Crop Profile for Grapes (Wine) in California

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General Production Information

- **Production.** California produces 90% of the grapes grown in the United States and 7.7 % of grapes grown in the world (5,6). California is ranked number one in production of wine, table, and raisin grapes in the United States. California supplies 81% of the nation's crushed grape production (5). California produces 52% of the grape concentrate produced in the United States (5).

- **Estimated bearing grape acreage** in California in 2000 was 955,000 acres, of which 568,000 (59.5%) were wine grapes. In addition, in 2000 production from approximately 37,000 acres of Thompson Seedless, which is a raisin variety, were crushed for wine and concentrate. Non-bearing wine grape acreages was estimated at 110,000 acres. About 42% of the bearing wine grape acreage is in the southern San Joaquin Valley, 18% is in the northern interior Sacramento Valley, Delta and Foothills), 22% is on the North Coast and 17% is on the Central and South Coast. Organic growing acreage accounts for about 1.5% of the total grape growing acreage, though this acreage is increasing (California Certified Organic Farmers, personal communication).

- **Ranking.** Grapes (wine, table and raisin) are California's number one-ranked crop in dollar value, and the number two-ranked commodity in dollar value, following dairy production. In 2000, California's wine grape crush was 3,951,185 tons, valued at about $2 billion.

- **Varieties.** Chardonnay accounted for 16.5% of the crush, followed by Thompson Seedless with 12.4%, French Colombard with 11%, Zinfandel with 10.2%, Cabernet Sauvignon with 9.1%, Merlot with 7.7%, Chenin Blanc with 3.8%, Rubired with 3.4%, Barbera with 3%, Grenache with 2.8% and all other varieties with 20.1%

- **Growing Regions.** . The southern San Joaquin Valley produced 60% of the tonnage crushed in 2000. Eighteen percent came from the Northern Interior, 11% came from the North Coast and 10% came from the Central and South Coast.

- **Primary Counties.** Grapes represent the number one leading commodity for the following California Counties: Amador, Fresno, Kern, Madera, Mendocino, Napa, San Luis Obispo, San Joaquin, Sonoma, Sacramento and Lake Counties. Grapes represent a significant crop (top 10) in several other counties: Alameda, Calaveras, El Dorado, Kings, , Marin, Monterey, Nevada, Riverside, , San Benito, San Bernadino, Santa Barbara, Santa Clara, Solano, Stanislaus, and Tulare (5,6).

- **Exports.** Wine ranked 3rd for California exports in 2000. Valued at $510,400,000 it is California number one value-added agricultural crop. Exports make up 12% of total California shipments of wine.

- **Cost Per Acre.** The total cost to produce an acre of grapes ranges significantly with region, variety and end-user, ranging from $1,200 to $4,000 per acre including production and harvesting costs, land and development costs excluded (5).

Production Regions

Grapes are grown in all areas of California with the exception of the high country. The San Joaquin Valley of California is the major production area for table, raisin, and wine grapes. Other regions that also have significant grape production are in the north coast counties of Napa, Sonoma, Lake, and Mendocino and the central coastal counties of Santa Clara, Monterey, Santa Cruz, San Luis Obispo, and Santa Barbara. Smaller but significant clusters in the Coachella Valley, the southern coastal counties of San Diego and Riverside Counties, and elsewhere throughout the state. Each region has distinct climatic and geologic characteristics that lead to different cultural and pest management practices.

For grapes, the University of California identifies six regions for production within the state. All six regions produce at least some wine grapes. These regions can be summarized as follows:

1. **North Coast**: *About 10% of wine grape production* (5,7). Includes Lake, Mendocino, Napa, Sonoma and Solano Counties. The North Coast region is located north of San Francisco and includes the region from Napa to Ukiah. This region is dominated by relatively flat valley floor vineyards prone to frost, with silty, clay loam soils relatively high in organic matter. The hillsides above the valley floor consist of steep to rolling land with variably shallow or rocky soils requiring contour planting or contour terracing to control erosion.
2. **Central Coast**: *About 8% of wine grape production* (5,7). Includes Alameda, Monterey, San Luis Obispo, Santa Barbara, San Benito, Santa Cruz, and Santa Clara Counties. The Central Coast Region is located south of San Francisco, from Livermore to Santa Ynez. This area is comprised of rolling hillsides or benchlands with soils ranging from sandy loams to gravelly clay loams relatively high in organic matter.
3. **South Coast**: *Less than 0.5% of wine grape production* (5,7). Includes wine grape growing regions of San Diego, and Western Riverside counties. The South Coast region is located near San Diego and includes the region from Escondido to Temecula. In this region, soils are often low in organic matter. Vineyards are frequently planted on sandy soils or hillsides that need stabilization from erosion.
4. **Northern San Joaquin Valley**: *About 20% of wine grape production* (5,7). Includes San Joaquin, Calaveras, Amador, Sacramento, Merced, Stanislaus and Yolo Counties, (Foothill counties are often included here) with production almost exclusively focused on wine, but with a very small amount of raisin and table grape production. The Northern San Joaquin Valley region is the inland region from Sacramento to Merced. Light to medium textured soils with low organic matter predominate this region. Most vineyards are planted on flat land.
5. **Southern San Joaquin Valley**: *About 60% of wine grape production* (5,7). Includes Fresno, Kings, Tulare, Kern, and Madera Counties. This region focuses more on a mixture of grape production, with table and raisin grapes being produced in addition to wine grapes. The Southern San Joaquin Valley region is the inland region from south of Merced to the Tehachapi Mountain Range. Light to medium textured soils with low organic matter predominate this region. Most vineyards are planted on flat land.
6. **Coachella Valley**: *Less than 0.1% of wine grape production* (5,7). Includes Coachella regions of Riverside, Imperial, and San Bernadino counties, with primary production being table grapes. This desert region is the inland region surrounding Indio, north of the Salton Sea. Soils are generally low in organic matter.

Cultural Practices

Cultural practices for grape production vary widely, depending on the intended use of the crop (i.e., table, wine, or raisin), the growing region, and the management preferences of the grower. Pest management priorities are also impacted by the intended use where, for example, control of pests that cause cosmetic damage to the fruit can be much more important in the production of table grapes than in wine and raisin grapes.

Wine Grape Varieties. California produces about 100 different varieties of wine grapes, grown both in inland valleys with high temperatures and low humidity, and coastal valleys with cooler temperatures and higher humidity. There are more than 39 varieties of white wine grapes crushed for wine and more than 59 varieties of red wine grapes crushed in California.

The top four premium varieties are Chardonnay, Cabernet Sauvignon, Merlot, and Zinfandel. These four varieties represent 57% of all supermarket wine value and 61% of dollar sales (5). These varieties dominate production in the coastal growing regions and in the northern San Joaquin Valley. Varieties that are important in the southern San Joaquin Valley include French Colombard, Chenin Blanc, Barbera, Grenache, Zinfandel and Rubired.

General Practices. Vines are pruned during the dormant season and, for cane-pruned varieties, canes are tied to the trellis wires before spring growth starts. Pre-emergent herbicide applications are applied during the dormant season, and contact herbicides are applied from fall through late spring. Nitrogen and zinc fertilizers are applied in the spring, with potassium and boron fertilizers applied in fall through winter. Drip irrigation has recently become the preferred method of irrigation, though furrow irrigation still dominates in the southern San Joaquin Valley. Other production practices include canopy management (i.e., vine training, shoot positioning, leaf pulling, and trunk suckering), vineyard floor management (i.e., cover cropping, cultivation and mowing), pest management, and harvesting. Cultural practices such as irrigation and floor management can play a role in pest management. Once harvested, the grapes are transported to wineries where they are graded and crushed.

Grape Concentrate. Grape concentrate can be added to wines and other alcohol beverages such as brandy. If prices are low enough, grape juice concentrate can compete with traditionally lower priced pear and apple juice as a natural sweetener for food manufacturing. In California, grape juice concentrate is primarily supplied by several varieties grown in the San Joaquin Valley regions, whereas in other states Concord grapes are the primary source of juice concentrate (5).

Concentrate represents almost 20% of California's crushed grape tonnage. Production in 2000 was 744,828 tons with a value of almost $150,000,000 (5). California's grape concentration is largely produced from white varieties (80%), with almost all of this production from the Thompson Seedless variety). Red variety production of juice concentrate (20% of California's production) is produced primarily from Rubired, Royalty, and Salvador varieties (5).

PESTS OF CALIFORNIA WINE GRAPES

The following summaries of grape pests and their management are based, to a large extent, on the summaries compiled and distributed by the University of California Integrated Pest Management Project (UC-IPM Project)(2,25,39,49). These guidelines were authored by many different specialists and advisors from the University of California's Cooperative Extension. We wish to acknowledge this contribution.

The following pest management summaries are also based on publications and documentation from the UC Division of Agriculture and Natural Resources, the UC Sustainable Agriculture Research and Education Program, California's Department of Pesticide Regulation, the Lodi-Woodbridge Winegrape Commission, the Central Coast Vineyard Team, and other sources of documentation on grape pest management. The summaries are also based on extensive comments and suggestions from individuals from the agricultural community and members of the California Grape Advisory Team, who include: Jenny Broome, Associate Director, UC SAREP; Paul (Augie) Feder, Agricultural Policy Specialist, U.S. EPA Region 9; Karen Ross, President, California Association of Winegrape Growers (CAWG); Joe Kretsch, Project Coordinator, Sun-Maid Raisin Best Management Practices Program; Rick Melnicoe, WRPMC, University of California; Linda Herbst, WRPMC, University of California; Charlie Goodman, Research Manager, Office of Pesticide Analysis and Consultation, California Department of Food and Agriculture (CDFA); John Steggall, Office of Pesticide Consultation and Analysis, CDFA; Mike Vail, Viticulturist, Vino Farms, Inc.; _Frank Zalom, Director, UC Statewide IPM Program; Jennifer Curtis, Environmental Policy Consultant to the Natural Resources Defense Council (NRDC); Richard Matoian, California Grape and Tree Fruit League, Steve Quashnick, Western Farm Service, Clifford Ohmart, Lodi-Woodbridge Winegrape Commission. Special thanks to the following individuals for their helpful reviews of sections in their area of expertise: Drs. Jeffrey Granett and Amir Omer (phylloxera), Dr. Kent Daane (mealybugs), Dr. Alex (Sandy) Purcell (sharpshooters), Dr. Mike McKenry (nematodes), Dr. Doug Gubler (powdery mildew, measles) and Dr. Tim Prather (weeds).

The grape pests in this document are separated into major insect and mite pests, minor insect pests, nematodes, major and minor diseases, weeds, and vertebrate pests. The order of each pest is presented based on its importance to the pest management system, in terms of pesticide use, control efforts, or actual or potential damage.

Except where otherwise noted, the pesticide use data presented in the following summaries are based on the Department of Pesticide Regulation's (DPR) 2000 Pesticide Use Report (9).

Insect Pests

Leafhoppers

Grape leafhopper: *Erythroneura elegantula*
Variegated leafhopper: *Erythroneura variabilis*

Damage. Leafhoppers (Homoptera: Cicadellidae) are major pests of grapes throughout California (72). The grape leafhopper is a major pest of grapes north of the Tehachapi Mountains, especially in the San Joaquin (primarily Northern San Joaquin Valley Region), Sacramento Valley, and Napa Valleys (North Coast Region). It is occasionally a problem in coastal valleys (Central and South Coast Regions). The variegated leafhopper is a major pest of grapes in Southern California (Southern San Joaquin Valley, South Coast, and Coachella Valley regions). Variegated leafhopper is a major pest as far north as San Joaquin County (Northern San Joaquin Valley region). Actual pest damage varies according to location of the vineyard, variety, plant vigor, market use of the variety, and season. Substantial infestations result in loss of yield and/or quality. Large numbers of flying adults can cause significant worker annoyance, which can lower productivity.

As leafhoppers feed on leaves and injury increases, photosynthetic activity decreases. Heavily damaged leaves lose their green color, dry up, and may fall off the vine. This can result in fruit sunburn and can weaken the vine for the following season. Feeding can also delay berry sugar accumulation and leafhopper production of "honeydew" (excess carbohydrates) can result in spotting of fruit (mold which grows on the honeydew). Spotting is only an economic concern with "fresh pack" wine production and table grapes.

Life History of the Pest. Leafhoppers overwinter as adults, and are found in spring on newly emerged grape leaf tissue, cover crops and weeds. Eggs of the first brood are laid in leaf epidermal tissue in April and May. Both adults and nymphs feed on leaves by puncturing leaf cells and sucking out the contents.

Monitoring. Growers and pest control advisors monitor for leafhoppers by counting the number of nymphs per leaf and by visual assessment of leaf damage. The most critical period is during the second leafhopper generation, because it is then that leafhoppers are feeding primarily on photosynthetically active foliage. Economic loss probably does not occur until at least 20% of the photosynthetically active leaf area is damaged, which is roughly equivalent to 15-20 nymphs per leaf for Thompson Seedless in the San Joaquin Valley (72).

CONTROLS

Cultural

Basal Leaf Removal. Leaf removal is primarily performed to control botrytis and other bunch rots, but it can also help control leafhoppers (64). Removing basal leaves (up to the cluster) at the first generation nymphal peak (usually between bloom and berry set) should result in a substantial reduction in density of second generation leafhoppers. Also, leaf removal improves coverage and the effectiveness of pesticides.

Limiting Vine Growth. Because leafhoppers prefer vigorous, lush vegetation (20), preventing overly vigorous vine growth may help manage leafhoppers.

Cover Crops. There is no evidence that spring or summer cover crops make a significant contribution to leafhopper control by encouraging populations of beneficial insects or spiders (14,15). However, cover crops may reduce vine vigor through competition for water and/or nutrients (22).

Weed Control. Because weeds and cover crops are an overwintering location for leafhoppers, theoretically removal of vegetation on the vineyard floor and in surrounding areas helps reduce numbers of adults that might disperse to new grape foliage. Pre-budbreak discing of floor vegetation during early morning hours (before temperatures warm up to above the leafhopper flight threshold) may be effective in reducing populations of overwintering adults, although this has never been tested experimentally.

Sticky Tape. Yellow sticky tape can trap overwintering adults before they lay eggs, theoretically reducing first brood leafhopper infestations. It has never been tested experimentally. This is a labor-intensive practice in that the tape needs to be put up and taken down by hand.

Alternative Hosts for *Anagrus*. Border plantings of blackberries and French prunes have been tested as a way to enhance numbers of the leafhopper parasite *Anagrus* (54). However, attempts to implement such plantings on a commercial scale have not been successful (K.M. Daane, personal communication).

Biological

Several natural enemies of the grape leafhopper are considered important in biological control strategies. Use of broad spectrum insecticides can negatively affect these natural enemies and may exacerbate a leafhopper problem.

***Anagrus* spp.** The most important natural enemy of the grape and variegated leafhoppers is a microscopic wasp in the genus *Anagrus* (Hymenoptera: Mymaridae), most commonly *Anagrus erythroneurae* Triapitsyn. These wasps lay their eggs within leafhopper eggs. Immature *Anagrus* develop within and entirely consume leafhopper eggs. Growers and PCAs can examine grape leaves and monitor for parasitized leafhopper eggs, which are red compared to clear unparasitized eggs. Even a minimal level of parasite activity on eggs of the first generation may result in economic control of the grape leafhopper during the second and third generations (B.C. Murphy, unpublished data). *Anagrus* is not as effective on variegated leafhopper as it is on grape leafhopper, and economic control of variegated leafhopper is usually not achieved by parasitism alone.

Other predators. General predators of leafhoppers include green lacewings (*Chrysopa* spp.), minute pirate bugs (*Orius* spp.), nabid bugs (*Nabis americoferus*), big-eyed bugs (*Geocoris* spp.), lady beetles (*Hippodamia convergens*.), and the predatory mite, *Anystis agilis.* However, these predators are found at very low densities in the San Joaquin Valley (16), and have not been thoroughly documented in other areas. Spiders are the dominant predator on grapes in the San Joaquin Valley, but little effective relationship has been found between spiders and leafhoppers (15).

Chemical

Although leafhoppers infest most vineyards in California, they may not require chemical treatment because most vineyards can tolerate fairly high populations without harm. Grape leafhopper populations are easier to tolerate than variegated leafhoppers. On the average, less than 50% of wine and raisin grape vineyards require treatment, while most table-grape vineyards require at least one treatment a year. In some cases, chemical treatment of leafhoppers may exacerbate a mite problem if predatory mites are disrupted. Methomyl, carbaryl and dimethoate, all of which are registered for control of leafhoppers, are highly toxic to predatory mites. At present, imidacloprid is an extremely effective and long lasting material for leafhoppers and has little effect on natural enemies (23).

Imidacloprid. 0 day pre-harvest interval (PHI). Imidacloprid (PROVADO, ADMIRE), specifically Provado7, is the most popular chemical treatment for leafhoppers. Imidacloprid is in the chloronicotinyl chemical family. Provado7 is a wettable powder formulation. In 2000, 5,751 lb ai were applied to approximately 22% of wine grape acreage in a median of one application per field. The median application rate was 0.04 lb ai/acre. Single applications per season are often effective. If pest pressure requires additional treatment, growers are required to allow 14 days before reapplication. Admire7 received a special local needs registration in February 1999 for use on leafhoppers and mealybugs in California, and is a flowable intended for use in drip systems. Because imidacloprid is a systemic, the vine will take it up. Recommended application timing is between budbreak and pea-berry stage, at a rate of 0.25 to 0.50 lb ai/acre. The restricted-entry interval for imidacloprid is 12 hours. Some concern has been expressed about pest resistance to imidacloprid. Because there is no CODEX MRL for this product on grapes, there are trade concerns as well.

Naled. 3 day PHI. Naled (DIBROM), an organophosphate, is applied to the wine grape acreage to kill adult leafhoppers just before harvest. In 2000, 2,760 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median and maximum application rate was 1.01 lb ai/acre. The restricted-entry interval for naled is 48 hours. Although disruptive to beneficials, Naled is used as a late-season quick knock-down material. Post-bloom applications of Naled may cause fruit russeting and it may not be effective in all areas due to resistance

Pyrethrins/PBO in Combination. 1 day PHI. Pyrethrin and piperonyl butoxide (PBO) PYRENONE, PYRELLIN or equivalent) is applied alone or in combination with narrow range oils to treat first generation leafhoppers. In 2000, 48 lb ai piperonyl butoxide and 9 lb ai pyrethrins were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 0.12 lb piperonyl butoxide and 0.01 lb pyrethrins. It has a restricted-entry interval of 12 hours. This strategy may cause a secondary problem with a mite flare up.

Endosulfan. 7 day PHI. Endosulfan (THIODAN) is an organochlorine. In 2000, 23 lb were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 1.5 lb ai per acre. The restricted-entry interval for endosulfan is 2 days. Endosulfan may not be effective in all areas due to resistance. In addition, it has a prohibitively long restricted-entry interval and has been implicated in runoff and groundwater contamination.

Methomyl. 14 day PHI for wine grapes. Methomyl (LANNATE) is an oxime carbamate. In 2000, 10,804 lb ai were applied to approximately 3% of wine grape acreage in a median of one application per field. The median application rate was 0.67 lb ai/acre. Much of this usage is for late season control of OLR, orange tortrix or other minor pests. There is a 7 day restricted-entry interval. This product is often disruptive to beneficial mites and parasites of leafhoppers.

Pyridaben. 7 day PHI. Pyridaben (NEXTER) is a pyridazinone. It is a newly registered material for the control of leafhoppers and spider mites on winegrapes. In 2000, 2 lb ai were applied to less than 1% of wine grape acreage in a median of application per field. The median application rate was 0.33 lb ai/acre. There is a 12 hour restricted-entry interval.

Fenpropathrin. 21 day PHI. Fenpropathrin (DANITOL) is registered for control of variegated and grape leafhoppers, omnivorous leafroller and Glassy-winged sharpshooter. In 2000, 2 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 0.21 lb ai/acre. There is a restricted-entry interval of 24 hours.

Insecticidal Soaps (Potash soap). 0 day PHI. Insecticidal soaps are partially effective on low leafhopper populations if applied when nymphs are small. Insecticidal soaps may be more effective if used in combination with oil. Soap can spot the waxy bloom on the berry, but this is only a concern for table grapes. Insecticidal soaps have limited use and are relatively expensive. In 2000, 9,010 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 4.37 lb ai/acre. Approved for use on organically grown grapes. The restricted entry interval for insecticidal soaps is 12 hours.

Carbaryl. 7 day PHI (0 day PHI for dust). Carbaryl (SEVIN) is a carbamate and has a restricted-entry interval of 12 hours. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. Carbaryl, while known to flare mites and be disruptive to beneficials, is still used as a late-season quick knockdown. Use of carbaryl may encourage mite build up as it is very disruptive to the natural enemies of mites. It may not be effective in all areas due to resistance.

Dimethoate. 28 day PHI. Dimethoate (CYGON) is an organophosphate and has a restricted reentry interval of 2 days. In 2000, 4,176 lb ai were applied to approximately 1% of wine grape acreage in a median of one application per field. The median application rate was 0.37 lb ai/acre. This organophosphate is disruptive to beneficials, especially natural enemies of the leafhopper, and there are resistance concerns.

Petroleum Oil (Narrow Range Oil). 0 day PHI. Petroleum oils were applied to approximately 1% of treated acres of grape vineyards, but part of this treatment is for spider mites. In 2000, 64,752 lb ai were applied in a median of one application per field. The median application rate was 6.14 lb ai/acre. Approved for use on organically grown grapes. The restricted-entry interval is 4 hours.

Spider Mites

Willamette mite: *Eotetranychus willamette*
Pacific mite: *Tetranychus pacificus*
Twospotted mite: *Tetranychus urticae*

Damage. Webspinning spider mites (Acari: Tetranychidae) are a major pest of wine grapes (28). The Pacific mite is the most important mite species in the San Joaquin Valley regions. Pacific mite damage begins as yellow spots, and as damage progresses, these spots may turn brown (necrotic). High populations may cause leaf burning, which can decrease photosynthesis and accumulation of vine energy reserves. Willamette mite feeding causes foliage to turn yellowish bronze or red (depending upon the variety), but usually no burn occurs unless vines are weak. Willamette mites are primarily a problem in the northern growing regions (i.e., Central and Northern Coast Regions) and wine grapes in Northern San Joaquin Valley region. Willamette mite is seldom a pest of wine grapes in the South San Joaquin Valley region.

Life History of the Pest. Although it can cause damage early in the season, Pacific mite generally prefers the hotter, dryer part of the season. Willamette mite is an early season mite in the Southern San Joaquin Valley, where it prefers the cooler parts of the plant and is found mostly in the shady parts of the vine. Willamette mite is active throughout the season in the coastal areas and can cause significant damage. The twospotted mite, *Tetranychus urticae,* is only occasionally found on grapes in California and rarely causes damage.

Monitoring. Monitoring is conducted to determine the intensity of the mite population in relation to the treatment threshold. Typically, monitoring is accomplished by a binomial (presence-absence) sampling method, whereby infestation is estimated by the percentage of leaves that have one or more mites. Treatment is recommended if 50% or more of the leaves are infested, the population is increasing rapidly, and there are no predatory mites present (28).

CONTROLS

Cultural

Dust Reduction. Spider mite outbreaks frequently occur where vines are dusty. Roads may be oiled, watered, graveled or left untilled to reduce dust on vineyard edges. When possible, a weedy cover can be maintained in the summer to further reduce dust.

Irrigation. Water stressed vines are highly susceptible to mite build up. Therefore, maintaining adequate vine water status will decrease the risk of spider mite outbreaks. This can be done by frequent irrigations, and by ensuring that the soil chemistry is conducive to good water infiltration. Overhead watering has been shown to reduce mite problems, although it can also increase some disease problems.

Sulfur Use. The relationship between heavy sulfur use and spider mite outbreaks has long been observed. Several studies have documented this (11,27,43) with some researchers attributing it to the harmful effects of sulfur on predatory mites (27,43), whereas one (9) found no such connection.

Biological

***Galendromus occidentalis*.** The western predatory mite, *Galendromus occidentalis* (*Metaseiulus occidentalis)*, is commonly present in vineyard and preys upon all stages of spider mites. It can be effective in reducing spider mite populations, with the exception of Willamette mites. Disruptive sprays may reduce numbers of this beneficial mite. Predator mites are available commercially to augment populations in the field.

General Predators. Other predators, including sixspotted thrips (*Scolothrips sexmaculatus*), minute pirate bugs (*Orius* spp.) and the spider mite destroyer (*Stethorus picipes*) can also be important, but are not as common because they usually do not overwinter within vineyards. To preserve these natural enemies, growers should avoid using disruptive materials, especially carbaryl, dimethoate, dicofol, and methomyl.

Chemical

Chemical treatments must not be disruptive to predators of spider mites.

Propargite. 21 day PHI. Propargite (OMITE) is an organosulfur. In 2000, 138,315 lb a.i. were used to treat about 12.5% of wine grape acreage at a median application rate of 1.9 lb ai/acre. Fields were treated a median of one time. Propargite has a restricted-entry interval of 30 days in California and label restrictions allow no more than 2 applications per season. Resistance to propargite is showing up in some chronically affected areas of the state. In addition, Omite has worker safety issues and a prohibitively long restricted-entry interval. It is used as a last resort.

Dicofol. 7 day PHI. Dicofol (KELTHANE) is an organochlorine. In 2000, approximately 2.7% of wine grape acreage was treated at a median application rate of 1.25 lb ai/acre with 15,710 lb ai. The median number of applications per field was one. It has a restricted-entry interval of 48 hours. Dicofol is disruptive to predaceous mites and lady beetles typically necessitating use of other miticides later in the season. It may not be effective in all areas due to pest resistance.

