ENVIRONMENTAL JUSTICE PILOT PROJECT
PEST MANAGEMENT ASSESSMENT:
SOIL FUMIGANT AND ORGANOPHOSPHATE INSECTICIDE USE AND ALTERNATIVES - PARLIER, FRESNO COUNTY, CALIFORNIA

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I. Executive Summary

This assessment is part of a California Department of Pesticide Regulation (DPR) environmental justice pilot project that monitored pesticides in air in the low-income, predominantly Hispanic Fresno County farming community of Parlier during 2006. The purpose of the pilot project is to determine whether pesticides found in air pose a health concern, especially for children. This pest management assessment does not address human health effects of pesticide exposure, which will be analyzed in depth in the final report of the pilot project. It complements the air monitoring findings by focusing on ways to reduce pesticide risk, describing:

- Local use patterns of fumigants and organophosphate (OP) insecticides, which were detected often in Parlier air samples;
- Current pest management needs and practices in the seven major crops grown in the project area - grapes, nectarines, peaches, plums, almonds, tangerines, and oranges;
- Alternative, reduced-risk practices implemented by some growers in the project area; and
- Current research and outreach needs, as well as partnership and regulatory opportunities to support growers who voluntarily adopt reduced-risk practices.

Most fumigant applications in the project area are pre-plant soil treatments to kill nematodes, soilborne plant pathogens, weed seeds, and subterranean insects in orchards and vineyards. None of the fumigants detected in air samples were present at concentrations exceeding the acute health screening level developed by DPR to signal a need for further evaluation. However, they are a regulatory concern because volatile organic compound (VOC) emissions from fumigant applications combine with nitrogen oxide emissions from other sources to form ground-level ozone. DPR has proposed new fumigant regulations to help reduce ozone levels in the San Joaquin Valley and other California air basins where ozone frequently exceeds air quality standards.

DPR's proposed fumigant regulations describe lower-emission application methods including those involving tarpaulins, post-fumigation water treatments, or drip irrigation. Growers can also reduce risks related to soil fumigants by substituting alternative pest management practices to suppress soil pests. The practicality and effectiveness of these practices is situation-specific; combining several is almost always necessary for efficacy. Soil pest management in the project area is particularly challenging. Its sandy to sandy-loam soils worsen nematode problems while limiting some alternatives to fumigation.

OP insecticides are toxic to a broad spectrum of arthropods, and their use is part of the conventional approach to insect pest management on all of the project area's major crops. When formulated as emulsifiable concentrates, OPs are a source of VOC emissions that contribute to ozone formation. Human exposure via ambient air is also a concern. In Parlier, the OP diazinon exceeded its DPR health screening level for acute exposure on one day during 2006 (one of 468 samples). It has been prioritized by DPR for risk assessment due in part to this demonstrated potential for exposure through ambient air.

DPR has participated in integrated pest management (IPM) initiatives that have identified and promoted reduced-risk practices and pest management systems for most pests of major crops in the project area. The University of California Statewide IPM Program defines IPM as "…an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment."

Biological and cultural pest management practices and reduced-risk insecticides can replace OPs in almost all instances for project area crops. However, reduced-risk insecticides are not completely risk-free. They may have mammalian toxicity of concern. Some are toxic to beneficial arthropods such as aquatic organisms, the natural enemies of pests, and honeybees, or have the potential to pollute surface and ground water. Overdependence on them may create resistant pests. They should be used carefully to avoid the familiar scenario of dealing with over-reliance on problem pesticides by shifting to dependence on alternatives that are later found to pose problems of their own.

DPR takes a precautionary approach to protect public health and the environment by promoting and supporting the development and voluntary adoption of reduced-risk pest management practices and IPM systems. For example, a 2004-08 DPR IPM project for peaches and nectarines in the Parlier area is focusing on reduced-risk alternatives to OPs and other broad-spectrum insecticides, and pesticide application technologies that increase efficiency and reduce environmental exposure. DPR has also funded research on the efficacy of reduced-risk insecticides that could be used in combination with mating disruption and biological control for IPM of vine mealybug, an invasive pest of grapes. In addition, DPR and the University of California Statewide IPM Program are developing a fumigant subcategory for the Qualified Applicator License and Certificate that should help ensure the use of appropriate fumigant application methods.

This assessment highlights a number of research needs for reduced-risk pest management in the project area: study of the economics and environmental benefits of reduced-risk pest management practices, further work on innovative pesticide application technologies, alternatives to pre-plant soil fumigation, and ways to manage pests for which no alternatives to fumigant or OP treatments are currently available.

Outreach priorities include guidance for pest management decision making based on observation of the crop, pest control adviser services that help growers adopt those practices, pesticide resistance management, ant bait systems, new pesticide application technologies, and decision making guidance for the application of reduced-risk practices.

New research and outreach partnerships between DPR and agricultural stakeholders could strengthen future initiatives to reduce pesticide risk. These partnerships may tap sources of funding earmarked for the protection of human health and the environment.

II. Background

The California Environmental Protection Agency (Cal/EPA) is committed to integrating environmental justice (EJ) into all its programs, policies, and actions. EJ is defined in statute as:

> The fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws and policies.

As part of Cal/EPA's Environmental Justice Action Plan, the Department of Pesticide Regulation (DPR) conducted a pilot project focusing on concentrations of pesticides in air in the low-income, predominantly Hispanic Fresno County community of Parlier (DPR 2005). DPR and the Air Resources Board collected samples of ambient air at three primary schools throughout the 2006 calendar year. DPR scientists are analyzing the air sampling data to determine whether the pesticides found in air pose a health concern, especially for children (Segawa, Wofford and Ando 2006). Preliminary analyses do not indicate specific pesticide exposures (and resulting risks) that require immediate regulatory action. However, the Department is initiating actions that could reduce and/or further evaluate the exposures.

Cal/EPA takes a "precautionary approach" to protection of public health and the environment. That term can be defined many ways. Cal/EPA has adopted a working definition for all its EJ pilot projects:

> "Precautionary approach means taking anticipatory action to protect public health or the environment if a reasonable threat of serious harm exists based upon the best available science and other relevant information, even if absolute and undisputed scientific evidence is not available to assess the exact nature and extent of risk."

This pest management assessment highlights opportunities for DPR to take precautionary action by strengthening its support for reduced-risk pest management. The assessment is complementary to the final EJ Pilot Project report.

The goal of the assessment is to study and describe agricultural pest management in the Parlier area, in support of the following objectives (Matteson and Wilhoit 2006):

- Describe the agricultural uses of fumigants and organophosphate insecticides found in air in the project area.
- Better inform the community about local pest management needs, conventional pest management practices, and reduced-risk alternatives.
- Identify research and outreach needs and potential partnerships for strengthening DPR assistance to Parlier area pest managers who are interested in voluntarily

adopting integrated pest management (IPM)[1] systems based on reduced-risk practices.

- Identify any regulatory barriers to reducing pesticide risk.

III. The Assessment Area and Its Crops

Parlier is a small city (about 1.6 square miles) located in the San Joaquin Valley (SJV) about 20 miles southeast of Fresno. This assessment covers the same area that the EJ Pilot Project air monitoring did: the 152-sq-mile area (97,281 acres) within an approximately five-mile radius of the Parlier city limits (Fig. 1). This area also contains the cities of Reedley and Selma, as well as the southern portion of Sanger, the northern end of Kingsburg, and some smaller communities such as Del Rey. These are all rural communities surrounded by agriculture. In 2006, 58 percent of the pilot project area was planted with vineyards and fruit and nut orchards, as well as some vegetables and nurseries (2006 California Pesticide Use Report (PUR) data; Segawa, Wofford and Ando 2006, Wilhoit 2005).

