming numerous	Treatment not needed damage is not increasing
Very heavy (>75%)	Treat immediately	Treat immediately	Treat immediately unless predator-prey distribution ratio increasing very rapidly; carefully evaluate damage	Treatment may not be necessary if population is dropping because of very high (>1:1) predator-prey distribution ratios; carefully evaluate damage

Grower/Vineyard: ____ **Date**: ________________________

Comments: ____

Vine (leaf/ spur)	Number of leafhopper nymphs/leaf	Leafhopper species: Grape (G), Variegated (V), or Both (B) (circle species)	Parasitized leafhopper eggs (+ or -)	Spider mites (+ or -)	Predatory mites (+ or -)	Mealybug species: Grape (G), Vine (V), or Both (B) (circle species)	Other pests
1		G V B				G V B	
2		G V B				G V B	
3		G V B				G V B	
4		G V B				G V B	
5		G V B				G V B	
6		G V B				G V B	
7		G V B				G V B	
8		G V B				G V B	
9		G V B				G V B	
10		G V B				G V B	
11		G V B				G V B	
12		G V B				G V B	
13		G V B				G V B	
14		G V B				G V B	
15		G V B				G V B	
16		G V B				G V B	
17		G V B				G V B	
18		G V B				G V B	
19		G V B				G V B	
20		G V B				G V B	
	Total: ____________ **Average:** ____________		**Total:** ____________ **Percent:** ____________			**Add totals for vines 1 through 20**: ____________ **Divide by 20 vines**: ____________ **Multiply by 100**: ____________%	

Leafhopper treatment thresholds

Wine and raisin grapes

- *First generation*: No treatment necessary if less than 20 nymphs per leaf. If parasitized eggs are present, avoid treatments unless leafhopper numbers are significantly above 20.
- *Second and third generation*: Treat if there are 15 or more nymphs per leaf. Coastal vineyards with low parasitization have a threshold of 10.

Table grapes

- *First generation*: Treat if there is an average of 15 or more nymphs per leaf and no parasitization.
- *Second and third generation*: Treat if there are 5 to 10 or more nymphs per leaf (varies according to variety—see pest management guideline).

Mite treatment thresholds:

See previous page for treatment guidelines for various combinations of Pacific mite injury levels and predator-prey distribution ratios in Thompson Seedless vineyards. *These thresholds were developed for Pacific mite, which is more damaging than Willamette mite.*

Grape mealybug treatment thresholds

Wine and raisin grapes

If an average 20% or more of spurs have grape mealybug, treatment may be warranted.

Table grapes

For grape mealybug:

If an average 4% or more of spurs have grape mealybug, treatment may be warranted.

For vine mealybug:

If found consult PMG for treatment options.

UC IPM