Petroleum Oil. 0 day PHI. Petroleum oils were applied to approximately 1% of treated acres of grape vineyards, but part of this treatment is for spider mites. In 2000, 64,752 lb ai were applied in a median of one application per field. The median application rate was 6.14 lb ai/acre. Approved for use on organically grown grapes. The restricted-entry interval is 4 hours.

Fenbutatin-oxide. 28 day PHI. Fenbutatin-oxide (VENDEX) was applied to about 1% of wine grape acreage in a median of one application per field in 2000. A total of 4,131 lb were used at a median rate of 1 lb ai/acre. May not be applied more than twice per season. The restricted-entry interval is 48 hours. Vendex does not provide a sufficient knockdown of mites to provide adequate control.

Cinnamaldehyde. 0 day PHI. Cinnamaldehyde (VALERO) was registered for use on grapes in California in July 1999. In 2000, 2,484 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 2.55 lb ai/acre. It is a contact material that requires good coverage for control. The restricted-entry interval is 4 hours.

Pyridaben. 7 day PHI. Pyridaben (NEXTER) is a pyridazinone. It is a newly registered material for the control of leafhoppers and spider mites on winegrapes. In 2000, 2 lb ai were applied to less than 1% of wine grape acreage in a median of application per field. The median application rate was 0.33 lb ai/acre. There is a 12 hour restricted-entry interval.

Avermectin. 28 day PHI. Avermectin (AGRI-MEK) is a glycoside. It is a recently registered pesticide on winegrapes for the control of spider mites. The Manufacturer’s suggested rate of application per acre is 8 to 16 oz/per acre which is 0.009 to 0.018 lbs ai per acre. A minimum of 40 gallons of water per acre is required and only 2 applications are allowed per year with a minimum of 21 days between sprays. The restricted-entry interval is 12 hours.

Insecticidal Soap (Potash soap). 0 day PHI. Soap (M-Pede) is applied at a 2% solution in enough water to cover the vines. In 2000, 9,010 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 4.37 lb ai/acre. Approved for use on organically grown grapes. The restricted-entry interval for insecticidal soaps is 12 hours. Insecticidal soap has a short period of residual activity

Phylloxera

Daktulosphaira vitifoliae

Damage. Grape phylloxera is an aphid-like insect (Homoptera: Phylloxeridae) which damages grapevines by feeding on roots, either on growing rootlets, which then swell and turn yellowish, or on larger roots, which also swell and may decay (33). Feeding injury causes vines to become stunted, produce less fruit and eventually die. Recent work suggests that several soil borne fungi may play a role in phylloxera damage by infecting roots at sites of phylloxera feeding (34,57). Phylloxera prefers heavy, clay soils that are found in the cooler grape-growing regions of the state such as Napa, Sonoma, Lake, Mendocino, and Monterey counties, as well as the Sacramento Delta and the foothills. It will also take advantage of vines that are stressed or have a limited root area. Although phylloxera is present in the heavier soils of the San Joaquin Valley (mostly the foothill areas), damage is not as severe, possibly because soils are deeper and water more plentiful, or because phylloxera do not do well in the warm summer temperatures of the valley. Phylloxera is not a pest on sandy soils.

Life History of the Pest. Phylloxera adults are wingless and reproduce without males, laying up to several hundred eggs per female (33). Eggs hatch in about a week into nymphs that grow and molt four times to become adults. Grape phylloxera overwinter as small nymphs on roots, and in spring, they start feeding and developing. Once established on a root, phylloxera feed in groups. Infested vineyard areas expand concentrically, and may do so rapidly at a rate of two- to four-fold a year. Satellite infestations frequently establish downwind or along water channels from larger infested areas. In fall when soil temperatures decrease, all life stages die except the small nymphs (58). There are three to five generations each year.

Monitoring. Initial infestations of grape phylloxera appear as a few weakened vines. Therefore, monitoring vines in an area of the vineyard that has consistently displayed weaker growth is necessary. Aerial photography can be useful in detecting weak spots in vineyards (47). In North Coast vineyards infected vines may initially exhibit potassium deficiency symptoms (33).

CONTROLS

Cultural

Resistant Rootstocks. Resistant rootstocks are the only completely effective means for phylloxera control in the most severely affected areas. For durable protection against phylloxera, it is necessary for growers to use rootstocks that have strong resistance to phylloxera, i.e., of Native American parentage and no *Vitis vinifera* parentage. Unfortunately, in order to use this method infested vineyards must be replanted at a substantial investment to the grower. Replanting affected vines is best done by block, though this approach is most expensive.

Sanitary Practices. Sanitary practices are critical when planting a new vineyard, using only clean propagating material from a certified nursery. Even though resistant to phylloxera, young resistant rootstock vines will support some phylloxera and may be stunted if replanting occurs in heavily infested soils. Equipment should also be cleaned to remove soil before moving between vineyards.

Water and Fertility Management. Good water management, fertilization, and other cultural practices that help limit plant stress may reduce phylloxera damage.

Increased Organic Matter. Some growers have found the use of compost and other sources of organic matter resulted in continued production in areas with phylloxera (55).

Biological

There are no specific biological controls targeting grape phylloxera.

Chemical

A pesticide treatment will not eradicate phylloxera populations because of the difficulties in penetrating the heavy soils that this pest prefers. Populations may rebound rapidly after a chemical treatment, and it may be difficult or impossible to stop overall vine decline (69).

Carbofuran. 200 day PHI. Carbofuran (FURADAN) is a restricted use carbamate that may only be applied by permit from a county agricultural commissioner. This use is also restricted under a 24(c) registration to certain counties and winegrape varieties. Carbofuran was applied post-harvest to about 1% of wine grape acreage at a median application rate of 3.2 lb ai/acre in 2000. A total of 19,218 lb were applied in a median of one application per field. Applications are made via drip irrigation between harvest and early December. This product is available for use under a special local needs permit. Reentry interval is 48 hours.

Sodium Tetrathiocarbonate. 14 day PHI. Sodium tetrathiocarbonate (ENZONE) was applied to 1.3% of wine grape acreage in 2000. A total of 206,141 lb were applied in a median of one application per field. The median application rate was 27.18 lb ai/acre. Applications may only be made to crops at least one year old or injury may occur. It can be applied anytime during the growing season by metering it into irrigation water in drip or furrow irrigation systems. It has a restricted-entry interval of 4 days.

Fenamiphos. 2 day PHI. Fenamiphos (NEMACUR) is an organophosphate. In 2000, 30,191 lb ai were applied to approximately 2.6% of wine grape acreage at a median application rate of 1.46 lb ai/acre. The median number of applications was one. The restricted entry interval is 48 hours.

Omnivorous Leafroller

Platynota stultana

Damage. The omnivorous leafroller (OLR) is a moth whose larval stage can cause serious damage in the Northern and Southern San Joaquin Valley regions (17). It is a major pest of wine grapes. It feeds on leaves, flowers, and developing berries. Damage to post-veraison berries allows rot organisms to enter the fruit.

Life History of the Pest. OLR larvae overwinter in old grape clusters (mummies) and vineyard weeds. In spring, the larvae complete their development and moths emerge and lay shingle-like egg masses on grape leaves. After about 5 days these eggs hatch, and larvae web together leaves or cluster parts to form a nest in which they feed.

Monitoring. Growers and PCAs monitor for OLR by examining grape bunches. Critical periods for monitoring are during the critical treatment window for each of the first two generations. Pheromone traps are used to catch male moths and provide the bio-fix dates. 700-900 degree days past biofix is the recommended treatment window for OLR (18).

CONTROLS

Cultural

Weed Control. Many weeds are also hosts of OLR, including mare's tail, panicle willow herb, and lamb's quarters. Growers should ensure that these and other host weeds are controlled by French plowing, discing or herbicides.

Sanitation. Destroy old clusters that fall on the berm or end up in the middles after pruning. Berm sweeping or berm-blowing will move these mummies out into the middles where they can be shredded or disked. In-row cultivation with a French plow or other cultivator will bury the mummies.

Biological

General Predators and Parasites. More than 10 species of parasites have been recovered from omnivorous leafroller. However, overall parasitism is usually low. Spiders are potentially good predators of OLR.

Chemical

Because the most widely used insecticides for OLR (cryolite and Bt, see below) are stomach poisons that need to be eaten by OLR larvae to be effective, spray timing and coverage are extremely important. However, because of winery restrictions on using cryolite after June 1, many growers feel compelled to treat for first brood OLR, even though recent research indicates that in some cases second brood treatments may be more effective (19). There are many cases in which OLR was not present in the vineyard in spring, but migrated in later in the season (M.J. Costello, personal observation). In these cases, broad spectrum OPs or carbamates are used for late-season control.

Cryolite. 30 day PHI. Cryolite (PROKIL OR KRYOCIDE) was applied to about 9.7% of wine grape acreage in 2000. A total of 272,053 lb ai were applied in a median of one application per field. The median application rate was 5.76 lb ai/acre. Cryolite is a mineral (sodium aluminofluoride) that must be ingested by OLR for it to be effective. Most wineries require that applications be made before full bloom or before June 1, and limit the total seasonal application to six lb ai per acre. The restricted-entry interval is 12 hours. This product, although effective, now has limited use due to restrictions imposed by California wineries with export markets. Nations that comprise the European Community have implemented a strict tolerance of 1 ppm with respect to fluoride residues in wine. Because there is a direct correlation between the use of Cryolite and fluoride residues, California wineries with export markets have responded in kind by prohibiting their growers from using Cryolite. Cryolite may also cause secondary pest outbreaks.

***Bacillus thuringiensis* (Bt) (Several strains).** 0 day PHI. In 2000, 9,299 lb Bt were applied to approximately 18.66% of wine grape acreage at median application rates of 0.01-0.15 lb ai/acre. Applications were made a median of one to two times per field. Bt is a bacterium that must be consumed by OLR in order to be effective. This material is approved for use on organically grown grapes. Bt is effective only against young larvae.

OLR Pheromone. 0 day PHI. Pheromones (NO-MATE, CHECKMATE) can be sprayed or hand-placed in vines at label rates to disrupt the mating of adult OLR. There is no restricted- entry interval. This pheromone is approved for certified organic production. *Bt* sprays are effective on small larvae, but have a short period of residual activity.

Methomyl. 14 day PHI for wine grapes. Methomyl (LANNATE) is an oxime carbamate. In 2000, 10,804 lb ai were applied to approximately 3% of wine grape acreage in a median of one application per field. The median application rate was 0.67 lb ai/acre. There is a 7-day restricted-entry interval. Methomyl is highly disruptive to the predators of spider mites

Carbaryl. 7 day PHI (0 day PHI for dust). Carbaryl (SEVIN) is a carbamate and has a restricted-entry interval of 12 hours. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. Use of carbaryl encourages mite buildup, as it is very disruptive to the natural enemies of mites.

Phosmet. 7 day PHI. Phosmet (IMIDAN) is an organophosphate. In 2000, 18,450 lb ai were applied to 2.7% of wine grape acreage at a median application rate of 1.4 lb ai/acre. A median of one treatment per field was applied. The restricted-entry interval for phosmet is 5 days. For an organophosphate, phosmet is relatively non-disruptive to natural enemies, however there are worker safety issues associated with its use.

Diazinon. 28 day PHI. Diazinon is an organophosphate. In 2000, 4,020 lb ai were applied to less than 1% of wine grape acreage at a median application rate of 1.00 lb ai/acre. A median of one treatment per field was applied. The restricted-entry interval for diazinon is 5 days. It is very disruptive to natural enemies and there are worker safety issues associated with its use.

Tebufenozide. 14 day PHI. Tebufenozide (CONFIRM) is a chemical that mimics the insect hormone that regulates larval molting from one instar to the next (ecdysone). It is highly active against most lepidopterous species and has almost no activity against all other insect orders. In 2000, 6,397 lb ai were applied to 7.2% of wine grape acreage at a median application rate of 0.19 lb ai/acre. A median of one treatment per field was applied. It is recommended that spraying is timed so that early larval instars are present. Because larvae must ingest the chemical to be affected thorough coverage of the foliage is essential for efficacy. The restricted-entry interval is 4 hours.

Fenpropathrin. 21 day PHI. Fenpropathrin (DANITOL) is registered for control of variegated and grape leafhoppers, omnivorous leafroller and Glassy-winged sharpshooter. In 2000, 2 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 0.21 lb ai/acre. There is a restricted-entry interval of 24 hours.

Sharpshooters

Blue-green sharpshooter*: Graphocephala atropunctata*
Green sharpshooter: *Draeculacephala minerva*
Red-headed sharpshooter: *Carneocephala fulgida*
Glassy-winged sharpshooter: *Homalodisca coagulata*

Damage. Sharpshooters vector the bacterium *Xylella fastidiosa*, which causes Pierce's disease (see section on disease) in grapes, one of the few grapevine diseases that can kill vines (32). Sharpshooters (Homoptera: Cicadellidae) are leafhoppers, but belong to a subfamily that feeds on the water conducting vessels of the plant (the xylem). The blue-green sharpshooter is the most important vector of Pierce's disease in coastal grape-growing areas (62), whereas the green sharpshooter and the red-headed sharpshooter are the primary vectors in the South and North San Joaquin Valley regions. The glassy-winged sharpshooter is a relatively new pest that has established high populations in southern California since the early 1990s, and was detected in the San Joaquin Valley in 1998 (61)**.**

Life History of Pest. The blue-green sharpshooter feeds, reproduces, and is often abundant on cultivated grapes. In late winter and early spring, adults become active when temperatures warm above 15ºC. Some begin moving into nearby vineyards when grape shoots are several inches long, but blue-green sharpshooters are usually more abundant in natural habitats than in vineyards.

The green sharpshooter and the red-headed sharpshooter prefer grasses for feeding and breeding, and can often be found in pastures, weedy alfalfa fields, and on roadside weeds. Grapes are only accidental hosts of these grass-feeding sharpshooters. The overwintering adults do not live long, thus it is probably the second generation that migrates to the vineyard. Their dispersal and rate of development are temperature dependent.

The glassy-winged sharpshooter is a native of the southeastern U.S. This insect invaded southern California in the early 1990s (61), and was detected in the San Joaquin Valley in 1998. It is considered a greater threat to vineyards than any of the other sharpshooter species because of its wide host range, strong flying ability, and it preference for grapes as a feeding and reproductive host. Therefore it is capable of spreading Pierce’s Disease from one grapevine to the next.

Monitoring. In addition to visual observations using sweep nets, sticky traps can be placed in areas adjacent to vineyards that serve as habitat for the blue-green and glassy-winged sharpshooters. Sticky traps are not effective monitoring tools for the green and red-headed sharpshooters. Insecticidal treatment of vector source areas may be warranted (with prior approval through the County Agricultural Commissioner in Napa and Sonoma Counties) where blue-green sharpshooter is the main vector near riparian or ornamental landscapes. Treatments should be applied if after several successive warm days there is a sharp increase in the number of sharpshooters trapped, or if visual inspections reveal more than one sharpshooter per vine. Sweep nets and trapping should also be used to monitor populations in non-crop vegetation adjacent to vineyards after treatment.

CONTROLS

Cultural

Neighboring Crops/Wildlands. Riparian areas bordering vineyards are often an important source of blue-green sharpshooters in coastal vineyards. In the San Joaquin Valley, the greatest amount of disease spread is usually near pastures, weedy hay fields, or other grassy areas. Growers should consider the presence of neighboring hay fields or permanent pastures or riparian areas when planting a vineyard. Though often not feasible, in some instances properties adjacent to vineyards are purchased or leased, and managed in such a way that does not encourage sharpshooter populations. Management of riparian woodlands and environmental restoration plantings with non-host species is a newly developed method that requires careful planning and advance approval by governmental agencies.

Weed Control. Perennial weedy grasses should be eliminated from areas adjacent to vineyards, such as along roads, ditches, and ponds. Bermuda grass and water grass are especially favored sharpshooter hosts. Alfalfa fields can be sources of sharpshooters if grass weeds are present. Annual weeds in vineyards that begin to grow after April or May usually do not support high sharpshooter populations.

Biological

Few biological control agents have been identified that are specific to sharpshooters. The most common parasitoids of sharpshooters are parasitic wasps in the families Mymaridae and Trichogrammatidae that attack sharpshooter eggs. Egg parasites of the Glassy-winged sharpshooter can parasitize up to 80% of the egg-mass.

Chemical

Imidacloprid. 0 days PHI. Imidacloprid (PROVADO, ADMIRE) is in the chloronicotinyl chemical family. Provado7 is a wettable powder formulation. In 2000, 5,751 lb ai were applied to approximately 22% of wine grape acreage in a median of one application per field. The median application rate was 0.04 lb ai/acre. Most of this is applied for leafhopper control. Growers are required to allow 14 days before reapplication. Admire7received a special local needs registration in February 1999 for use on leafhoppers (including sharpshooters) and mealybugs in California, and is a flowable intended for use in drip systems. Because imidacloprid is a systemic, it is taken up by the vine through the root system. Recommended application timing is between budbreak and pea-berry stage, at a rate of 0.25 to 0.50 lb ai/acre. The restricted-entry interval for imidacloprid is 12 hours. Although growers prefer this material, there are resistance concerns. In addition, no CODEX MRL exists for this product on grapes.

Dimethoate. 28 day PHI. Dimethoate (CYGON) is an organophosphate. In 2000, 4,176 lb ai were applied to approximately 1% of wine grape acreage in a median of one application per field. The median application rate was 0.37 lb ai/acre. Treatment to border (riparian) vegetation may be made by permit from the county agricultural commissioner under a special local needs permit. Applications may be made with a ground rig-handgun sprayer to a band of natural vegetation about 50-100 ft wide along the vineyard edge. When sharpshooters have migrated into the vineyard and there is more than a couple of inches of new shoot growth on the vines, the first 200-300 ft in from the edge of the vineyard is also treated. The restricted-entry interval is 2 days. Use of this product is authorized through a Section 24(c) Special Local Needs registration in Napa, Sonoma, Mendocino, and Lake counties only. Dimethoate is reputed to not be as effective against adult sharpshooters but it is the only material that may be used near riparian environments.

Kaolin. 14 days PHI. Kaolin (SURROUND) is a mineral product and has recently been registered for control of the Glassy-winged sharpshooter in California. In 2000, 489 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 23.75 lb ai/acre. Surround7 is an organically accepted pesticide. There is a 4 hour restricted entry interval.

Fenpropathrin. 21 day PHI. Fenpropathrin (DANITOL) is registered for control of variegated and grape leafhoppers, omnivorous leafroller and Glassy-winged sharpshooter. In 2000, 2 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 0.21 lb ai/acre. There is a restricted-entry interval of 24 hours.

Cyfluthrin. 7 day PHI. Cyfluthrin (BAYTHROID) is allowed under a Section 18. Cyfluthrin is fully registered on a number of crops for control of several insects including Glassy-winged sharpshooter. The manufacturer's recommended rate for control of GWSS is 6.4 fluid ounces per acre or 0.10 lbs. a.i. per acre per crop season. Allow a minimum of 14 days between applications with an average of 3 applications per crop season. Restricted entry interval is 12 hours.

Mealybugs

Grape Mealybug: *Pseudococcus maritimus*
Longtailed mealybug: *Pseudococcus longispinus*
Obscure mealybug: *Pseudococcus viburni*
Vine Mealybug: *Planococcus ficus*

Damage. Mealybugs (Homoptera: Pseudococcidae) are not a major pest of wine grapes in California, with the exception of the obscure mealybug in the southern Central Coast region (21), and the vine mealybug, which until recently had been confined to the Coachella Valley but is now present in the San Joaquin Valley (1). Mealybugs can damage grapes by feeding on leaves and by contaminating clusters with honeydew that supports the growth of black sooty mold (29). In addition, all mealybugs tested have been shown to vector leafroll viruses. Feeding by mealybugs can be severe enough to stunt vine growth, but this only commonly occurs with obscure and vine mealybugs. Because cosmetic injury is not usually a concern for wine grapes, grape mealybug is not often a pest. The exception to this is the Eastern fresh pack market, where mealybug contamination is not allowed. Cluster contamination by mealybugs is related to variety and pruning method. It can be worse on spur-pruned varieties and on varieties that produce a high percentage of clusters close to the base of the shoot, resulting in clusters that touch old wood. Mealybugs also take advantage of tight clustered varieties, where there are better hidden. The vine mealybug can, potentially, cause far greater damage than the other vineyard mealybugs. By the end of the season, vine mealybugs can be found on the leaves, grape bunches, canes and roots. The vine mealybug produces far greater amounts of honeydew and may have up to 8 generations per year in the San Joaquin Valley (compare with 2-4 for the grape mealybug).

Life History of the Pest. Mealybugs overwinter as adults, eggs (in white, cottony egg sacs) and first instar crawlers. Most of the overwintering population is found underneath the bark, quite often on the upper trunk sections, cordons and spurs (30). Crawlers emerge in late winter and make their way to buds, where they begin feeding once bud break occurs. Adult females return to the bark to lay eggs of the next generation, which, when hatched, colonize grape bunches.

Monitoring. Growers and PCAs can most easily monitor for the presence of mealybugs in the winter. Just prior to budbreak the crawlers will be active, and their numbers can be estimated by recording mealybug presence under bark on spurs. Double-sided tape wrapped around spurs can be used to trap crawlers, but this is a less reliable method than direct counts. However, there are no established treatment thresholds for these methods. Early summer infestation can be estimated by counting mealybugs on spurs (3,30), and late-season evaluation consists of analyzing clusters that are not free hanging (touching the cordon, trunk or stake) and recording by presence/absence. There are no reliable methods of monitoring for parasitism.

CONTROLS

Cultural

Pruning/training. Pruning which helps clusters hang free can reduce infestation, because grape mealybug prefers to feed on grape berries that touch old wood. Training vines so that spurs are positioned horizontally and leaving long spurs helps clusters hang free. Cane pruned varieties are less susceptible because clusters are produced on canes far from the old wood.

Ants. Because ants feed on mealybug honeydew, ants play an important role in the development of mealybug pest populations. Ants physically move young mealybugs to desirable feeding areas of the vine in order to collect mealybug honeydew. The spread of mealybugs can be slowed if ant populations are controlled.

Irrigation Control. Drip irrigation favors ant populations since this leaves large areas of dry soil on the berm, which tends to be a good, safe habitat for ants.

Biological

Parasitoids. Several species of parasitic wasps (Hymenoptera: Encyrtidae) attack mealybugs in California. The impact of the different species varies from time to time and place to place. The most significant parasites of grape mealybug are, *Acerophagus notativentris*, *Pseudaphycus angelicus*, and *Zarhopalus corvinus* (21). These parasites may attack longtailed mealybug as well. Two parasites (*Pseudaphycus flavidulus* and *Leptomastix epona*) have been imported from Chile for the obscure mealybug, and four parasitoids (*Anagyrus pseudococci*, *Leptomastidea abnormalis*, *Coccidoxenoides peregrinus*, and *Leptomastix dactylopii*) were imported from Argentina, Spain, Israel, or Turkmenistan for the vine mealybug (31). Recently, *Anagyrus* sp. (possibly *A. pseudococci*) has been recovered from vine mealybug in the South San Joaquin Valley.

Other Predators. Mealybug predators include a ceciodomyiid fly (*Diadiplosis californica* Felt) and a lady beetle called the mealybug destroyer, *Cryptolaemus montrouzieri*. The mealybug destroyer was originally collected in northern Australia, where winter temperatures are warmer than in most of California's grape growing regions. For this reason, populations of the mealybug destroyer dramatically decline or disappear altogether during the winter. To "re-inoculate" the vineyard, insectary-purchased beetles must be released.

Natural enemies can keep mealybugs under control in some cases, but mealybug parasites are very sensitive to broad-spectrum insecticides. It is generally recommended that if chemical treatment is necessary, some areas of the vineyard should be left untreated as a refuge for parasite populations. Controlling ants will also help parasites control mealybugs.

Chemical

Delayed Dormant

Chlorpyrifos. 45 day PHI. A pre-budbreak (delayed dormant) application of chlorpyrifos (LORSBAN) in combination with a dormant oil is recommended to control mealybugs. Oil provides better coverage and penetration, and therefore better kill than chlorpyrifos alone. In 2000, 10,898 lb ai were applied to 1.7% of wine grape acreage at a median application rate of 2.0 lb ai/acre. A median of one treatment per field was applied. Chlorpyrifos can also be sprayed onto the soil surface during spring to kill ants. The restricted entry interval for chlorpyrifos is 24 hours.

In-Season

Azinphos Methyl. RESTRICTED AS OF AUG. 2, 1999. 21 day PHI. Application of azinphos methyl (GUTHION) in combination with a narrow range oil is sometimes recommended to control grape mealybug during the dormant, spring and summer seasons. The oil provides better coverage and kill than azinphos methyl alone. Azinphos methyl, alone, may not provide adequate control, but there are few alternatives available for this use. Azinphos methyl is rarely used in vineyards and was applied to less than 0.01% of wine grape acreage in 2000. The median rate of application was 1.5 lb ai/acre. The restricted entry interval is 45 days if l lb or less of active ingredient is applied per acre, or only 1 application per season is made; otherwise the restricted entry interval is 50 days. No more than 3 applications per season are permitted. Note that the restricted entry interval exceeds the pre-harvest interval (10 days).