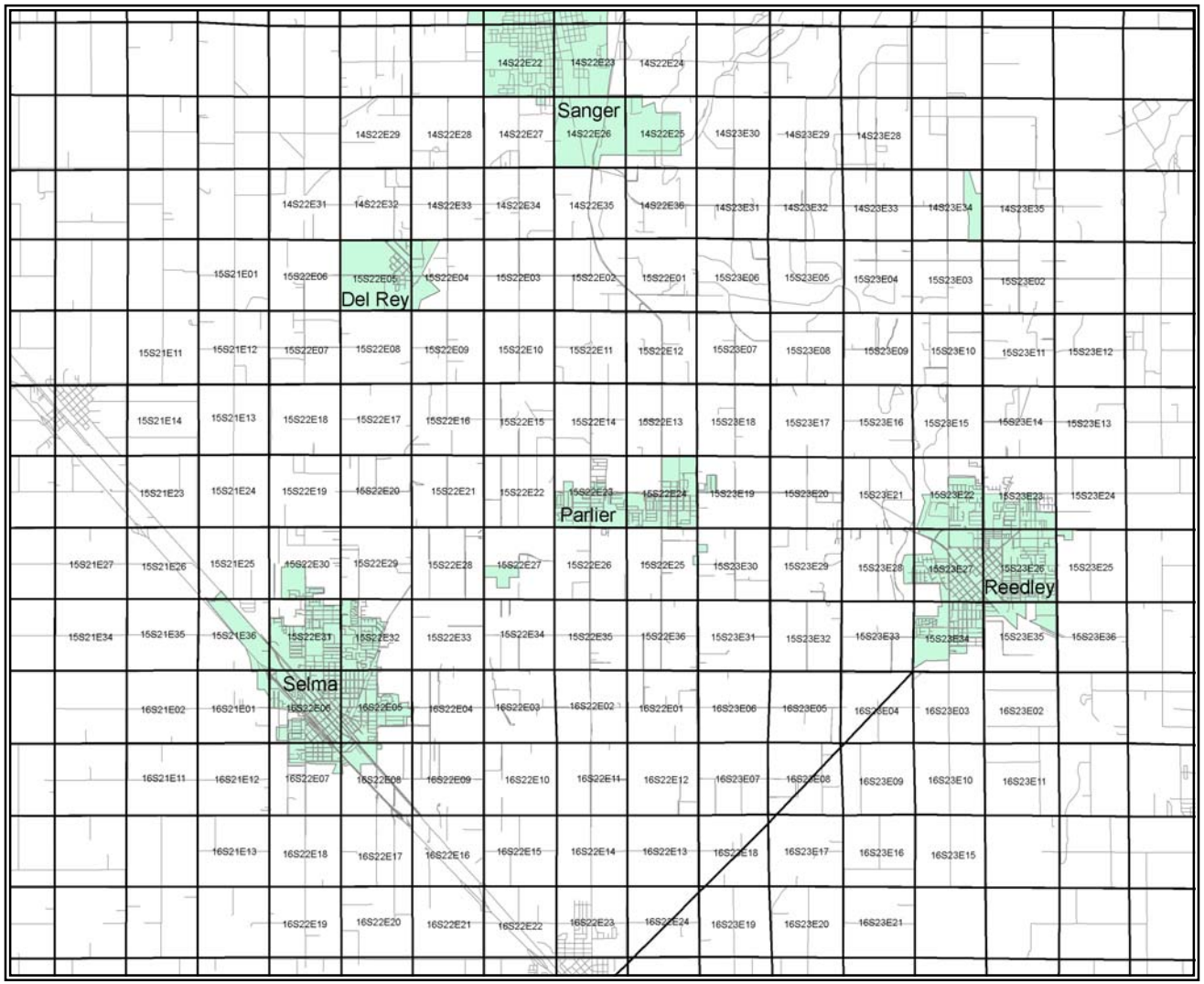
Table 1. Grower acreages, Parlier EJ Pilot Project area major crops 2006.

Crop	Number of Growers	Total Acres (Change 2001-06)	Growers With < 100 Acres (%)	Largest Grower (Acres)
GRAPE (Table/raisin)	404	21,220 (- 22%)	90	1,024
NECTARINE	193	10,136 (- 4%)	89	926
PEACH	219	9,152 (+ 4%)	89	551
PLUM	193	5,648 (+ 5%)	94	352
GRAPE (Wine)	65	2,734 (- 10%)	92	344
ALMOND	26	1,307 (+ 151%)	88	353
TANGERINE	18	1,193 (+3222%)	78	253
ORANGE	39	1,167 (+ 161%)	95	459

Source: California Pesticide Use Reports 2001-06, which pool table and raisin grape data and present wine grape data separately.

[1] The University of California Statewide IPM Program defines IPM as "…an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment." http://www.ipm.ucdavis.edu/WATER/U/ipm.html

Figure 1. Township, range, and sections used to define the agricultural boundary for the Parlier air monitoring study.



Seven major crops are considered in this pest management assessment: grapes, nectarines, peaches, plums, almonds, tangerines, and oranges. In 2006, these crops accounted for 93 percent of the 56,493 planted acres in the EJ Pilot Project area (2006 PUR data). Within the last five years, grape acreage has declined while citrus and almond acreages increased. Most growers farm less than 100 acres of a given crop, although there are some large holdings (Table 1). For the purposes of this assessment, the major crops will be consolidated into four categories: stone fruit (nectarines, peaches and plums), grapes, almond, and citrus (orange and tangerine).

IV. Priority Pesticides

DPR and the Air Resources Board (ARB) monitored for 40 pesticides in Parlier air, including fumigants, insecticides, herbicides, and fungicides. A total of 22 pesticides and pesticide breakdown products were detected (DPR 2007b). This assessment focuses on two groups of agricultural pesticides that were detected often in the air samples:

- Fumigants, including methyl isothiocyanate (MITC, a breakdown product of the soil fumigant metam-sodium and other chemically related pesticides), methyl bromide, and 1,3-dichloropropene (1,3-D); and
- Organophosphate (OP) insecticides. Chlorpyrifos, diazinon, phosmet, and the oxygen analogs (breakdown products) of chlorpyrifos, diazinon, and malathion were detected.

This assessment does not address human health effects of pesticide exposure. The final EJ Pilot Project report will contain an in-depth analysis of the Parlier air monitoring results and their significance (DPR 2006a and b, 2007a and b).

This assessment does explain which fumigants and OPs are used on the seven major crops in the pilot project area (Table 1), highlights those that were found in air, identifies the major crops and pests for which the fumigants and OPs are used, and describes alternative, reduced-risk pest management practices that are already being implemented by some local growers. Pesticide use is discussed in terms of pounds of active ingredient (AI), since that measurement can be related to pesticide concentrations detected in air and water.

Fumigant use in the EJ Pilot Project area[2]

Most of the fumigant applications in the project area are pre-plant soil treatments to kill nematodes, soilborne plant pathogens, weed seeds, and subterranean insects in orchards and vineyards. Several kinds of nematodes damage the roots of perennial crops, reducing

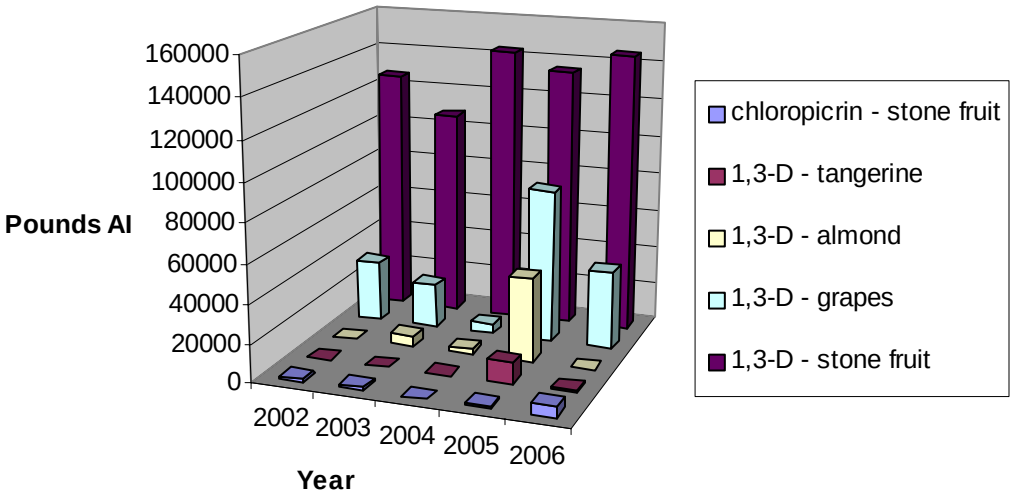
[2] Except for referenced items, pest management information in this report is from the University of California Statewide IPM Program's Pest Management Guidelines, www.ipm.ucdavis.edu/PMG, and the 2002 California Department of Food and Agriculture report *The Economic Importance of Organophosphates in California Agriculture* (Metcalfe et al. 2002). The authors are grateful to UC scientists J. Bi , W. Bentley, K. Giles, E. Grafton-Cardwell, M. McKenry, C. Pickel and N. Toscano, as well as R. Dufour of the National Center for Appropriate Technology, for their reviews of portions of the draft.

plant vigor and yield and increasing susceptibility to disease: ring nematode (*Mesocriconema xenoplax*), root knot nematode (*Meloidogyne* spp.), root lesion nematode (*Pratylenchus vulnus*), and citrus nematode (*Tylenchulus semipenetrans*). Dagger nematodes (*Xiphinema americanum* and *X. index*) transmit grapevine fan leaf virus and a strain of tomato ringspot virus that causes yellow bud mosaic in almonds and stone fruit. Soilborne diseases in the area include bacterial canker (*Pseudomonas syringae*) (Cao et al. 2006) and oak root fungus (*Armillarea melea*) that may kill trees and vines. Larvae of the tenlined June beetle (*Polyphilla decemlineata*) girdle orchard tree roots in localized infestations.

The conventional way to replace orchards and vineyards is to remove the old trees or vines, work the soil to the desired profile, fumigate the soil in the fall, and replant in spring. Soil fumigants are broad-spectrum biocides that protect young plants by eliminating harmful soil organisms and alleviating "replant disorder," the still-poorly understood failure of young plants to thrive for the first few years after replanting, even in the absence of known pests and pathogens.

Plant stunting caused by replant disorder has been associated with poor development and health of roots ≤ 1 mm diameter (McKenry 1999, Browne 2005, Browne et al. 2006, Browne, Connell and Schneider 2006). The new root system, particularly roots of similar parentage to the old tree or vine, is damaged by the soil ecosystem that evolved in association with its predecessor (McKenry, Buzo and Kaku 2006). Yields from unfumigated land are lower for about five years, after which trees and vines planted without soil fumigation "catch up." The long-term effects of the replant problem may be overestimated by focusing on the stunting of young trees. Trees and vines grow vigorously and are pruned and thinned to desired size and fruit density, reducing the effects of early growth differences (Trout et al. 2003).

