Crop Profile for Grapes (Raisin) in California

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General Production Information

- **Production.** California produces 90% of the grapes grown in the United States and 8 % of the world's production (5, 60), and is ranked the number one in production of wine, table, and raisin grapes in the United States. California supplies 99% of the nation's raisin production (54). Average raisin production for the years 1996-1997 was 373,000 tons, with average annual value of $450,000,000 (5, 55).

- **Acreage.** Bearing grape acreage in California in 1998 was 691,664 acres, of which 269,843 acres (39%) were planted to raisin grape varieties (4). Thompson seedless grapes, which are the primary variety for raisin grapes, totaled 262,956 acres (38% of state grape acreage). About 150,000 acres of Thompson Seedless are devoted to making raisins each year, the remainder going to table and wine grape production. Organic growing acreage accounts for about 1.5% of the total grape growing acreage (California Certified Organic Farmers, personal communication).

- **Ranking.** Grapes are the number two-ranked commodity in California, following dairy production (5). Grapes have been the number one crop in California since 1997 (5).

- **Varieties.** Thompson Seedless is the primary variety used to produce raisin grapes. Other important varieties of raisin grapes in California are Fiesta, Black Corinth and the recently released DOVine.

- **Growing Regions.** 99% of California's raisin grape production is in the southern San Joaquin Valley region (5). Fresno County alone produces about 70% of California's raisins. Merced County is the only northern San Joaquin Valley county with any significant commercial production of raisins.

- **Exports.** In 1997, raisin grapes ranked 9th for California exports, with a value of $199,800,000 (5).

- **Production Costs Per Acre.** The estimated total cost to produce an acre of raisin grapes in 1997 was $2,114 per acre ($1286/ac operating costs, $184/ac cash overhead costs, and $645/ac non-cash investment costs) (44).

Production Regions

Grapes are grown in all areas of California with the exception of the high country. The University of California identifies six regions for grape production within the state:

1); 2) The northern San Joaquin Valley: San Joaquin, Calaveras, Amador, Sacramento, Merced, and Stanislaus Counties; 3) The Coachella Valley: The Coachella regions of Riverside, Imperial, and San Bernadino Counties; 4) North Coast: Lake, Mendocino, Napa, and Sonoma Counties; 5) Central Coast: Alameda, Monterey, San Luis Obispo, Santa Barbara, San Benito, Santa Cruz, and Santa Clara Counties and 6) South Coast:San Diego, and Western Riverside counties. Each region has distinct climatic and geologic differences that lead to different cultural and pest management practices.

1. **Southern San Joaquin Valley:** *99% of raisin production*. Fresno, Madera, Tulare, Kern, and Kings Counties. This region focuses more on a mixture of grape production, with raisin, wine, and table grapes being produced. The Southern San Joaquin Valley region is the inland region from south of Merced to the Tehachapi Mountain Range. The region represents a wide variety of soil types. Light to medium textured soils with low organic matter predominate this region. Most vineyards are planted on flat land.

2. **Northern San Joaquin Valley**: *1% of raisin production*. San Joaquin, Calaveras, Amador, Sacramento, Merced, and Stanislaus Counties, 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. The region represents a wide variety of soil types. Light to medium textured soils with low organic matter predominate this region. Most vineyards are planted on flat land.

3. **Coachella Valley**: *0% of raisin production*. 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 and nitrogen.

4. **North Coast**: *0% of raisin grape production*. Includes Lake, Mendocino, Napa, and Sonoma Counties. The North Coast region is located north of San Francisco and includes the region from Napa to Ukiah.

5. **Central Coast**: *0% of raisin grape production*. 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.

6. **South Coast**: *0% of raisin grape production*. 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.

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 the production of wine and raisin grapes.

Raisin Grape Varieties. The most common varieties of grapes used for raisin production are Thompson Seedless, Fiesta, Black Corinth (Zante Currant). The acreage for other varieties are not significant, although there is increasing acreage of the recently released DOVine.

Practices. Raisins are produced by harvesting grapes when they have attained sufficient sugar and then either drying the grapes on paper trays on the ground in between rows or artificially in a dehydrator. Some raisins are dried on the vine (DOV).

Vines are pruned during the dormant season and canes are tied to the trellis wires before spring growth starts. Pre-emergent herbicide applications are applied during the dormant season, and most contact herbicide applications are made from fall through late spring. Nitrogen and zinc fertilizers are applied in the spring, with potassium and boron fertilizers applied in fall through winter. Raisin grapes are harvested when sugar levels reach a minimum of 19 Brix. Higher sugar levels are best for yields and drying ratios (ratio of grape fresh weight to dry weight). Raisin grapes are harvested onto paper trays on sloped terraces in the vineyard row centers to dry in the sun. No materials are added during the drying processes. When sufficiently dry, the raisins are transported, stemmed, screened, and washed. Prior to this processing, the stored raisins are fumigated (typically with aluminum phosphide) to prevent insect and rodent infestation.

Pests Of California Raisin 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)(2,26,37,45). 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, CAPIAP; Linda Herbst, CAPIAP; 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. 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) 1997 Pesticide Use Report (7). This data base does not differentiate table and raisin grape production so our quantitative summaries are a combination of both commodities unless stated otherwise.

Insect Pests

LEAFHOPPERS

Western grape leafhopper: *Erythroneura elegantula*
Variegated leafhopper: *Erythroneura variabilis*

Damage. Leafhoppers (Homoptera: Cicadellidae) are major pests of raisin grapes. The grape leafhopper is more problematic in northern San Joaquin Valley Region, whereas the variegated leafhopper is the primary species in the southern San Joaquin Valley (64). Actual pest damage varies according to location of the vineyard, variety, plant vigor, 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 not a concern for raisin 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 (PCAs) 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 (64).

CONTROLS:

Cultural:

- **Basal Leaf Removal.** Currently, leaf removal is performed by hand and is not cost effective for raisin production, but this practice would be adopted by many raisin growers if it were mechanized. Leaf removal is very effective at controlling botrytis and other bunch rots, and removing basal leaves (up to the cluster) at the first generation nymphal peak (usually between bloom and berry set) results in a substantial reduction in density of leafhoppers (57). Also, leaf removal improves coverage and the effectiveness of pesticides.

- **Managing Vine Vigor.** Because leafhoppers prefer vigorous, lush vegetation (21), 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 (13). However, cover crops may reduce vine vigor through competition for water and/or nutrients (23).

- **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 disking 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.

- **Hedgerows.** In the past, there has been interest in using blackberries, French prunes or other hedgerow vegetation as an overwintering refuge for the leafhopper egg parasite *Anagrus* (49). However, recent work suggests that the ratio of hedgerow to vineyard necessary to have an impact on leafhoppers is too great to be cost effective (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. *Anagrus* is not as effective on variegated leafhopper (the major leafhopper pest of raisin grapes) 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* spp.), and the predatory mite, *Anystis agilis*. However, these predators are found at very low densities in the San Joaquin Valley (15) , 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 (14).

Chemical:
Although leafhoppers infest most vineyards in California, they may not require chemical treatment because most vineyards can tolerate fairly high populations without harm. Varigated leafhoppers are a much more significant threat to raisin grape growing regions than grape leafhoppers. About 30% of raisin and table grape vineyards require treatment in a given 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 minimal negative effects on natural enemies (24).

- **Imidacloprid**. 0 day PHI. Imidacloprid (PROVADO, ADMIRE), specifically Provado®, is the most popular chemical treatment for leafhoppers. Imidacloprid is in the chloronicotinyl chemical family. Provado® is a wettable powder formulation. In 1997, 4,998 lb ai were applied to approximately 32% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.03 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. Admire® 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, it will be taken up by the vine. 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.

- **Naled.** 3 day PHI. Naled (DIBROM), an organophosphate, is applied to less than 1 % of the raisin and table grape acreage to kill adult leafhoppers just before harvest. In 1997, 2,694 lb ai were applied to approximately 0.75% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.8 lb ai/acre. Post-bloom applications of naled may cause fruit russeting. Naled may not be effective in all areas due to resistance. The restricted-entry interval for naled is 24 hours.

- **Pyrethrins/PBO in Combination.** 1 day PHI. Pyrethrin and piperonyl butoxide (PBO) (PYRENONE, PYRELLIN) is applied alone or in combination with narrow range oils to treat first generation leafhoppers. In 1997, 226 lb ai were applied to approximately 1% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.04 lb ai/acre. 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 1997, 3,767 lb ai were applied to approximately 1% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.0 lb ai/acre. Endosulfan may not be effective in all areas due to resistance. The restricted-entry interval for endosulfan is 2 days.