Methyl Parathion. RESTRICTED AS OF AUG. 2, 1999. 40 day PHI. Methyl parathion is an organophosphate that is applied at a median rate of 0.67 lb ai per acre in the spring. Application may be made until bloom. Methyl parathion is disruptive to beneficials and 8 lb ai were applied to less than 0.01% of wine grapes in 2000. The restricted-entry interval for methyl parathion is 48 hours. In areas where annual rainfall is less than 25 inches (which includes much of California's grape growing regions), methyl parathion is applied only as dormant or pre-bloom spray. Product is used infrequently and is disruptive to beneficials.

Imidacloprid. 0 day PHI. Imidacloprid (PROVADO, ADMIRE) is in the chloronicotinyl chemical family. Provado7 is a wettable powder formulation. In 2000, 5,751 lb ai were applied to approximately 22% of wine grape acreage in a median of one application per field. The median application rate was 0.04 lb ai/acre. The vast majority of these applications were for leafhoppers. Growers are required to allow 14 days before reapplication. Admire7received a special local needs registration in February 1999 for use on leafhoppers (including sharpshooters) and mealybugs in California. , and is a flowable intended for use in drip systems. Because imidacloprid is a systemic, it will be taken up by the vine through the root system. Recommended application timing is between budbreak and pea-berry stage, at a rate of 0.25 to 0.50 lb ai/acre. The restricted - entry interval for imidacloprid is 12 hours. There is concern about pest resistance to this product..

MINOR INSECT PESTS OF WINE GRAPES

Some insect pests are considered minor either because they are restricted to a relatively small region in the state, or because they only occasionally surface at densities high enough to cause damage. Therefore, collective treatment for any given minor pest is minimal. However, the damage that a minor pest can cause in a particular vineyard can be major, resulting in a significant loss to that grower. Often there is a lack of knowledge of cultural and biological controls for minor pests, and as a result, their control is almost entirely chemical dependent.

Thrips

Grape thrips: *Drepanothrips reuteri*
Western flower thrips: *Frankliniella occidentalis*

Damage. Grape thrips and western flower thrips (Thysanoptera: Thripidae) are the primary species that can cause damage on grapes (46). In general, thrips are a minor problem on wine grapes in California. Damage from both species occurs from feeding on actively growing shoot tips, which can distort leaves and stunt shoots. Western flower thrips shoot damage can occur in spring and summer, whereas grape thrips damage occurs in mid-summer. In the northern San Joaquin Valley, North Coast and Central Coast, feeding by western flower thrips occasionally causes enough damage to require treatment, but damage by grape thrips is rare because there is usually sufficient foliage by the time populations peak. Damage can also occur by grape thrips feeding on berries, which may scar and crack, although this is almost never economically significant for wine grapes.

Life History of the Pest. Western flower thrips overwinter as adults and nymphs. They will feed on a variety of plant, adults feeding on pollen, and nymphs feeding on shoot tissue. Eggs are laid in soft tissues, especially of young flowers. Western flower thrips populations peak in May, coinciding with grape bloom. Grape thrips overwinter as virgin females, and the first generation in spring is produced asexually. They feed on grapes, and have also been found on poison oak (*Rhus diversiloba*). Populations reach their greatest numbers in July.

Monitoring. Visual inspection of shoots in spring is the only practical method of monitoring for western flower thrips, but no treatment thresholds have been established. No specific monitoring guidelines have been developed for grape thrips on shoot tips.

CONTROLS

Cultural

Cover crops. Western flower thrips may be present on cover crops and other vineyard floor vegetation, but there are no guidelines for managing cover crops to avoid thrips damage to shoots.

Biological

Little is known about natural control of thrips in vineyards. An important thrips predator is the minute pirate bug, but its numbers are usually quite low on grapes.

Chemical

Chemical treatment may be necessary in spring if western flower thrips populations are high enough to stunt shoots.

Carbaryl. 7 day PHI (0 day PHI for dust). Carbaryl (SEVIN) is a carbamate. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. Some of this usage is for leafhoppers and other pests. Carbaryl has a restricted-entry interval of 12 hours. Use of carbaryl may encourage mite buildup as it is very disruptive to the natural enemies of mites.

Methomyl. 14 day PHI for wine grapes. Methomyl (LANNATE) is an oxime carbamate. In 2000, 10,804 lb ai were applied to approximately 3% of wine grape acreage in a median of one application per field. The median application rate was 0.67 lb ai/acre. Some of this usage is for leafhoppers and other pests. Methomyl is a restricted use material and may only be used by permit from the county agricultural commissioner. This product may be disruptive to beneficial mites and parasites of leafhoppers. The reentry period is 7 days.

Dimethoate. 28 day PHI. Dimethoate (CYGON) is an organophosphate. In 2000, 4,176 lb ai were applied to approximately 1% of wine grape acreage in a median of one application per field. The median application rate was 0.37 lb ai/acre. Some of this use is for leafhoppers and other pests. The restricted entry interval is 48 hours. Dimethoate is moderately disruptive to beneficial insects.

Orange Tortrix

Argyrotaenia citrana

Damage. Orange tortrix (Lepidoptera: Tortricidae) is found in all coastal grape growing areas. Orange tortrix (OT) causes the same kind of damage on the coast as the omnivorous leafroller in inland areas. On rare occasions, early spring damage occurs from larvae feeding on buds and newly emerging shoots, but primarily, damage occurs when larvae feed on bunches and make nests of webbing among the berries. This feeding allows entry of bunch rot disease organisms.

Life History of the Pest. OT overwinters as larvae, and feed throughout the winter on old grape clusters and weeds. In spring the larvae pupate and emerge as adults, mate, and lay eggs. There are three generations per year.

Monitoring. Pheromone traps can be used to determine a biofix date, and should be placed in the vineyard in December. Chemical treatments should be timed to correspond to 1000 degree days F from the biofix date. Monitoring for OT larvae is done by visual inspection of the clusters in spring and summer.

CONTROLS

Cultural

Weed Control. Many weeds are also hosts of OT, including mallow, curly dock, mustard, filaree, lupine, and California poppy. Growers should ensure that these and other host weeds are controlled by French plowing, discing or herbicides.

Sanitation. Old clusters that fall on the berm or end up in the middles after pruning should be destroyed. Berm sweeping or berm-blowing will move these mummies out into the middles where they can be shredded or disked. In-row cultivation with a French plow or other cultivator will bury the mummies.

Biological

***Exochus* Wasp.** In the Salinas Valley the dominant parasite of orange tortrix is *Exochus nigripalpus subobscurus*. The adult *Exochus* wasp is about 0.25 inch (6 mm) long, with a black head and body and yellow legs. This internal larval parasite emerges after the larva pupates. Moderate to heavy parasitism in late spring has resulted in season long biological control in the Salinas Valley.

Coyote Brush. There are indications that coyote brush grown near vineyards in the Salinas Valley will increase parasitism by this parasite by allowing the parasite to overwinter on orange tortrix and other hosts found in the coyote brush.

Other Parasites and Predators. At least two other wasp species and one fly parasite are known to attack orange tortrix. Spiders may also feed on larvae.

Chemical

If stomach poisons are used, good coverage is essential for control. OPs and carbamates are used late in the season if the population is high.

Cryolite. 30 day PHI. Cryolite (PROKIL OR KRYOCIDE) was applied to about 9.7% of wine grape acreage in 2000. A total of 272,053 lb ai were applied in a median of one application per field. The median application rate was 5.76 lb ai/acre. Cryolite is a mineral (sodium aluminofluoride) that must be ingested by OLR for it to be effective. Most wineries require that applications be made before full bloom or before June 1, and limit the total seasonal application to six lb ai/acre. The restricted-entry interval is 12 hours. Cryolite, while effective, can cause secondary pest outbreaks. In addition, wineries with export markets do not allow its use. Nations that comprise the European Community have implemented a strict tolerance of 1 ppm with respect to fluoride residues in wine. Because there is a direct correlation between the use of Cryolite and fluoride residues, California wineries with export markets have responded in kind by prohibiting their growers from using CryoliteCryolite may also cause secondary pest outbreaks.

***Bacillus thuringiensis* (Bt) (Several strains).** 0 day PHI. In 2000, 9,299 lb Bt were applied to approximately 18.66% of wine grape acreage at median application rates of 0.01-0.15 lb ai/acre. Bt is a bacterium that must be consumed by OT in order to be effective. This material is approved for use on organically grown grapes. Bt is most effective against young larvae. While effective on small larvae, *Bt* sprays have a short period of residual activity.

Methomyl. 14 day PHI for wine grapes. Methomyl (LANNATE) is an oxime carbamate. In 2000, 10,804 lb ai were applied to approximately 3% of wine grape acreage in a median of one application per field. The median application rate was 0.67 lb ai/acre. Some of this usage is for leafhoppers and other pests. The restricted-entry interval is 7 days. Methomyl is disruptive to predators of mites and parasites of leafhoppers.

Carbaryl. 7 day PHI. Carbaryl (SEVIN) is a carbamate. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. Some of this usage is for leafhoppers and other pests. The restricted-entry interval is 24 hours. Carbaryl is disruptive to predators of mites and parasites of leafhoppers so the product should not be used where mites are a chronic problem. Carbaryl is extremely toxic to honeybees.

Methyl Parathion. RESTRICTED AS OF AUG. 2, 1999. 40 day PHI. Methyl parathion is an organophosphate that is applied at a median rate of 0.67 lb ai per acre in the spring. Application may be made until bloom. Methyl parathion is disruptive to beneficials and 8 lb ai was applied to less than 0.01% of wine grapes in 2000. The restricted-entry interval for methyl parathion is 48 hours. In areas where annual rainfall is less than 25 inches (which includes much of California's grape growing regions), methyl parathion is applied only as dormant or pre-bloom spray. Product is used infrequently and is disruptive to beneficials.

Western Grapeleaf Skeletonizer

Harrisina brillians

Damage. Western grapeleaf skeletonizer (WGLS) (Lepidoptera: Zygaenidae) larvae feed gregariously on lower leaf surfaces, leaving only the veins and upper cuticle, and giving damaged leaves a whitish paper like appearance (66). Maturing larvae completely remove all interveinal tissue, leaving only the larger veins. When abundant, larvae can defoliate vines. If there is no leaf area left, larvae may feed on grape clusters as well. Defoliation can result in sunburn of the fruit and quality loss, as well as reducing reserves for the next year's crop.

Life History of the Pest. WGLS overwinters as a pupa in a dirty, whitish cocoon under the bark. The metallic bluish-black moths emerge in spring and can be seen flying during early morning hours. There are three generations per year in the Central Valley and two generations in the cooler coastal regions. Female moths lay pale yellow or whitish capsule-shaped eggs in clusters on the underside of grape leaves. After hatching, the larvae line up and feed side-by-side on the leaf underside until the early fourth instar stages, and feed in isolation for the remainder of their development. When mature, larvae crawl under the loose bark or under ground litter to pupate.

Monitoring. Because WGLS has become a minor pest since the mid-1990s, formal monitoring for it is rare. Early larval infestations can be detected by the presence of whitish paper-like leaves.

CONTROLS

Cultural

No cultural methods have been identified to control WGLS.

Biological

Insect Parasites. Two insect parasites, the tachinid fly *Ametadoria misella* and the braconic wasp *Apanteles harrisinae*, attack western grapeleaf skeletonizer larvae. *Ametadoria misella* is common in the San Joaquin Valley, and, together with the granulosis virus, provides excellent biological control.

Pathogenic Virus. A granulosis virus, first discovered infesting laboratory colonies of WGLS in southern California in the 1950s, was introduced into the San Joaquin Valley in the early 1980s. Disease-carrying adults that survive a low degree of infection in the larval stage transmit this virus from one generation to the next. Most WGLS infestations are wiped out by the second generation by the combined action of *A. misella* and the granulosis virus.

Chemical

Treatments applied for omnivorous leafroller will usually control WGLS early in the season.. If the biological control agents are not present or have been disrupted by broad-spectrum insecticides, the amount of leaf damage will increase with each generation.

Cryolite. 30 day PHI. Cryolite (PROKIL OR KRYOCIDE) was applied to about 9.7% of wine grape acreage in 2000. A total of 272,053 lb ai were applied in a median of one application per field. The median application rate was 5.76 lb ai/acre. These applications are typically targeting OLR or OT, not WGLS. A maximum of two applications per season are allowed and no more than 20 lb/acre/year may be applied. The restricted-entry interval is 12 hours. Most wineries require that applications be made before full bloom or before June 1. More importantly, while Cryolite is effective, wineries with export markets do not allow its use. Nations that comprise the European Community have implemented a strict tolerance of 1 ppm with respect to fluoride residues in wine. Because there is a direct correlation between the use of Cryolite and fluoride residues, California wineries with export markets have responded in kind by prohibiting their growers from using Cryolite. Cryolite may also cause secondary pest outbreaks. Cryolite can also cause secondary pest outbreaks.

***Bacillus thuringiensis* (Bt) (Several strains).** 0 day PHI. In 2000, 9,299 lb Bt were applied to approximately 18.66% of wine grape acreage at median application rates of 0.01-0.15 lb ai/acre. Bt is a bacterium that must be consumed by WGLS in order to be effective. This material is approved for use on organically grown grapes. Bt is most effective against young larvae but has a short period of residual activity.

Methomyl. 14 day PHI for wine grapes. In 2000, 10,804 lb ai were applied to approximately 3% of wine grape acreage in a median of one application per field. The median application rate was 0.67 lb ai/acre. Some of this usage is for leafhoppers and other pests. It is a restricted use material and may only be used by permit from the county agricultural commissioner. The reentry restriction period is 7 days. Methomyl is disruptive to predators of mites and parasites of leafhoppers.

Carbaryl. 7 day PHI. Carbaryl (SEVIN) is a carbamate and has a restricted-entry interval of 24 hours. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. Some of this usage is for leafhoppers and other pests. The restricted-entry interval is 24 hours. Carbaryl is disruptive to predators of mites and parasites of leafhoppers so the product should not be used where mites are a chronic problem. Carbaryl is extremely toxic to honeybees.

Branch and Twig Borer

Melalqus confertus

Damage. Both adults and larvae of the branch and twig borer (Coleoptera: Bostrichidae) injure grapevines. This beetle is also known as the grape cane borer. Adults burrow into the canes through the base of the bud or into the crotch formed by the shoot and spur. Larvae bore into wood at dead or dying parts of vines, often in old pruning scars. Once established, they feed on both living and dead wood. In chronically infested vineyards, their burrows can weaken vine structure, permitting spurs or even cordons to break.

Life History of the Pest. The branch and twig borer occurs throughout California. Adults emerge from March through May, mate, and lay eggs. Larvae emerge in May and June, bore into dead wood, and feed for 10 months before pupating within a hollow cell.

Monitoring. Vines can be examined for active feeding sites and by looking for adult beetles in spring. Old pruning scars and dead parts of vines can be examined for brown frass and fine wood dust filling the holes that were made by borer larvae.

CONTROLS

Cultural

The best way to manage branch and twig borer in vineyards is to prevent invasion and establishment of the beetles through cultural methods.

Disease control. Managing Eutypa and other canker diseases (see Major Diseases) minimizes the amount of dead wood available for the branch and twig borer to make use of.

Brush Removal. Wood and brush piles of any kind of tree or shrub should be completely removed from the vineyard or burned before emergence of adult beetles in March.

Pruning. Dead or dying portions of vines should be removed and destroyed, along with all prunings. When mechanical cane chipping or cutting is used for pruning disposal, the residue should be incorporated into the soil before adult emergence.

Vine Health. Good vine health is important for reducing sites of borer establishment in vineyards.

Biological

The many species of naturally occurring general predators found under the bark of grapevines may assist in maintaining lower populations.

Chemical

Chemical control is normally not necessary if good cultural controls are practiced.

Carbaryl. 7 day PHI (0 day PHI for dust). Carbaryl (SEVIN) is a carbamate and has a restricted-entry interval of 24 hours. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. Carbaryl is rarely applied just to control branch and twig borer. Treatments for cutworms (e.g., carbaryl) may offer some measurable control of adult borers. The restricted-entry interval for carbaryl is 24 hrs. Application of carbaryl causes mite flare-ups so use is not recommended where mites are a chronic problem.

Endosulfan. 7 day PHI. Endosulfan (THIODAN) is an organochlorine. In 2000, 23 lb were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 1.5 lb ai per acre. The restricted-entry interval for endosulfan is 1 day. Endosulfan may not be effective in all areas due to resistance. In addition, endosulfan has a prohibitively long restricted-entry interval and has been implicated in runoff and groundwater contamination.

Cutworms

Variegated Cutworm: *Peridroma saucia*
Spotted Cutworm: *Amathes c-nigrum*
Brassy Cutworm: *Orthodes rufula*

Damage. Cutworms (Lepidoptera: Noctuidae) damage grapevines by feeding on buds about to break and newly opened shoots. Injured buds may fail to develop canes or clusters and, depending on variety, cause yield reduction, primarily on varieties with non-fruitful secondary buds such as Thompson Seedless. However, even on such varieties, a certain amount of damage can be tolerated because the vine can compensate for bud loss by increasing berry size on the remaining clusters. Many varieties of grapes (e.g., Ruby Cabernet) can tolerate a significant amount of damage without any economic loss.

Life History of the Pest. Cutworms are inconspicuously marked, dull-colored caterpillars. Variegated cutworm is the predominant species in the San Joaquin Valley, whereas spotted cutworm is predominant on the north and central coast. Cutworms overwinter in soil, trash and weeds, and become active in spring. They feed nocturnally on grapes for 10 days to several weeks, pupate in the soil, and emerge as adults in April and May. Adult cutworms are dull, gray-brown moths. After mating, females lay eggs, and the summer brood feed on various forms of vegetation. Depending on the species, cutworms have from one to four generations per year. Variegated cutworm generally returns to the soil to rest during the day in coastal areas, but remains on the vine under bark in the San Joaquin Valley. Spotted cutworm generally remains on the vine in all areas.

Monitoring. Historical records of cutworm infestations are useful in developing monitoring strategies for individual vineyards, because cutworm problems are normally spotty or localized. Visual inspection beginning at bud swell is the best way to monitor.

CONTROLS

Cultural

Cultural practices have not been demonstrated to successfully control cutworms; however, some practices do affect their population abundance.

Weed Control. Weed removal in late summer or fall, particularly in vine rows, may be beneficial in disrupting cutworm life cycles. Plowing or discing of weeds is not recommended before bud swell in spring because it can cause movement of cutworms to the grapevines.

Irrigation. Furrow and flood irrigation can be manipulated to bring cutworm larvae to the soil surface, exposing them to adverse weather and predators.

Biological

Natural Enemies. Natural enemies of cutworms include predaceous or parasitic insects, mammals, parasitic nematodes, pathogens, birds, and reptiles. However, little information is available on the impact of specific natural enemies or how they might be manipulated.

Chemical

No chemicals are highly effective in controlling cutworms, so treatments may not be economically justified. However, hand applied bait applications allow for treatment of only the affected area.

Carbaryl. 7 day PHI (0 day PHI for dust). Carbaryl (SEVIN) is a carbamate and has a restricted-entry interval of 24 hours. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. Carbaryl is available in an 80S formulation (80% soluble powder) and as a 5% bait. The 80S formulation is considered more effective than baits on the cutworm species that remain on the vine day and night. Carbaryl is disruptive to predators of mites and parasites of leafhoppers so product should not be used where mites are a chronic problem. Carbaryl is extremely toxic to honeybees. On the North Coast, the 5% bait can be applied to the soil in banded treatments for variegated cutworm, or hand applied so it adheres to the upper portions of vines for other cutworm species. The restricted-entry interval is 24 hours.

Methomyl. 14 day PHI for wine grapes. Methomyl (LANNATE) is an oxime carbamate. In 2000, 10,804 lb ai were applied to approximately 3% of wine grape acreage in a median of one application per field. The median application rate was 0.67 lb ai/acre. Applications are rarely for control of cutworms. There is a 7 day restricted-entry interval. Methomyl may be disruptive to beneficial predators of mites and parasites of leafhoppers.

Diazinon. 28 day PHI. Diazinon is an organophosphate. In 2000, 4,020 lb ai were applied to less than 1% of wine grape acreage at a median application rate of 1.00 lb ai/acre. A median of one treatment per field was applied. The restricted-entry interval for diazinon is 5 days. It is very disruptive to natural enemies and there are worker safety issues associated with its use.

Methyl Parathion. RESTRICTED AS OF AUG. 2, 1999. 40 day PHI. Methyl parathion is an organophosphate that is applied at a median rate of 0.67 lb ai per acre in the spring. Application may be made until bloom. Methyl parathion is disruptive to beneficials and 8 lb ai were applied to less than 0.01% of wine grapes in 2000. The restricted-entry interval for methyl parathion is 48 hours. In areas where annual rainfall is less than 25 inches (which includes much of California's grape growing regions), methyl parathion is applied only as dormant or pre-bloom spray. Product is used infrequently and is disruptive to beneficials.

False Chinch Bug

Nysius raphanus

Damage. The false chinch bug (Hemiptera: Lygaeidae) occurs sporadically, but may occasionally cause rapid and serious damage to young vines. They suck plant juices and inject a toxin that causes vines to wilt and turn brown. They are especially damaging to young vineyards. Because of the great number of bugs involved and their toxic injections, all the leaves on border vines can be killed in a few hours.

Life History of the Pest. This pest breeds in great numbers in grass or weedy areas, especially on mustard family members such as London rocket and shepherd's purse, and may migrate en masse into vineyards in late spring when these areas dry up and the pests search for green growth. September and October migrations are also possible.

Monitoring. An effective monitoring program can be undertaken by paying close attention to the types of vegetation within and adjacent to young vineyards, and visually inspecting them for false chinch bug.

CONTROLS

Cultural

Host Weed Removal. It's a good idea to reduce stands of host weeds in young vineyards or if false chinch bug has been a problem in the past. This should be done at least three weeks before budbreak.

Biological

No biological controls have been identified for this pest.

Chemical

If high populations of false chinch bugs are found on weeds at budswell or after vines leaf out, applications of insecticides to the weeds may be applied. If nymphs are found moving onto vines, spot treatment to both vines and weeds may improve control. Insecticides should be applied in early morning or late evening when the majority of the population is exposed.

Diazinon. 28 day PHI. Diazinon is an organophosphate. In 2000, 4,020 lb ai were applied to less than 1% of wine grape acreage at a median application rate of 1.00 lb ai/acre. A median of one treatment per field was applied. The restricted-entry interval for diazinon is 5 days. It is very disruptive to natural enemies and worker safety issues are associated with its use.

Malathion. 3 day PHI. Malathion is an organophosphate. In 2000, 5,013 lb ai were applied to less than 0.5% of wine grapes in a median of one application per field. The median application rate was 2.02 lb ai per acre. The restricted-entry interval for malathion is 24 hours.

Methomyl. 14 day PHI for wine grapes. Methomyl (LANNATE) is an oxime carbamate. In 2000, 10,804 lb ai were applied to approximately 3% of wine grape acreage in a median of one application per field. The median application rate was 0.67 lb ai/acre. Applications are rarely for control of this pest. Methomyl may be disruptive to beneficial predators of mites and parasites of leafhopper. There is a 7 day reentry restriction period.

Carbaryl. 7 day PHI (0 day PHI for dust). Carbaryl (SEVIN) is a carbamate and has a restricted-entry interval of 24 hours. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. The restricted-entry interval is 24 hours. Carbaryl is disruptive to predators of mites and parasites of leafhoppers so the product should not be used where mites are a chronic problem. Carbaryl is extremely toxic to honeybees.

Grape Bud Beetle

Glyptoscelis squamulata

Damage. The grape bud beetle (Coleoptera: Chrysomelidae) is found in the San Joaquin Valley and desert areas. It can be a significant pest in the Coachella Valley, but there are very few acres of commercial wine grapes there. Adult beetles cause crop loss by feeding on newly opened buds and eating the bud center, which contains the immature leaves and flower cluster primordia. Once the new shoots are 1 to 1.5 inches long, feeding damage is negligible.

Life History of the Pest. The immature stages (grubs) of the beetle are spent in the soil, where grubs feed on grape roots. Adults may begin emerging from the soil several weeks prior to budbreak, mate, lay eggs under bark, and feed once buds have opened. Beetles are long lived, and their numbers accumulate into the spring. There is one generation per year.

Monitoring. Growers and PCAs may monitor for grape bud beetle to determine if chemical treatment is necessary. Adults come out of daytime hiding places about 1 hour after sundown. Although beetles can be monitored with a flashlight, an ultra-violet lamp is preferred because the beetles naturally fluoresce a bright silvery blue when under UV light.

CONTROLS

Cultural

No cultural practices have been identified to control this pest.

Biological

No biological controls have been identified to control this pest.

Chemical

During budbreak, treatment is recommended when there are one to three beetles per vine and bud damage is noticeable.

Azinphos Methyl. RESTRICTED AS OF AUG. 2, 1999. 21 day PHI. Application of azinphos methyl (GUTHION) in combination with a narrow range oil is sometimes recommended to control grape mealybug during the dormant, spring and summer seasons. The oil provides better coverage and kill than azinphos methyl alone. Azinphos methyl, alone, may not provide adequate control, but there are few alternatives available for this use. Azinphos methyl is rarely used in vineyards and was applied to less than 0.01% of wine grape acreage in 2000. The median rate of application was 1.5 lb ai/acre. The restricted entry interval is 45 days if l lb or less of active ingredient is applied per acre, or only 1 application per season is made; otherwise the restricted entry interval is 50 days. No more than 3 applications per season are permitted. Note that the restricted entry interval exceeds the pre-harvest interval (10 days).