Figure 2. Fumigant use for major crops in the EJ Pilot Project area, Parlier, 2002-06.



The predominant pre-plant soil fumigant for trees and vines within the project area is 1,3-D. From 2002-06, most of the 1,3-D was used for stone fruit (peaches, nectarines, plums) and grapes (Fig. 2). Chloropicrin, a fumigant that is exceptionally effective against pathogens, was also applied for those crops, but in much smaller amounts, often in combination with 1,3-D. According to PUR data, no pre-plant soil fumigants were applied for oranges within the project area, and their use for almonds and tangerines was relatively small in terms of pounds AI applied.

A total of 36,480 pounds of MITC-generating pesticides were applied within the project area in 2006. Sixteen applications were reported (DPR 2007b). It is likely that most of the MITC detected in Parlier originated outside the project boundaries.

The fumigant methyl bromide is being phased out under the Montreal Protocol, an international agreement to reduce emissions of chemicals that deplete atmospheric ozone.[3] A total of 11,700 pounds of methyl bromide was used to fumigate soil in the project area during 2006. PUR data indicate that about a third was used for nectarines and plums, and none for the five other major crops. In 2006, methyl bromide was also used to fumigate harvested commodities in storage approximately four miles southeast of Parlier (DPR 2006b).

Fumigants and air quality

The three pre-plant soil fumigants detected in Parlier air samples—1,3-D, MITC, and methyl bromide (chloropicrin was not monitored)—are a regulatory concern.
.
All three of those chemicals are considered to be 100 percent volatile organic compound (VOC). VOCs combine with emissions of nitrogen oxides from other sources to form ground-level ozone (Wilhoit et al. 2004). DPR has proposed new regulations for the reduction of fumigant emissions to help reduce ozone levels in the SJV and other California air basins where ozone often exceeds federal regulatory standards.[4]

1,3-D was detected in 34 percent, and methyl bromide in 66 percent, of 71 EJ Pilot Project air samples collected in Parlier in 2006 by ARB. MITC was detected in 84 percent of DPR's 468 air samples. None of the sample concentrations exceeded the acute health screening level (DPR 2007b).

Organophosphate insecticide use in the EJ Pilot Project area

According to 2002-06 PUR data, nine OP insecticides have been used on the project area's major crops within the last five years. Only four were applied to any major crop in a given year in an amount that exceeded 1,000 pounds of AI: chlorpyrifos, phosmet, diazinon, and methidathion. Fig. 3 illustrates the average number of pounds per year of those insecticides applied to major crops in the project area from 2002-06.

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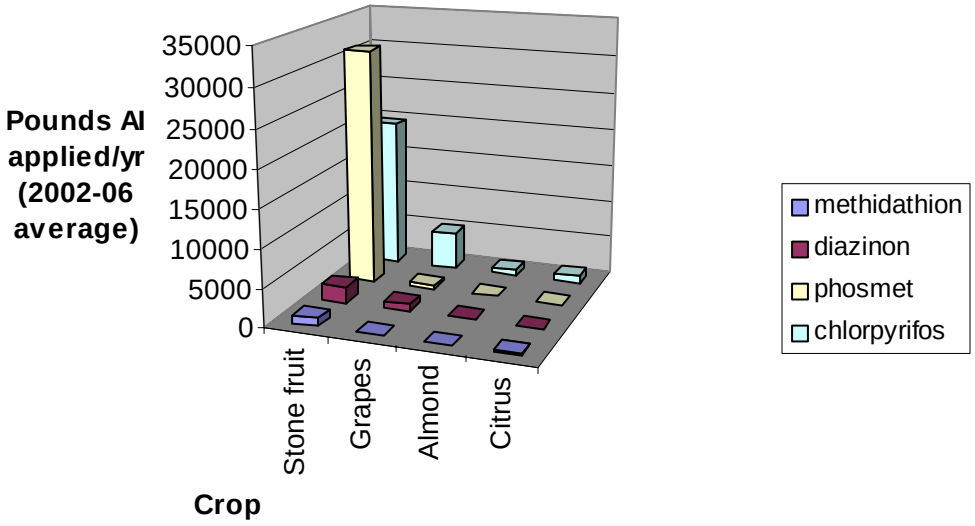
[3] (http://ozone.unep.org/Ratification_status/evolution_of_mp.shtml and http://ozone.unep.org/pdfs/Montreal-Protocol2000.pdf)
[4] http://www.cdpr.ca.gov/docs/emon/vocs/vocproj/voc_reg_issues.htm

Figure 3. Use of four OPs in major crops in the EJ Pilot Project area, Parlier, 2002-06.



Crop- and pest-specific details corresponding to this overview of OP use in the project area are provided in section IV of this report.

Organophosphate insecticides and air quality

Ozone - OPs formulated as emulsifiable concentrates (EC) are a source of VOC emissions. The project area is part of the San Joaquin Valley Ozone Nonattainment Area, where ozone often exceeds regulatory standards, especially during the May-October period. Reducing the contribution of pesticides to total VOC emissions is a state regulatory priority.

Ambient air - Five of the seven pesticides detected most often in Parlier air samples are OPs or their breakdown products.[5] Chlorpyrifos was found in 64 percent of the 468 air samples, and its oxygen analog in 22 percent; diazinon in 32 percent, and its oxygen analog in 19 percent; and phosmet in 19 percent (DPR 2007b). Although malathion was not detected, its oxygen analog was detected in five percent of the samples. Phosmet breakdown products and dimethoate and its breakdown products were not detected. Methidathion was not monitored.

Diazinon exceeded its DPR health screening level for acute exposure on one day (one of 468 samples).[6] It has been prioritized by DPR for initiation of risk assessment due in part

[5] The parent compound and its breakdown product often occur together in a sample.

[6] Enforceable state or federal health standards have not been established for most pesticides in air. For the EJ Pilot Project, DPR and Cal/EPA's Office of Environmental Health Hazard Assessment developed acute (1-day) and chronic (two-week) health screening levels for each pesticide. By itself, a screening level does not indicate the presence or absence of a hazard, but detections above a screening level point to a need for further evaluation.

to this demonstrated potential for exposure through ambient air.[7] Chlorpyrifos and phosmet did not exceed DPR health screening levels for acute exposure.

V. Reduced-risk Pesticides

Preference should be given to reduced-risk pesticides if crop monitoring indicates that a pesticide application is needed. There are several types of reduced-risk pesticides, including biopesticides and conventional (synthetic) reduced-risk pesticides. According to the U. S. Environmental Protection Agency (U.S. EPA), in general reduced-risk pesticides have relatively

- Low impact on human health,
- Lower toxicity to non-target organisms (birds, fish, plants),
- Low potential for groundwater contamination,
- Low use rates,
- Low pest resistance potential, and/or
- Compatibility with IPM practices.[8]

Biopesticides[9]

Biopesticides are derived from natural materials such as animals, plants, fungi, bacteria, and certain minerals. There are a number of biopesticide categories, including biochemicals such as pheromones that interfere with mating; scented plant extracts that are used to attract insects to traps; microbial pesticides - products with a microorganism (e.g., a bacterium, fungus, virus, or protozoan) as the AI; and plant-incorporated protectants such as toxin from the bacterium *Bacillus thuringiensis* (Bt) that is contained in some genetically modified corn cultivars. Subspecies and strains of Bt are the most widely used microbial pesticides. Each Bt strain specifically kills one or a few related species of insect larvae. California growers often apply Bt products to control moth larvae that can damage crops.

Conventional reduced-risk pesticides

Conventional reduced-risk pesticides are synthetic chemicals that directly kill or inactivate pests, or influence their behavior. U.S. EPA has listed chemicals that have received reduced-risk and/or OP alternative status.[10] The list includes insect growth regulators (IGRs, chemicals that prevent normal development) and a number of other chemicals that, along with biopesticides, are being used by California growers as alternatives to OPs.

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[7] http://www.cdpr.ca.gov/docs/risk/final_notice.pdf
[8] http://www.epa.gov/opprd001/workplan/reducedrisk.html
[9] http://www.epa.gov/pesticides/biopesticides/whatarebiopesticides.htm .
[10] http://www.epa.gov/opprd001/workplan/completionsportrait.pdf

Concerns regarding reduced-risk pesticides

The use of reduced-risk pesticides is likely to increase significantly. They are not, however, entirely risk-free. Some have mammalian toxicity of concern, although they are less toxic than many broad-spectrum pesticides. Some are toxic to beneficial arthropods, including aquatic invertebrates, or have the potential to pollute surface and ground water. Overdependence on them may create pesticide resistance. They should be used carefully to avoid the familiar scenario of dealing with over-reliance on problem pesticides by shifting to dependence on alternatives that are later found to pose problems of their own.