- **Methomyl.** 1 day PHI for raisin grapes. Methomyl (LANNATE) is an oxime carbamate. In 1997, 27,343 lb ai were applied to approximately 7.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.9 lb ai/acre. Much of this usage is for late season control of OLR or other minor pests. This product is often disruptive to beneficial mites and parasites of leafhoppers. There is a 7 day re-entry period.

- **Insecticidal Soaps.** 0 day PHI. In 1997, 1,637 lb ai of soap (M-PEDE) were applied to approximately 3% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.04 lb ai/acre. Insecticidal soaps are partially effective on low leafhopper populations if applied when nymphs are small, and 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. 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. In 1997, 14,622 lb ai were applied to approximately 1.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 2.0 lb ai/acre. Carbaryl has a restricted-entry interval of 24 hours. Use of carbaryl may encourages mite buildup 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. In 1997, 20,904 lb ai were applied to approximately 3% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.5 lb ai/acre. It has a restricted reentry interval of 2 days. Dimethoate may disrupt leafhopper natural enemies. It may not be effective in all areas due to pest resistance.

- **Narrow Range Oil.** 0 day PHI. In 1997, 142,242 lb ai of narrow range oils were applied to approximately 3% of table and raisin grape acreage in a median of one application per field. The median application rate was 8.8 lb ai/acre. Part of this treatment is for spider mite and powdery mildew control. 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 raisin grapes. The Pacific mite is the most important mite species in the southern San Joaquin Valley (9,29). 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, but usually no burn occurs unless vines are weak. Willamette mite is almost never a pest of raisin grapes, and can actually be beneficial in that they serve as a food source for predtory mites.

Life History of the Pest. Pacific mites overwinter as mated females, and begin feeding on grape foliage when spring temperatures warm up. Although it can cause damage early in the season, Pacific mites generally prefer the hotter, dryer part of the season. Willamette mites are early season mites in the Southern San Joaquin Valley, where they prefer the cooler parts of the plant and are found mostly in the shady parts of the vine. Willamette mites can be active on sun-exposed leaves throughout the season in the Southern San Joaquin Valley, but are rarely damaging. 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 for Pacific mite is accomplished by a binomial (presence-absence) sampling method, whereby infestation is estimated by the percentage of leaves which have 1 or more mites (29). Treatment is recommended if 50% or more of the leaves are infested and there are no predatory mites present. No monitoring guidelines have been established for Willamette mite.

CONTROLS:

Cultural:

- **Dust Reduction.** Spider mite outbreaks frequently occur where vines are dusty. Roads may be oiled, watered, gravelled 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 (10,28,40) with two researchers (28,40) attributing results to the sulfur harming the predatory mites, whereas one (10) 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. 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 1997, 270,642 lb ai were applied to approximately 31% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.6 lb ai/acre. Resistance to propargite is showing up in some chronically affected areas of the state. Propargite has a restricted-entry interval of 30 days in California and label restrictions allow no more than 2 applications per season.

- **Dicofol.** 7 day PHI. Dicofol (KELTHANE) is an organochlorine. In 1997, 21,907 lb ai were applied to approximately 4% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.0 lb ai/acre. It has a restricted-entry interval of 12 hours. Dicofol is disruptive to predaceous mites and the spider mite destroyer (a lady beetle). It may not be effective in all areas due to pest resistance.

- **Narrow Range Oil.** 0 day PHI. In 1997, 142,242 lb ai of narrow range oils were applied to approximately 3% of table and raisin grape acreage in a median of one application per field. The median application rate was 8.8 lb ai/acre. Some of this usage is for leafhopper and powdery mildew control. For Pacific mites, it is applied at a 1-2% solution with enough water to thoroughly cover the vines. It is a contact material with almost no residual, and may have to be applied repeatedly to maintain control (12). Approved for use on organically grown grapes. The restricted-entry interval is 4 hours.

- **Fenbutatin-oxide**. 28 day PHI. Fenbutatin-oxide (VENDEX) may not be applied more than twice per season. In 1997, 19,890 lb ai of fenbutatin-oxide (VENDEX) were applied to approximately 5% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.0 lb ai/acre. Restricted-entry interval is 48 hours.

- **Cinnamaldehyde**. O day PHI. Cinnamaldehyde (VALERO) was registered for use on grapes in California on July 1999. It is used at a rate of one to three gallons per acre in 100-150 gallons of water per acre. It is a contact material that requires good coverage for control. Restricted-entry interval is 4 hours.

- **Insecticidal Soap.** 0 day PHI. In 1997, 1,637 lb ai of soap (M-PEDE) were applied to approximately 3% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.04 lb ai/acre. Insecticidal soaps are partially effective on spider mites, and 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. Approved for use on organically grown grapes. The restricted entry interval for insecticidal soaps is 12 hours.

OMNIVOROUS LEAFROLLER

Platynota stultana

Damage. The omnivorous leafroller can cause serious damage on grapes in the Northern and Southern San Joaquin Valley regions, and is a major pest of raisin grapes (16,17). Although it feeds on leaves, flowers, and developing berries, the primary damage is that it allows rot organisms to enter berries at the sites where it feeds. Once this infection is started and grapes are placed on the trays to dry, rot can quickly spread to the neighboring clusters.

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 marestail, panicle willow herb, and lambsquarters. Growers should ensure that these and other host weeds are controlled by French plowing, discing or herbicides.

- **Sanitation.** Old clusters which 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 disced. 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 which 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 raisin growers (who may decide to send some of all of their crop to the winery) 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 immigrated 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, KRYOCIDE) is a mineral (sodium aluminofluoride) which must be ingested by OLR for it to be effective. In 1997, 1,794,689 lb ai were applied to approximately 54% of table and raisin grape acreage in a median of one application per field. The median application rate was 5.7 lb ai/acre. Most wineries require that applications be made before full bloom or before June 1, and limit the total seasonal application to six lbs ai per acre. The reentry period is 12 hours.

- ***Bacillus thuringiensis* (Bt).** 0 day PHI. In 1997, 4,654 lb ai were applied to approximately 13% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.07 lb ai/acre. Bt is a bacterium which 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 reentry period. This pheromone is approved for certified organic production.

- **Methomyl.** 1 day PHI for raisin and table grapes. Methomyl (LANNATE) is an oxime carbamate. In 1997, 27,343 lb ai were applied to approximately 7.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.9 lb ai/acre. Some of this usage is for leafhoppers and other minor pests. Methomyl is highly disruptive to the predators of spider mites. There is a 7 day reentry period.

- **Carbaryl.** 7 day PHI (0 day PHI for dust). Carbaryl (SEVIN) is a carbamate. In 1997, 14,622 lb ai were applied to approximately 1.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 2.0 lb ai/acre. Use of carbaryl encourages mite buildup, as it is very disruptive to the natural enemies of mites. Carbaryl has a restricted-entry interval of 24 hours.

- **Phosmet.** 7 day PHI. Phosmet (IMIDAN) is an organophosphate. For an organophosphate, it is relatively non-disruptive to natural enemies. In 1997, 3,813 lb ai were applied to approximately 0.75% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.9 lb ai/acre. The restricted interval for phosmet is 5 days.

- **Diazinon.** 28 day PHI. Diazinon is an organophosphate. In 1997, 12,199 lb ai were applied to approximately 1.8% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.0 lb ai/acre. It is very disruptive to natural enemies. The restricted entry interval for diazinon is 5 days.

MEALYBUGS

Vine Mealybug: *Planococcus ficus*

Damage. The most common mealybug in the San Joaquin Valley has until recently been the grape mealybug, which is not a pest of raisins. However, there is increasing concern about the vine mealybug, which hails from the Mediterranean region, and was first found in the Coachella Valley in 1994 (1). Since then it has infested virtually all acreage in the Coachella region and has become a major pest there. In 1998 it was also discovered in Kern and Fresno Counties (Southern San Joaquin Valley). The vine mealybug can potentially cause far greater damage than the other vineyard mealybugs, as it feeds on leaves, shoots and roots and can severely stunt vine growth. Vine mealybug can also contaminate grape bunches with honeydew, producing far greater amounts of honeydew than the grape mealybug, 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 which 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:

- **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. 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 Southern San Joaquin Valley.