Dimethoate. 28 day PHI. Dimethoate (CYGON) is an organophosphate. In 2000, 4,176 lb ai were applied to approximately 1% of wine grape acreage in a median of one application per field. The median application rate was 0.37 lb ai/acre. Applications are made by permit from the county agricultural commissioner under a special local needs permit. The restricted entry interval is 48 hours. Dimethoate is moderately disruptive to beneficial insects. Pest resistance may be a problem in some populations.

Phosmet. 7 day PHI. Phosmet (IMIDAN) is an organophosphate. In 2000, 18,450 lb ai were applied to 2.7% of wine grape acreage at a median application rate of 1.4 lb ai/acre. The restricted interval for phosmet is 5 days.

Grape Leaf Folder

Desmia funeralis

Damage. Grape leaffolder (GLF) (Lepidoptera: Pyralidae) is a pest in the Southern San Joaquin Valley that can cause damage by constructing leaf rolls and feeding within. Damage occurs due to loss of leaf area, and sun exposure from excessive leaf rolling may lead to sunburning. Usually damage occurs only late in the season.

Life History of the Pest. The first moth flight is usually in late March or early April. Eggs are laid on leaves, and after hatching, larvae feed in groups between two webbed leaves for about 2 weeks. Then each larva rolls a leaf edge and feeds from the inside on the leaf edge. Mature larvae construct a separate leaf envelope on the edge of a leaf in which they pupate.

Monitoring. Growers and PCAs may monitor for GLF by counting the number of rolls in a given area. There are no established treatment thresholds.

CONTROLS

Cultural

There are no identified cultural practices for the control of GLF.

Biological

Naturally occurring parasites play an important role in keeping grape leaffolder below a level that will cause damage. Several parasites attack GLF.

Bracon cushmani. Among the most common is the larval parasite *Bracon cushmani*. After stinging and paralyzing GLF larvae, female *B. cushmani* lay from one to several eggs on the body of leaffolder larva. *B. cushmani* larvae feed externally and, after completing their development, pupate next to the consumed host. Parasitism by frequently reduces second and third generation populations to below economic levels.

Other Parasites. In addition to *B. cushmani*, several other hymenopteran parasites and at least two species of tachinid flies parasitize leaffolder. Generalist predators such as lacewings and spiders may also attack GLF larvae.

Chemical

Treatment of the first generation is rarely needed. Usually first brood control of grape leaf folder is achieved because of spring treatment for OLR (see Omnivorous Leafroller in Major Insect Pests).

Cryolite. 30 day PHI. Cryolite (PROKIL OR KRYOCIDE) was applied to about 9.7% of wine grape acreage in 2000. A total of 272,053 lb ai were applied in a median of one application per field. The median application rate was 5.76 lb ai/acre. Treatments are rarely for the leaffolder. Cryolite treatments applied for omnivorous leafroller frequently will control GLF. This material must be ingested by the leaffolder to be effective. Good coverage is essential. Ground applications are typically applied before full bloom. A maximum of two applications per season is allowed. The restricted-entry interval is 12 hours. Nations that comprise the European Community have implemented a strict tolerance of 1 ppm with respect to fluoride residues in wine. Because there is a direct correlation between the use of Cryolite and fluoride residues, California wineries with export markets have responded in kind by prohibiting their growers from using Cryolite. Cryolite may also cause secondary pest outbreaks.

***Bacillus thuringiensis* (Bt) (Several strains).** 0 day PHI. In 2000, 9,299 lb Bt were applied to approximately 18.66% of wine grape acreage at median application rates of 0.01-0.15 lb ai/acre. Treatment is, rarely for the control of GLF. This material must be ingested by the leaffolder to be effective and good coverage is essential. It is most effective against young larvae. This chemical material is approved for use on organically grown grapes. The restricted-entry interval for Bt is 4 hours.

Methomyl. 14 day PHI for wine grapes. Methomyl (LANNATE) is an oxime carbamate. In 2000, 10,804 lb ai were applied to approximately 3% of wine grape acreage in a median of one application per field. The median application rate was 0.67 lb ai/acre. Applications are rarely for GLF. Methomyl may be disruptive to beneficial predators of mites and parasites of leafhopper. There is a 7 day reentry period.

Carbaryl. 7 day PHI (0 day PHI for dust). Carbaryl (SEVIN) is a carbamate and has a restricted-entry interval of 24 hours. In 2000, 11,034 lb ai were applied to approximately 1.3% of wine grape acreage in a median of one application per field. The median application rate was 1.2 lb ai/acre. Carbaryl is rarely used for GLF. Use of carbaryl may encourage mite build up as it is very disruptive to the natural enemies of mites.

Nematodes

Root Knot Nematodes *Meloidogyne incognita, M. javanica, M. arenaria,* and *M. hapla*
Ring Nematode *Criconemella xenoplax*
Dagger Nematodes *Xiphinema americanum* and *X. index*
Root Lesion Nematode *Pratylenchus vulnus*
Citrus Nematode *Tylenchulus semipenetrans*

Plant parasitic nematodes are microscopic, unsegmented roundworms that feed on plant roots by puncturing and sucking the cell contents. They live in soil and within or on plant tissues. Of the many genera of plant parasitic nematodes detected in soils from California vineyards, root knot, ring, dagger, root lesion and citrus nematodes are the most important (51). Other nematodes associated with grape in California include stubby root nematode, *Paratrichodorus minor*; spiral nematode, *Helicotylencus pseudorobustus*; and needle nematode, *Longidorus africanus*. Of these, only needle and spiral nematodes have been found to be damaging to grapes in California. Pin nematode, *Paratylenchus hamatus,* is frequently found in vineyards but is not thought to cause damage.

Dagger, ring, and root lesion nematodes are most prevalent in north and central coast vineyards, and in the San Joaquin Valley. Root knot and citrus nematodes occur most commonly in the San Joaquin Valley and southern California. The needle nematode is found mainly in southern California. Presence of species, soil texture, grape cultivar, cropping history, weed spectrum, and growing region are the determining factors as to which nematode is present in which vineyard as well as the extent of damage they will cause.

Damage. Plant parasitic nematodes feed on roots, reducing water and nutrient uptake, and ultimately, vigor and yield of grapevines (51). Nematodes fall into two categories with respect to feeding: some feed externally on roots (ectoparasitic nematodes), and some penetrate into roots and feed internally (endoparasitic nematodes). Damage is often associated with soil textural differences. Root knot nematode (RKN) (*Meloidogyne* spp.) is most damaging on coarse-textured soils (sands, loamy sands and sandy loams). R.N. penetrates into roots and induces giant cell formation, usually resulting in root galls. Giant cells and galls disrupt uptake of nutrients and water, and interfere with plant growth. Ring nematode (RN) (*Criconemella xenoplax*) can be damaging on coarse or fine-textured soils, but does not do well on fine sandy loam soils. RN feeds externally. The dagger nematode, *X. index*, can cause yield reduction in some varieties, but is more important for its transmission of grapevine fanleaf virus. A closely related species, *X. americanum*, is the most common species of dagger nematode, weakening the vine by feeding just behind the root tip and vectoring yellow vein virus (also known as tomato ringspot virus). Root lesion nematode restricts the growth of roots as it feeds and migrates in and out of roots; it can be especially damaging to newly planted vines. Citrus nematodes establish feeding sites with their heads embedded in cortical tissue and their posterior ends outside the roots.

Life History of the Pest. Juvenile RKN and other endoparasitic nematode species penetrate roots and establish feeding sites in the vascular tissues. Their development stimulates the vine to produce galls, which may be occupied by one or several adult female RKN. Upon maturity, the sedentary RKN female may lay up to 1,500 eggs apiece. RN and other ectoparasitic species remain in the soil during their entire life cycle.

Monitoring. To make management decisions, it is important that growers know the nematode species present and have an estimate of their population level. Growers and PCA's may take soil samples and have them assayed for nematodes. Soil and root samples should be taken within the row, preferably one to two feet from the trunk, down to a depth of 3 feet (51). Samples may be taken any time of the year, but the economic threshold will vary.

CONTROLS

Cultural

Fallow Periods. Fallow periods of up to 10 years can be used to manage nematode populations, but is not considered an economically feasible option for most growers. This time period is required to allow old roots to decompose and nematode numbers to decrease. This will reduce initial populations but will not prevent re-infestation.

Resistant Varieties. No single commercially available rootstock is resistant to all nematode species. Broadest resistance is present in Ramsey, Freedom, and several rootstocks in the Teleki series (52). However, their resistance mechanisms are not thought to be permanent. Several new rootstocks exhibiting broader nematode resistance are under study.

Soil and Water Management. Any measures taken which can minimize vine stress can increase vine tolerance to nematode attack. Soil management practices include preventing soil compaction and stratification and improving soil structure through the addition of compost, manure, cover crops, gypsum and other soil amendments, and proper fertilizer rates and timing. Irrigations should be scheduled to ensure as few water stress periods as possible. Drip irrigation systems allow precise water timing.

Cover Crops. In addition to the effect of cover crops on soil structure, which may help ultimately reduce vine stress, most cover crops grown in the same site for too many years can build nematode populations. Several have also been shown to be relatively safe with regards to nematode build-up, including Cahaba white vetch, Barley turned under by mid March, Blando Brome Grass and Rye Grass (M. McKenry, personal communication). Cover crops exhibiting antagonism to nematode populations are not at this time useful in vineyards.

Biological

There are many soil dwelling organisms that will feed on nematodes, including predatory species of nematodes. However, they usually do not provide enough mortality to control plant parasitic nematode populations. Predatory nematodes are considered to have low survivorship in agricultural fields. They reside in the shallower depths of the soil and do not penetrate roots.

Chemical.

Vineyards planted in fumigated ground are known to have improved growth and yields compared to those planted on non-fumigated ground.

Pre-plant treatments

Methyl Bromide. Methyl bromide is estimated to be applied to approximately 45% of new vineyard land or 90% of replanted vineyards (Pers. com M. McKenry). However in any one year, only a small percent of vineyard land is fumigated, in 1996 only 1-2% were fumigated with methyl bromide. (Note that the county use reports are inaccurate for San Joaquin Valley counties because they categorize this type of new vineyard and replanted vineyard fumigation under the crop category of "bare ground," not "grapes.") In 2000, methyl bromide was used on 0.13% of wine grape acres at a median application rate of 348 lb ai/acre. Methyl bromide is a pre-plant broadcast fumigant that is applied with or without tarps. It is applied to soil at an average rate of 350 lb ai per acre. Higher rates are recommended for fine textured soils. The restricted-entry interval for methyl bromide is 48 hours. Methyl bromide is being phased out and will no longer be available after 2005.

Metam Sodium. Metam sodium (VAPAM) is applied at average rates of about 180 to 318 lb ai per treated acre. It is seldom applied to grapes. In 2000 about 0.02% of wine grape acreage was treated. Any references to treatments averaging 50 lb per acre are treatments applied via the drip system pre-plant and there must be either no nematodes of concern or involve the planting of rootstocks having broad nematode resistance. Metam sodium is a restricted use material and may only be applied by permit from a county agricultural commissioner. It is seldom as effective as methyl bromide because it is difficult to get 4-5 ft down from the surface and is a poor root penetrant. Pre-application soil preparation is critical to the effectiveness of the treatment. Before applying this material, growers must thoroughly cultivate the area to be treated to break up clods and deeply loosen the soil. After cultivation and 1 to 2 weeks before treatment, the field is wetted to as deep as 5 feet. Treatments are designed to transport water and metam-sodium to the 5 ft depth. After treatment, planting should not occur for 30 days to 60 days. Soils that do not infiltrate 6 inches of water in 8 hours or less are not suitable candidates for this treatment. The restricted-entry interval for metam sodium is 48 hours.

1,3-Dichloropropene. 1,3-Dichloropropene (TELONE) is an organochlorine that was applied to 0. 3% of wine grape acreage at a median application rate of 332 lb ai per acre in 2000. This preplant restricted-use material may only be applied by permit from the county agricultural commissioner. There is a cap placed on acreage use per township in California. This cap essentially limits treatments to about 300 acres per township per year. The restricted-entry interval is 7 days.

Post-plant treatments

Sodium Tetrathiocarbonate. Sodium tetrathiocarbonate (ENZONE) was applied to 1.3% of wine grape acreage in 2000. A total of 206,141 lb were applied in a median of one application per field. The median application rate was 27.18 lb ai/acre. This product is an even poorer root penetrant than metam sodium, thus its use as a preplant treatment is very limited. ENZONE is most effective against ectoparasitic nematodes such as RN and dagger nematodes, and less effective against RKN in the San Joaquin Valley. The restricted-entry interval is 4 days.

Fenamiphos. Fenamiphos (NEMACUR) is an organophosphate. In 2000, 30,191 lb ai were applied to approximately 2.6% of wine grape acreage at a median application rate of 1.46 lb ai/acre. The median number of applications was one. It is a restricted use material that is applied by permit from the county agricultural commission. This product is typically used against endoparasitic nematodes such as RKN, and is useful against ectoparasitic nematodes only when used at higher rates. It is also only effective when applied via drip irrigation. The restricted-entry interval is 48 hours. This product has become less useful as the application procedures now demand several hours of water only following a one hour injection of product.

Carbofuran. 200 day PHI. Carbofuran (FURADAN) is a restricted use carbamate that may only be applied by permit from a county agricultural commissioner. Carbofuran is applied post-harvest to about 1% of wine grape acreage at a median application rate of 3.2 lb ai/acre in 2000. A total of 19,218 lb were applied in a median of one application per field. Applications are made via drip irrigation between harvest and early December. This product is available for use under a special local needs permit. Reentry interval is 48 hours. Carbofuran is most effective against ectoparasitic nematodes such as

RN and dagger nematodes, and less effective against RKN in the San Joaquin Valley.

Myrothecium verrucaria. A toxin produced by the fermentation of the fungus *Myrothecium verrucaria* (DITERA) has recently been registered under FIFRA to control nematodes. Products with this active ingredient have been registered in California since 1996. Currently, these products are being used primarily by growers to determine how they can be optimized for field-use conditions. In 2000, 5, 723 lb ai were applied at a median rate of 11.34 lbs ai/acre to 0.07% of the wine grape acres. The restricted entry period is 4 hours. The fungus is heat-killed after the toxin is produced.

Diseases

Powdery Mildew

Uncinula necator

Damage. Powdery mildew is the most significant disease affecting grapes in California. The mycelia (fungal strands) penetrate into leaf, stem and berry tissue. Whereas severely affected leaves may have reduced photosynthetic rates, most damage occurs because mildewed berries may be stunted, crack and collapse, and lead to secondary bunch rot. Sugar accumulation may be delayed in severely affected vines, and off flavors may be produced in wines. It is estimated that powdery mildew is present in virtually all vineyards each year, the only variable being the severity of the infection between vineyards. Central Coast region vineyards commonly have extremely high powdery mildew pressure, because weather conditions are often ideal for development of the disease. Approximately 90% of the grape acreage in California (88% in 1996) is treated for powdery mildew. The non-treated acreage is largely non-bearing acreage.

Description of Symptoms and Disease Cycle. In coastal regions and in the Northern San Joaquin Valley, powdery mildew overwinters as ascospores (sexually produced spores) within cleistothecia (fruiting bodies) on the bark, canes and spurs. Ascospores require free moisture to germinate, and are released onto new grape leaves with spring rains or sprinkle irrigation. Mycelial growth takes on a white, web-like appearance. As conidia (asexual spores) are produced, the colony takes on a white, powdery appearance. Optimal temperatures for hyphal growth and conidia production are between 70 and 86EF. Free moisture plays a negative role and relative humidity plays a minor role in the asexual phase of powdery mildew in California. Ascospores are produced in the fall and winter.

Monitoring. Powdery mildew can be monitored directly in the field by visual inspection and by using weather data and disease risk models. Because it is such an explosive disease, most growers still base their disease control program on prevention and maintaining grapevine coverage from early in the season until berry softening. All fungicides have standard treatment intervals, based largely on the residual activity of the material. Preventive treatments for powdery mildew are necessary as long as temperatures are conducive to growth and development. In coastal regions, this generally occurs from late spring through harvest, whereas in the San Joaquin Valley this period occurs from shortly after budbreak through early July. Wet springs can extend the release period of ascospores. There is increasing use of localized, weather data combined with disease risk models for scheduling of chemical applications. Several risk models exist, the most recent of which, the Gubler-Thomas model, assists the grower in determining when weather conditions indicate a higher risk of disease outbreak. Risk is higher when temperatures fall between 70 and 86E F, and risk decreases sharply when temperatures exceed 95E F. When this risk is high, the interval between treatments is shortened, whereas if the risk is low, intervals can be lengthened. It has been estimated that weather data is being collected and the model being used to time applications on approximately 80,000-100,000 acres (40).

CONTROLS

Cultural

Vine Training. Trellising, cane cutting and training techniques that create a more open canopy can improve coverage of materials for powdery mildew.

Leaf Removal. Leaf removal at berry set improves coverage for chemical treatments.

Varieties. Grape varieties vary in susceptibility to powdery mildew. Theoretically, treatment intervals on varieties that exhibit more resistance (e.g., Merlot, Sauvignon blanc, Malbec, Johannesburg Riesling, etc.) can be lengthened relative to susceptible varieties (e.g., Cabernet Sauvignon, Carignane, Chardonnay, etc.).

Biological

Ampelomyces quisqualis is a naturally occurring fungal hyperparasite of powdery mildew, which has recently been registered under FIFRA as a pesticide (AQ10), and is also listed below under chemical controls for powdery mildew. *A. quisqualis* has been found to provide some natural control on the east coast. Under California conditions AQ10 has been shown to give excellent diseases control when used early in the spring and applied prior to disease onset. It also has been shown to give excellent control of powdery mildew when used during periods of low disease pressure (38).

Chemical

Powdery mildew materials can be classified as preventatives or contacts. The vast majority of materials used are preventatives. Late season control is dependent upon early season disease control and reduction in inoculum and subsequent infection. Sterol-inhibiting fungicides (SIs, also called demethylation inhibitors or DMIs), such as triadimefon, myclobutanil, and fenarimol, triflumizole (BAYLETON, RALLY, AND RUBIGAN, PROCURE respectively), as well as sulfur or copper are not used as an eradicants, but as protectants before infection is present. Lime sulfur is sometimes used during the dormant season to kill ascospores. DMIs are systemic, but only for 1 or 2 cm around each spray droplet. Therefore, thorough coverage is critical for efficacious disease control. Oil, soaps, potassium bicarbonate (KALIGREEN) and cinnamaldehyde (VALERO) are contact materials that kill mildew spores on contact but cannot prevent colonization. The only true eradicant for powdery mildew is oil used as a 2% spray (22). Treatments for powdery mildew may be discontinued for wine grapes when fruit reaches 10 to 12E Brix.

Preventatives

Sulfur. 0 day PHI. Sulfur is applied at label rates to approximately 88% of wine grapes in California, the vast majority of which is for control of powdery mildew. In 2000, 23,733,878 lb ai were applied a median of six times per field. The median application rate was 7.73 lb ai/acre. Sulfur dust rates being higher (10 to 12 lb ai per acre) and wettable sulfur rates being lower (typically 3 to 5 lb ai per acre). It is the most commonly used pesticide in California's grape industry. Approximately 80% of the sulfur applications are as the dust, with 20% being the wettable powder formulations. Treatment is initiated at bud-break to 2-inch shoot growth and is reapplied at 7 to 10-day intervals. Re-application is necessary if the sulfur is washed off by rain or irrigation. Sulfur can cause injury to foliage and fruit when applied just before or on days when the temperature exceeds 100EF. Use of sulfur is approved for organically grown produce. The reentry interval is 24 hours in most counties however in some counties in the Southern San Joaquin Valley region the restricted-entry interval is 3 days. There are worker exposure and off-site movement issues associated with the use of dusting sulfur.

Myclobutanil. 14 day PHI. Myclobutanil (RALLY) is a DMI that is applied only for the control of powdery mildew. Myclobutanil is an azole that is applied at a median application rate of 0.1 lb ai per acre. In 2000, 26,187 lb ai were applied to 32.6% of wine grape acreage a median of two times per field. The restricted-entry interval is 1 day.

Myclobutanil and Sulfur. 14 day PHI. Myclobutanil (RALLY) in a dust formulation combined with sulfur may be applied at label rates. This combination is sometimes used during period of high risk of infection or ongoing infestation. It is estimated that 0.5% of acreage is treated with this combination. This formulation has a 24 hour reentry period.

Fenarimol. 30 day PHI. Fenarimol (RUBIGAN) is a DMI. In 2000, 3,875 lb ai were applied to approximately 16.8% of wine grapes, all for the control of powdery mildew. It was applied a median of one time per field. The median application rate was

0.03 lb ai/acre. The restricted-entry interval for fenarimol is 12 hours. Fenarimol causes phytotoxicity on young shoots in the spring and its use is limited in table grapes for that reason, as well as, spotting of fruit.

Triflumizole. 7 day PHI. Triflumizole (PROCURE) is a DMI that is applied to approximately 13.3% of wine grapes, all for the control of powdery mildew. In 2000, 14,262 lb ai were applied a median of one time per field. The median application rate was 0.16 lb ai/acre. The restricted reentry interval for triflumizole is 12 hours.

Copper Hydroxide. 0 day PHI. Copper hydroxide is a resistance management tool used in rotation with other products. In 2000, 285,932 lb ai were applied to 38.5% of wine grape acreage a median of one time per field. The median application rate was 0.81 lb ai per acre. Copper hydroxide is used to control several diseases in addition to powdery mildew such as phomopsis and downy mildew, as well as for frost management. Use of copper hydroxide may burn grape leaves. Certain copper sprays require a closed-mixing system.

Triadimefon. 14 day PHI. Triadimefon (BAYLETON) is a DMI that was applied to less than 1% of wine grape acreage. In 2000, 179 lb ai were applied in a median of one application per field. The median application rate was 0.13 lb ai per acre. Bayleton is not cost effective for control of powdery mildew and is a Group C carcinogen. A substantial amount of resistance has been built up to this active ingredient and, therefore, its use has greatly decreased in recent years. The restricted-entry interval is 12 hours.

Ampelomyces quisqualis 0 day PHI. *A. quisqualis* (AQ10) is a biofungicide which is a selective fungal hyperparasite. Rates are 0.5 B 1.0 oz/acre. In 2000, 2 lb ai were applied to 0.36% of wine grape acreage. Mixture should be adequately agitated, and applications should be made early in the morning or late in the evening when humidity is at its highest. It is most effective when powdery mildew pressure is light and no disease is present. It has a 4 hour REI.

Azoxystrobin. 14 day PHI. Azoxystrobin (ABOUND) is a natural product derived from mushrooms and is a good broad spectrum material (also effective against phomopsis, leafspot, and downy mildew.) It is used as a preventative and contact. In 2000, 18,465 lb ai were applied to 13.9% of the acreage in a median of one application per field. The median application rate was 0.21 lb ai/acre. Abound is a relatively new and relatively expensive chemical tool in California and use reports are not available. The restricted entry interval is 4 hours.

Bacillus subtilis**.** 0 day PHI. *Bacillus subtilis* (SERENADE) is a bacterium. It is a newly registered material so there is no pesticide use reporting data available. The manufacturer’s recommended application rate is 4 to 8 lbs per acre of material (0.4 to 0.8 lbs ai per acre). Recommended application timing is when shoots are ½ to 1 ½ inches long, repeat at 5 inches and then again when shoots are 8 to 10 inches long. From this point repeat every 7 to 10 days while vines and fruit are susceptible to powdery mildew. Intervals between applications should be shortened under high disease pressure. There is a 4 hour restricted-entry interval.

Tebuconazole. 14 day PHI. Tebuconazole (ELITE) is a DMI fungicide in the triazole family. In 2000, 11,362 lb ai were applied to 13.5% of the winegrape acreage at a median rate of 0.11 lb ai/acre. The median number of applications per field was one. Under severe powdery mildew conditions a 10 day interval between sprays is recommended. Elite is a new fungicide to California and use reports are not available. It can be used almost interchangeably with myclobutanil and fenarimol. It is more costly than sulfur, copper or lime sulfur. The use of this chemical should be alternated with a non-DMI fungicide to reduce the likelihood of resistance developing. The restricted-entry interval is 12 hours.

Kresoxim-methyl. 14 day PHI. Kresoxim-methyl (SOVRAN) is a Phenyl acetic acid ester. The recommended application rate is 3.2 to 4.8 oz per acre (0.1 to 0.15 lbs ai) at an interval of 14 days unless disease pressure is low in which case it can be stretched to 21 days. At 4.8 oz per acre a maximum of 5 treatments can be applied. There is a 12 hour restricted-entry interval. Sovran is a newly registered fungicide on grapes and use reports are not available.

Trifloxystrobin. 14 day PHI. Trifloxystrobin (FLINT) is a strobilurin. It is effective against powdery mildew, Botrytis bunch rot and downy mildew. In 2000, 17,029 lb ai were applied to 13.9% of the winegrape acres at a median rate of 0.06 lb ai/acre. The median number of applications per field was one. A normal interval between sprays is 14 to 21 days depending on the disease pressure. The restricted-entry interval is 12 hours.