Toxicity to beneficial arthropods - Many reduced-risk pesticides, while being less toxic to humans and some other non-target species, can harm beneficial arthropods such as aquatic organisms and the insect predators and parasitoids of pests in orchards and vineyards.[11] These chemicals must be used judiciously to make sure they do not reach surface or ground waters, and to avoid causing outbreaks of secondary pests because of failures in natural control. For example, the IGRs buprofezin and pyriproxyfen are toxic to ladybird beetles. This can be a problem in crops where ladybird beetles help keep important pests under control, such as in grapes, plums, and citrus (Grafton-Cardwell and Reagan 2004).

Neonicotinoid insecticides are systemic, meaning that they are absorbed by the crop and travel throughout the plant. They can be found in pollen and nectar from flowers and extrafloral nectaries (Johnson 2007), as well as in the sucking insects that are the targets of the treatments. These are important food sources for the natural enemies of pests. Neonicotinoid insecticides are also toxic to insects on contact. For example, they contribute to outbreaks of cottony cushion scale in citrus by killing their principal predator, the Vedalia ladybird beetle, directly as well as via residues in the scales.[12]

The U.S. EPA has found some neonicotinoid chemicals to be highly toxic to bees. There has been much speculation about imidacloprid as a possible cause of severe honeybee colony losses (Johnson 2007). Sunflower seed treatment with imidacloprid was suspended in France in 1999 because of potential effects on pollinators. Many semi-field and field studies indicate, however, that imidacloprid seed treatments pose negligible risk to pollinators (Maus, Curé and Schmuck 2003). Residues in pollen and nectar are not acutely lethal. Some studies found that low concentrations may produce chronic toxicity (Suchail, Guez and Belzunces 2001) or effects that impair bees' navigational and foraging abilities (Decourtye et al. 2004a and b). It is not yet clear what role, if any, neonicotinoid insecticides play in the honeybee "colony collapse disorder" that is currently harming beekeeping in the United States. A pathogen called Israel acute

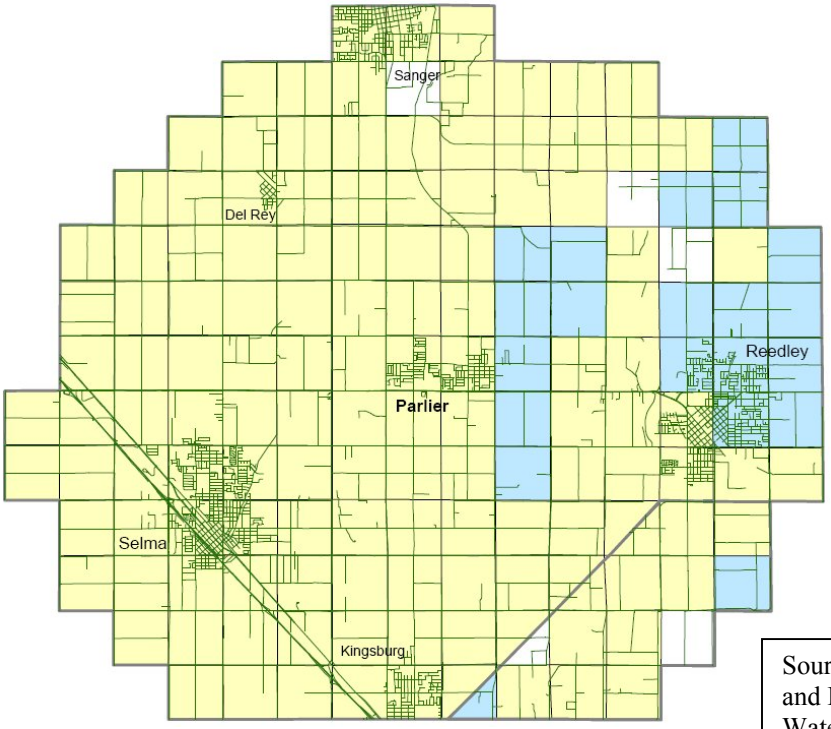
[11] UC IPM Pest Management Guidelines provide crop-specific guidance about the relative toxicities of insecticides and miticides to honeybees and the natural enemies of pests, and how to time pesticide applications to minimize disruption of natural control; e.g. for plum see http://www.ipm.ucdavis.edu/PMG/r611900411.html for relative pesticide toxicities and http://www.ipm.ucdavis.edu/PMG/r611900311.html for relative impact of the timing of applications on natural enemies.

[12] http://www.ipm.ucdavis.edu/PMG/r107301611.html

paralysis virus has been associated with affected hives, but it is possible that the syndrome is caused by a combination of stress factors (Stokstad 2007).

Potential water quality risks - Almost the entire pilot project zone has been designated by DPR as ground water protection area because it is vulnerable to pesticide contamination from leaching (coarse soils) or runoff (hardpan soils) (Fig. 4).[13] Neonicotinoid insecticides are relatively persistent, water soluble, and mobile in soil. Imidacloprid is on DPR's Groundwater Protection List of pesticides that have the potential to pollute ground water, and dinotefuran and thiamethoxam are proposed for inclusion on the list.[14] Since runoff is one of the ways pesticides reach ground water, pesticides on this list also have the potential to pollute surface water. Given the shallow water table and the sandy or hardpan soils in the project area, these pesticides should be used with appropriate irrigation management and other site-specific precautions to prevent them from leaving the application area through percolation or runoff.

Figure 4. EJ Pilot Project study area ground water protection areas: leaching (yellow) and runoff areas (blue).



Source: Joe Marade and DPR Ground Water Program 2007

[13] DPR, February 2007, *How Pesticides are Regulated to Protect Ground Water* http://www.cdpr.ca.gov/docs/gwp/gwregsinfo0702.pdf

[14] California Code of Regulations Title 3, section 6800(b). The list was established pursuant to Food and Agricultural Code section 13145(d).

Resistance - California pest management specialists are concerned that the usefulness of widely- and repeatedly-used reduced-risk insecticides could be cut short by pests developing resistance to them. For example, citrus entomologists expect that over-reliance on the IGR pyriproxyfen for California red scale control will result in the scales becoming resistant (Morse, Luck, and Grafton-Cardwell 2007). There is also concern about the potential for development of resistance to neonicotinoid insecticides (Zalom, Toscano and Byrne 2005). Four of these chemicals are registered for use on major crops in the project area: imidacloprid, thiamethoxam, acetamiprid, and dinotefuran. Since all neonicotinoid insecticides share a common mode of action, it is possible for the development of resistance to one of them to confer resistance to others without prior exposure. This phenomenon is called cross-resistance (Rauch and Nauen 2003, Mota-Sanchez et al. 2006, Alyokhin et al. 2007). Cross-resistance patterns appear to depend in part on the ecological and cropping situation (Prabhaker et al. 2005).

As of August 2007, one California pest appears to have developed resistance to neonicotinoid insecticides. Greenhouse whiteflies (*Trialeurodes vaporariorum*) attack many of the crops that are grown intensively year-round in the Oxnard/Ventura area, which include strawberry, pepper, tomato, celery, cucumber, lettuce, cut flowers, and citrus. Imidacloprid was available through Section 18 emergency exemption from registration to control the whitefly on some of those crops in the mid-1990s, and in 1999 to control it on strawberries. Imidacloprid has been applied extensively to strawberries since then. Thiamethoxam and acetamiprid were registered in 2002, and dinotefuran in 2005, for many local crops. Bioassays indicate that whiteflies collected from Oxnard/Ventura commercial strawberry crops in 2004/05 could no longer be controlled effectively by imidacloprid, thiamethoxam, acetamiprid, or dinotefuran at maximum label rates (Bi and Toscano 2007).

To retain reduced-risk pesticides as effective and reliable pest management tools, growers should use them in a way that minimizes selection pressure that could lead to the development of resistance. Tactics useful in a resistance management program in orchards and vineyards might include: crop monitoring and the use of treatment thresholds to avoid unnecessary pesticide applications; manipulating the timing, formulations, and/or number of applications of AIs that have a common mode of action; and rotation of AIs with different modes of action. (OPs or other broad-spectrum materials may be needed for some rotations.) Coordination with neighboring growers, across crops where applicable, can reduce population buildup of resistant insects at the community or regional level (Williams, Dennehy and Palumbo 1998, Nauen and Denholm 2005, Dively 2006).

IV. Alternative pest management practices for fumigant and OP risk reduction

To reduce risks associated with fumigants and OPs, alternative practices that reduce exposure (including the use, when appropriate, of reduced-risk pesticides) should be incorporated into sustainable pest management systems. IPM systems have been developed for California crops to meet that need (Getz and Warner 2006, Warner 2006).

Pest managers who practice IPM use reduced-risk practices according to these principles (Pickel et al. 2004, Bentley et al. 2006):

- Plant crop varieties that are resistant or tolerant to pests and diseases.
- Use cropping practices that help prevent pest and disease problems. Examples include: crop rotation; planting orchard trees on mounds and managing irrigation to suppress diseases such as *Phytophthora* root and crown rots, which are typical of chronically damp soil; and crop sanitation to remove pests or disease inoculum from the field.
- Monitor populations of pest and beneficial insects and mites.
- Tolerate low pest populations and take action only if the relative numbers of a pest and its natural enemies reach a "threshold" value indicating that pest numbers are likely to reach economically damaging levels. Monitoring and threshold decision making guidelines exist for most pests. The "threshold" for quarantine pests or pests that do direct, serious damage to the marketed commodity may be detection in the crop during monitoring.
- Protect natural enemies of pests by using cultural or biological pest control methods whenever possible. Examples of these methods are: mechanical trapping devices; the release of natural predators or parasitoids of pests (i.e., insects, mites, or nematodes that kill pests); and mating disruption chemicals (pheromones) and other biological pesticides, which mimic or are derived from natural materials.
- If it is necessary to use a synthetic pesticide, choose a reduced-risk pesticide whenever possible. Selectivity - the degree to which a pesticide is toxic only to the target pest species - is an important consideration. (OPs are an example of broad-spectrum insecticides, which are toxic to many kinds of arthropods.)
- Use innovative pesticide application technologies that can make treatments more efficient and cost-effective through better timing and/or targeting, or vary application rates according to need. This can reduce pesticide use and off-site movement.