- **Other Predators.** Mealybug predators include a cecidomyiid 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) is recommended to control mealybugs. Oil is sometimes added, but recent research shows no better control from it. In 1997, 53,380 lb ai were applied to approximately 6% of table and raisin grape acreage in a median of one application per field. The median application rate was 2.0 lb ai/acre. 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 ON AUG. 2, 1999**. 7 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. In 1997, 103 lb ai were applied to approximately 0.03% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.0 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 ON AUG. 2, 1999**. 40 day PHI. Methyl parathion is an organophosphate that is applied in the spring. Application may be made until bloom. Methyl parathion is disruptive to beneficials. In 1997, 18,896 lb ai were applied to approximately 0.7% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.4 lb ai/acre. 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.

- **Imidacloprid**. 0 day PHI. Imidacloprid (PROVADO, ADMIRE) is in the chloronicotinyl chemical family. Provado® is a wettable powder formulation. In 1997, 4,998 lb ai were applied to approximately 32% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.03 lb ai/acre. Single applications per season are often effective. Most of this is applied for leafhopper control. Growers are required to allow 14 days before reapplication. Admire® received a special local needs registration in February 1999 for use on leafhoppers (including sharpshooters) and mealybugs in California; this formulation is a flowable intended for use in drip systems. Because imidacloprid is a systemic, it will be taken up by the vine. 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.

SHARPSHOOTERS

Glassy-winged sharpshooter: *Homalodisca coagulata*
Green sharpshooter: *Draeculacephala minerva*
Red-headed sharpshooter: *Carneocephala fulgida*

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). Until recently, the green sharpshooter (GSS) and the red-headed sharpshooter (RHSS) are the primary vectors in the South and North San Joaquin Valley regions. However, in 1998, the glassy-winged sharpshooter (GWSS) was detected in the Southern San Joaquin Valley, and in 1999 it was found in the Northern San Joaquin Valley. GWSS invaded California from the southeastern US, and was first found on eucalyptus in Ventura County in 1990 (54). GWSS is a large insect (10-12 mm or 0.5 inch) and a strong flyer, which feeds and reproduces on over 70 species of plants in at least 35 different families. Cultivated host plants include citrus, apricot, grape and eucalyptus, and native host plants include sycamore and oak. It has established high populations in southern California, and has become troublesome on grapes in the Temecula Valley. Because of its strong flying ability, its broad host range and ability to transmit Pierce's Disease (PD), GWSS is potentially a major problem for table grape production. PD has been detected in the Southern San Joaquin Valley.

Life History of Pest. GSS and RHSS 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. Citrus is a primary overwintering host for GWSS, which can also overwinter in vineyards, feeding on dormant wood. Sharpshooter dispersal and rate of development is temperature dependent.

Monitoring. Sticky traps are not very effective monitoring tools for sharpshooters, because these insects are not attracted to the yellow cards. Sweep nets can be used to monitor populations in non-crop vegetation adjacent to vineyards. Light traps may be more effective monitoring tools.

CONTROLS:

Cultural:

- **Neighboring Crops.** In the San Joaquin Valley, the greatest amount of disease spread has heretofore been near pastures, weedy hay fields, or other grassy areas, which are habitats for GSS and RHSS. However, the presence of alternative hosts for the GWSS, especially citrus, will become increasingly important.

- **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 GSS and RHSS hosts. Alfalfa fields can be sources of GSS and RHSS 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 GSS and RHSS are parasitic wasps in the families Mymaridae and Trichogrammatidae that attack eggs. A mymarid egg parasite has been found attacking GWSS.

Chemical:
In the Central Valley, insecticide treatments on border vegetation are of little value overall because overlapping generations result in the continuous presence of eggs inside protective leaf tissues of host plants from February through fall. Sprays are not effective against eggs. Also, there are few chronically affected areas that would require treatment every year.

- **Imidacloprid.** 0 days PHI. Imidacloprid (PROVADO, ADMIRE) is a wettable powder formulation. In 1997, 4,998 lb ai were applied to approximately 32% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.03 lb ai/acre. Single applications per season are often effective. Imidacloprid applications are almost never for sharpshooters. ADMIRE was registered in February 1999 as a soil applied systemic. The restricted entry interval for imidacloprid is 12 hours.

- **Dimethoate.** 28 day PHI. Dimethoate (CYGON) is an organophosphate. In 1997, 20,904 lb ai were applied to approximately 3% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.5 lb ai/acre. This usage is almost never for sharpshooters. The restricted entry interval is 2 days.

MINOR INSECT PESTS

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 (59). 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 this pest.

Biological:

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- **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. This virus is transmitted from one generation to the next by disease-carrying adults that survive a low degree of infection in the larval stage. 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, KRYOCIDE) is applied by ground application. In 1997, 1,794,689 lb ai were applied to approximately 54% of table and raisin grape acreage in a median of one application per field. The median application rate was 5.7 lb ai/acre. The vast majority of these applications are for OLR, 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. Many processors must be informed if this product has been used on the crop.

- ***Bacillus thuringiensis* (Bt).** 0 day PHI. In 1997, 4,654 lb ai were applied to approximately 13% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.07 lb ai/acre. The vast majority of these applications are for OLR, not WGLS. Bt is a bacterium which 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.

- **Methomyl.** 1 day PHI for raisin grapes. Methomyl (LANNATE) use against WGLS is rare. In 1997, 27,343 lb ai were applied to approximately 7.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.9 lb ai/acre. It is a restricted use material and may only be used by permit from the county agricultural commissioner. Methomyl is disruptive to predators of mites and parasites of leafhoppers. The reentry restriction period is 7 days.

- **Carbaryl.** 7 day PHI. Carbaryl (SEVIN) is a carbamate. In 1997, 14,622 lb ai were applied to approximately 1.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 2.0 lb ai/acre. Most of although some of this is for leafhoppers and other pests, and use against WGLS is rare. Disruptive to predators of mites and parasites of leafhoppers so product should not be used where mites are a chronic problem. Restricted-entry interval is 24 hours. Carbaryl is extremely toxic to honeybees.

GRAPE LEAFFOLDER

Desmia funeralis

Damage. Grape leaffolder (GLF) (Lepidoptera: Pyralidae) is a pest in the Southern San Joaquin Valley which 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 paralizing 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).

- **Cryolite.** 30 day PHI. Cryolite (PROKIL, KRYOCIDE) is rarely applied for GLF. Cryolite treatments applied for omnivorous leafroller frequently will control GLF. In 1997, 1,794,689 lb ai were applied to approximately 54% of table and raisin grape acreage in a median of one application per field. The median application rate was 5.7 lb ai/acre. This material must be ingested by the leaffolder to be effective. Good coverage is essential. Ground applications are made at average rates of 6 lbs ai per acre and typically applied before full bloom. A maximum of two applications per season are allowed. The restricted-entry interval is 12 hours. Some processors are restricting the use of cryolite due to concerns regarding fluoride.

- ***Bacillus thuringiensis* (Bt).** 0 day PHI. In 1997, 4,654 lb ai were applied to approximately 13% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.07 lb ai/acre. Applications are 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.** 1 day PHI for raisin and table grapes. Methomyl (LANNATE) is an oxime carbamate. In 1997, 27,343 lb ai were applied to approximately 7.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.9 lb ai/acre. Methomyl usage is 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. In 1997, 14,622 lb ai were applied to approximately 1.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 2.0 lb ai/acre. This usage is rarely for GLF. It is applied at average rates of 1.5 lbs ai/acre. Carbaryl has a restricted-entry interval of 24 hours. Use of carbaryl may encourage mite buildup as it is very disruptive to the natural enemies of mites.

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 1997, 12,199 lb ai were applied to approximately 1.8% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.0 lb ai/acre. The restricted interval for diazinon is 5 days.

- **Malathion.** 3 day PHI. Malathion is an organophosphate. In 1997, 384 lb ai were applied to approximately 0.03% of the table and raisin grape acreage in a median of one application per field. The median application rate was 4.0 lb ai/acre. This usage is rarely for false chinch bug. The restricted-entry interval for malathion is 24 hours.

- **Methomyl.** 1 day PHI for raisin and table grapes. Methomyl (LANNATE) is an oxime carbamate rarely used for control of this pest. In 1997, 27,343 lb ai were applied to approximately 7.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.9 lb ai/acre. 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. In 1997, 14,622 lb ai were applied to approximately 1.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 2.0 lb ai/acre. This usage is rarely for false chinch bug. Disruptive to predators of mites and parasites of leafhoppers so product should not be used where mites are a chronic problem. Restricted-entry interval is 24 hours. Carbaryl is extremely toxic to honeybees.