Contact materials

Petroleum Oil. 0 day PHI. Petroleum oils were applied to approximately 1% of treated acres of grape vineyards, but part of this treatment is for spider mites. In 2000, 64,752 lb ai were applied in a median of one application per field. The median application rate was 6.14 lb ai/acre. Approved for use on organically grown grapes. The restricted-entry interval is 4 hours. Narrow range oils (petroleum oils) offer good control. They have performed consistently in all areas of California but can be phytotoxic in the valley due to high temperatures and the prevalence of sulfur use. Narrow range oils are also difficult to fit into a spray schedule due to restrictions on sulfur use following applications.

Insecticidal soaps. 0 day PHI. Insecticidal soap kills mildew on contact. It is applied at rates of 1.5 to 2% in 100 to 150 gallons of water per acre. Complete coverage of upper and lower leaf surfaces, as well as grape clusters, is essential for control. Insecticidal soap may also be alternated with the sterol inhibitors, but should not be applied within 3 days of a sulfur application. It can be used in rotation with one of the sterol inhibitors. Soaps are also used for control of soft-bodied insects such as leafhoppers. In 2000, 9,010 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 4.37 lb ai/acre. Insecticidal soaps are approved for organic use. The restricted-entry interval is 12 hours.

Potassium Bicarbonate. 1 day PHI. Potassium bicarbonate (KALIGREEN) is applied at a median rate of 2.05 lb ai per acre. In 1999, 72,630 lb ai were applied to wine grapes. The restricted entry interval is 4 hours.

Cinnamaldehyde. 0 day PHI. Cinnamaldehyde (VALERO) was registered for use on grapes in California on July 1999. In 2000, 2,484 lb ai were applied to less than 1% of wine grape acreage in a median of one application per field. The median application rate was 2.55 lb ai/acre. It is a contact material that requires good coverage for control. The restricted-entry interval is 4 hours.

Azoxystrobin. 14 day PHI. Azoxystrobin (ABOUND) is a natural product derived from mushrooms and is a good broad spectrum material (also effective against phomopsis, leafspot, and downy mildew.) This material is used as a preventative and contact. In 2000, 18,465 lb ai were applied to 13.9% of the acreage in a median of one application per field. The median application rate was 0.21 lb ai/acre. Abound is a relatively new and relatively expensive chemical tool in California and use reports are not available. The restricted entry interval is 4 hours.

Botrytis Bunch Rot

Botrytis cinerea

Damage. Botrytis is a fungal disease that can infect grape leaves, shoots and berries (50). Because its optimal temperature is 72EF and it does not grow above 90EF, and because its spores require free moisture for germination, it is a more serious problem in the coastal regions, especially if there is rainfall in the weeks prior to harvest. Once berries are infested with Botrytis, they may split and leak, allowing new spores to germinate on neighboring clusters. Spores from infected fruit can directly infect intact berries, but also enter through wounds caused by insect, bird or other mechanical damage, or damage caused by powdery mildew. Tight clustered (e.g., Zinfandel) or thin-skinned (e.g., Sauvignon blanc) varieties are particularly susceptible. The risk of external berry infection increases with increasing berry sugar.

Description of Symptoms and Disease Cycle. Botrytis overwinter as dormant structures called sclerotia. With spring rains, sclerotia germinate and produce gray spores (conidia). Early season shoot, leaf and flower blight may occur following spring rains. The infection resembles a brown lesion. "Latent infections" can occur when flowers become infected during bloom, and the fungus lays dormant within the berry until sugar concentration increases. The fungus then resumes growth and spreads throughout the berry. The skin of infected berries will slip off easily. The production of conidia gives the fungus its characteristic fuzzy gray appearance.

Monitoring. Botrytis can be monitored by visual inspection for gray mold symptoms on leaves, shoots, flowers, and/or clusters. In the past, fungicide treatments were largely based on prevention and a calendar or plant growth based timing of fungicide applications. Recent work out of UC Davis with Californian and Chilean grapes have shown that weather conditions can be monitored to estimate the risk of infection and to time chemical treatments based on the temperature and wetness requirements of the fungus (4). Botrytis infection increases with longer periods of wetness from rain or dew, and temperatures within its wide developmental range of 1E to 30E C (35E- 86E F) with a temperature optimum of around 18E-20E C (65E- 68E F).

CONTROLS

Cultural

Canopy Management. Good control has been achieved using canopy management and leaf removal in particular. Removal of four to five basal leaves (the leaves around the clusters) when berries are approximately "pea size" has resulted in significantly reduced incidence and severity of disease (60,64,65). In addition, use of vertical trellis systems with shoot positioning wires can provide excellent air and sunlight exposure and reduced disease pressure.

Irrigation. Over irrigation should be avoided because lush vine growth can decrease air circulation, and because too much water can increase berry size and increase the risk of splitting.

Biological

***Trichoderma*.** *Trichoderma* spp. (TRICHODEX) is being used in other countries as an experimental biological control of botrytis. This microbial control agent has been recently registered as a pesticide under FIFRA and is registered in California. See the chemical control section for more information.

Chemical

There are two key treatment periods if wet weather conditions occur: 1) bloom time and 2) pre-harvest. Preventive treatments are commonly applied at bloom time, pre-close (late-June to mid-July, and veraison (early to late-July). Thorough coverage is essential for all fungicide treatments.

Benomyl. All uses of benomyl have been cancelled. 50 day PHI. Benomyl (BENLATE) is a carbamate. It is applied principally for botrytis bunch rot control. In 2000, 6,964 lb ai were applied to approximately 2.9% of wine grape acreage in a median of one application. The median application rate was 0.37 lb ai/acre. Benomyl may not be as effective in areas of the state where benomyl-resistant pathogens are present. The restricted-entry interval is 1 day.

Iprodione. 14 day PHI. Iprodione (ROVRAL) is a dicarboximide fungicide applied mainly to control Botrytis bunch rot. In 2000, 16,892 lb ai were applied to approximately 4.6% of wine grape acreage in a median of one application. The median application rate was 0.5 lb ai/acre. The addition of a narrow range oil (1%) may increase the effectiveness of this material. Iprodione has a restricted-entry interval of 12 hours.

Captan 50 WP. 0 day PHI. Captan is a phthalimide fungicide and it may be applied alone or in combination with benomyl. In 2000, 1,536 lb ai were applied to approximately 0.2% of wine grape acreage in a median of one application. The median application rate was 1.47 lb ai/acre. Captan treated grapes are prohibited in Canada. Applications of Captan should not be made immediately before or closely following oil sprays. Captan is restricted by many wineries. The restricted reentry period is 4 days.

Mancozeb. 0 day PHI. Mancozeb (DITHANE) is an alkylenebis (dithiocarbamate) applied for spring foliar treatment and should not be applied after bloom. In 2000, 72,641 lb ai were applied to approximately 9% of wine grape acreage in a median of one application. The median application rate was 1.5 lb ai/acre. The restricted reentry interval is 24 hours.

Dicloran (DCNA). 0 day PHI. Dicloran (BOTRAN) is an aniline. In 1999, 14,687 lb ai were applied to approximately 2.4% of wine grape acreage in a median of one application. The median application rate was 1.8 lb ai/acre. Applications are made at the onset of bloom or soon after shatter. The restricted-entry interval for dicloran is 12 hours.

Petroleum Oil. 0 day PHI. Petroleum oils were applied to approximately 1% of treated acres of grape vineyards, but part of this treatment is for spider mites. In 2000, 64,752 lb ai were applied in a median of one application per field. The median application rate was 6.14 lb ai/acre. Approved for use on organically grown grapes. The restricted-entry interval is 4 hours. Oil is used at a 2% rate with enough water volume (100-150 gallons/acre) to ensure good coverage. Should not be used within two weeks of a sulfur or captan treatment as foliage may burn.

Fenhexamid. 0 Day PHI**.** Fenhexamid (ELEVATE) was registered for use in California in June 1999. During the remainder of 1999, 4,487 lb ai were applied in a median of one application per field. The median application rate was 0.5 lb ai/acre. It was applied to approximately 1.5% of wine grape acreage. The active ingredient is in a new chemical class the products will be of immediate importance to resistance management. The reentry interval is 4 hours.

Cyprodinil. 7 day PHI. Cyprodinil (VANGARD) is a new fungicide, which was registered in California in April, 1998. In 1999, 18,381 lb ai were applied. The median application rate was 0.47 lb ai/acre. It was applied to approximately 7.3% of wine grape acreage.

Trifloxystrobin. 14 day PHI. Trifloxystrobin (FLINT) is a strobilurin. It is a relatively newly registered fungicide in California and use reports are not yet available. It is effective against powdery mildew, Botrytis bunch rot and downy mildew. The manufacturer's recommended rate for Botrytis bunch rot control is 1.5 2 oz (0.06 lbs ai) per acre. No more than 4 applications are allowed per season. The restricted-entry interval is 12 hours.

***Bacillus subtilis*.** 0 day PHI. *Bacillus subtilis* (SERENADE) is a bacterium. It is a newly registered material so there is no pesticide use reporting data available. The manufacturer’s recommended application rate is 4 to 8 lbs per acre of material (0.4 to 0.8 lbs ai per acre). Recommended application timing is when shoots are ½ to 1 ½ inches long, repeat at 5 inches and then again when shoots are 8 to 10 inches long. From this point repeat every 7 to 10 days while vines and fruit are susceptible to powdery mildew. Intervals between applications should be shortened under high disease pressure. There is a 4 hour restricted-entry interval.

Summer Bunch Rot (Sour Rot)

***Aspergillus niger, Alternaria tenuis, Botrytis cinerea,Cladosporium herbarum, Rhizopus arrhizus, Penicillium* spp., and others.**

Damage. The summer bunch rot complex consists of secondary microbial invaders that take advantage of mechanical damage to berries. Berries may split due to tight clusters or powdery mildew, or may be damaged by insects (especially OLR) or birds. Fungi and bacteria quickly colonize damaged berries, and once a single berry becomes infected, bunch rot can spread throughout an entire cluster. Dripping juice from a rotting cluster can spread infection to adjacent healthy clusters. Masses of spores develop on the surface of infected berries. Bunch rot often culminates in sour rot, especially in the central and southern San Joaquin Valley. Sour rot is caused by a variety of microorganisms, including *Acetobacter* bacteria, which are spread by vinegar flies attracted to the rotting clusters.

Description of Symptoms and Disease Cycle. As berries ripen and sugar content exceeds 8%, injured fruit become increasingly susceptible to invasion by a wide variety of naturally-occurring microorganisms. Invasion occurs at the point of injury caused by insect or bird feeding, mechanical or growth cracks, or lesions resulting from powdery mildew or black measles. The resulting rot can be severe as it progresses beyond the original injury. A characteristic vinegar smell is present if sour rot organisms are present.

Monitoring. Growers and PCAs should monitor for rotting clusters by visual inspections between veraison and harvest.

CONTROLS

Cultural

Leaf Removal. Removal of leaves between berry set and "pea size" increases air flow and decreases humidity around the clusters. This has provided equivalent control to any chemical treatment (64,65).

Irrigation Management. Over-irrigation can contribute to increased berry size and tight clusters, making them more prone to splitting.

OLR Management. Feeding damage by OLR creates wounds that are entry points for bunch rot organisms. Therefore, control of OLR can decrease the incidence bunch rot.

Biological

There are some promising biologicals for use as antagonists against the bunch rot complex. The bacterium *Pseudomonas fluorescens* (BlightBan7) has performed well in this manner (R.A. Duncan, personal communication), but is as yet not registered for use on grapes.

Chemical

Copper/sulfur dust. 0 day PHI. Copper/sulfur dust (COCS) is applied at a median rate of 7 lb ai per acre.

Phomopsis Cane and Leafspot

Phomopsis viticola

Damage. *Phomopsis* is a fungal disease that is most severe when spring rainfall is high (36). It is common in northern grape growing regions where spring rains are common after bud break. Splashing rain is required for infection. Basal leaves with heavy infection become distorted and usually never develop to full size. Canes may be stunted or break off at the base, and infected buds may not open. Severe infections may cause clusters to shrivel and dry up. On cane pruned varieties, stunted canes may not allow enough fruiting wood for the following year's crop.

Description of Symptoms and Disease Cycle. *Phomopsis* overwinters as fruiting bodies called pycnidia. In spring, spores are exuded from the pycnidia, and infections can occur anytime that rain splashes spores onto green leaf tissue. Tiny dark brown spots with yellowish margins occur on leaf blades and veins, appearing several weeks following rain. On shoots, black scabby streaks appear. Infected canes appear bleached during the dormant season. Severely affected cane or spurs exhibit an irregular dark brown to black discoloration intermixed with whitish bleached areas.

Monitoring. Growers and PCAs should look for bleached out canes to determine overwintering inoculum potential and to prune out infected canes or spurs.

CONTROLS

Cultural

Pruning. Spur and cane lesions provide most of the inoculum for new infections. Reducing the source of the disease is important. Growers can prune out badly infected canes to reduce the carryover of spores, however, it has yet to be proven that pruning helps control phomopsis. Pyncidia are usually found at the base of shoots and canes and therefore pruning these out would decrease yield substantially. It is recommended that growers not use overhead sprinklers to decrease the chance of spread of the disease.

Biological

No biological controls have been identified that are effective against phomopsis cane and leafspot.

Chemical

In all areas, spring foliar treatments may be advisable if the risk of rain after budbreak is high, or if overhead water is used for frost protection. Apply materials before the first rain after bud-break and before 0.5 inch shoot length (and again when shoots are 5 to 6 inches in length).

Azoxystrobin. 14 day PHI. Azoxystrobin (ABOUND) is a natural product derived from mushrooms and is a good broad spectrum material (also effective against phomopsis, leafspot, and downy mildew.) This material is used as a preventative and contact. In 2000, 18,465 lb ai were applied to 13.9% of the acreage in a median of one application per field. The median application rate was 0.21 lb ai/acre. Abound is a relatively new and relatively expensive chemical tool in California and use reports are not available. The restricted entry interval is 4 hours. Azoxystrobin is very costly.

Copper Hydroxide. 0 day PHI. Copper hydroxide is a resistance management tool used in rotation with other products. In 2000, 285,932 lb ai were applied to 38.5% of wine grape acreage a median of one time per field. The median application rate was 0.81 lb ai per acre. Copper hydroxide is used to control several diseases in addition to powdery mildew such as phomopsis and downy mildew, as well as for frost management. Use of copper hydroxide may burn grape leaves. Certain copper sprays require a closed-mixing system. Copper hydroxide is approved for organic production of grapes. It is the preferred control for this disease.

Captan 50 WP. 0 day PHI. Captan is a phthalimide fungicide and it may be applied alone or in combination with benomyl. In 2000, 1,536 lb ai were applied to approximately 0.2% of wine grape acreage in a median of one application. The median application rate was 1.47 lb ai/acre. Captan treated grapes are prohibited in Canada. Applications of Captan should not be made immediately before or closely following oil sprays. Captan is restricted by many wineries. The restricted reentry period is 4 days.

Mancozeb. 0 day PHI. Mancozeb (DITHANE) is an alkylenebis (dithocarbamate) applied for spring foliar treatment and should not be applied after bloom. In 2000, 72,641 lb ai were applied to approximately 9% of wine grape acreage in a median of one application. The median application rate was 1.5 lb ai/acre. The restricted reentry interval is 24 hours. Dithane is used on a limited basis because of trade issues associated with the use of this product.

Sulfur. 0 day PHI. Sulfur is applied at label rates to approximately 88% of wine grapes in California, the vast majority of which is for control of powdery mildew. In 2000, 23,733,878 lb ai were applied a median of six times per field. The median application rate was 7.73 lb ai/acre. Sulfur dust rates being higher (10 to 12 lb ai per acre) and wettable sulfur rates being lower (typically 3 to 5 lb ai per acre). It is the most commonly used pesticide in California's grape industry. Approximately 80% of the sulfur applications are as the dust, with 20% being the wettable powder formulations. Treatment is initiated at bud-break to 2-inch shoot growth and is reapplied at 7 to 10-day intervals. Re-application is necessary if the sulfur is washed off by rain or irrigation. Sulfur can cause injury to foliage and fruit when applied just before or on days when the temperature exceeds 100EF. Use of sulfur is approved for organically grown produce. The reentry interval is 24 hours in most counties however in some counties in the Southern San Joaquin Valley region the restricted-entry interval is 3 days.

There are worker exposure and off-site movement issues associated with the use of dusting sulfur. It has been demonstrated that dormant applications of lime-sulfur do an excellent job of reducing viable spores in pycnidia and therefore can be used for both powdery mildew and phomopsis.

Ziram. 0 day PHI. Ziram is a dithiocarbamate. In 2000, 11,067 lb ai were applied to approximately 1.1% of wine grape acreage in a median of one application. The median application rate was 1.52 lb ai/acre. The restricted entry interval is 48 hours. Ziram is used on a limited basis because of trade issues associated with the use of this product.

Pierce's Disease

Xylella fastidiosa

Damage. The bacterium that causes Pierce's disease lives in the water-conducting system of plants (the xylem) and is spread from plant to plant by xylem-feeding sharpshooters (32) (see Sharpshooters in Major Insect Pests). Symptoms of Pierce's disease first appear as water stress in midsummer and are caused by blockage of the water-conducting system by the bacteria. Leaves become slightly yellow or red along margins in white and red varieties, respectively, and eventually leaf margins dry or die in concentric zones. By mid-season some or all fruit clusters on infected canes may wilt and dry. Tips of canes may die back, and roots may also die back. Vines may deteriorate rapidly after appearance of symptoms.

Description of Symptoms and Disease Cycle. Sharpshooters are active in the spring after average temperatures warm up above 59EF, and can transmit the bacterium to the vines anytime thereafter. Usually only one or two canes on a vine will show Pierce's disease symptoms in the same season that infection has occurred, and this happens late in the season. Symptoms gradually spread along the cane from the point of infection out towards the end and more slowly towards the base. In the following year, some canes or spurs may fail to bud out. New leaves become chlorotic (yellow) between leaf veins and scorching appears on older leaves. From late April through summer infected vines may grow at a normal rate, but the total new growth is less than that of healthy vines. Not all vines that have been infected will develop the disease. The probability of recovery depends on variety, the date of infection, the point of infection on the plant, and the age of the vineyard. Recovery is high in Sauvignon blanc, Chenin blanc, Sylvaner, Ruby Cabernet, and White Riesling, but low in Barbera, Chardonnay, Mission, and Pinot Noir. Once the vine has been infected for over a year (i.e., bacteria survive the first winter) recovery is much less likely. Young vines are more susceptible than mature vines, probably because during the training period, much less wood is pruned off than mature vines. Infections are often removed with pruning. However, in areas where Glassy-winged sharpshooter is present this may not be the case. Unlike the other sharpshooter species, which feed on new cane tissue, Glassy-winged sharpshooter will feed on older wood, which can result in infections that do not get pruned out. Rootstock species and hybrids vary greatly in susceptibility. The date of infection strongly influences the likelihood of recovery. Late infections (after June) are least likely to persist the following growing season.

Monitoring. Growers and PCAs can monitor for insect vectors such as sharpshooters (see Sharpshooters in Major Insect Pests), and can make visual observations for symptoms of Pierce's disease.

CONTROLS

Cultural

Neighboring Crops/Wildlands. Riparian areas bordering vineyards are often an important source of Pierce's disease in coastal vineyards because these are areas favored by Blue-green sharpshooter. In the San Joaquin Valley, the greatest amount of disease spread is usually near pastures, weedy hay fields, or other grassy areas. Growers should consider the presence of neighboring hay fields or permanent pastures or riparian areas when planting a vineyard. Though often not feasible, in some instances properties adjacent to vineyards are purchased or leased, and managed in such a way that does not encourage sharpshooter populations. Management of riparian woodlands and environmental restoration plantings with non-host species is a newly developed method that requires careful planning and advance approval by governmental agencies. Non-host plant species include alder, cottonwood, spicebush, toyon and walnut. Systemic hosts include big leaf maple, buckeye, California blackberry, and wild grape (A.S. Purcell, personal communication).

Glassy-winged sharpshooter has a very large host range. Some plant species are particularly attractive, such as citrus. In the areas where this pest occurs, populations are highest in vineyards near citrus orchards. As the Glassy-winged sharpshooter spreads in California it will become clear what plant communities are conducive to higher sharpshooter populations than other plant communities.

Weed Control. In areas where Pierce's Disease has historically been a problem it may be prudent to eliminate perennial weedy grasses from areas adjacent to vineyards, such as along roads, ditches, and ponds. Bermuda grass and water grass are especially favored sharpshooter hosts. Alfalfa fields can be sources of sharpshooters if grass weeds are present. Annual weeds in vineyards that begin to grow after April or May do not support high sharpshooter populations.

Tolerant Varieties. If a vineyard is near an area with a history of Pierce's disease, varieties that are less susceptible to this disease can be planted.

Vine Removal. Vines that have had Pierce's symptoms for more than one year should be removed as they area source of infection. This is particularly important in areas where Glassy-winged sharpshooter is present.

Biological

No biological controls are known for Pierce's disease.

Chemical

There are no known chemical controls for Pierce's Disease.

Removal of Disease Vector. Insecticide treatments aimed at controlling the vector in areas adjacent to the vineyard have reduced the incidence of Pierce's disease by reducing the numbers of sharpshooters immigrating into the vineyards in early spring. The degree of control, however, is not promising for very susceptible varieties such as Chardonnay and Pinot Noir. Because Glassy-winged sharpshooter is such an effective vector of Pierce's Disease it is felt that insecticide treatments for this pest will not be an effective long-term management strategy for controlling Pierce's Disease.

Eutypa and Other Canker Diseases

Eutypa Dieback *Eutypa lata*

Bot canker *Botryodiplodia theobromae*

Damage. Eutypa and other canker diseases are caused by two species of fungi, *Eutypa lata* and *Botryodiplodia theobromae* (35). Eutypa dieback is an important problem in the Northern San Joaquin Valley and coastal regions, but is also found in the Southern San Joaquin Valley. Bot canker is the main cause of arm and cordon death in the southern San Joaquin Valley region. It is an occasional problem in the South Coast region. Both Eutypa and Bot canker enter the vine through pruning wounds, and move slowly towards the roots. The fungi form cankers in the permanent wood of the vine, and eventually cause death of spurs, cordons, and ultimately, the entire vine.

Description of Symptoms and Disease Cycle. Eutypa survives in diseased wood and produces fruiting bodies (perithecia) in old, affected host tissue under conditions of high moisture. Eutypa spores are produced in the northern part of California in grapevines, apricots, cherries, kiwi, manzanita and *Ceanothus*. Ascopores are discharged from perithecia soon after rainfall. Bot canker produces fruiting bodies (pycnidia) on the surface of the canker, which produce spores. Spores of both diseases are carried with winter storms, and infection on grapes occurs through pruning wounds. Symptoms in the wood of both diseases are similar in appearance, characterized by wedge-shaped, darkened cankers that develop in the vascular tissue. Eutypa dieback delays shoot emergence in the spring, and causes shoot stunting and a "witch's broom" appearance. Leaves are chlorotic and tattered. No foliar symptoms have been associated with Bot canker. Disease is not generally visible in vines younger than 5 to 6 years old and is seen most frequently in vineyards established for 10 or more years.

Monitoring. Eutypa and bot canker can be detected by observing dead sections of cordon. Growers and PCAs should monitor for Eutypa by looking for symptoms in late spring before stunted shoots can be masked by growth from adjacent shoots.

CONTROLS

Cultural

Training and Pruning. The most effective method of managing Eutypa and bot canker is to minimize the amount of inoculum entering the vine, both in space and time. Spatially, the number and size of pruning cuts should be minimized, and vines should be properly trained initially to avoid the large cuts necessary in re-training efforts. Pruning should occur as late in the dormancy period as possible, after most rains have reduced the spore load. Late pruning also encourages quick wound healing, minimizing the amount of time that the vines are vulnerable to infection. Pruning wounds remain susceptible for some 4-5 weeks in December, but only for about 7-10 days in February. Cutting out dead sections of cordons can be done, but it is probably more cost effective to simply retrain a cane from an uninfected part of the vine to replace dead cordons.

Pre-Pruning. Recently, vineyardists have been employing pre-pruning, where a mechanized pruner is used once in the fall, leaving canes of 2 feet or more. The vines are then hand pruned in the late-dormant period. The brush removed by the mechanized pre-pruning allows for much more rapid hand pruning in the spring.

Biological

A few fungal antagonists to Eutypa have been identified and applied experimentally to pruning wounds to control it. Research in California has shown that *Fusarium lateritium* and *Cladosporium herbarum* can colonize pruning wounds and provide control of Eutypa (53), but no fungal antagonistic products are available commercially.

Chemical

Chemical treatments are most effective if applied directly to the pruning wounds immediately after pruning. There are no registered chemical treatments for Eutypa since the withdrawal of benomyl. Promising research continues with several materials including soaps and boric acid. However, a registrant will need to register these products.

Benomyl. All uses of benomyl have been withdrawn. 50 day PHI. Benomyl (BENLATE) is a carbamate. It was applied principally for botrytis bunch rot control. In 2000, 6,964 lb ai were applied to approximately 2.9% of wine grape acreage in a median of one application. The median application rate was 0.37 lb ai/acre. Benomyl may not be as effective in areas of the state where benomyl-resistant pathogens are present. The restricted-entry interval is 1 day.

MINOR DISEASES OF WINE GRAPES

Measles (Black Measles/Spanish Measles)

Damage. For many years the cause of measles was unknown, but recent work points to several species of wood rotting fungi, particularly in the genus *Phaeoacremonium*. Affected leaves display necrotic interveinal areas with a chlorotic outline. Severely affected leaves may drop and canes may dieback from the tips. On berries, measles is expressed as small, round, dark spots, each bordered by a brown purple ring. These spots may appear at any time between fruit set and ripening. In severely affected vines the berries often crack and dry on the vine. This disease is more prevalent in areas with consistently high summer temperatures such as the San Joaquin Valley, although the disease in recent years has been observed in all production areas including the central coast. Generally, plantings that are 10 years of age or older are affected, although measles has been seen on fruit and foliage on 2-4 year-old vines.