<u>Alternatives to soil fumigation in orchards and vineyards</u>

Growers can reduce risks related to soil fumigants by using alternative pest management practices that suppress soil pests and counteract "replant disorder." Organic producers rely on these practices. Their practicality and effectiveness are situation-specific, depending on region, soil type, crop and cropping system, the history and pest and disease spectrum of an individual planting block, and surrounding habitat. The variable performance of some alternative practices is not well enough understood for them to be effective management tools (Chellemi et al. 2006). However, an IPM approach that combines several practices can be useful and is almost always necessary for efficacy. Decision making about the most effective treatment for a given piece of land is, therefore, challenging. Soil sampling for identifying problems, particularly nematode species and numbers, is essential when deciding steps for replanting a specific orchard (McKenry 2000, Duncan, McKenry and Scow 2003).

Below is a list of currently available soil pest management practices for orchard and vineyard managers who do not wish to rely on fumigation. Each has its limitations, and is not necessarily appropriate in all locations.

Fallowing and crop rotation - Fallowing, which means leaving fields without a crop or weeds for an extended period, and/or rotating the crop with nematode-suppressing plants leave soil pests and diseases without suitable hosts, causing soil-related problems to decline over time. Fallowing and crop rotation can be an expensive option for orchard and vineyard owners. Although perennial crops may be productive for decades, some are replanted often due to changing varietal trends and crop prices. A limitation of rotating major crops in the Parlier area is that the pest nematode species have broad host ranges. For example, citrus nematode also attacks grapes, as do the root knot, dagger, ring, and root lesion nematodes that can damage almond and stone fruit plantings.

Soil solarization - is used commercially on a small scale in the SJV for almond, stone fruit, and citrus. Moistened soil is covered with plastic sheeting and exposed to hot sun, for a summer as a pre-plant soil treatment or for one or two seasons around trees. Solar heat pasteurizes the soil, killing pests and weed seeds to a depth of 6 to 8 inches below the soil surface (Klunk, 2005). Solarization can not control nematodes, fungi, or other pests deep in the soil (Stapleton, Elmore and DeVay 2000). It is recommended by the University of California (UC) for managing *Verticillium* wilt disease in almonds and peaches. Additional benefits include conservation of soil moisture and reducing humidity in the crop canopy. Solarization is labor-intensive, however, and its effectiveness declines in soils with low water-holding capacity, like many of those around Parlier (Braun and Supkoff 1994).

Soil amendments including biofumigants - Certain organic materials such as manure, compost, and residues of *Brassica* crops have pesticidal activity when incorporated into soil. They enhance soil quality and increase the activity of soil organisms, which can indirectly improve the vigor and pest tolerance of trees and vines and suppress nematodes, insect pests and diseases (Braun and Supkoff 1994). Some organic additives release biotoxic compounds during their degradation in soil; if these chemicals are volatile, the soil amendments are sometimes referred to as “biofumigants” (Stapleton, Elmore and DeVay 2000, Roubtsova et al. 2007).

Good nutrition and irrigation management - keep the crop healthy and unstressed, reducing susceptibility to disease and increasing tolerance to pests and diseases.

Sanitation measures - Planting material should be certified nematode- and disease-free. Cleaning equipment before moving between planting areas and avoiding the re-use of tailwater help prevent the spread of soil pests.

Resistant rootstocks - Tolerance or resistance to diseases and nematode feeding are important rootstock qualities. Most almond and stone fruit orchards are planted with Nemaguard rootstock, which is resistant to all root knot nematode species in California. The nematode resistant grape rootstocks Freedom and Harmony are recommended for

very sandy soils such as many of those around Parlier (Halprin 2000, Hashim-Buckey 2007). Resistant citrus rootstocks are available for citrus nematode and several diseases, notably *Phytophthora* root rots (Verdejo-Lucas and McKenry 2004, UC ANR 2007). Researchers are developing new rootstocks that are useful for more problems or situations. Any given rootstock, however, will still have a limited breadth of resistance, may not be useful in all soil types, and can produce excessive or inadequate growth in certain situations (McKenry and Anwar 2006). Moreover, even pest-resistant rootstocks need protection until their roots become well-established (McKenry 1999).

Bionematicides - Nematicides derived from plant and microbial metabolites are likely to become increasingly available. Bionematicides may wash out of sandy soils quickly, however, requiring multiple applications, and their commercial-scale production can be a challenge (Beem 2007).

Microbial pesticides - Antagonistic microorganisms may be used to kill soil pests, prevent disease infection, or arrest disease development. Beneficial microbes tend to control specific pests or diseases, which can be a drawback with complex syndromes such as replant disorder. Sometimes, high levels of these agents do not persist long enough to protect plants adequately, so multiple applications are needed. Their performance is slower and more variable than that of fumigants (Braun and Supkoff 1994).

Non-fumigant synthetic pesticides - can be used to protect crops from soil-related problems. These pesticides generally lack active dispersal mechanisms and the broad-spectrum efficacy of fumigants. There are also concerns about the toxicity and environmental effects of some. The development of resistance by pests after frequent application is another limitation. Non-fumigant synthetic pesticides should be used in integrated pest management systems with provision for resistance management (Braun and Supkoff 1994, UC Davis 2006, Giboney 2007).

Soil pest management in the Parlier area is particularly challenging. Its sandy to sandy-loam soils worsen nematode problems while limiting some alternatives to soil fumigation, such as solarization and soil-applied nonfumigant pesticides. Avoiding "replant disorder" without fumigants in conventional commercial tree crops and grapes normally involves three to four years of fallow and/or crop rotation before replanting, depending on the crop and site-specific conditions (McKenry 1999, Halprin 2000, Trout et al. 2003). Growers continue to rely on soil fumigation because alternatives are perceived as too costly and not effective.

Reduced-risk application methods for soil fumigants

DPR has proposed regulations to reduce smog-producing emissions from field soil applications of fumigant pesticides.[15] The regulations focus on both limiting the total pounds of pesticide emissions and reducing the amount of fumigant emitted from each application. The proposed regulations define specific requirements for how May 1-

[15] http://www.cdpr.ca.gov/docs/emon/vocs/vocproj/voc_reg_issues.htm

October 31 field fumigations must be done in areas of the state where emissions reduction is needed, including the San Joaquin Valley.

Different methods of applying fumigants emit different amounts of VOCs. DPR has estimated the percentage of VOCs emitted for each fumigant and for each application method. The proposed regulations prohibit some high-emission methods, and set limits on others. Lower-emission application methods are typically those that are:

- Covered with tarpaulins,
- Covered with three or more post-fumigation water treatments, or
- Applied through drip irrigation.

Other ways of limiting emissions are also specified in the regulations, depending on which fumigant is used. They include reduced application rates, soil moisture requirements, injection depth specifications, soil compaction requirements, and a mandate for a tarpaulin repair response plan.

Alternatives to organophosphate insecticide applications in orchards and vineyards

The following summaries describe the degree to which alternatives to OPs are available and in use for major crops in the project area. Accompanying tables list the pests against which OPs are often applied, the damage those pests cause, conventional management practices, and reduced-risk alternatives.

An important element not mentioned in detail here is the relative cost of conventional and alternative pest management: the cost of integrated systems as well as of individual practices. In many cases—but not all—reduced-risk alternatives are more expensive. Thus financial incentives are an important consideration for promoting sustainable pest management, along with development of additional reduced-risk practices and technical support for their voluntary adoption by growers.

Grapes

SJV grapes are used for four products: fresh market fruit, raisins, wine, and juice concentrate. Consumer and export demand for unblemished, pest-free fresh fruit results in greater pesticide use in table grapes than is usual for the other three products. The California grape industry and UC Farm Advisers and IPM Advisers have participated in sustainability initiatives that have identified alternatives for the use of OPs (Table 2). From 2000-02, DPR funded a Wine Grape Pest Management Alliance Project for IPM outreach to growers, in partnership with the California Association of Winegrape Growers (CAWG).[16] The Positive Points System offered by the Central Coast Vineyard Team since 1998 (CCVT 2006) and the *Code of Sustainable Winegrowing Workbook* (Dlott et al. 2002) produced by the Wine Institute and CAWG in 2002 enable producers to measure their progress toward sustainable operations. California's first third-party certified sustainability label, the Lodi-Woodbridge Winegrape Commission's "Lodi Rules"[17] uses standards based on those tools. A Year-Round IPM Program for Wine and

[16] http://www.cdpr.ca.gov/docs/pestmgt/grants/alliance/01-02/01-0194C.pdf
[17] http://www.lodiwine.com/lodirules_home1.shtml

Raisin Grapes is available on the website of the UC Statewide IPM Program (UC IPM).[18] A year-round program for table grapes will be produced by the UC project Biologically Integrated Farming Systems (BIFS) for Table Grapes in the Southern San Joaquin Valley, which started demonstrating and promoting an environmentally friendly pest management system for table grapes in 2005.[19]

Table 2. Major pests for which OPs are often used, their damage, and reduced-risk management alternatives for San Joaquin Valley grapes.