Raisin Moth

Cadra figuliella

Damage. Raisin moth can cause the same type of damage to grapes as OLR, and is also a significant post-harvest storage pest of raisins. Feeding by raisin moth larvae is generally shallower than OLR, and takes place in a meandering fashion. They produce no webbing. Infestations generally come late enough in the season that damage to unharvested raisin grapes is limited. However, raisin moth is an increasing concern for DOV raisins, which require twice as long to dry than tradition methods.

Life History of the Pest. Raisin moths are 1 cm, gray drab moths. Larvae overwinter on a variety of unharvested fruits in the field. Eggs are laid on ripening grape berries or on grapes which have been laid on trays to dry.

Monitoring. Growers and PCAs can look for raisin moth damage at the same time they inspect grape clusters for presence of OLR. Pheromone traps are available for raisin moth, but are primarily used to monitor for its presence in raisin storage areas.

Post Harvest Insect Pests

Raisin Moth

Cadra figuliella

Damage. The raisin moth is a significant concern for post-harvest storage of raisins. These pests are the most common and widespread post-harvest pests for California raisins during storage. Young larvae hatched on stored raisins feed chiefly on the ridge crests of the raisins but can get into the flesh. They often move about the stored raisin, never completely consuming individual fruit. They leave masses of excreta and webbing. An individual larva can damage about 20 Thompson Seedless raisins.

Description of Pest. Raisin moths are 1 cm, drab gray, fore-winged pests. The raisin moth egg is white. The adult female generally lays her eggs on drying trays or on raisins in storage.

Monitoring. Infestations by raisin moths can usually be detected once the raisins are boxed for storage. Pheromone sticky tape traps are also used for detection.

CONTROLS

Cultural:
Cover Tarps. Cover tarps are occasionally used to minimize infestations by raisin moths.

Biological:
Parasitioids. Several parasitoids are known to attack raisin moth, including the braconid wasp *Bracon hebetor* and the ichneumonids *Devorgilla canescens* and *Mesostenus gracilis.* However, there are few if any attempts made to control raisin moth in storage using these biological control agents.

Chemical:

- **Aluminum Phosphide.** Aluminum phosphide is a phosphide fumigant that is used to control post-harvest pests such as raisin moths in post-harvest storage. It is the most effective and economical treatment currently available. In 1997, 1,837 lb ai of aluminum phosphide was applied to 12.7 million ft^3 of table grape and raisin storage space, primarily for raisin pests.

- **Methyl Bromide.** Though methyl bromide is available for post-harvest use on raisins, it is rarely the treatment of choice. In 1997, 10,065 lb ai of MeBr were applied to 1.7 million ft^3 of table grape and raisin storage space, primarily for table grapes being exported. Methyl bromide is being phased out and will no longer be available after 2006.

Indian Meal Moth

Plodia interpunctella

Damage. The Indian meal moth is a significant concern for post-harvest storage of raisins. The moth seriously affects raisins. Although not a widespread as the raisin moth for post-harvest storage infestation in California, the Indian meal moth is considered the world's number one storage pest. Moths lay eggs on raisins in storage and first-instar larvae can enter crevices, resulting in infested commodities. It is common for raisin stored for more that 30 to 60 days to have some level of indianmeal moth infestation. Normal handling and cleaning usually deter rejection by the purchaser.

Description of Pest. Indian meal moths are similar to raisin moths but have a reddish outer wing compared to the dull gray of the raisin moth. The white eggs have a purplish luster. Eggs are often laid in storage and/or warehouse situations.

Monitoring. Infestations by Indian meal moths are determined by pheromone sticky traps and visual observations.

CONTROLS

Cultural:
Cover Tarps. Cover tarps are occasionally used to minimize infestations by raisin moths.

Biological:
Parasitioids. The braconid wasp *Bracon hebetor* can be quite abundant on Indian meal moth. However, there are few if any efforts made to target Indian meal moth using parasitoids.

Chemical:

- **Aluminum phosphide.** In 1997, 1,837 lb ai of aluminum phosphide was applied to 12.7 million ft^3 of table grape and raisin storage space, primarily for raisin pests.

- **Methyl bromide (MeBr)**. In 1997, 10,065 lb ai of MeBr were applied to 1.7 million ft^3 of table grape and raisin storage space, primarily for table grapes being exported. Methyl bromide is being phased out and will no longer be available after 2006.

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. 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. Approximately 90% of the grape acreage in California (89% in 1997) is treated for powdery mildew. The non-treated acreage is largely non-bearing acreage.

Description of Symptoms and Disease Cycle. 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 86F. 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. In the Southern San Joaquin Valley, where the vast majority of raisin grape acreage is found, viable ascospores are not produced.

Monitoring and Treatment. Powdery mildew can be monitored by visual inspection and by use of the weather-driven disease risk models, particularly in the early season. Treatment is largely based on prevention. All preventive fungicides have a standard treatment interval, based largely on the half life of the material. Preventive treatments for powdery mildew are necessary as long as temperatures are conducive to growth and development. In the San Joaquin Valley this period occurs from shortly after budbreak through early July. There is increasing use of localized, weather data combined with disease risk models for scheduling of chemical applications (62). The Gubler-Thomas model is estimated to be used currently on approximately 80,000-100,000 acres to help determine when weather conditions indicate a higher risk of disease outbreak (38). When this risk is high, the interval between treatments is shortened, whereas if the risk is low, intervals can be lengthened. Risk is higher when temperatures fall between 70 and 86F, but below 95F. Wet springs can extend the release period of ascospores.

CONTROLS

Cultural

- **Vine Training.** Trellising, cane cutting and training techniques which 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. However, as mentioned earlier (see Leafhoppers), leaf removal is not currently economically feasible for raisin production.

- **Varieties.** Grape varieties vary in susceptibility to powdery mildew. Theoretically, treatment intervals on varieties which exhibit more resistance (e.g., Thompson Seedless) can be lengthened relative to susceptible varieties (e.g., Fiesta).

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 (36).

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, RUBIGAN and 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, but on raisin grapes this is rare, as viable ascospores are not produced in the Southern San Joaquin Valley. 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 cinnemaldehyde (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 (25). Treatments for powdery mildew on raisin grapes can be halted once the berries reach an average sugar level of 8%.

Preventatives

- **Sulfur.** 0 day PHI. In 1997, 20,835,975 lb ai were applied to 89.2% of the raisin and table grape acreage in California. The median application rate was 9.8 lb ai/acre. The vast majority of applications is for control of powdery mildew, and most of the rest is for *Phomopsis*. The average application rate is about 8 lbs ai per acre with sulfur dust rates being higher (10 to 12 lbs ai per acre) and wettable sulfur rates being lower (typically 3 to 5 lbs 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 100F. Use of sulfur is approved for organically grown produce. Reentry interval is 24 hours in most counties. In the Southern San Joaquin Valley region the restricted-entry interval is 3 days after May 15.

- **Myclobutanil.** 14 day PHI. Myclobutanil (RALLY) is a DMI that is applied only for the control of powdery mildew. In 1997, 36,212 lb ai were applied to 33.8% of the table and raisin grape acreage. The median application rate was 0.1 lb ai/acre. Myclobutanil is an azole that is applied at average rates of 0.1 lb ai per acre. 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 that is applied only for the control of powdery mildew. In 1997, 6,257 lb ai were applied to 24.6% of the raisin and table grape acreage in a median of one application. The median application rate was 1.11 lb ai/acre. The restricted-entry interval for fenarimol is 12 hours.

- **Triflumizole.** 7 day PHI. Triflumizole (PROCURE) is a DMI that is applied only for the control of powdery mildew. In 1997, 23,432 lb ai were applied to 22.9% of the table and raisin grape acreage in a median of one application. The median application rate was 0.13 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 1997, 255,097 lb ai were applied to 35.7% of the table and raisin grape acreage in a median of one application. The median application rate was 1.23 lb ai/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.