Description of Symptoms and Disease Cycle. Symptoms may occur at any time during the growing season but are most prevalent during July and August. Most likely, spores of *Phaeoacremonium* spp. enter the vine through pruning wounds.

CONTROLS

Cultural, Biological and Chemical

Although there are no recommended treatments for measles at this time, because it is most likely a pruning wound infection, strategies to minimize pruning cuts (as for Eutypa and other canker diseases) should minimize the risk of measles infection.

Armillaria Root Rot (Oak Root Fungus)

Armillaria mellea

Damage. Armillaria is a fungus found on a number of woody plants. It persists in the soil, and infects vines through contact with the roots. Once disease has progressed sufficiently to weaken the root system, the vines usually completely collapse. The disease results in reduced yields and, eventually, vine death.

Description of Symptoms. White mycelial mats can be found under the bark at the soil line. Dark, root like structures grow into the soil after symptoms develop on vines. The fungus survives on diseased wood and roots below ground for many years, and is favored by soil that is continually damp. Although the pathogen produces spore-producing mushrooms, they are not considered significant in disease spread.

Monitoring. Evidence of Armillaria root rot is observed by removal of soil around the crown of the vine (where the root systems leave the soil) and cutting into the bark below the ground level. Early detection (a flat, creamy mycelial fans and mushroom odor) can enhance the probability of limiting the spread of the disease from vine to vine through root contact. It is also useful to monitor nearby oak trees.

CONTROLS

Cultural

Removal. Infected plants or roots can be removed to reduce risk of infection to neighboring plants. This practice is primarily effective at early stages of vineyard infection.

Control of Neighboring Plants. Placement of vineyards next to potential carriers of Armillaria, such as oak trees, that have extensive root systems should be avoided. Intermingling of root systems should be minimized.

Biological

No biological controls have been identified that effectively control Armillaria root rot, though efforts are underway to develop commercially viable products in this area. Use of *Trichoderma* spp. has been shown in research to be a promising method of Armillaria control (41).

Chemical

Pre-plant

Methyl Bromide. A pre-plant application of methyl bromide is applied at label rates. The restricted-entry interval is 48 hours. In 2000, methyl bromide was used on 0.13% of wine grape acres at a median application rate of 348 lb ai/acre. Methyl bromide is rarely used to control Armillaria in grapes.

Post-plant

Sodium Tetrathiocarbonate. Sodium tetrathiocarbonate (ENZONE) was applied to 1.3% of wine grape acreage in 2000. A total of 206,141 lb were applied in a median of one application per field. The median application rate was 27.18 lb ai/acre. Treatment is rarely for *Armillaria*. For post-plant applications the crop must be at least 1 year old or injury may occur. The restricted entry interval is 4 days.

Crown Gall

Agrobacterium tumefaciens

Damage. Crown gall is one of the few bacteria that affect grapes. Gall formation, usually at the crown or base of the trunk, is the typical symptom of this disease.

Description of Symptoms and Disease Cycle. The bacteria may enter the vines through wounds. Infections may enter through suckering or cultivation, but rarely through pruning wounds. Freeze damage also provides sites for entry. Galls may be produced on canes, trunks, roots, and cordons and may grow to several inches in diameter. Internally galls are soft and have the appearance of disorganized tissue. The bacterium is systemic throughout the vine. Crown gall is a particular problem for nurseries.

CONTROLS

Cultural

Good Sanitation. Crown gall can be controlled by good sanitation, the avoidance of injury, and the avoidance of using wood systemically infected by the pathogen. Growers should use indexed stock certified free of crown gall infection.

Biological

There are no biological controls that are effective against the grape crown gall. However, *Agrobacterium radiobactor*, a non-pathogenic competitor, does provide effective control of this pathogen on other crops (63).

Chemical

In areas where winter injury to the vines occurs, chemical treatments may be effective.

2,4-Xylenol and Meta Cresol. 0 day PHI. This combination product (GALLEX™) is applied at label rates in enough water to provide complete coverage. This combination is applied to less than 0.1% of grapes in California. The restricted entry interval is 0 days.

Downy Mildew

Plasmopara viticola

Damage. Downy mildew is a fungus that is common in areas with high summer rainfall (eastern USA and Europe) (59), but was unknown in California until 1995. It was problematic in several South San Joaquin Valley vineyards in the wet springs of 1995 and 1998. It has so far not shown up in the coastal regions or the Northern San Joaquin Valley. Oily lesions develop on the upper sides of the leaves, and the fungus sporulates in a dense white fluffy growth within the lesions. Severely infected berries and clusters may completely shrivel within weeks.

Description of Symptoms and Disease Cycle. The fungus overwinters as oospores in leaf litter and soil, as well as in buds and shoot tips on the vine. Spring rains splash the spores onto green tissue. Downy mildew attacks all green parts of the vine. Lesions can be yellowish and oily or angular and yellow to reddish brown, depending on leaf and lesion age. Infected shoot tips thicken, curl and become white with sporulation, eventually dying. Young berries are more susceptible to the disease than more mature berries.

Monitoring. Growers and PCAs should be on the lookout for signs of the disease, especially during wet springs. Eradicative treatments can be applied at the first sign of the disease.

CONTROL

Cultural

Disease Free Plants. Use of disease-free planting materials reduces the introduction of downy mildew to a new vineyard.

Biological

No biological practices have been identified for this disease.

Chemical

Materials for downy material can be classified as preventatives or contacts. No systemic materials are registered (some systemic fungicides against downy mildew are used in other countries).

Preventatives

Copper Hydroxide. 0 day PHI. Copper hydroxide is a preventative, and a resistance management tool used in rotation with other products. In 2000, 285,932 lb ai were applied to 38.5% of wine grape acreage a median of one time per field. The median application rate was 0.81 lb ai per acre. Copper hydroxide is used to treat several diseases such as phomopsis, botrytis bunch rot and frost management. Use of copper hydroxide may burn grape leaves.

Basic Copper Sulfate. 0 days PHI. Applications with basic copper sulfate, also known as BORDEAUX mixture, are initiated when shoots are 0.5 inches long and then repeated every two weeks as needed. In 2000, 2,543 lb ai were applied to approximately 0.2% of wine grape acreage in a median of one application. The median application rate was 1.06 lb ai/acre. It is a preventative material. The reentry period is 1 day.

Maneb (MANEX). 1 day PHI. In 2000, 664 lb ai were applied to approximately 0.09% of wine grape acreage in a median of one application. The median application rate was 1.0 lb ai/acre. Begin applications shortly after budbreak (0.5-1.5 inch long shoots) and repeated every 7-10 days if conditions require it. The reentry period is 1 day.

Mancozeb (DITHANE). 66 day PHI. In 2000, 72,641 lb ai were applied to approximately 9% of wine grape acreage in a median of one application. The median application rate was 1.5 lb ai/acre. Begin applications shortly after budbreak (0.5-1.5 inch long shoots) and repeated every 7-10 days if conditions require it. The reentry period is 1 day.

Azoxystrobin. 14 day PHI. Preventative and contact. Azoxystrobin (ABOUND) is a natural product derived from mushrooms and is a good broad spectrum material (also effective against phomopsis, leafspot, and downy mildew.) In 2000, 18,465 lb ai were applied to 13.9% of the acreage in a median of one application per field. The median application rate was 0.21 lb ai/acre. Abound is a relatively new and relatively expensive chemical tool in California and use reports are not available. The restricted entry interval is 4 hours.

Bacillus subtilis**.** 0 day PHI. *Bacillus subtilis* (SERENADE) is a bacteria. It is a newly registered material so there is no pesticide use reporting data available. The manufacturer's recommended application rate is 4 to 8 lbs per acre of material (0.4 to 0.8 lbs ai per acre). Recommended application timing is when shoots are ½ to 1 ½ inches long, repeat at 5 inches and then again when shoots are 8 to 10 inches long. From this point repeat every 7 to 10 days while vines and fruit are susceptible to powdery mildew. Intervals between applications should be shortened under high disease pressure. There is a 4 hour restricted entry interval.

Contact materials

Mefenoxam + Copper Hydroxide. 66 day PHI. Mefenoxam + copper hydroxide (RIDOMIL GOLD) is a contact material which is applied at a median application rate of 0.1 lb ai (mefenoxam)/ac. In 2000, 9 lb ai of mefenoxam were applied to 0.01% of wine grapes. Must not be applied after bloom. The reentry period is 2 days.

Azoxystrobin. 14 day PHI. Preventative and contact. Azoxystrobin (ABOUND) is a natural product derived from mushrooms and is a good broad spectrum material (also effective against phomopsis, leafspot, and downy mildew.) In 2000, 18,465 lb ai were applied to 13.9% of the acreage in a median of one application per field. The median application rate was 0.21 lb ai/acre. Abound is a relatively new and relatively expensive chemical tool in California and use reports are not available. The restricted entry interval is 4 hours.

Weeds

Weed Management. Weeds reduce vine growth and yields by competing for water, nutrients, and sunlight, and typically are controlled to enhance the establishment of newly planted vines and to maintain growth and yield of established vines. Competition is most severe during the first 2 to 3 years of the vine's life or where root growth is limited. For mature vines, competition is greatest under drip irrigation with decreasing competition under furrow and basin flood irrigation. Annual weeds are more easily controlled than perennial weeds. Perennials typically are less susceptible to herbicides and to cultivation. Weeds have impacts other than competition and include interference with harvest because of a tall growth habit (examples: prickly lettuce and horseweed), seed contaminant in the crop (examples: sandbur in raisins and black nightshade in mechanically harvested grapes), and finally, interference with pesticide applications for insect and disease control. However, weeds can also provide some benefits if carefully managed. They can provide erosion control on steep hillsides. Weeds can keep the dust down, especially along roadsides, and can also improve soil structure by adding organic matter, providing root channels and exuding soil stabilizing gums, all of which can improve water infiltration. In areas with intense sunlight, weeds can cut down on reflected light from the vineyard floor, which can potentially sunburn grapes. However the long-term benefits of using weeds as a vineyard floor cover are unclear since these weeds are a continued source for weed colonization of the vine row.

Weed Management As Part of IPM. Weed management is part of an overall vineyard management system. Plants on the vineyard floor influence other vineyard pests such as insects, mites, nematodes, diseases and vertebrates. As an example, bermudagrass, dallisgrass, and many other grassy weeds have been identified as host reservoirs of the Pierce's disease bacterium. This pathogen can be vectored to grapevines by sharpshooter leafhoppers that have fed on host reservoirs. Many species of broadleaf weeds and perennial grasses are hosts to nematodes that also infest grapevines. Some weeds are alternative hosts for insects such as OLR and orange tortrix. Gophers are most prevalent in non-tilled vineyards and are common where broadleaf weeds predominate. They feed on vine roots and can kill young vines. Weeds provide a good habitat for field mice or voles, which can girdle and kill vines.

Monitoring. Weed surveys, at least once a year, allows growers to identify the spectrum of weed present within the vineyard and to develop a weed management strategy for control. These surveys are the basis for decisions about herbicide choice or cultivation equipment and practices. In season monitoring aids decision making for timing of postemergent herbicide applications. Proper postemergent herbicide timing allows application of the lowest dose while maintaining control.

CONTROLS

Cultural

Cultivation

For young vineyards, many pre-emergent and contact herbicides pose too great a risk of damage because young vine roots are shallow and because foliage is close to the ground. Hand cultivation can be used effectively to control weeds in newly established vineyards. A wide variety of cultivation implements are used in mature vineyards. Cultivation between rows (the middles) is relatively simple, requiring only a disk harrow, and is by far the most common method of between-row weed control in California. In-row cultivation is less common, but increasing in popularity as the types of implements available increases. In-row mechanical control of weeds is best achieved when done on young, immature weeds, so frequent passes are advised. Mowing is a very common method of between-row control, and is essential for managing cover crops. Some growers are using in-row mowers as well. Recently, propane flamers have been designed for use in vineyards. An Australian company is perfecting a machine that produces super-heated steam that is directed under the vine and kills any weeds that it contacts. A prototype machine is now in California for fine-tuning and possible commercial production.

Knives or blades. (BEZZERIDES, L&H MFG, CLEMENS.) Knives or blades sweep across the berm and cut or scrape weeds just below soil line. Some are fit with a spring-loaded retractor for moving around the vine trunk.

Berm sweepers. (L&H MFG, REDHEAD MFG.) Berm sweepers consist of rotating rubber paddles that clear away vegetation on the berm.

Rotary hoes. (KIMCO). Rotary hoes stir the soil, uprooting vegetation. Travel time is faster compared to the French plow.

Flaming. (RED DRAGON MFG.) This flamer uses propane as the fuel source. Burners are trained on the berm and the heat produced disrupts membranes and cuticles causing desiccation.

Plows. (L&H MFG., BEZZERIDES, KIMCO). Perennial weeds such as Johnsongrass are not easily controlled with cultivation or herbicides. Plowing has been an effective control method for weeds like Johnsongrass. The French plow is the standard in-row plow for vineyards and has been used for decades with success. It consists of a moldboard plow with a spring loaded attachment which pulls the plow around the vine trunks. One pass is usually made just prior to or at budbreak, which opens up a furrow within the row, and some weeks later, the soil is moved back into the row. For added control of sprouting rhizomes, Treflan can be incorporated into the plowed soil prior to reforming the berms. A major drawback to French plowing is the time it takes: Usually only one-half of a row can be done at a time. Recently, innovations have been made which allow two plows to be operated at the same time. In addition, French plows can uproot vines if rows are not perfectly straight. Other manufacturers have constructed systems that move soil extensively in the vine row. Some have small plows that work within the row like the French plow. Others use rotating plates with heavy cables attached that churn soil in the row. Still others use a form of rotovation in the row (Rotary Hoe).

Cover Crops. Most cover crops are grown as cool season annuals, which mean they are planted in the fall and disked under in the spring (usually March or April). Most well managed cover crop species, whether grasses or legumes, will be competitive enough to crowd out weeds during this period, but once the cover crop is turned under, summer weeds usually take over. The cover crops have predictable growth habits and usually have a low percentage of dormant seed that make them easily managed. Using resident vegetation rather than a managed cover crop does not have a predictable growth habit and the weeds present in this mixture of species allows for continual colonization of the berm area that is normally maintained without any vegetation. Perennial cover crops, once established, can provide good weed control all year long, but most perennials available (e.g., perennial ryegrass, orchardgrass, white clover) are too competitive with the vines. Interest has been shown recently in the use of perennial native grasses, which can crowd out weeds once established, but go dormant during the growing season and not compete severely with the vines. Some growers are experimenting with the use of perennial native grasses for in-row weed control.

Mulches. Weeds growing in the vine row can also be controlled with mulches made of natural or synthetic materials. Natural mulches can consist of wood chips, ground almond hulls or vegetation from the vineyard middles that has been "mown and thrown" (26). Synthetic mulches of polyethylene, polypropylene, or polyester can be used as well. Synthetic mulches maintain uniform moisture conditions, which promotes young vine growth. Synthetic mulches allow water to penetrate but prevent weeds from growing up through the mulch. Synthetic mulches are expensive, but may last for as much as ten years. Natural mulches need to be continually amended, and may provide a good habitat for voles, field mice, and snakes. These mulches add organic matter to the soil and can be used to delay maturity of some varieties in order to take advantage of market price fluctuations. However, natural mulches also lower soil temperature and so they may slow development of the root system of young vines.

Biological

Few vineyard weed biological controls have been identified, although there are biological control agents for puncturevine and yellow starthistle.

Chemical

Herbicides registered for use in vineyards vary in their mode of action, soil persistence, and the timing and method of application. Pre emergent herbicides are applied directly on the soil surface before seed germination and growth of the weeds. Weeds are killed as they germinate. This type of treatment does not typically control established weeds or dormant weed seed. Herbicides applied to established, growing weeds are called post-emergent herbicides. Post emergent herbicides may kill tissue directly contacted (contact herbicides) or they may translocate within the plant (systemic herbicides).

Postemergent

Fluazifop-P-Butyl. 0 day PHI. Fluazifop-p-butyl (FUSILADE) is an aryloxyphenoxy propionate. In 2000, 93 lb ai were applied to approximately 0.17% of wine grape acreage in a median of one application. The median application rate was 0.22 lb ai/acre. It is a systemic herbicide intended to control perennial grasses in nonbearing dormant or growing grapes. It cannot be applied to vines from which grapes will be harvested within 1 year. This product is not effective against broadleaf plants and sedges. The residual period for Fluazifop-p-butyl is less than 1 month. The restricted entry interval is 12 hours.

Glyphosate. 14 day PHI. Glyphosate (ROUNDUP, GLYPHOS, TOUCHDOWN) is a postemergent herbicide that translocates to vine growing points. It may be used as a preplant or postplant postemergence herbicide in the vineyard. In 2000, 409,521 lb ai were applied to approximately 54% of wine grape acreage in a median of one application. The median application rate was 0.91 lb ai/acre. It is applied with a controlled application or with low pressure flat fan nozzles. Glyphosate is sometimes tank mixed with one or more of the following pre-emergent herbicides: diuron, napropamide, norflurazon, oxyfluorfen, oryzalin, or simazine. The restricted entry interval is 4 hours.

Oxyfluorfen. Oxyfluorfen (GOAL) is a diphenyl ether compound. It has both pre-emergent and contact properties. In 2000, 117,686lb ai were applied to approximately 35.36% of wine grape acreage in a median of one application. The median application rate was 0.51 lb ai/acre. It must not be disturbed mechanically or poor weed control will result. The residual period is 4 to 10 months. It is often used in combination with oryzalin to broaden control. Oxyfluorfen can damage grapevines if applied close to budbreak and heavy spring rains occur. The restricted entry interval is 24 hours.

Paraquat Dichloride. 0 day PHI. Paraquat dichloride (GRAMOXONE) is a bipyridilium herbicide used for postemergence weed. In 2000, 102,788 lb ai were applied to approximately 19.16% of wine grape acreage in a median of one application. The median application rate was 0.72 lb ai/acre. Paraquat dichloride is often combined with oxyfluorfen to broaden the spectrum of weeds controlled. The restricted entry interval is 2 days.

Sethoxydim. 50 day PHI. Sethoxydim (POAST) is a cyclohexanedione. In 2000, 1,382 lb ai were applied to approximately 1.79% of wine grape acreage in a median of one application. The median application rate was 0.18 lb ai/acre. It is a systemic herbicide that may be applied to nonbearing and bearing vines. Sethoxydim controls many annual and perennial grasses, but not broadleaves. The restricted entry interval is 12 hours.

2,4-D. 2,4-D (ENVY) is an arkyloxyalkanoic acid that was applied to less than 1% of treated wine grape vineyards. In 2000, 2,4-D was applied once per field at median application rates of 0.02-0.74 lb ai/acre. It may only be applied to vineyards that are 3 or more years old. It is prohibited from use in some areas of the state due to the potential to drift onto susceptible crops. The residual period for 2,4-D is 4 to 6 weeks. The restricted entry interval is 2 days.

Soap. Pelargonic acid + related C6-C12 fatty acids (SCYTHE) is applied at rates of 1-2 lb a.i. acre on less than 1% of winegrapes in California. It is a contact herbicide.

Preemergent

Dichlobenil. 7 day PHI. Dichlobenil (CASORON) a nitrile. In 2000, 160 lb ai were applied to 0.01% of winegrape acreage at a median application rate of 4.6 lb ai/acre. It is used as a post plant pre-emergence material applied to the soil under vines that are at least 3 years of age. For best results, apply and follow with 0.5-1 inch of water or an immediate shallow mechanical incorporation. Caution: In non-tilled areas (e.g., non-tilled, drip-irrigated areas where roots are shallow) vines have a tendency to be damaged by dichlobenil, especially those growing in sand to sandy loam soils; apply to medium or heavy soils only. It often causes leaf margin chlorosis. Dichlobenil can be very effective in controlling perennial weeds around sprinkler heads. Residual period: 4-6 months. The restricted-entry interval is 12 hours.

Diuron. 0 day PHI. Diuron (KARMEX) is a phenylurea. In 2000, 22,843 lb ai were applied to approximately 5.2% of wine grape acreage in a median of one application. The median application rate was 0.8 lb ai/acre. It is applied in a 2 to 4 foot wide band in the vine row, and is only applied in vineyards where the vine trunk is at least 1.5 inches in diameter. Once applied to the soil, it must be incorporated into the soil by rainfall or irrigation to be effective. The residual period for diuron is 8 to 12 months. The restricted-entry interval for diuron is 12 hours.

Napropamide. 35 day PHI. Napropamide (DEVRINOL) is an amide. In 2000, 18,165 lb ai were applied to approximately 1.6% of wine grape acreage in a median of one application. The median application rate was 3.0 lb ai/acre. It is applied to the soil and must be incorporated with 7 days of application or sprinkler irrigated. It may be applied in combination with a postemergent herbicide, such as glyphosate, to broaden the control. The residual period is 4 to 10 months. The restricted entry interval is 12 hours.

Norflurazon. Norflurazon (SOLICAM) is a pyridazinone. In 2000, 18,326 lb ai were applied to approximately 3.9% of wine grape acreage in a median of one application. The median application rate was 0.79 lb ai/acre. It can be used on vines at least 2 years of age. Due to the risk of ground water contamination it may not be used on coarse textured soils or south of Monterey, Kings, and Tulare counties. May not be used on sandy loam soils after budbreak. Apply in 20-100 gal water/acre. Residual period: 6-12 months. The restricted-entry interval is12 hours.

Oryzalin. 0 day PHI. Oryzalin (SURFLAN) is a 2,6-dintroaniline compound. In 2000, 106,494 lb ai were applied to approximately 11.4% of wine grape acreage in a median of one application. The median application rate was 1.94 lb ai/acre. It is incorporated to the soil by rain or irrigation. The treated area must be clear of vegetation in order to provide effective control. Oryzalin may be applied in combination with other herbicides, such as glyphosate, for broader control. The residual period is 6 to 12 months. The restricted-entry interval is 12 hours.

Oxyfluorfen. Oxyfluorfen (GOAL) is a diphenyl ether compound. It has both pre-emergent and contact properties. In 2000, 117,686 lb ai were applied to approximately 35.4% of wine grape acreage in a median of one application. The median application rate was 0.51 lb ai/acre. It must not be disturbed mechanically or poor weed control will result. The residual period is 4 to 10 months. It is often used in combination with oryzalin to broaden control. Oxyfluorfen can damage grapevines if applied too close to budbreak and heavy spring rains occur. The restricted entry interval is 24 hours.

Simazine. 50 day PHI. Simazine (PRINCEP) is a 1,3-5-triazine compound. In 2000, 139,299 lb ai were applied to approximately 23% of wine grape acreage in a median of one application. The median application rate was 1.0 lb ai/acre. It is applied in a 2 to 4 foot wide band in the vine row any time between harvest and early spring in vineyards where the vine trunk is at least 1.5 inches in diameter. Once applied to the soil, it must be moved into the soil by rainfall or irrigation to be effective. It is sometimes applied at lower rates in combination with other pre-emergence herbicides, such as diuron to broaden the spectrum of control. It is also commonly applied with glyphosate, which kills the existing weeds at the time of application. Simazine is relatively inexpensive and is more effective than diuron in controlling wild oats, henbit and groundsel, although some groundsel populations have now become resistant. This product should not be used on extremely sandy or gravelly soils where product may move to root zone and cause damage to grapevines. It is important that growers consult the pesticide management zones established by the Department of Pesticide Regulation to assure that the product does not leach into ground water. Residual period is 8 to 12 months. The restricted-entry interval is 12 hours.

Trifluralin. 60 days PHI. Trifluralin (TREFLAN) is a 2,6-dintroaniline compound. In 2000, 8,570 lb ai were applied to approximately 2.5% of wine grape acreage in a median of one application. The median application rate was 0.88 lb ai/acre. Trifluralin must be mechanically incorporated into the top 2 to 6 inches of the soil after application. It may be applied to vineyards with newly planted vines. It is effective in controlling grass species, including broadleaf weeds. The residual period is 4 to 12 months. The restricted-entry interval is 12 hours.

Pendimethalin. Pendimethalin (PROWL, STOMP) is a 2,6-Dintroaniline compound applied to dormant nonbearing vines. In 2000, 11,249 lb ai were applied to approximately 1.4% of wine grape acreage in a median of one application. The median application rate was 1.67 lb ai/acre. The residual period for pendimethalin is 4 to 10 months. The restricted entry interval is 24 hours.

Vertebrates

Overview. A number of vertebrate species may move into or live near grape vineyards and seek the vineyards for food or shelter. The potential for damage by vertebrates varies from region to region. Migratory and resident birds can cause significant damage. Vineyards located near rangeland, wooded areas or other uncultivated areas are more likely to be invaded or re-invaded by certain vertebrates. Predators, diseases and food sources all may influence vertebrate populations. Predators such as coyotes, foxes, snakes, hawks and owls feed on rodent and rabbit species. Growers cannot, however, rely on predators to prevent rodents or rabbits from becoming agricultural pests.