Pest/damage/conventional management	**Reduced-risk alternatives**
Leafhoppers: grape leafhopper, *Erythroneura elegantula*, variegated leafhopper *E. variabilis* - Puncture leaf cells, causing stippling and defoliation; moldy droppings damage table grapes. Large populations at harvest annoy pickers and reduce their productivity. Some raisin and wine vineyards and most table grape vineyards require at least one application of a broad-spectrum insecticide such as the OP dimethoate.	Populations can be reduced by managing nutrition and irrigation to prevent overly vigorous vine growth. Narrow-range oil with insecticidal soap can be applied early in the season to reduce populations. Application of the neonicotinoid insecticides imidacloprid or acetamiprid, or the insect growth regulator (IGR) buprofezin will control leafhoppers with less harm to natural enemies than broad-spectrum insecticides cause.
Moths: omnivorous leafroller, *Platynota stultana*, grape leaffolder, *Desmia funeralis*, western grape leaf skeletonizer, *Harrisina brillians* - Feed on leaves, flowers, and developing berries, causing fruit injuries that promote rot. These are often treated with broad-spectrum chemicals including OPs, especially phosmet and diazinon.	Moth habitat can be reduced through weed management and burying unharvested grape clusters. Moths can be controlled with applications of cryolite, the IGR methoxyfenozide, spinosad, or the microbial insecticide *Bacillus thuringiensis*.
Thrips: western flower thrips, *Frankliniella occidentalis*, grape thrips, *Drepanothrips reuteri* - Feeding and oviposition spot and scar table grapes. Often treated with broad-spectrum insecticides such as the OP dimethoate.	To avoid migration into the vineyard early in the season, do not mow nearby alternate hosts. Spinosad or imidacloprid will control thrips.
Mealybugs: grape mealybug, *Pseudococcus maritimus*, vine mealybug, *Planococcus ficus* - the mealybugs, the honeydew they produce, and sooty mold growing on the honeydew contaminate fruit. Chlorpyrifos applied prior to bud break has been the standard mealybug	Delayed-dormant and/or summer treatment with buprofezin or drip-applied imidacloprid at bloom will control these pests, but are more expensive than chlorpyrifos.

[18] http://www.ipm.ucdavis.edu/PMG/C302/m302yi01.html
[19] http://news.ucanr.org/newsstorymain.cfm?story=657

treatment, and also eliminates black widow spiders that sometimes infest table grape bunches. Post-harvest and delayed-dormant applications of chlorpyrifos are part of current eradication and management programs for vine mealybug, which is an invasive pest. The OPs diazinon and dimethoate can be applied to grapes during the season for mealybugs.	
Ants: Native gray ant, *Formica aerata*, is the most common species in SJV vineyards - Interfere with biological control by tending and defending sucking pests that produce honeydew. Spot applications of chlorpyrifos made to the vine, stakes, and the surrounding soil control ants for eight or nine weeks (Tollerup et al. 2004).	Several new liquid sugar baits have come on the market, with borax, methoprene (an IGR), and imidacloprid AIs. Ways to deploy them in cost-effective ant bait systems for native gray ant are still under study.
Glassy-winged sharpshooter, *Homalodisca coagulata* - This large, leafhopper-like sucking pest does not harm grapevines with its feeding, but spreads lethal Pierce's disease, caused by the bacterium *Xylella fastidiosa*. Its detection in a vineyard triggers treatment. OPs were used initially to control this pest.	Imidacloprid and acetamiprid are being used to kill sharpshooters. Applications of kaolin clay will repel them.

Relatively little OP insecticide was applied to grapes in the SJV until the invasive vine mealybug (VMB) arrived in 1998 and became a pest management priority. Heading north, the mealybug reached Fresno County in 2000 and has been spreading within the project area. Tending of mealybugs by ants in flood-irrigated SJV vineyards has therefore become more of a problem as well (Metcalfe at al. 2002). Chlorpyrifos is widely applied to control both mealybugs and ants, and its use has increased correspondingly. Currently, growers are allowed to apply chlorpyrifos for either ants or VMB, but not both, in a single year.

Outreach to growers about alternatives to chlorpyrifos for VMB management and the development of additional reduced-risk options for control of mealybugs and ants are needed to reverse the current upswing in OP use in grapes. DPR is funding UC research on the efficacy of reduced-risk insecticides as part of a VMB IPM system based on mating disruption and biological control (see *Initiatives related to this assessment*, below).

Stone fruit (peaches, nectarines, plums)

Research and outreach by the California Tree Fruit Agreement (CTFA), UC Farm Advisers and IPM Advisers, a 1999-2002 DPR-funded stone fruit Pest Management

Alliance project[20] in partnership with CTFA, and DPR's current U. S. EPA-funded SJV peach and nectarine IPM project (described below) have made reduced-risk alternatives to OPs and other broad-spectrum pesticides available for managing damage from most stone fruit pests. The core of the reduced-risk pest management system is a dormant or delayed-dormant spray of oil and in-season use of pheromone mating disruption for managing Oriental fruit moth, a key pest. Fruit harvested after August 1 requires more protection to ensure blemish-free fresh market product and pest-free export shipments. Outreach materials such as the UC Year-Round Programs for IPM in peaches,[21] nectarines[22] and plums[23] and the *Seasonal Guide to Environmentally Responsible Pest Management Practices in Peaches and Nectarines* (Bentley et al. 2006) provide growers with detailed guidance for every stage of crop development.

Table 3. Major pests for which OPs are often used, their damage, and reduced-risk management alternatives for San Joaquin Valley stone fruit.

Pest/damage/conventional management	**Reduced-risk alternatives**
San Jose scale, *Quadraspidiotus perniciosus* - Feeding on limbs, twigs and fruit can reduce tree vigor, weaken or kill branches, and leave marks on fruit that render them unmarketable. Managed with a dormant application of oil. High populations are treated with oil and an OP (diazinon, chlorpyrifos, methidathion, phosmet) or other broad-spectrum insecticide.	Dormant oil application alone suppresses low- to medium-level infestations. The insect growth regulators (IGR) pyriproxyfen or buprofezin added to dormant spray oil or applied in the spring will control heavy infestations.
Oriental fruit moth, *Grapholita molesta* - feeds within, and damages, growing shoot tips and fruit of peaches and nectarines. Management relies on multiple in-season applications of OPs (diazinon, phosmet) or other broad-spectrum insecticides.	1) Mating disruption with pheromones is an effective control measure. 2) Well-timed applications of the IGR methoxyfenozide will control this pest. 3) The impact of *Macrocentrus ancilivorus*, a wasp that is a common parasitoid of Oriental fruit moth and peach twig borer larvae, can be increased by planting a small plot of sunflowers (0.3-0.5 acre) next to the orchard. The sunflower moth *Homoeosoma electellum* is a winter host that allows the wasps to survive and parasitize developing moths effectively in spring.

[20] http://www.cdpr.ca.gov/docs/pestmgt/grants/alliance/01-02/01-0191C.pdf
[21] http://www.ipm.ucdavis.edu/PMG/C602/m602yi01.html
[22] http://www.ipm.ucdavis.edu/PMG/C540/m540yi01.html
[23] http://www.ipm.ucdavis.edu/PMG/C611/m611yi01.html

Peach twig borer moth, *Anarsia lineatella* - feeds within, and damages, growing shoot tips and fruit. Controlled by a dormant application of oil mixed with an OP (diazinon, chlorpyrifos, methidathion, phosmet) or a pyrethroid insecticide. Recent twig borer tolerance to pyrethroids may be increasing reliance on OPs. In varieties harvested after August 1, an additional in-season application may be necessary.	1) Dormant oil sprays with the IGR diflubenzuron or spinosad, or bloom time treatments of the microbial insecticide *Bacillus thuringiensis,* spinosad, or the IGRs methoxyfenozide or diflubenzuron will control this pest. 2) Mating disruption with pheromones can help, but is not reliable as a stand-alone control practice. 3) Planting sunflower to increase orchard populations of the parasitoid *Macrocentrus ancilivorus* can improve natural control (see Oriental fruit moth above).
Other moths: Codling moth, *Cydia pomonella*, and citrus cutworm, *Xylomyges curialis*, on plums; fruit tree leafroller, *Archips argyrospila*, obliquebanded leafroller, *Choristoneura rosaceana*, and omnivorous leafroller, *Platynota stultana* - Feed on foliage, blossoms, and fruit, making fruit unmarketable. Historically controlled by dormant or in-season applications of broad-spectrum insecticides applied for other pests, including diazinon, chlorpyrifos, methidathion and phosmet.	Leafrollers can be managed with an oil spray during the dormant season, supplemented by spinosad or diflubenzuron then or at petal fall. Moths can also be treated in-season with well-timed applications of *Bacillus thuringiensis* and methoxyfenozide.
Aphids: Leaf curl plum aphid *Brachycaudus helichrysi* and mealy plum aphid, *Hyalopterus pruni* - Overwintering eggs are killed by adding a broad-spectrum insecticide such as phosmet or diazinon to a dormant or delayed-dormant spray. Diazinon is sometimes used in-season as well.	Aphids can be controlled by adding the neonicotinoid insecticides thiamethoxam or imidacloprid to a delayed-dormant spray. Those chemicals or horticultural or neem oils can also be applied in-season.
Katydids: angularwinged katydid, *Microcentrum retinerve*, forktailed bush katydid, *Scudderia furcata* - Historically, katydids have been a sporadic problem usually prevented by OPs applied for other pests. Now that growers are switching to more selective pesticides, katydid infestations have become chronic. High numbers are often treated with an OP such as phosmet at a low rate.	Diflubenzuron or spinosad are effective providing treatments are properly timed.