- **Triadimefon.** 14 day PHI. Triadimefon (BAYLETON) is a DMI. In 1997, 2,888 lb ai were applied to 1.3% of the table and raisin grape acreage in a median of two applications. The median application rate was 0.13 lb ai/acre. 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 - 1.0 oz/acre. In 1997, 2 lb ai were applied to 0.8% of the table and raisin grape acreage in a median of two applications. The median application rate was less than 0.01 lb ai/acre. 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. Preventative and contact. Azoxystrobin (ABOUND) is applied at label rates. In 1997, 18,828 lb ai were applied to 1.6% of the table and raisin grape acreage in a median of one application. The median application rate was less than 3.21 lb ai/acre. It is a natural product derived from mushrooms which is a good broad spectrum material (also effective against phomopsis and downy mildew. The restricted entry interval is 12 hours.

Contact materials

- **Narrow Range Oil.** Narrow range oil is an eradicant that kills mildew hyphae and spores on contact. In 1997, 142,242 lb ai of narrow range oils were applied to approximately 3% of table and raisin grape acreage in a median of one application per field. The median application rate was 8.8 lb ai/acre. Part of this usage is for other pests such as spider mites and leafhoppers. Narrow range oil should be used at a 2% rate, with enough volume to ensure good coverage (100-150 gallons of water/acre). It can be used in rotation with one of the sterol inhibitors. Applications are made at 14- to 18-day interval. Use should be discontinued after bloom. Most narrow range oils are approved for organic production. The restricted-entry interval is 12 hours.

- **Insecticidal soap.** 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. In 1997, 5,983 lb ai were applied to approximately 0.8% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.2 lb ai/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. Use should be discontinued after bloom. Soaps are also used for control of soft bodied insects such as leafhoppers. 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 rates of 2.5 to 3 lbs per acre. Potassium bicarbonate was recently registered and use report information is not yet available for this chemical. The restricted entry interval is 4 hours.

- **Cinnamaldehyde**. O day PHI. Cinnamaldehyde (VALERO) was registered for use on grapes in California in July 1999. It is used at a rate of one to three gallons per acre in 100-150 gallons of water per acre. Restricted-entry interval is 4 hours.

- **Azoxystrobin.** 14 day PHI. Preventative and contact. Azoxystrobin (ABOUND) is applied at label rates. In 1997, 18,828 lb ai were applied to 1.6% of the table and raisin grape acreage in a median of one application. The median application rate was less than 3.21 lb ai/acre. It is a natural product derived from mushrooms which is a good broad spectrum material (also effective against phomopsis and downy mildew. The restricted entry interval is 12 hours.

Phomopsis Cane And Leafspot

Phomopsis viticola

Damage. Phomopsis is most severe when spring rainfall is high. It is common in northern grape growing regions where spring rains are common after bud break, but it has even been severe in the Southern San Joaquin Valley during the 1990s because of high rainfall. 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 to 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.

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).

- **Sulfur.** 0 day PHI. In 1997, 20,835,975 lb ai were applied to 89.2% of the raisin and table grape acreage in California. The median application rate was 9.8 lb ai/acre. Sulfur dust rates are from 10-15 lbs/ac, and wettable sulfur applications are typically at 3 to 5 lbs ai per acre. Most of this sulfur is for controlling powdery mildew and not phomopsis. For phomopsis control, wettable sulfur is often combined with copper hydroxide. In some counties the restricted-entry interval for sulfur is 3 days. Sulfur can cause injury to foliage and fruit when applied just before or on days when the temperature exceeds 100F. The use of sulfur is approved for organically grown produce.

- **Azoxystrobin.** 14 day PHI. Azoxystrobin (ABOUND) is in a class of compounds called the strobilurines. It is applied at label rates. In 1997, 18,828 lb ai were applied to 1.6% of the table and raisin grape acreage in a median of one application. The median application rate was less than 3.21 lb ai/acre. The restricted entry interval is 12 hours.

- **Copper Hydroxide.** 0 day PHI. Copper hydroxide is a resistance management tool used in combination with wettable sulfur and in rotation with other products. In 1997, 255,097 lb ai were applied to 35.7% of the table and raisin grape acreage in a median of one application. The median application rate was 1.23 lb ai/acre. It is also used for other fungal diseases such as downy mildew, summer bunch rot, and for frost management. Use of copper hydroxide may burn grape leaves. Copper hydroxide is approved for organic production of grapes.

- **Captan.** 0 day PHI. Captan is applied for spring foliar treatment. In 1997, 43,443 lb ai were applied to approximately 5.4% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.5 lb ai/acre. Captan treated grapes are prohibited in Canada. Applications of captan should not be made immediately before or closely following oil sprays. There is a 1 day reentry period.

- **Mancozeb.** 0 day PHI. Mancozeb (DITHANE) is an alkylenebis (dithocarbamate) applied for this disease and for bunch rot. In 1997, 75,296 lb ai were applied to approximately 6.2% of table and raisin grape acreage in a median of two applications per field. The median application rate was 1.6 lb ai/acre. Mancozeb should not be applied after bloom. There is a 24 hour reentry period.

- **Ziram.** 0 day PHI. Ziram is a dithiocarbamate. In 1997, 35,807 lb ai were applied to approximately 2.7% of table and raisin grape acreage in a median of one application per field. The median application rate was 2.3 lb ai/acre. The restricted entry interval is 48 hours.

Summer Bunch Rot (Sour Rot)

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

Damage. The summer bunch rot complex consists are secondary 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. Damaged berries are quickly colonized by fungi and bacteria, 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 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 (35). This has provided equivalent control to any chemical treatment (R.A. Duncan, personal communication). As mentioned earlier (see Leafhoppers), it is not currently an economically justifiable practice for raisin grapes.

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

Biological:
There are some promising biologicals for use as antagonists against the bunch rot complex. The bacterium *Pseudomonas fluorescens* (BlightBan®) 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 of raisin grape acreage at an average rate of 7 lb ai per acre.

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 also Sharpshooters). 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 59 F, 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 which have been infected will develop the disease. The probability of recovery depends on variety, the date of infection and the age of the vineyard. Recovery is high in Thompson Seedless, but low in Fiesta. 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. 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, and can make visual observations for symptoms of Pierce's disease.

CONTROLS

Cultural:

- **Neighboring Crops.** 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. This situation may change with the introduction of the glassy-winged sharpshooter, which has a much broader host range than native sharpshooters and is a stronger flier.

- **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 hosts of red-headed and green sharpshooters. 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. The most susceptible raisin grape variety known is Fiesta.

- **Vine Removal.** Vines that have had Pierce's symptoms for more than one year should be removed as they area source of infection.

Biological:
No biological controls are known for Pierce's disease.

Chemical:
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 Fiesta.

<u>Eutypa and Other Canker Diseases</u>

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* (33). Eutypa dieback is an important problem in the Northern San Joaquin Valley, 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. 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 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.

- **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 (48), but no fungal antagonistic products are available commercially.

Chemical:
Chemical treatments are most effective if applied directly to the pruning wounds immediately after pruning.

- **Benomyl.** Benomyl (BENLATE) has a restricted-entry interval of 1 day. In 1997, 15,601 lb ai were applied to approximately 5.9% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.5 lb ai/acre. Should be re-applied every two weeks for most effective control. Because benomyl is applied by hand, it is not a cost effective measure for raisin production.

MINOR DISEASES

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 common in areas with consistently high summer temperatures such as the San Joaquin Valley. 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.

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 bacteria is systemic throughout the vine. Crown gall is a particular problem for nurseries.

CONTROLS

Cultural:
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 (56).

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 approximately 0.1% of grapes in California. In 1997, 3 lb 2,4-xylenol and 3 lb meta cresol were applied. The restricted entry interval is 0 days.

DOWNY MILDEW

Plasmopara viticola

Damage. Downy mildew is a fungus which is common in areas with high summer rainfall (eastern USA and Europe) (52), 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 resistance management tool used in rotation with other products. In 1997, 255,097 lb ai were applied to 35.7% of the table and raisin grape acreage in a median of one application. The median application rate was 1.23 lb ai/acre. It is applied for several diseases such as phomopsis, bunch rot and frost management. Use of copper hydroxide may burn grape leaves.

- **Basic Copper Sulfate.** 0 days PHI. Basic copper sulfate was applied at a median rate of 0.99 lb ai/ac on 0.3 % of table and raisin grape acreage in 1997. 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. The reentry period is 1 day.

- **Maneb**. 66 day PHI. In 1997, 4,957 lb ai were applied to approximately 0.3% of table and raisin grape acreage in a median of two applications per field. The median application rate was 2.1 lb ai/acre. Begin applications shortly after budbreak (0.5-1.5 inch long shoots) and repeat every 7-10 days. The reentry period is 1 day.