Birds

House finch - *Carpodacus mexicanus*
Robin - *Turdus migratorius*

Starling - *Sturnus vulgaris*
Long-billed curlew - *Numenius americanus*

Damage. Several species of birds can cause severe damage when they feed on ripening berries in vineyards. House finches are one of the most troublesome bird pest in grapes. They are residents in all grape growing regions and may feed on berries whenever ripe fruit is present. Robins are a common pest in grape vineyards feeding on ripening berries. Starlings may feed in vineyards any time ripening fruit are present. Long-billed curlews move through vineyards on the central and southern coast. They are large birds with a wingspan of about 2 feet with long legs and are characterized by a long bill that curves downward at the tip. Curlews feed in flocks of 10 to 20 and tend to return to the same areas each spring.

Monitoring. The best strategy for reducing bird damage depends on the species feeding on the crop. Growers and PCAs should identify the birds that are causing damage before choosing controls. Keeping records of bird problems and the time of year they occur helps growers to plan control actions.

CONTROLS

Cultural.

Habitat modification. Birds such as house finches will make use of nesting and perching sites such as weedy ditches, power lines, brush piles, etc. If these can be eliminated or reduced it will reduce the risk of damage. Because power line removal is usually not feasible, other control efforts might have to be concentrated in areas next to power lines.

Flags. Mylar stake flags are placed in fields to frighten away finches. Noisemakers are not effective against this species. When the finch population is high, trapping is an effective alternative, but may only be done with permit from the U.S. Fish and Wildlife Service. Visual frightening devices such as mylar stake flags can also be used to reduce damage from robins.

Noise. Starlings can be controlled effectively with noisemakers. However, starlings quickly become accustomed to one type of noise, and therefore combinations of noisemakers (propane exploders and shell crackers) are necessary to achieve control. Growers start using noisemakers as soon as the birds begin feeding in the vineyard. Occasional shooting may be used, which increases the effectiveness of other noise making devices. Curlews are usually easily frightened. Noisemakers, such as shell crackers fired from shotguns are an effective control. Distress call recordings are available for some bird species.

Trapping. Starlings can be trapped in modified Australian crow traps or converted cotton trailers placed near feeding or roosting sites.

Netting. Netting can be draped over high risk areas. In most cases, the expense of netting and the labor involved in installing and removing it does not justify its use over the entire vineyard.

California Ground Squirrel

Spermophilus beecheyi

Damage. Ground squirrels are primarily a nuisance in vineyards, but can be a serious problem if populations build up to high levels. The squirrels gnaw on vine trunks, sometimes girdling and killing young vines. They may also feed on shoots and fruit and sometimes damage polyethylene irrigation hoses.

Monitoring. Growers monitor for ground squirrels by checking the perimeter of the vineyard about once per month for animals or their burrows. If monitoring indicates that a squirrel population is moving in, they can be controlled with traps, fumigants, or toxic bait.

CONTROLS

Cultural

Trapping. Trapping ground squirrels works well in small areas or for a small number of squirrels. Box type traps are baited and the squirrels are trapped when passing through. Ground squirrels are classified as non-game mammals and can be eliminated at any time if injuring crops. Trapped animals must be either destroyed, or, a permit must be obtained to release them elsewhere.

Chemical

Strychnine. Strychnine bait is applied at label rates to control ground squirrels. In 2000, 574 lb ai were applied to approximately 2.2% of wine grape acreage in a median of one application. The median application rate was 0.01 lb ai/acre. Baiting by hand is probably the most effective method. Single dose baits can also be placed in traps and in burrows. Strychnine is not the most effective bait for squirrels. Acceptable for organic production if grower demonstrates continued research into alternatives.

Aluminum Phosphide. Aluminum phosphide (PHOSTOXIN) is a fumigant used to control burrowing rodents. It works best in early spring when moist soil helps retain a high toxic gas level in the burrows. The burrows are checked after about three days. Where squirrels have dug out, re-treatment is necessary. Aluminum phosphide is rarely used in vineyards. In 2000, 207 lb ai were applied to approximately 0.32% of wine grape acreage in a median of one application. The median application rate was 0.07 lb ai/acre.

Diphacinone. Diphacinone is an anti-coagulant rodenticide bait intended to control ground squirrels. It is applied at labeled rates to traps or in bait stations. Baiting by hand is one of the most effective control mechanisms. Baits can also be placed at intervals in the main tunnel. Diphacinone is a restricted use material that may only be applied with a permit from a county agricultural commissioner. In 2000, approximately 0.7% of wine grape acreage was treated with diphacinone.

Zinc Phosphide. Zinc phosphide is applied as a bait that can be used to treat ground squirrels. It is rarely used in California. In 2000, 95 lb ai were applied to approximately 0.47% of wine grape acreage in a median of one application. The median application rate was 0.02 lb ai/acre.

Pocket Gopher

Thomomys bottae

Description of Pest. Pocket gophers are important vertebrate pests. They gnaw on root systems and girdle vines below the soil line. Their burrows run through the vineyard, diverting water and contributing to soil erosion, and can result in an uneven vineyard floor making tractor travel through the vineyard extremely uncomfortable

Monitoring. Growers monitor for gophers by inspecting vines near the borders of the vineyard where gophers may move in from adjacent fields. Gophers should be controlled as soon as they are detected.

CONTROL

Cultural

Trapping. Trapping or baiting by hand are the most effective control mechanisms, although also the most laborious. Traps are placed in the main tunnel between two fresh mounds. The traps should be checked daily. Pocket gophers are classified as non-game mammals and can be eliminated at any time if injuring crops.

Owl Boxes. Increasingly, owl boxes are set up in vineyards to help control gophers.

Floor management. Gophers are more attracted to weeds and cover crops with a taproot. Leguminous cover crops will provide better gopher habitat than grasses.

Chemical

Strychnine. Strychnine bait is applied at label rates to control ground squirrels and gophers. In 2000, 574 lb ai were applied to approximately 2.2% of wine grape acreage in a median of one application. The median application rate was 0.01 lb ai/acre. Baiting by hand is probably the most effective method. Single dose baits can also be placed in traps and in burrows. Acceptable for organic production if grower demonstrates continued research into alternatives.

Aluminum Phosphide. Aluminum phosphide (PHOSTOXIN) is a fumigant used to control burrowing rodents. It works best in early spring when moist soil helps retain a high toxic gas level in the burrows. The burrows are checked after about three days. Where squirrels have dug out, re-treatment is necessary. In 2000, 207 lb ai were applied to approximately 0.32% of wine grape acreage in a median of one application. The median application rate was 0.07 lb ai/acre.

Zinc Phosphide. Zinc phosphide is applied as a bait that can be used to treat ground squirrels and gophers. It is rarely used in California. In 2000, 95 lb ai were applied to approximately 0.47% of wine grape acreage in a median of one application. The median application rate was 0.04 lb ai/acre.

Meadow Vole

Microtus spp.

Damage. Meadow voles, which are also referred to as meadow mice or field mice, inhabit roadsides, meadows, canal banks, fence-rows and many field crops. When mouse populations reach high levels in their native grassy habitats, they invade and occupy neighboring vineyards, gnawing on trunks and cordons.

Description. Full-grown meadow voles are larger than house mice but smaller than rats. They feed on grasses, so grassy areas are a good food source as well as habitat for them. Well-established populations can be recognized by the network of small runways through the grass or other cover and the openings of numerous shallow burrows. Meadow voles are active year round, day and night.

Monitoring. Growers monitor the vineyards by visually looking for active runways and burrows. Snap traps baited with a mixture of peanut butter and oats are also used to monitor vole populations.

CONTROL

Meadow voles are classified as non-game mammals and may be eliminated in any manner at any time if they are injuring crops.

Cultural

Eliminate Habitats. Preventative measures are taken by growers to eliminate favorable mouse habitats adjacent to vineyards. Growers can clear grass, brush and weeds around vine trunks, long fence lines, field margins and irrigation and drainage ditches.

Chemical

Diphacinone. Diphacinone is an anti-coagulant rodenticide bait applied at labeled rates. Baiting by hand is one of the most effective control mechanisms. Baits can also be placed at intervals in an active runway, or burrow entrance. Diphacinone is a restricted use material that may only be applied with permit from a county agricultural commissioner. In 2000, approximately 0.7% of wine grape acreage was treated with diphacinone.

Zinc Phosphide. Zinc phosphide is applied as a bait used to treat meadow voles at labeled rates. It is rarely used in grape vineyards in California. In 2000, 95 lb ai were applied to approximately 0.47% of wine grape acreage in a median of one application. The median application rate was 0.02 lb ai/acre.

Deer

Damage. Deer feed on vines and berries in vineyards located near good deer habitat. Deer are most likely to be a problem from late spring to midsummer in low-elevation vineyards. Deer feed at night and early in the morning.

Monitoring. Growers identify deer pests by footprints in the field and deer droppings.

CONTROL

Cultural

Fencing. Fencing is the only reliable method to prevent damage by deer.

Elimination. Depredation permits may be obtained from the California Department of Fish and Game to eliminate a few animals. This is a temporary solution.

Coyotes

Canis latrans

Damage. Coyotes damage drip irrigation hoses.

CONTROL

Cultural

Elimination. Depredation permits may be obtained from the California Department of Fish and Game to eliminate a few animals.

Rabbits

Primarily Jackrabbits: *Lepus californicus*

Damage. Rabbits can cause problems in new vineyards. Rabbits feed on the leaves and stems of young plants. Jackrabbits are the primary pest, though cottontail and brush rabbits also cause adverse affects.

CONTROLS

Cultural.

Grow Tubes. Grow tubes are used to protect young vines from rabbit damage.

Fencing. Fencing can be an effective control for smaller vineyards.

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Appendices

Implementation

Research results alone will not initiate changes in farming practices, and there is a critical need for information delivery methods to growers. Early efforts to implement integrated pest management (IPM) systems and the use of low impact chemicals in grapes include the California Clean Growers, which was established in 1988. Gallo, Inc. has been instrumental in restricting the kinds of chemicals used to those that have the least negative impacts on beneficials and the environment. The American Vineyard Foundation has granted research and extension funds to develop some grape IPM programs. The model system, which has proven successful over the past six years, is the Biologically Integrated Orchard Systems program (BIOS), now known as the Ag Partnership model.

The Ag Partnership model recognizes that agricultural systems are made up of many biological components, including the crop, but also the soil dwelling organisms (microbes, nematodes and arthropods), the organisms that exist on the crop, and even the weeds. The Ag Partnership model promotes farming practices that encourage the beneficial organisms in the system, and encourages the use of practices and inputs that have minimal negative impact on beneficials, human health and the environment. Relatively "high risk" materials such as organophosphate and carbamate insecticides, and B_2 carcinogens, are strongly discouraged. Because soil and plant health are often important in limiting the impact of pests, practices such as long term soil building, optimizing plant nutrition levels and improving irrigation efficiency can increase plant tolerance to pest attack and may also prevent pests from reaching the economic injury level. At the crux of the model is the active participation of growers, who are directly involved in defining problems, developing creative approaches to their solutions, participating in research efforts, and helping deliver educational information to fellow program participants and wider audiences. Grower input is integrated with that of cooperative extension advisors, researchers, PCAs and community members.

Successful grape programs utilizing the Ag Partnership model include the Lodi-Woodbridge Winegrape Commission (56), Central Valley Biologically Integrated Vineyard Systems (12), the Central Coast Vineyard Team (10), the Sonoma Valley Vintners and Growers (71) and the Napa Sustainable Winegrowing Group (55). More funds are needed to fund Ag Partnership projects, expand grower participation, and develop similar groups in other areas.

Research

This section addresses pest research priorities for California winegrapes. Needs are prioritized in three ways: By the percentage of grape acreage in California treated with FQPA priority I materials, by the number of registered, effective chemical substitutes for FQPA priority I materials, and by a survey of California grape growers and vintners conducted by the American Vineyard Foundation (AVF) in 2001 (Table 1). Research needs can be separated into three areas: 1) The development and evaluation of alternative chemical control methods; 2) Short term research needs, including cultural and biological controls, and basic pest and plant biology; and 3) Long term research needs, including host plant resistance, interactions within the agroecosystem, and foreign exploration for natural enemies.

Pest priorities

Column 1 of Table 1 prioritizes grape pest research needs based on the percentage of grape acreage in California treated with FQPA priority I and II materials. Weeds and powdery mildew are the top two priorities, with 90% and 44% of grape acre treated, respectively. Botrytis and spider mites are the number three and four priorities, respectively, with 17% and 17% of acreage treated, respectively. These are followed by leafhoppers, omnivorous leafroller and nematodes, at 7%, 6% and 5% of grape acreage, respectively. The last two in the list of priorities are mealybugs and sharpshooters, at 0.7% and 1.4% of grape acreage treated, respectively.

Column 2 of Table 1 is based on the number of registered, effective chemical substitutes for FQPA priority I and II materials. The top three priorities are materials for late-season OLR control, root knot nematode and mealybugs, because there are currently no effective materials registered which can substitute for FQPA Priority I and II materials. Late-season OLR is specified as a priority because early-season control can be achieved with cryolite (Kryocide7 or Prokil7), which is not allowed by wineries after June 1. Root knot nematode is distinguished from ectoparasitic nematodes (e.g., ring nematode) because the latter can be effectively controlled with sodium tetrathiocarbonate (Enzone7). Mealybugs do have one in-season chemical registered (Admire7), but it is a drip-applied systemic which cannot be considered a substitute for foliar OPs or carbamates. Spider mites, leafhoppers and sharpshooters each have one effective substitute, Botrytis has three, and powdery mildew and weeds each have four.

Column 3 of Table 1 comes from the AVF, and is based on the responses of 218 growers and vintners throughout the state. The survey was not conducted in light of the FQPA, but rather includes all viticulture issues including rootstock evaluation, water use and trellising systems, as well as pest management issues. Listed are the top nine pest priorities of the survey. Such surveys are necessarily fluid; many of the priorities are long term, but some needs are reflective of the situation in the most current season (i.e., a survey taken after a bad mildew year will skew priorities toward mildew control). Because the highest numbers of respondents were from the north coast, the overall result tends to reflect those regional priorities.

Current and alternative chemicals

Table 2 lists the priority pest categories with corresponding FQPA priority I, II and III materials and the corresponding 2000 percentage of acres treated. Materials registered since 1996 are marked with an asterisk. Table 2 also lists unregistered alternative chemicals for these pests. Although all of the nine pest categories has at least one FQPA priority I and II material registered, none is completely dependent on these materials, and in the short term, six out of the nine pests can be effectively controlled using currently registered materials as substitutes. The three exceptions are late-season OLR, root knot nematode and mealybugs. In the long run, there are several alternative materials pending registration for powdery mildew and spider mites, one or two for weeds, leafhoppers, sharpshooters, Botrytis and OLR, but none for nematodes.

Table 1. Order of research priorities based on the percentage of acreage treated with FQPA Priority I and II materials, the number of effective, registered substitutes for FQPA Priority I and II materials, and the 2001 AVF survey.

Priority based on percentage of grape acreage treated with Priority I materials (in parentheses)	**Priority based on the number of effective, registered substitutes for FQPA I materials (in parentheses)**	**Priority based on 2001 AVF survey**
Weeds (90)	OLR (0)	Pierce's disease
Powdery mildew (44)	Root knot nematode (0)	Sharpshooters
Botrytis bunch rot (17)	Mealybugs (0)	Eutypa and other canker diseases
Spider mites (17)	Spider mites (1)	Powdery Mildew
Leafhoppers: Grape and variegated (7)	Leafhoppers (1)	Nematodes
Omnivorous leafroller (6)	Sharpshooters (1)	Bunch rots
Nematodes (5)	Botrytis bunch rot (3)	Mites
Mealybugs: Grape and obscure (0.7)	Weeds (4)	Young Vine Decline
Sharpshooters: Blue-green, green and red-headed (1.4)	Powdery mildew (4)	Phylloxera

Weeds: Current and alternative chemical controls: The closest substitute for the pre-emergent herbicides simazine and oxyfluorfen (Goal7) which will still control a similar complex of broadleaf weeds is diuron (Karmex7). Diuron is also more effective than either of these materials in controlling annual grasses (48). However, diuron has been detected in groundwater (8), and is restricted in some areas (called pesticide management zones or PMZs). Another possible substitute is norflurazon (Solicam7), which controls a smaller spectrum of annual broadleaves, but is more effective at controlling annual grasses and certain perennial weeds (48). The most popular herbicide used on grapes in California is glyphosate (Roundup7), which is a priority III material. More use can be made of glyphosate and the other contact herbicides, paraquat dichloride (Gramoxone7), glyphosate (Roundup7, Touchdown7) and sethoxydim (Poast7). Contact herbicides have a lower risk of environmental contamination than pre-emergent materials; especially if they are used with new application technologies such as light activated sprayers and shielded misters, which help apply them more efficiently.

Weeds: Short term research needs: Successful weed control can be accomplished with in-row cultivation, and there are currently many in-row cultivators available, some of which allow for quicker, more efficient tillage than the traditional French plow. Another non-chemical technique is flaming. Research is needed on the most efficient, effective and economical use of these implements.

Other cultural weed controls have been looked into over the past decade. The best known was the "mow and throw" system, which chopped up cover crop and weed biomass from the middles and blew into the rows to create a weed smothering mulch (68). Other mulches, such as wood chips and almond hulls, could be used but have not had much attention. Synthetic mulches are expensive, but if amortized over the life of the mulch (ca. 10 years) are probably cost effective. Any of these mulches combined with a light activated contact herbicide sprayer would cut herbicide use drastically.

Cover crops could be considered a cultural weed control, but currently cover crops provide a very minor role in weed management. This is because the most difficult area for weed control (and where the vast majority of herbicides are applied) is *within the row*, but cover crops are grown *in the middles,* usually as winter annuals, and are usually disked up at budbreak or shortly thereafter. After this, a complex of summer weeds replaces them. Therefore, because cover crops are not grown in the most critical place (i.e., within the vine row) for weed control, and are usually not perennial, they currently have a very limited role to play in weed management.

There is potential for cover crops to serve as a component of weed management. Conventional perennial cover crops such as perennial ryegrass, creeping red fescue, orchardgrass, strawberry cover and white clover, can effectively crowd out weeds. However, they are high water users and can excessively de-vigorate vines. Also, because they require summer water, they are not compatible with drip irrigation systems. Perennial native grasses, which go dormant to varying degrees depending on the species, have great potential to be permanent, weed smothering and less competitive than resident weeds. Because of the great number of native grass species, there is a need for research on how to use them under different vineyard conditions. There is also potential for planting native grasses within the row, where weed control innovations are most needed. Such in-row cover cropping for weed control has been tested by innovative vineyard managers with Mondavi in the Napa Valley and Gallo of Sonoma.

Subsurface drip irrigation can be looked upon as a cultural weed control for summer weeds. With subsurface systems, the drip line is buried 12-18" under the ground, usually 1-2 ft from the vine row. Irrigating underground cuts down on the number of weeds germinating at the soil surface. The downfall is the potential for vine root intrusion into the underground emitters, but this problem seems to have been solved with herbicide impregnated emitters. Also, in all but the lightest of soils, some water will make its way to the surface, so some weed growth can be expected. Some growers have begun to bury the subsurface drip line between the vine rows, where weeds can be disked up more easily. This system has no effect on winter weeds, and control for them would still be necessary.

Weed surveys can define which weed species are most problematic. At present, this can help growers decide which herbicide(s) would be most effective, but does little to reduce herbicide use. Weed surveys could help growers time contact herbicides more effectively, but little information exists on the most effective timing for different weed species.

Powdery mildew: Current and alternative chemical controls: The loss of myclobutanil (Rally7), triflumizole (Procure7) and triadimefon (Bayleton7) would not have a major impact on powdery mildew management in the short run. Fenarimol (Rubigan7), a priority III material, is a suitable substitute that is widely used. The loss would also not significantly affect powdery mildew resistance management, because fenarimol, myclobutanil and triflumizole all have a similar mode of action and currently cannot be used alternately for resistance management. Bayleton7 has not been widely used for several years because of resistance. Azoxystrobin (Abound7) is a relatively newly registered material that is an effective preventative and eradicant, and falls into a novel chemical class, the strobilurins. The fungal parasite, *Ampelomyces quisqualis* (AQ107), is an effective material in the cooler, more humid part of the season, and when powdery mildew infestation has not taken place and pressure is low. Several other materials, some of which are foliar nutrients, and others which fall into unique chemical classes, are pending registration and have potential to fit into a powdery mildew control and resistance management program (8). Finally, by far the most popular material for powdery mildew control is sulfur, which is a priority III material. Many growers, both conventional and organic, rely exclusively on sulfur for powdery mildew control.

Powdery mildew: Short term research needs. Cultural practices such as canopy management may provide some powdery mildew control by influencing the ambient temperature. However, the incremental effect in most cases is so small that it probably would not allow for a reduction in treatments for powdery mildew. Note also that in warm climate regions such as the San Joaquin Valley, canopy management practices such as overhead trellising may actually make summertime temperatures cooler, thus improving conditions for mildew. Cover cropping could be considered a part of powdery mildew management in wet springs, because it allows greater access to the vineyards (to apply treatments) under wet soil conditions.

Short term research needs also include evaluation of newly registered and soon to be registered products, and their role in resistance management. There is also a great need for information on how to use contact materials like Kaligreen7, Valero7, Elexa7, and foliar applied nutrients such as calcium (e.g., Vigor-Cal7), as well as how to use them with low volume sprayers. The Gubler-Thomas model needs to be more thoroughly evaluated and refined for different regions and vineyard conditions.

Powdery mildew: Long term research needs. Long term research of powdery mildew might involve the bioengineering of resistant genes, but this has proven difficult to do. Moreover, the current reluctance of some sectors of the public to accept agricultural products containing genetically engineered material may prove problematic.

Botrytis: *Current and alternative chemical controls:* Four of the five most commonly used materials for Botrytis are priority I materials: Iprodione (Rovral7), mancozeb (Dithane7), benomyl (Benlate7) and captan. The fifth, dicloran (Botran7) is a priority III material and quite effective (R.A. Duncan, personal communication). There are also two newly registered materials: cyprodinil (Vanguard7) was found to be effective in a recent trial (R.A. Duncan, personal communication), and fenhexamid (Elevate7). A third material, Serenade7, has recently been registered. Two other alternative materials are pending registration, Elexa7 and the biologicalTrichodex7.

Botrytis: Short term research needs. Cultural controls such as leaf pulling and shoot positioning help increase air circulation and lower humidity. Most growers in coastal regions have gone to either vertical shoot positioned systems or Y/lyre systems to spread the canopy. Other cultural controls for Botrytis are crop load and irrigation management to help keep cluster and berry size low so as to reduce the risk of berry splitting. Work is needed on integrating leaf pulling, crop load management and irrigation management for Botrytis management with improvements in wine quality and the management of leafhoppers. Gibberellic acid, a plant growth regulator, can be used as an early spring "stretch spray" to elongate clusters and reduce bunch rot (R. Duncan, unpublished data). It is only registered in certain areas (e.g., Clarksburg appellation) and on certain varieties (e.g., Zinfandel) under a Special Local Needs (SLN) permit. Work is needed on determining rates of gibberellic acid which are effective but will not reduce the following year's crop. There is a need for research in evaluating the Broome model (4) in different regions and under different vineyard conditions, and a need to test newly registered materials such as Vanguard7, Elevate7 and Serenade7, and soon to be registered materials such as Elexa7and the biological Trichodex7.

Botrytis: Long term research needs. Long term research might involve improvement in the mechanization of leaf removal, and bioengineering genes for resistance to Botrytis.

Spider mites: Current and alternative chemical controls. The most widely used materials for spider mites, propargite (Omite7) and dicofol (Kelthane7), are FQPA priority I. Research is needed on the recently registered materials avermectin (Agri-Mek7) and pyrimaden (Nextor7) to determine is these materials can be considered substitutes for propargite and dicofol. At the moment the material considered to be the closest alternative is fenbutatin-oxide (Vendex7), which is not as effective in cool conditions (<80EF), nor when spider mite population density is high. Narrow range oil is a contact material, and effective if coverage is thorough. However, oil does not kill eggs and therefore several applications per season may be necessary. Cinnamaldehyde (Valero7), which was only registered in July 1999, is also a contact, and apparently has good kill on mite eggs (B. Murphy, personal communication).

Spider mites: *Short term research needs.* Specific guidelines are needed for the management of soil, water and dust, to keep spider mites under control. Research is needed to determine acceptable stress thresholds, e.g., vine water or soil chemistry status. There is also an increasing amount of data that shows that sulfur use exacerbates mite outbreaks. Research is needed on the mechanisms involved, and how sulfur can be integrated with other fungicides to minimize spider mite damage. There is also a great need for basic information on economic injury levels for Pacific mite and Willamette mite. The current guidelines are based on bionomial sampling methods for Pacific mite, and are very inaccurate. There are no treatment recommendations for Willamette mite. New monitoring techniques are needed that provide more information on the total spider mite load on the vine, but which are economically justifiable. Information is needed on the release of the western predatory mite and other predatory mite species, including when to begin releases, how often to release, and the rate of release. The use of other spider mite predators such as the 6-spotted thrips also needs to be looked at.

Spider mites: *Long term research needs.* Because spider mite outbreaks are so obviously linked to soil conditions, long term research might look at the possibility of intense soil management (use of compost, gypsum, pH adjustment, other soil amendments) so that "problem" soils are no longer mite susceptible. This would be a multidisciplinary effort, analyzing soil and vine condition as well as economics.