Citrus (oranges, tangerines)

Ever since the 1888 importation of the Vedalia ladybird beetle wiped out a devastating cottony cushion scale outbreak in California citrus, the industry has tried to maintain a biologically-based citrus pest management system, with fluctuating success (Luck, 2007). The key to this approach is to augment and protect predators and parasitoids that normally keep pests under control. This is done by minimizing the use of broad-spectrum pesticides and by controlling dust and ants that can interfere with natural pest control.

During the 1990s, UC scientists worked with pest control advisers (PCAs) to develop a model program for the SJV. It combined intensive monitoring, intervention thresholds, management of red scale with mass releases of insectary-raised parasitoids, and the application of selective insecticides. Some of those selective pesticides are among the current recommendations, which now also include spinosad and neonicotinoid and IGR products (Table 4). The biologically-based system produced equal or better fruit quality and economic returns compared with the conventional broad-spectrum pesticide-based program. Adoption peaked in 1997, with participation by about 30 percent of growers (Morse, Luck, and Grafton-Cardwell 2007). A DPR-funded Southern San Joaquin Valley Citrus Pest Management Alliance[24] supported further IPM outreach to growers in 2001-02 in partnership with the Citrus Research Board and other stakeholders. A UC Year-Round IPM Program[25] provides guidance for every stage of the crop.

Table 4. Major pests for which OPs are often used, their damage, and reduced-risk management alternatives for San Joaquin Valley citrus.

Pest/damage/conventional management	Reduced-risk management alternatives
Citrus thrips, *Scitothrips citri* – Thrips scar the top of young fruit. Growers relied on OP and carbamate insecticides until resistance reduced their efficacy. Some have switched to pyrethroids and other broad-spectrum materials, but most use spinosad because of its effectiveness.	Populations vary greatly from year to year. If treatment is needed, sabadilla, spinosad, or abamectin are recommended to avoid harm to natural enemies.
California red scale, *Aonidiella aurantii* - Sucks juices from all aerial parts of the tree, reducing fruit quality and sometimes causing leaf yellowing and drop, twig and limb dieback, and even tree death. Heavy use of OPs and carbamates since the 1950s caused resistance in the 1990s. Most growers have switched to the insect growth regulator (IGR) pyriproxyfen.	1) Inundative releases of the wasp parasitoid *Aphytis melinus* can control the scale, providing broad-spectrum pesticides and ants do not interfere. Pyriproxifen is sometimes used to reduce scale numbers before parasitoid release. 2) Narrow-range oil (440) is least damaging to natural enemies. 3) Pyriproxyfen or another IGR, buprofezin, are effective and not damaging

[24] http://www.cdpr.ca.gov/docs/pestmgt/grants/alliance/01-02/01-0193C.pdf
[25] http://www.ipm.ucdavis.edu/PMG/C107/m107yi01.html

	to most natural enemies, except ladybird beetles needed for cottony cushion scale control.
Cottony cushion scale, *Icerya purchasi* - Sucks sap from leaves, twigs, and branches, reducing tree vigor, and can cause leaf drop, dieback, sooty mold and yield loss. If this pest escapes biological control, most growers apply broad-spectrum OPs and carbamates.	1) Predatory Vedalia ladybird beetles (*Rodolia cardinalis*) keep this scale under control unless the beetles are harmed by pesticides. 2) Buprofezin is recommended for this pest even though it kills Vedalia beetle pupae for 2-3 months.
Fork-tailed bush katydid, *Scudderia furcata* - Damages young fruit at petal fall, and eats holes in leaves and young fruit. Many growers apply low rates of chlorpyrifos or pyrethroid insecticides tank mixed with a spinosad treatment for citrus thrips.	Cryolite or the IGR diflubenzuron are effective, providing treatments are properly timed.
Citricola scale, *Coccus pseudomagnoliarum* - A severe infestation may reduce tree vigor, kill twigs, and reduce flowering and fruit set. Excreted honeydew and sooty mold accumulate on leaves and fruit, interfering with photosynthesis and reducing fruit quality. Yield loss can be significant. Growers use chlorpyrifos every 1-5 years (depending on the rate and the level of chlorpyrifos resistance in the scale population).	Light to moderate infestations can be controlled with narrow range oil or buprofezin. There is no comparably cost-effective alternative to chlorpyrifos for control of moderate to heavy infestations under SJV conditions. The neonicotinoid insecticides imidacloprid and acetamiprid are moderately effective, suppressing scale populations below threshold for one year. Neonicotinoids, however, are toxic to most natural enemies.
Ants: southern fire ant, *Solenopsis xyloni* and native gray ant, *Formica aerata* - Tend and defend honeydew-producing insect pests (notably scales), interfering with biological control. Fire ants feed on the twigs and bark of young trees, sometimes girdling them. Spot applications of chlorpyrifos on the lower trunk and around the base of the tree are the standard control measure. Some growers spray chlorpyrifos repeatedly beneath the trunk wrap of young trees over a 1-2 year period (E. Grafton-Cardwell, Director, UC Lindcove Citrus Research and Extension Center, personal communication, 1/11/07).	1) Preventive measures include: planting, irrigation, and cultivation practices that discourage ants; prevention or control of *Phytophthora* gumming; and applying sticky barriers on trunks and trunk wraps. Cultivation may, however, create dust that disrupts biological control of other pests. 2) Fire ants can be controlled with bait products made of corn cob grit and soy oil plus the IGR AIs abamectin or pyriproxyfen. Several new liquid sugar baits have come on the market, with borax, methoprene (an IGR), and imidacloprid AIs. Ways to deploy them in cost-effective ant bait systems for the native gray ant are still under study.

Biologically-based citrus pest management in the SJV is currently threatened by an upsurge in secondary pests, new pesticides that can disrupt biological control, and the introduction of new pest species that must be integrated into an evolving pest management system. Once pest resistance to OPs and carbamate insecticides prompted growers to switch to pyriproxyfen for red scale and spinosad for citrus thrips, the greater selectivity of those newer products released katydid and citricola scale from control. (They had been easily controlled by the OP treatments applied for other pests.) Growers are increasingly using IGRs and neonicotinoid insecticides, which can disrupt natural pest control in the orchard by harming natural enemies. The resulting outbreaks of secondary pests are contributing to an escalation in the use of OPs and other broad-spectrum insecticides that is worsened by treatments to suppress invasive insects such as the glassy-winged sharpshooter, citrus peelminer, citrus leafminer, and Diaprepes root weevil (Morse, Luck, and Grafton-Cardwell 2007; E. Grafton-Cardwell, Director, UC Lindcove Citrus Research and Extension Center, personal communication, 9/18/07).

Ants and citricola scale pose particularly intractable problems and are increasing chlorpyrifos use in SJV citrus. Making ant bait systems more cost-effective and motivating growers to use them would help reduce chlorpyrifos use and environmental exposure. Chlorpyrifos is currently the only insecticide that provides good control of moderate to high infestations of citricola scale. UC researchers believe, however, that they have found scale populations showing resistance (UC Citrus Entomology Laboratory 2007). Application rates are likely to increase and the usefulness of chlorpyrifos against this pest may end. It is urgent that some effective, reduced-risk alternative be found.

Almonds

Research and development by the Almond Board of California, UC Farm Advisers and IPM Advisers, the Biologically Integrated Orchard Systems (BIOS) project of the Community Alliance with Family Farmers, and the DPR-funded 1998-2002 multi-stakeholder Almond Pest Management Alliance[26] have made reduced-risk alternatives to OPs and other broad-spectrum pesticides available for managing major pests of almonds in the SJV (Table 5). The backbone of the program is winter orchard sanitation and prompt harvest followed by a dormant spray of oil, supplemented if necessary with reduced-risk pesticides. Outreach materials such as the UC Year-Round Program for IPM in Almonds[27] and the *Seasonal Guide to Environmentally Responsible Pest Management Practices in Almonds*[28] (Pickel et al. 2004) provide growers with detailed guidance for every stage of the crop.

[26] http://www.cdpr.ca.gov/docs/pestmgt/grants/alliance/01-02/01-0197C.pdf
[27] http://www.ipm.ucdavis.edu/PMG/C003/m003yi01.html
[28] http://www.ipm.ucdavis.edu/IPMPROJECT/seasonalguidealmonds.html

Table 5. Major pests for which OPs are often used, their damage, and reduced-risk management alternatives for San Joaquin Valley almonds.