- **Mancozeb**. 66 day PHI. In 1997, 75,296 lb ai were applied to approximately 6.2% of table and raisin grape acreage in a median of two applications per field. The median application rate was 1.6 lb ai/acre. Begin applications shortly after budbreak (0.5-1.5 inch long shoots) and repeat every 7-10 days. The reentry period is 1 day.

- **Azoxystrobin.** 14 day PHI. Preventative and contact. In 1997, 18,828 lb ai were applied to 1.6% of the table and raisin grape acreage in a median of one application. The median application rate was less than 3.21 lb ai/acre. The restricted entry interval is 12 hours.

Contact materials

- **Mefenoxam + Copper Hydroxide**. 66 day PHI. Mefenoxam+copper hydroxide (RIDOMIL GOLD) is applied at a median rate of 0.08 lb ai (mefenoxam)/ac. Must not be applied after bloom. The reentry period is 2 days.

- **Azoxystrobin.** 14 day PHI. Preventative and contact. Azoxystrobin (ABOUND) was applied at a median rate of 3.2 lb ai/ac on 1.6% of table and raisin grape acreage in 1997. The restricted entry interval is 12 hours.

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 (46). 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.

Root knot and ring nematodes are the most common nematode pests of raisin grapes, although dagger, root lesion and citrus nematodes also occur in the San Joaquin Valley. 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 (46). 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). RKN 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 roots samples should be taken within the row, preferably one to two feet from the trunk, down to a depth of 3 feet (46). 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 (47). 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, improve 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 nonfumigated 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 1997 less than 1% was 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".) 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 lbs 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 200 to 325 lb ai per treated acre. It is seldom applied to grapes, in 1997 less than 0.1% of the 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 which 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 at label rates to approximately 0.1% of grape acreage in 1997 at a median rate of 192 lb ai per acre. 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 72 hours.

Post-plant treatments

- **Sodium Tetrathiocarbonate.** In 1997, 295,136 lb ai of sodium tetrathiocarbonate (ENZONE) were applied to approximately 1.5% of table and raisin grape acreage in a median of one application per field. The median application rate was 22 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 1997, 69,699 lb ai were applied to approximately 7% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.1 lb ai/acre. 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. In 1997, 21,690 lb ai were applied to approximately 1% of table and raisin grape acreage in a median of one application per field. The median application rate was 3.2 lb ai/acre. The restricted-entry interval is 2 days. 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 these products can be optimized for field-use conditions. There are no data on the extent of DITERA's use by the grape industry during the few years since it was registered in California. The restricted entry period is 4 hours. The fungus is heat-killed after the toxin is produced.

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 benefit 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, allow 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. Recently, propane flamers have been designed for use in vineyards.

- **Knives or blades**. (BEZZERIDES, L&H MFG.) 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 which 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 dessication.

- **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 which 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 means 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. In addition, perennials are incompatible with traditional raisin production systems because of the need to prepare the ground for raisin drying. For dry-on-the vine raisin systems, there is interest 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.

- **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 which has been "mown and thrown." 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 add organic matter to the soil, but need to be continually amended, and may provide a good habitat for voles, field mice, and snakes. 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 Butyl.** 0 day PHI. Fluazifop butyl (FUSILADE) is an aryloxyphenoxy propionate. In 1997, 165 lb ai were applied to approximately 0.2% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.25 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 butyl is less than 1 month. The restricted entry interval is 12 hours.

- **Glyphosate.** 14 day PHI. Glyphosate (ROUNDUP, GLYPHOS, TOUCHDOWN) is a postemergent herbicde that translocates to vine growing points. It may be used as a preplant or postplant postemergence herbicide in the vineyard. In 1997, 148,445 lb ai were applied to approximately 41.4% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.5 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.** Oxylfluorfen (GOAL) is a diphenyl ether compound applied to bearing dormant vines only. It has both pre-emergent and contact properties. In 1997, 40,753 lb ai were applied to approximately 25% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.26 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 control. In 1997, 91,934 lb ai were applied to approximately 27.9% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.43 lb ai/acre. Paraquat dichloride is often combined with oxylfluorfen to broaden the spectrum of weeds controlled. The restricted entry interval is 2 days.

- **Sethoxydim.** 50 day PHI. Sethoxydim (POAST) is a cyclohexanedione. In 1997, 1,111 lb ai were applied to approximately 1.8% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.11 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. In 1997, 1,710 lb ai were applied to approximately 1.2% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.4 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 drift. 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 fattyacids (SCYTHE) is applied at rates of 1-2 lbs a.i. acre.

Preemergent

- **Dichlobenil.** Dichlobenil (CASORON) a nitrile that is applied at 4-6 lb a.i. per acre to less than 1% of raisin and table grape acreage. Dichlobenil was not used in 1997. 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. Restricted-entry interval is 12 hours.

- **Diuron.** 0 day PHI. Diuron (KARMEX) is a phenylurea. In 1997, 26,644 lb ai were applied to approximately 9.1% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.5 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 1997, 5,361 lb ai were applied to approximately 1% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.0 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 1997, 26,026 lb ai were applied to approximately 7.9% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.6 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. Restricted-entry interval is12 hours.

- **Oryzalin.** 0 day PHI. Oryzalin (SURFLAN) is a 2,6-dintroaniline compound. In 1997, 106,789 lb ai were applied to approximately 14.3% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.3 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.** Oxylfluorfen (GOAL) is a diphenyl ether compound applied to bearing dormant vines only. It has both pre-emergent and contact properties. In 1997, 40,753 lb ai were applied to approximately 25% of table and raisin grape acreage in a median of one application per field. The median application rate was 0.3 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.** 0 day PHI. Simazine is a 1,3-5-triazine compound. In 1997, 141,001 lb ai were applied to approximately 35.2% of table and raisin grape acreage in a median of one application per field. 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 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 1997, 14,179 lb ai were applied to approximately 3% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.0 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 1997, 8,308 lb ai were applied to approximately 1% of table and raisin grape acreage in a median of one application per field. The median application rate was 1.5 lb ai/acre. The residual period for pendimethalin is 4 to 10 months. The restricted entry interval is 12 hours.

Vertebrate Pests

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*

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.

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 if 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 a 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. 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 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. It is applied to less than 1% of raisin and table grape vineyards. 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 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 and is applied to less than 1% of grape acreage.

- **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. It is applied to less than 1% of raisin and table grape vineyards.

- **Zinc Phosphide.** Zinc phosphide is a bait that can be used to treat ground squirrels. It is rarely used in California; less than 1% of raisin and table grape vineyards.

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.

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.

- **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. It is applied to less than 1% of grape vineyards. 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 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 and is applied to less than 1% of grape acreage.

- **Zinc Phosphide.** Zinc phosphide is a bait that can be used to treat ground squirrels. It is rarely used in California; less than 1% of raisin and table grape vineyards are treated.

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. It is applied to less than 1% of raisin and table grape vineyards.

- **Zinc Phosphide.** Zinc phosphide is a bait used to treat meadow voles at labeled rates. It is rarely used in grape vineyards in California; less than 1% of raisin and table grape vineyards are treated.

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 effects.

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

PLANT GROWTH REGULATORS

GIBBERELLIC ACID:
Description. Gibberellic acid (GA) is applied to approximately 35% of raisin and table grapes. Most of this is for thinning and sizing of table grapes. GA is applied to raisin grapes either in early spring at 2-4" shoot growth for "bunch stretch" or during bloom for berry thinning.

ETHEPHON:
Description. Ethephon (ETHREL) is used on 8% of table and raisin grape acreage at an average application rate of 0.25 lb ai per acre. Ethephon accelerates the rate of sugar accumulation, but has the negative effect of decreasing acidity.

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. 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 B2 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 Sun-Maid Best Management Practices Program, the Lodi-Woodbridge BIFS (51), Central Valley Biologically Integrated Vineyard Systems (11), the Central Coast Vineyard Team (8), the Sonoma Valley Vintners and Growers (63) and the Napa Sustainable Winegrowing Group (50). Although funding groups such as the Raisin Marketing Board (formerly the Raisin Advisory Board) and various programs within the University of California have done a good job of funding grape IPM research projects, much more can be done on the part of these groups to support Ag Partnership projects, expand grower participation, and develop similar groups for table grape growers.