Leafhoppers: Current and alternative chemical controls. There are five chemicals registered for leafhoppers that are priority I FQPA: Methomyl (Lannate7), carbaryl (Sevin7), dimethoate (Clean Crop7), naled (Dibrom7) and endosulfan (Thiodan7). All of these were commonly used for leafhopper control prior to 1995. However, in 1995 imidacloprid (Provado7) was registered on grapes, and chemical control for leafhoppers has become largely dependent on this material. Although there have been attempts to associate the use of Provado7 with secondary pest outbreaks, formal studies have not borne this out (22, 45). It is an extremely flexible material for growers to use, because it is equally effective on leafhopper adults as well as nymphs, and because it can be used up to the date of harvest. The other priority III materials registered for leafhoppers at present are not as effective, either because they are contact materials for which timing and coverage are critical (e.g., narrow range oil and soap), or are natural materials that have short residuals and are expensive (e.g., neem and pyrethrins/rotenone). Although the potential for resistance to imidacloprid is low and has not yet been reported in California, it is generally accepted that resistance to any insecticide will develop given enough time and exposure. That imidacloprid is being used almost exclusively at this time for leafhopper control is likely to increase the rate of resistance. It is therefore important that new materials be registered and incorporated into the arsenal of chemical tools for leafhopper control. An example is the insect growth regulator buprofezin (Applaud7), which has been effective in early trials (M.J. Costello, unpublished data). A very promising product is a material made of fine clay particles (kaolin [Surround7]).

Leafhoppers: Short term research needs. It is well known that leafhoppers are sensitive to irrigation management, and more research is needed on how leafhoppers respond to vine water status at different points in the season. Leaf pulling (leafing) at berry set is often a useful way to decrease first brood nymphal density. Irrigation management and leafing could be integrated with cover cropping and crop load management for leafhopper control, Botrytis management and improvements in wine quality. Sticky tape has also been used successfully in trapping overwintering adults and reducing first brood nymphal density. Basic information is needed on economic injury levels and action thresholds for different varieties and in different regions. Improvements are needed in monitoring techniques and tools, e.g., the use of portable data loggers to record nymphal counts in the field. Quick, effective, PCA-friendly field assessments of first brood parasitism by Anagrus are also needed. There is a need to register and test new chemistry materials for leafhoppers such as kaolin and IGRs.

Leafhoppers: Long term research needs. Mechanization of harvesting will help reduce the need for pre-harvest "annoyance" treatments, and mechanization of leaf pulling will help reduce early season leafhopper numbers. Another important long term need is the importation of a more effective *Anagrus* species for variegated leafhopper.

OLR: Current and alternative chemical controls. For OLR, loss of the OPs and carbamates will have a very minor impact on early season control, which currently is largely undertaken with cryolite. However, in light of winery restrictions on the use of cryolite after bloom, the loss of OPs and carbamates is a major problem for winegrape growers with late-season OLR infestations. Bt can be used late, but is often not effective. Solutions to this problem include more research on how to make Bt more effective, including the development of forms that biodegrade more slowly. New materials such as spinosad (Success7) and tebufenozide (Confirm7) should be thoroughly tested and registered if found effective.

OLR: Short term research needs. Cultural practices can do a lot to keep OLR under control early in the season. Sanitation (removal/destruction of mummified clusters) and weed control can keep within-vineyard OLR density low, which minimizes early season infestation. Work is needed on showing the benefits of such cultural controls to growers. Two brands of OLR pheromone products have been registered (No-mate7 and Checkmate7), but results have been erratic. The Achilles heel of mating disruption is the omnivorous diet of OLR and the OLR migration into the vineyard. More work is needed on mated female OLR flight patterns. Research is also needed on refining the OLR development model to time treatments. Better tools and methodology are needed to expedite monitoring. Development of a lure for OLR females might help PCAs determine the need for treatment. There is a great need for low risk chemicals that can be utilized late-season. Biological control research might involve the inundative release of Trichogramma, as has been done for codling moth, and the use of flowering cover crops to enhance populations of other OLR parasites (braconid and ichneumonid wasps, tachinid flies).

OLR: Long-term research needs. A long-term research goal for OLR should be the importation of more effective natural enemies.

Nematodes: Current and alternative chemical controls. Two of the top three chemicals for nematodes are FQPA priority I materials, fenamiphos (Nemacur7) and carbofuran (Furadan7). The third chemical, sodium tetrathiocarbonate (Enzone7) is an FQPA priority III material. Enzone7 is a suitable substitute for Furadan7, as both are used primarily for the ectoparasitic nematodes such as ring nematode, and Enzone7has been found to be quite effective (M. McKenry, personal communication). However, there is no substitute for Nemacur7, which is primarily used for endoparasitic nematodes such as root knot nematode. Oxycom7 and DiTera7 are newly registered and have not been thoroughly tested on grapes in California, and there is much uncertainty on how to use them most effectively. There is therefore a need for more research on Oxycom7 and DiTera7, and other new materials that are effective and environmentally safe. One possibility is Admire7, which appears to have an effect on root knot nematode similar to Nemacur7.

Nematodes: Short-term research needs. Nematodes take advantage of stressed vines, so any soil management measures taken which can minimize vine stress can theoretically reduce nematode impact. Soil management practices include preventing soil compaction and stratification, improve soil structure through the addition of compost, manure, cover crops, gypsum and other soil amendments, and proper fertilizer rates and timing. Still, there is little information available on specific indicators of good soil and water management that will help increase vine tolerance to nematode attack. Research is needed as to how irrigation practices for improving wine quality will affect vine tolerance to nematode infestation. Short-term research needs test newly registered materials such as DiTera7 and Oxycom7.

Nematodes: Long-term research needs. Information is always needed on rootstock resistance to nematodes, and the long-term use of soil amendments such as cover crops and compost to help boost vine tolerance to nematodes.

Mealybugs: Current and alternative chemical controls. The only two effective in-season foliar controls for mealybugs, methyl parathion and azinphos-methyl, were restricted on August 1, 1999. Imidacloprid (Provado7), although registered, has not been found to be very effective. Imidacloprid applied through the drip system (Admire7) is the only other in-season control. Chlorpyrifos (Lorsban7), which is registered for application as a delayed dormant (just prior to budbreak), is effective, but with few effective in-season controls available, it is possible that the use of Lorsban7 might increase by growers as insurance sprays. There is a need for research into other early season controls, particularly the use of narrow range oil. There is also a need for new materials more specific to mealybugs that could be used late in the season.

Mealybugs: Short-term research needs. Work is needed immediately on the vine mealybug, a new arrival in the San Joaquin Valley and a potentially devastating pest. Much effort has gone into foreign exploration for vine mealybug parasites, but effort also needs to be focused on domestic parasites, which have already attacked vine mealybug in Fresno County. For vine and other mealybugs, formal study is needed on trellising systems and pruning methods can help minimize the risk of mealybug infestation. There is also a big need for mealybug monitoring tools that are quick and effective. There is also a need for more information on the various mortality factors that can act upon mealybugs during the season. Short term needs also include registration and testing of new chemistry materials, especially those that are somewhat specific to mealybugs. There are currently no effective in-season foliar chemical controls, and the efficacy of Admire7is still under investigation. Controlling ants may help contain the spread of mealybugs, but ant control alone will not necessarily provide mealybug control. More information is needed on low-risk ant baits.

Mealybugs: Long-term research needs. Effective biological controls are needed for the vine and obscure mealybugs. Information is needed on why mealybug parasites more effective in some vineyards than others. At present, no link has been established between parasitism levels and the use of chemicals. Research is also needed into vine tolerance factors: Are some vines more resistant to mealybugs?

Sharpshooters: Current and alternative chemical controls. Dimethoate has traditionally been the material used to treat border vegetation as well as vines for sharpshooters. However, imidacloprid (Provado7), it just as effective and is already widely used. However, just as with *Erythroneura* leafhoppers, there is a great concern about resistance, and there is a need for additional materials that are effective and environmentally safe. The particle films (kaolin), because of its anti-feedant properties, would be particularly suitable against sharpshooters.

Sharpshooters: Short-term research needs. In 2000 the state and federal governments and University researchers began a comprehensive research and development program for management of Pierce's Disease, including work on the management of Glassy-winged sharpshooter. Support for this program needs to continue. In the short-term efficacious and environmentally sound control strategies for the glassy winged sharpshooter need to be developed. This strong flying insect feeds on a variety of cultivated plants, and is a carrier of Pierce's disease. The presence of this pest may make moot efforts to control blue-green, green and red-headed sharpshooters. Research is needed and is underway on glassy winged sharpshooter biology, host preferences, non-host plants, migration patterns, overwintering abilities and biological controls. For the other sharpshooters, research is needed on better monitoring tools. Sharpshooters are mildly attracted to yellow sticky cards but better tools are needed. Light traps are a possibility. There is a need to register and test new chemistry materials, like the particle film kaolin (Surround7). Research could also be conducted on the inundative release of natural enemies such as Trichogramma in the riparian areas.

Sharpshooters: Long-term research needs. Long-term research needs include riparian vegetation management, and the use of non-host barriers between the riparian corridor and the vineyard, such as cedars and conifers. There is also the possibility of biotechnology, incorporating resistant genes into vines.

Minor pests. Minor pests are by definition not consistent in their pest status, which means that growers often are either unaware of their potential damage, or unwilling to take preventive measures because they may not be cost effective in any given year. Therefore, when minor pests reach the economic injury level, their control is largely taken care of with chemicals. There are almost no specific chemicals for minor pests, so broad spectrums (OPs and carbamates) are heavily relied upon. This is an extremely tricky area in terms of chemical alternatives. Few chemical companies have an economic incentive to develop products for minor pests. Research is needed into why outbreaks of minor pests like grapeleaf folder and grape bud beetle occur. However, there is little incentive to commit funding to this research because such little acreage is affected in any given year.

Table 2. Winegrape pests associated registered chemicals by FQPA priority status and alternative chemicals pending registration. Percentage of acreage treated with a given material in 2000 is in brackets.

Winegrape Pest	FQPA Priority I Chemicals	FQPA Priority II & III Chemicals	Alternative Chemicals Pending Registration
	$Oxyfluorfen (Goal7) [35.4%] $Simazine (Princep7) [23.0%] $Paraquat dichloride (Gramoxone7) [19.2%] $Oryzalin (Surflan7) [11.4%]	$Diuron (Karmex7) [5.2%] $Norflurazon (Solicam7) [3.6%] $Glyphosate (Roundup7, Touchdown7, Glyphos7) [53.9%] $Sethoxydim (Poast7) [1.8%]	$Thiazopyr (Visor7) [0.45%]

Weeds	$Trifluralin (Treflan7) [2.5%] $Pendimethalin (Prowl7) [1.28%] $2, 4-D (Envy7) [0.02%] $Dichlobenil (Casoron7) [0.01%]	$Napropamide (Devrinol7) [1.6%] $Fluazifop (Fusilade7) [0.17%] $Herbicidal soap (Scythe7) $Isoxaben (Gallery7) [0.07%]	$Milestone7
Powdery mildew	$Myclobutanil (Rally7) [32.6%] $Triflumizole (Procure7) [13.3%] $Triadimefon (Bayleton7) [0.23%]	$Sulfur (various trade names) [88.4%] $Fenarimol (Rubigan7) [16.8%] $Narrow range oil (various trade names) [1%] $Insecticidal soap (M-pede7) [0.3%] $Azoxystrobin (Abound7) [13.9%] $*Ampelomyces quisqualis* (AQ107) [0.37%] $Potassium bicarbonate (Kaligreen7) [4.1%]	$Chitosan (Elexa7)

		Bacillus subtilis (Serenade) Kresoxim-methyl (Sovran) Trifloxystrobin (Flint) Tebuconazole (Elite)	
Botrytis bunch rot	$Iprodione (Rovral7) [4.6%] $Mancozeb (Dithane7) [10.2%] $Benomyl (Benlate7) 2.9%] $Captan [0.2%]	$Dicloran/DCNA (Botran7) [2.4%] $Narrow range oil (various trade names) [1%] $Cyprodinil (Vanguard7) [8.3%] $Fenhexamid (Elevate7) [3.8%] Bacillus subtilis (Serenade)	$Elexa7 $Trichodex7
Spider mites: Willamette and Pacific	$Propargite (Omite7) [12.5%] $Dicofol (Kelthane7) [2.7%]	$Narrow range oil (various trade names) [2%] $Fenbutatin-oxide (Vendex7) [1%] $Cinnamaldehyde (Valero7) [0.14%] Avermectin (Agri-mek) Pyridaben (Nexter)	$Biomite7 $Alert7 $Clofentazin (Apollo7)

Leafhoppers: Grape and variegated	$Methomyl (Lannate7) [3.18%] $Carbaryl (Sevin7) [1.3%] $Dimethoate (Clean Crop7) [1.2%] $Naled (Dibrom7) [0.61%] $Endosulfan (Thiodan7) [0.01%]	$Imidacloprid (Provado7) [22%] $Imidacloprid (Admire7) [n/a] $Narrow range oil (various trade names) [1%] $Pyrethrin (Pyrenone7) [0.09%] $Insecticidal soap (M-pede7) [0.3%] $Neem (Neemix7)* Fenpropathrin (Danitol) Pyridaben (Nexter)	$Buprofezin (Applaud7) $Kaolin (Surround7)
Omnivorous leafroller	$Methomyl (Lannate7) [3.18%] $Carbaryl (Sevin7) [1.3%] $Phosmet (Imidan7) [2.7%] $Diazinon [0.42%]	$Cryolite (Prokil7, Kryocide7) 9.7%] $Bt (Various trade names) [6%] Tebufenozide (Confirm) [7.2%]	$Spinosad7

Nematodes	$Fenamiphos (Nemacur7) [2.6%] $Carbofuran (Furadan7) [0.8%]	$Methyl bromide# [0.13%] $Metam sodium# (Vapam7) [0.02%] $1,3-Dichloropropene# (Telone7) [0.3%] $Sodium Tetrathiocarbonate (Enzone7) [1.3%] $*Myrothecium verrucaria* (DiTera7)* $Oxycom7	$Imidacloprid (Admire7) [22%]
Mealybugs: Grape and obscure	$Azinphos methyl ([0.01%]restricted 8/2/1999) $Methyl parathion ([0.01%] restricted 8/2/1999) $Chlorpyrifos (Lorsban7) [1.2%]	$Imidacloprid (Admire7) $Imidacloprid (Provado7) [22%]	$Applaud7
Sharpshooters	$Dimethoate (Clean Crop7) [1.24%]	$Imidacloprid (Provado7) [22%] $Imidacloprid (Admire7)* Cyfluthrin (Baythroid)	$Kaolin (Surround7)

#Pre-plant use only

Table 3. Key winegrape pests, their current cultural, biological and other IPM controls, and short/long term

research priorities.

Winegrape Pest	Cultural, Biological and IPM Controls	Short Term Research Priorities	Long Term Research Needs
Weeds	7In-row cultivation 7Mulches: Synthetic and organic 7Subsurface drip irrigation 7 Cover crops	7Test low volume application technologies 7Test in-row cultivation implements 7Test organic and synthetic mulches 7Test in-row cover crop use 7Develop action thresholds using contact herbicides 7Develop monitoring protocols and action thresholds for weeds 7Implement weed surveys by growers/ PCAs	7Nonchemical under-the-vine weed management
Powdery mildew	7Use of mildew model	7Test new chemistry fungicides 7Test, improve and implement use of mildew model 7Resistance management 7Improve dormant controls 7Foliar nutrients to improve vine resistance	7Biotechnology employing resistant genes 7Induced resistance

Botrytis bunch rot	7Leafing/canopy management/ trellising 7Use of botrytis model 7Regulation of crop load 7Irrigation management	7Test new chemistry and biological fungicides 7Resistance management	7Improved mechanization of leafing 7Test trellising systems 7Biotechnology employing resistant genes
Spider mites	7Soil, irrigation and dust management 7Reduce sulfur use 7Monitoring and use of action thresholds 7Release of predatory mites	7Use of sulfur 7Timing/rate of predatory mite release 7New tools/ methodology to expedite monitoring 7Use of 6-spotted thrips	C@Fixing@ problem soils
Leafhoppers	7Monitoring/use of action thresholds 7Vine water status 7Sticky tape 7Anagrus monitoring	7New tools/ methodology to expedite monitoring 7Establish EILs/action thresholds for varieties/ regions 7Register and test new chemistry materials 7Irrigation/cover cropping to manage vine water status	7Importation of a more effective biocontrol *Anagrus* sp. for variegated leafhopper
OLR	7Pheromone mating disruption 7Use of OLR model 7Sanitation/weed control	7New tools/ methodology to expedite monitoring 7Use of natural enemies such as Trichogramma 7Test pheromone disruption	7Importation of new natural enemies

Nematodes	7Soil/water/fertility management 7Resistant rootstocks 7Soil amendments (cover crops, compost)	7Test new chemistry and biological materials	7Improving soil health 7Test new rootstocks
Mealybugs	7Trellising/pruning 7Monitoring	7Register and test new chemistry materials 7Evaluate use of Admire 7Use of ant baits	7Improve biological controls
Sharpshooters	7Weed control 7Monitoring	7Register and test new chemistry materials 7Test light traps for monitoring 7Inundative biological controls	7Riparian vegetation management 7Non-host barriers 7Biotechnology employing resistant genes

Table 4. California Winegrape Three-year Pesticide Useage Table 1998 - 2000

	2000			1999			1998		
Common Chemical Name	**% Ac Treated**	**Base Ac Treated**	**Total Lbs AI**	**% Ac Treated**	**Base Ac Treated**	**Total Lbs AI**	**% Ac Treated**	**Base Ac Treated**	**Total Lbs AI**
1,3-DICHLOROPROPENE	0.30	1,474	438,293	0.13	608	222,418	0.10	474	150,469
2,4-D	0.02	92	64	0.03	120	4	0.06	256	43
ALUMINUM PHOSPHIDE	0.32	1,597	207	0.27	1,272	190	0.24	1,077	162
AMPELOMYCES QUISQUALIS	0.04	1,800	2	0.37	1,749	1	0.93	4,251	2
AVERMECTIN	8.64	42,819	525	0.01	38	1	0.01	68	>1
AZADIRACTIN	0.00	0	0	0.02	87	2	0.01	31	>1
AZINPHOS-METHYL	0.01	43	43	0.14	648	1,292	0.02	75	56
AZOXYSTROBIN	13.90	68,940	18,465	15.15	71,651	31,150	19.08	86,923	25,539
BACILLUS SUBTILIS	0.00	0	0	0.00	0	0	0.00	0	0
BACILLUS THURINGIENSIS	18.66	95,522	9,299	15.00	70,933	8,990	8.23	37,483	4,882
BENOMYL	2.87	14,227	6,964	3.91	18,517	7,941	9.83	44,795	27,325
BORIC ACID	0.22	1,083	704	0.00	15	101	0.01	38	8

CAPTAN	0.20	997	1,536	0.25	1,202	1,873	0.49	2,218	4,009
CARBARYL	1.32	6,551	11,034	1.61	7,615	14,314	1.31	5,967	10,003
CARBOFURAN	0.83	4,127	19,218	1.04	4,899	17,480	1.32	6,003	22,480
CHLORPYRIFOS	1.17	5,782	10,898	0.86	4,088	8,089	0.73	3,309	5,860
CINNAMALDEHYDE	0.14	680	2,484	0.43	2,016	6,300	0.00	0	0
COPPER HYDROXIDE	38.52	191,005	285,932	40.46	191,408	316,750	35.25	160,610	248,661
COPPER SULFATE	0.20	969	2,543	0.60	2,831	5,959	0.63	2,863	14,049
CRYOLITE	9.65	47,844	272,053	14.00	66,242	388,934	22.05	100,468	579,667
CYPRODINIL	8.33	41,314	23,082	7.30	34,517	18,381	12.09	55,104	29,105
DIAZINON	0.42	2,095	4,020	0.84	3,969	3,687	0.70	3,182	4,558
DICHLOBENIL	0.01	38	160	0.00	1	3	0.00	0	0
DICLORAN	2.39	11,874	22,766	2.41	11,415	22,357	4.20	19,136	45,043
DICOFOL	2.70	13,370	15,710	3.62	17,137	21,983	3.68	16,766	17,123
DIMETHOATE	1.24	6,163	4,176	1.20	5,687	4,014	1.32	6,010	5,303
DIPHACINONE	0.70	3,454	1	0.55	2,580	1	1.13	5,171	1
DIURON	5.22	25,907	22,843	4.52	21,364	20,706	5.46	24,878	25,322
ENDOSULFAN	0.00	15	23	0.09	440	376	0.16	742	731
FENAMIPHOS	2.62	12,994	30,191	2.51	11,887	29,666	3.23	14,733	35,146
FENARIMOL	16.77	83,135	3,875	21.62	102,295	5,437	25.02	113,999	6,668
FENBUTATIN-OXIDE	0.94	4,642	4,131	4.19	19,814	17,030	2.07	9,431	8,156
FENHEXAMID	3.84	19,041	10,065	1.49	7,041	4,487	0.00	0	0
FENPROPATHRIN	0.00	10	2	0.00	0	0	0.00	0	0
FLUAZIFOP BUTYL	0.17	842	93	0.21	973	201	0.49	2,252	746
GLYPHOSATE	53.85	267,018	409,521	53.94	255,184	338,666	53.27	242,750	332,367
IMIDACLOPRID	22.15	109,809	5,751	25.07	118,595	6,014	16.62	75,732	2,656
IPRODIONE	4.55	22,545	16,892	8.05	38,090	31,305	18.74	85,394	69,057
KRESOXIM-METHYL	0.00	0	0	0.00	0	0	0.00	0	0
MALATHION	0.36	1,803	5,013	0.43	2,030	4,639	0.30	1,363	1,693
MANCOZEB	9.01	44,679	72,641	10.18	48,180	92,408	13.14	59,891	114,251
MANEB	0.09	434	664	0.11	536	1,629	0.44	2,009	5,599
METAM SODIUM	0.02	85	19,714	0.02	84	23,992	0.03	144	3,472
METHOMYL	3.18	15,791	10,804	3.27	15,460	11,100	4.32	19,676	12,305
METHYL BROMIDE	0.13	638	222,906	0.48	2,269	823,720	0.30	1,382	478,272
MYCLOBUTANIL	32.56	161,469	26,187	35.88	169,743	32,181	42.93	195,644	37,460
MYROTHECIUM VERRUCARIA	0.07	332	5,723	0.01	59	1,157	0.01	25	273
NALED	0.61	3,015	2,760	0.32	1,520	1,777	0.22	1,013	998
NAPROPAMIDE	1.56	7,868	18,165	0.49	2,308	5,780	0.65	2,940	5,417
NEEM OIL	0.19	966	3,272	0.20	965	6,191	0.02	102	822

NORFLURAZON	3.85	19,087	18,326	4.59	21,712	17,818	4.68	21,330	20,452
ORYZALIN	11.41	56,571	106,494	16.67	78,876	154,631	18.04	82,220	156,516
OXYFLUORFEN	35.36	175,354	117,686	33.74	159,635	102,460	33.97	154,814	98,050
PARAQUAT DICHLORIDE	19.16	95,023	102,788	19.73	93,345	89,624	21.68	98,808	96,580
PARATHION, METHYL	0.00	21	24	0.02	77	250	0.02	79	120
PENDIMETHALIN	1.44	7,124	11,249	1.28	6,037	10,418	1.93	8,780	15,758
PETROLEUM OILS	1.07	5,295	64,752	1.54	7,280	74,039	1.37	6,263	65,918
PHOSMET	2.73	13,526	18,450	2.40	11,357	16,647	1.16	5,275	5,381
PIPERONYL BUTOXIDE	0.05	239	48	0.07	335	47	0.22	1,004	201
POTASH SOAP	0.26	1,289	9,010	0.90	4,272	24,308	1.28	5,822	64,706
POTASSIUM BICARBONATE	3.97	19,665	93,318	4.10	19,414	72,630	4.08	18,596	49,484
PROPARGITE	12.55	62,206	138,315	15.38	72,747	151,963	7.89	35,959	70,916
PYRETRHINS	0.09	446	9	0.08	387	7	0.23	1,061	26
PYRIDABEN	0.00	5	2	0.00	0	0	0.00	0	0
SETHOXYDIM	1.79	8,890	1,382	1.44	6,798	7,061	2.02	9,216	2,202
SIMIZINE	23.03	114,190	139,299	21.51	101,745	120,816	23.87	108,776	133,386
SODIUM TETRATHIOCARBONATE	1.32	6,568	206,141	2.26	10,707	366,763	3.57	16,250	546,593
STRYCHNINE	2.24	11,118	574	3.63	17,191	391	1.96	8,916	101
SULFUR	88.44	438,514	23,733,878	87.49	413,898	26,238,134	87.81	400,118	29,765,485
TEBUCONAZOLE	13.52	67,028	11,362	11.10	52,530	7,451	0.00	0	0
TEBUFENOZIDE	7.16	35,511	6,397	0.00	0	0	0.00	0	0
TRIADIMEFON	0.23	1,153	179	0.33	1,551	231	1.16	7,336	2,322
TRIFLOXYSTROBIN	13.86	68,716	17,029	0.00	0	0	0.00	0	0
TRIFLUMIZOLE	13.30	65,949	14,262	14.87	70,346	15,594	17.80	81,103	24,113
TRIFLURALIN	2.52	12,472	8,570	1.95	9,203	7,101	3.27	14,914	13,505
ZINC PHOSPHIDE	0.47	2,341	95	1.66	7,839	870	0.39	1,784	72
ZIRAM	1.09	5,426	11,067	2.89	13,685	38,755	3.40	15,485	45,791