RESEARCH

This section addresses pest research priorities for California raisin grapes. Needs are prioritized in three ways: By the percentage of grape acreage in California treated with FQPA Priority I materials for raisin grape pests, and by the number of registered, effective chemical substitutes for FQPA Priority I materials (Table 1). Research needs can be separated into three areas: 1) the development and evaluation of alternative chemical control methods and 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 raisin grape pest research needs based on the percentage of raisin and table grape acreage in California treated with FQPA Priority I materials in 1997. Weeds, spider mites, and powdery mildew are the top three priorities, with at least 35%, 34.5%, 34% of raisin and table grape acreage treated, respectively. These are followed by nematodes, leafhoppers and omnivorous leafroller with at least 10%, 7% and 7% of raisin and table grape acreage treated, respectively. Mealybugs and sharpshooters are pests which have not historically been chemically treated for by raisin growers. However, because of the recent invasions of vine mealybug and glassy-winged sharpshooter, these categories are included as priorities. Mealybugs and sharpshooters received treatment on at least 6% and 3% of raisin and table grape acreage, respectively.

Column 2 of Table 1 is based on the number of registered, effective Priority II or III chemical substitutes for FQPA Priority I materials on raisin grapes. The top two priorities for raisin grapes are root knot nematode and mealybugs, because there are currently no effective materials registered against them which can substitute for FQPA Priority I materials. The only Priority II or III materials registered against spider mites are either most effective under fairly narrow environmental conditions or are contact materials, which are not always consistently effective. There are no Priority III substitutes for fenamiphos (Nemacur®), a Priority I material used to treat root knot nematode, an endoparasitic nematode. Ectoparasitic nematodes (e.g., ring nematode) can be effectively controlled with sodium tetrathiocarbonate (Enzone®), a Priority III material. Mealybugs would not traditionally be a concern for raisin grapes, but are included here because of the recent arrival of the vine mealybug. For mealybugs, only one in-season chemical is registered (Admire®), but it is a drip-applied systemic which cannot be considered a substitute for foliar OPs or carbamates. Weeds have a significant contact herbicide available (glyphosate, Priority III), one Priority II contact material available, two Priority II pre-emergent herbicides available, and no Priority III pre-emergents. Spider mites, omnivorous leafroller, leafhoppers and sharpshooters each have one effective substitute, and powdery mildew has four.

Table 1. Order of research priorities based on the minimum percentage of acreage treated with FQPA Priority I materials (column 1) and the number of effective, registered substitutes for FQPA Priority I materials (column 2).

Priority based on percentage of raisin and table grape acreage treated in 1997 with Priority I materials (in parentheses)	**Priority based on the number of effective, currently registered substitutes for FQPA I materials (in parentheses)**
Weeds (35)	Root knot nematode (0)
Spider mites (34.5)	Mealybugs (0)
Powdery mildew (34)	Spider mites (1)
Nematodes (10)	Leafhoppers (1)
Leafhoppers: Grape and variegated (7)	Omnivorous leafroller (1)

Omnivorous leafroller (7)	Sharpshooters (1)
Mealybugs (6)	Weeds (4)
Sharpshooters (3)	Powdery mildew (4)

Current and alternative chemicals

Table 2 lists the priority pest categories with corresponding FPQA Priority I and Priority II and III materials, and the corresponding 1997 percentage of acres treated. Materials registered since 1997 are marked with an asterisk. Table 2 also lists unregistered alternative chemicals for these pests. Although all of the raisin pest categories has at least one FPQA Priority I material registered, none is completely dependent on these materials, and in the short term, six out of the eight pests can be effectively controlled using currently registered Priority II and III materials as substitutes. The two exceptions are root knot nematode and vine mealybug. In the long run, there are several alternative materials pending registration for powdery mildew and spider mites, and at least one for weeds, leafhoppers, sharpshooters, OLR, and root knot nematode, but none for mealybugs.

Spider mites: Current and alternative chemical controls. The most widely used materials for spider mites, propargite (Omite®) and dicofol (Kelthane®), are FQPA Priority I. There is no direct substitute for either. The closest is fenbutatin-oxide (Vendex®), an FQPA Priority II material, which is not as effective in cool conditions (<80F), nor when spider mite population density is high. Narrow range oil is a contact material, and effective if coverage is thorough. Oil does not kill eggs and therefore several applications per season may be necessary. Cinnemaldehyde (Valero®), which was only registered in July 1999, is also a contact, and apparently has good kill on mite eggs (B. Murphy, personal communication). There are also several alternative materials pending registration, including avermectin (Agri-Mek®), pyridaben (Pyramite®), and clofentizine (Apollo®), all of which have been shown to be effective on Pacific mite (M.J. Costello, unpublished data).

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 binomial 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.

Weeds: Current and alternative chemical controls: Although there are no FQPA Priority III substitutes for any of the Priority I pre-emergent herbicides, diuron (Karmex®) is a Priority II material which is the closest substitute for the pre-emergents simazine and oxyfluorfen (Goal ®). Diuron is more effective than either of these materials in controlling annual grasses (43). However, diuron has been detected in groundwater (6), and is restricted in some areas (called pesticide management zones or PMZs). Another possible substitute is norflurazon (Solicam®), also a Priority II material, which controls a smaller spectrum of annual broadleaves, but is more effective at controlling annual grasses and certain perennial weeds (43). The most popular herbicide used on grapes in California is glyphosate (Roundup®, Touchdown®, Glyphos®), a contact herbicide which is a Priority III material. More use can be made of glyphosate, especially if it is used with new application technologies such as light activated sprayers and shielded misters, which will help apply contact materials more efficiently (T. Prather, unpublished data).

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 (61). 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, they are replaced by a complex of summer weeds. 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, but has not been tested in raisin grape vineyards.

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 disced 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 (Rally®), triflumizole (Procure®) and triademefon (Bayleton®) would not have a major impact on powdery mildew management in the short run. Fenarimol (Rubigan®), 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. Bayleton® has not been widely used for several years because of resistance. Azoxystrobin (Abound®) is a relatively newly registered material which is an effective preventative and eradicant, and falls into a novel chemical class, the strobilurines. The fungal parasite, *Ampelomyces quisqualis* (AQ10®), 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 (36). 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 Kaligreen®, Valero®, Elexa®, and foliar applied nutrients such as calcium (e.g., Vigor-Cal®), 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.

Nematodes: Current and alternative chemical controls. Two of the top three chemicals for nematodes are FQPA Priority I materials: Fenamiphos (Nemacur®) and carbofuran (Furadan®). The third chemical, sodium tetrathiocarbonate (Enzone®) is an FQPA Priority III material. Enzone® is a suitable substitute for Furadan®, as both are used primarily for the ectoparasitic nematodes such as ring nematode, and Enzone® has been found to be quite effective (M. McKenry, personal communication). However, there is no substitute for Nemacur®, which is primarily used for endoparasitic nematodes such as root knot nematode. Oxycom® and DiTera® 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 Oxycom® and DiTera®, and other new materials which are effective and environmentally safe. One possibility is Admire®, which appears to have an effect on root knot nematode similar to Nemacur®.

Nematodes: Short term research needs. Nematodes take advantage of stressed vines, so any measures taken which can minimize vine stress can reduce the risk of nematode damage. 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 which will help increase vine tolerance to nematode attack. Research is needed as to how irrigation practices for improving grape quality will affect vine tolerance to nematode infestation. Short term research needs test newly registered materials such as DiTera® and Oxycom®.

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.

Leafhoppers: Current and alternative chemical controls. There are five chemicals registered for leafhoppers which fall into Priority I of FQPA: Methomyl (Lannate®), carbaryl (Sevin®), dimethoate (Clean Crop®), naled (Dibrom®) and endosulfan (Thiodan®). All of these were commonly used for leafhopper control prior to 1995. However, in 1995 imidacloprid (Provado®), a Priority III material, 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 Provado® with secondary pest outbreaks, formal studies have not borne this out (24,42). 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 (Applaud®), 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 [Surround®]). Pyridaben (Pyramite®) is a broad spectrum material that is effective on spider mites as well as leafhoppers, and is close to registration.

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. Irrigation management and cover cropping could be integrated for leafhopper control, and improvements raisin 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 raisin varieties. Improvements are needed in monitoring techniques and tools, e.g., the use of scanners to record nymphal counts in the field. There is a need to register and test new chemistry materials for leafhoppers such as kaolin, pyridaben and IGRs.

Leafhoppers: Long term research needs. Mechanization of leafing will help make this very effective practice more economically feasible for raisin growers. 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 (all Priority I) will have a very minor impact on control, which currently is largely undertaken with cryolite (Priority III). The only other material commonly used by raisin growers is B.t., which 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 (Success®) and tebufenozide (Confirm®) 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-mate® and Checkmate®), 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 coddling 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.

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. Imidacloprid (Provado®), although registered, has not been found to be very effective. Imidacloprid applied through the drip system (Admire®) is the only other in-season control. Chlorpyrifos (Lorsban®) is a Priority I material 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 Lorsban® 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 which 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 that 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 which are somewhat specific to mealybugs. There are currently no effective in-season foliar chemical controls, and the efficacy of Admire® is 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 such as Clinch® (active ingredient abamectin).

Mealybugs: Long term research needs. Effective biological controls are needed for the vine mealybug. Information is needed on why grape mealybug parasites are 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 (Priority I) has traditionally been the material used to treat border vegetation as well as vines for sharpshooters. However, imidacloprid (Provado®), 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 which are effective and environmentally safe. The particle film kaolin, because of its anti-feedant properties, would be particularly suitable against sharpshooters.

Sharpshooters: Short term research needs. Work needs to begin immediately on long term control strategies for the glassy winged sharpshooter. This strong flying insect feeds on a variety of cultivated plants, and is a carrier of Pierce's disease. The presence of this glassy winged sharpshooter may make moot efforts to control blue-green, green and red-headed sharpshooters. Research is needed 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 not attracted to yellow sticky cards, and light traps are a possibility. There is a need to register and test new chemistry materials, like the particle film kaolin (Surround®). 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 should focus on vine resistance to PD, including the incorporation of resistant genes into vines. Long term research needs for blue-green sharpshooters include riparian vegetation management, and the use of non-host barriers between the riparian corridor and the vineyard, such as cedars and conifers.

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. Raisin grape pests, associated registered chemicals by FQPA priority status and alternative chemicals pending registration. Percentage of raisin and table grape acreage treated with a given material in 1997 is in brackets.

Raisin Grape Pest	FQPA Priority I Chemicals	FQPA Priority II & III Chemicals	Alternative Chemicals Pending Registration

Weeds	•Simazine (Princep®) [35%] •Paraquat dichloride (Gramoxone®) [28%] •Oxyfluorfen (Goal®) [25%] •Oryzalin (Surflan®) [14%] •Trifluralin (Treflan®) [3%] •Pendimethalin (Prowl®) [1%] •Napropamide (Devrinol®) [1%] •Dichlobenil (Casoron®) [1%] •2, 4-D (Envy®) [0.5%] •Fluazifop (Fusilade®) [0.2%]	•Glyphosate (Roundup®, Touchdown®, Glyphos®) [41%] •Diuron (Karmex®) [9%] •Norflurazon (Solicam®) [8%] •Sethoxydim (Poast®) [2%] •Herbicidal soap (Scythe®) •Isoxaben (Gallery®)*	•Thiazopyr (Visor®)

Spider mites: Willamette and Pacific	•Propargite (Omite®) [30.5%] •Dicofol (Kelthane®) [4%]	•Fenbutatin-oxide (Vendex®) [5%] •Narrow range oil (various trade names) [3%] •Cinnamaldehyde (Valero®)*	•Avermectin (Agri-mek®) •Biomite® •Alert® •Clofentezine (Apollo®) •Pyridaben (Pyramite®)
Raisin Grape Pest	**FQPA Priority I Chemicals**	**FQPA Priority II & III Chemicals**	**Alternative Chemicals** **Pending Registration**
Powdery mildew	•Myclobutanil (Rally®) [34%] •Triflumizole (Procure®) [23%] •Triademefon (Bayleton®) [1%]	•Sulfur (various trade names) [89%] •Copper hydroxide (various trade names) [36%] •Fenarimol (Rubigan®) [25%] •Narrow range oil (various trade names) [3%] •Insecticidal soap (M-pede®) [3%] •Azoxystrobin (Abound®) [2%] •*Ampelomyces quisqualis*	•Chitosan (Elexa®) •Serenade® •Flint® •Sovran®

		(AQ10®) [1%] •Potassium bicarbonate (Kaligreen®)*	
Nematodes	•Fenamiphos (Nemacur®) [7%] •Carbofuran (Furadan®) [1%] •Methyl bromide# [0.4%] •Metam sodium# (Vapam®) [0.05%] •1,3-Dichloropropene# (Telone®) [0.1%]	•Sodium Tetrathiocarbonate (Enzone®) [2%] •*Myrothecium verrucaria* (DiTera®) •Oxycom®*	•Imidacloprid (Admire®)
Raisin Grape Pest	**FQPA Priority I Chemicals**	**FQPA Priority II & III Chemicals**	**Alternative Chemicals** **Pending Registration**

Leafhoppers: Grape and variegated	•Methomyl (Lannate®) [7%] •Carbaryl (Sevin®) [1.5%] •Dimethoate (Clean Crop®) [3%] •Naled (Dibrom®) [1%] •Endosulfan (Thiodan®) [1%]	•Imidacloprid (Provado®, Admire®) [32%] •Narrow range oil (various trade names) [3%] •Insecticidal soap (M-pede®) [3%] •Pyrethrin (Pyrenone®) [1%] •Azadirachtin (Neemix®) [0.05%]	•Buprofezin (Applaud®) •Kaolin (Surround®)
Omnivorous leafroller	•Methomyl (Lannate®) [7%] •Carbaryl (Sevin®) [1.5%] •Phosmet (Imidan®) [1%] •Diazinon [2%]	•Cryolite (Prokil®, Kryocide®) [54%] •Bt (Various trade names) [12%]	•Spinosad® •Confirm®

Mealybugs: Grape and vine	•Azinphos methyl ([0.05%] restricted 8/2/1999) •Methyl parathion ([1%]restricted 8/2/1999) •Chlorpyrifos (Lorsban®) [6%]	•Imidacloprid (Provado®, Admire®) [32%]	•Buprofezin (Applaud®)
Sharpshooters: Green, red-headed and glassy-winged	•Dimethoate (Clean Crop®) [3%]	•Imidacloprid (Provado®, Admire®) [32%]	•Kaolin (Surround®)

*Material not registered on grapes in 1997.

Table 3. Key raisin grape pests, their current cultural, biological and other IPM controls, and short and long term research priorities.

Raisin Grape Pest	**Cultural, Biological and IPM Controls**	**Short Term Research Priorities**	**Long Term Research Needs**
Weeds	In-row cultivation Mulches: Synthetic and organic Subsurface drip irrigation Cover crops	Test low volume application technologies Test in-row cultivation implements Test organic and synthetic mulches Test in-row cover crop use Develop action thresholds	

		using contact herbicides Implement weed surveys by growers/PCAs	
Spider mites	Soil, irrigation and dust management Reduce sulfur use Monitoring and use of action thresholds Release of predatory mites	Use of sulfur Timing/rate of predatory mite release New tools/methodology to expedite monitoring Use of 6-spotted thrips	"Fixing" problem soils
Powdery mildew	Use of mildew model	Test new chemistry fungicides Test, improve and implement use of mildew model Resistance management Improve dormant controls Foliar nutrients to improve vine resistance	Biotechnology employing resistant genes Induced resistance
Nematodes	Soil/water/fertility management Resistant rootstocks Soil amendments (cover crops, compost)	Test new chemistry and biological materials	Improving soil health Test new rootstocks

Leafhoppers	Monitoring/use of action thresholds Vine water status Sticky tape Anagrus monitoring	New tools/methodology to expedite monitoring Establish EILs/action thresholds for varieties/ regions Register and test new chemistry materials Irrigation/cover cropping to manage vine water status	Importation of a more effective Anagrus for variegated leafhopper
OLR	Pheremone mating disruption Use of OLR model Sanitation/weed control	New tools/methodology to expedite monitoring Use of natural enemies such as Trichogramma Test pheremone disruption	Importation of new natural enemies
Mealybugs	Trellising/pruning Monitoring	Register and test new chemistry materials Evaluate use of Admire Use of ant baits	Improve biological controls
Sharpshooters	Weed control Monitoring	Register and test new chemistry materials Test light traps for monitoring Inundative biological controls	Biology and control of glassy-winged sharpshooter Riparian vegetation management Non-host barriers Biotechnology employing resistant genes

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