Pest/damage/conventional management	**Reduced-risk alternatives**
Navel orangeworm, *Ameyelois transitella* - This moth overwinters in mummies (unharvested nuts). Larvae eat nuts after hull split, making them unmarketable. Dormant sprays do not control this pest. Broad-spectrum pesticides including phosmet and chlorpyrifos provide marginal control.	Removal and destruction of mummies by February and prompt harvest can prevent damage without the use of broad-spectrum insecticides.
Peach twig borer, *Anarsia lineatela* - Larvae of this moth damage rapidly growing shoots, as well as nuts after hull split. OPs and other broad-spectrum pesticides are applied in dormant sprays or in-season to reduce populations of this pest. Resistance to diazinon has developed in the SJV, and also to pyrethroids in some growing areas (Metcalfe et al. 2002).	1) Mating disruption with pheromones can control this pest, but results in almonds are variable and the cost is too high for wide adoption (Metcalfe et al. 2002). 2) Peach twig borer can be managed with the microbial pesticide *Bacillus thuringiensis,* spinosad, or the insect growth regulators (IGR) diflubenzuron, methoxyfenozide, or tebufenozide.
San Jose Scale, *Quadraspidiotus perniciosus* – Scales suck plant juices from the inner bark of twigs and branches. Severe infestations will kill fruitwood and reduce production. Broad-spectrum insecticides including OPs are added to dormant sprays to control this pest.	Dormant oil application alone suppresses low to medium level infestations. High rates of oil or adding the IGRs pyriproxifen or buprofezin to a lower rate of dormant spray oil will control heavy infestations.
Ants: Pavement ant, *Tetrameorium caespitum* and southern fire ant, *Solenopsis xyloni* – Ants burrow in nuts on the ground after trees are shaken at harvest. Spot sprays of chlorpyrifos are used to control them.	Remove nuts from the orchard floor quickly. Ant baits containing pyriproxyfen or abamectin are available for use before harvest to reduce potentially damaging populations of these species.
Tenlined June beetle, *Polyphylla decemlineata* - Grubs feed on the roots of trees, causing severe injury and death. Infestations spread slowly outward from an affected group of trees. No chemical controls are currently registered in California for this beetle (Johnson et al. 2003). The only proven way to eliminate this pest is to remove the infested trees and one or two buffer trees in every direction, fumigate the soil, and replant.	None.

In 2006, high populations of leaffooted bug, *Leptoglossus clypealis*, triggered application of broad-spectrum pesticides, notably chlorpyrifos and phosmet, in Central Valley almond orchards. More selective insecticides are ineffective for controlling this pest. The bug damages young nuts by feeding on the nutmeats before the almond shell hardens. It is an infrequent problem usually kept under natural control by egg parasitoids. Treatment thresholds have not yet been developed; growers should monitor the crop and treat only if bugs are present (W. Bentley, UC IPM Entomologist, personal communication 9/25/07).

Reduced-risk insecticide application methods and equipment

Several recently developed technologies applicable to orchards and vineyards improve pesticide application efficiency and may enable applicators to reduce pesticide use by applying pesticides with more precision. These technologies generally decrease off-target application and/or improve the timing of sprays, allowing a reduced per-acre application rate or a reduction in the number of sprays needed. Innovative technology can reduce pesticide use from 15 to 80 percent.

Equipment and chemicals designed to improve non-fumigant pesticide application efficiency include:

- Specialized spray nozzles,
- Controlled droplet application (CDA),
- Adjuvants,
- Electrostatic spraying systems, and
- Positive shutoff valves that prevent leakage.

Variable-rate pesticide application technologies to improve the precision of applications include:

- Operator-controlled rate adjustment,
- Built-in application sensors (target-sensing sprayers),
- High-resolution field mapping of pests or disease (with or without geographic information systems [GIS] capability),
- Guidance and steering technology using a global positioning system (GPS) to control variable-rate pesticide application, and
- Remote sensing for precision pesticide application.

Newer spray nozzles and CDA systems allow the production of a narrow range of droplet sizes, simultaneously reducing the very fine droplets that are likely to move long distances and large droplets that might splash or drip from target surfaces. The addition of adjuvants to pesticide solutions can improve droplet size profiles as well. Adjuvants can also improve the distribution and adhesion of pesticides on target surfaces and reduce production of fine droplets by droplet recoil. In some cases, electrostatic spray systems can improve distribution of pesticides over target surfaces and reduce off-site movement.

Variable-rate application systems improve the precision and timing of pesticide application. For example, target-sensing sprayers with ultrasonic sensors are used in orchard cropping systems. They have multiple spray nozzles that can be activated

independently to target pesticide to the tree. The nozzles automatically shut off if sensors indicate that they are directed above, below, or between trees, or at the end of rows. Where the canopy is solid, pesticide savings from target sensing are less. A 15 to 45 percent reduction in pesticide use can be achieved in orchards using this technology, without loss of efficacy (Giles and Downey 2005). Similarly, herbicide application equipment with photometric sensors can be used in orchards, vineyards, and adjacent ditch banks and roadsides. Herbicide use reductions of 50 to 80 percent with this equipment have been documented (Brownhill 2006).

High-resolution field mapping can be combined in GIS systems with pest and disease monitoring data to help identify incipient pest problems. This allows earlier and more localized pest management interventions. GPS-based steering and sprayer guidance systems can provide detailed location information for crop monitoring and pesticide application, increasing the precision of applications.

Remote sensing is increasingly linked to GIS/GPS systems to guide agricultural field operations. These systems employ aerial or satellite photography of fields at a specific wavelength. Changes in the reflectance of light in comparison to a standard can indicate areas affected by pests or disease. The sensitivity of these systems may allow earlier and/or more localized pest management measures than does visual monitoring on the ground.

Many grape growers use remote sensing images as a vineyard monitoring tool, including for pest monitoring and pest management decision making (Johnson et al. 1996). Application of remote sensing technology for pest management in California tree crops is still at the experimental stage. DPR is funding research on remote sensing for monitoring mite populations in stone fruit (see *Stone fruit IPM and improved pesticide application technology*, below).

VII. DPR's Precautionary Approach

DPR takes a precautionary approach to protect public health and the environment by promoting and supporting the development and voluntary adoption of reduced-risk pest management practices and IPM systems. For example, a DPR stone fruit IPM project has been active in the Parlier area for several years, helping growers to evaluate and adopt effective alternatives to OPs and to increase pesticide application efficiency. DPR is also strengthening its regulatory support for reduced-risk fumigant application.

Information and contacts gained in the course of this assessment have highlighted further opportunities for DPR to help reduce pesticide risk while preserving growers' ability to manage pests. As described below, DPR has already seized some of those opportunities.

In addition, this assessment identifies further research, outreach, and new partnerships to broaden participation in risk reduction initiatives. Those concluding recommendations are meant for consideration by DPR and other stakeholders.

Stone fruit IPM and improved pesticide application technology

DPR is promoting IPM practices among peach and nectarine growers, particularly among 53 large-scale growers around Parlier. The goal of the project is to reduce the use of the pesticides diazinon, chlorpyrifos, phosmet, methidathion, and carbaryl by 20 percent through demonstration and promotion of reduced-risk practices and efficient pesticide application technology. This work is funded by a 2004-08 grant from U.S. EPA Region 9. Other project partners are the UC Statewide IPM Program (UC IPM), the California Tree Fruit Agreement, the U.S. Department of Agriculture (USDA)-Natural Resources Conservation Service (NRCS), Kings River Resource Conservation District, and the Coalition for Urban Rural Environmental Stewardship.

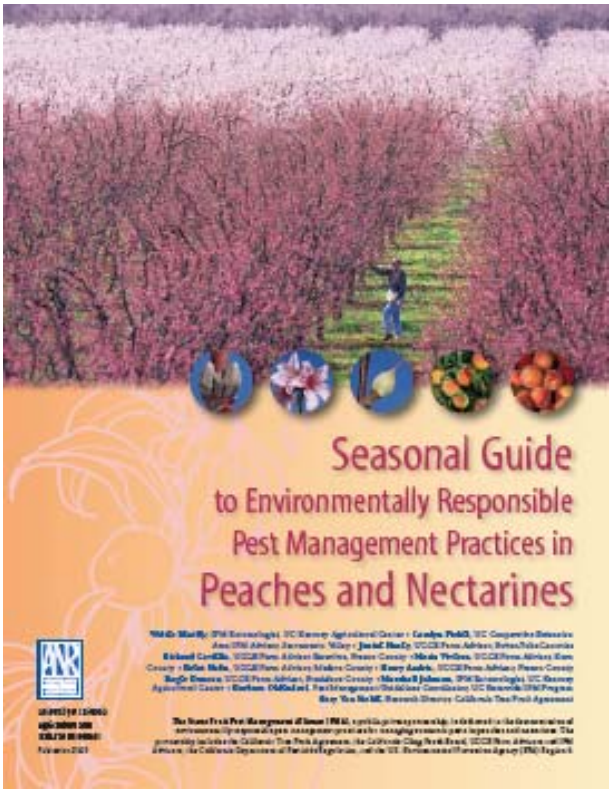
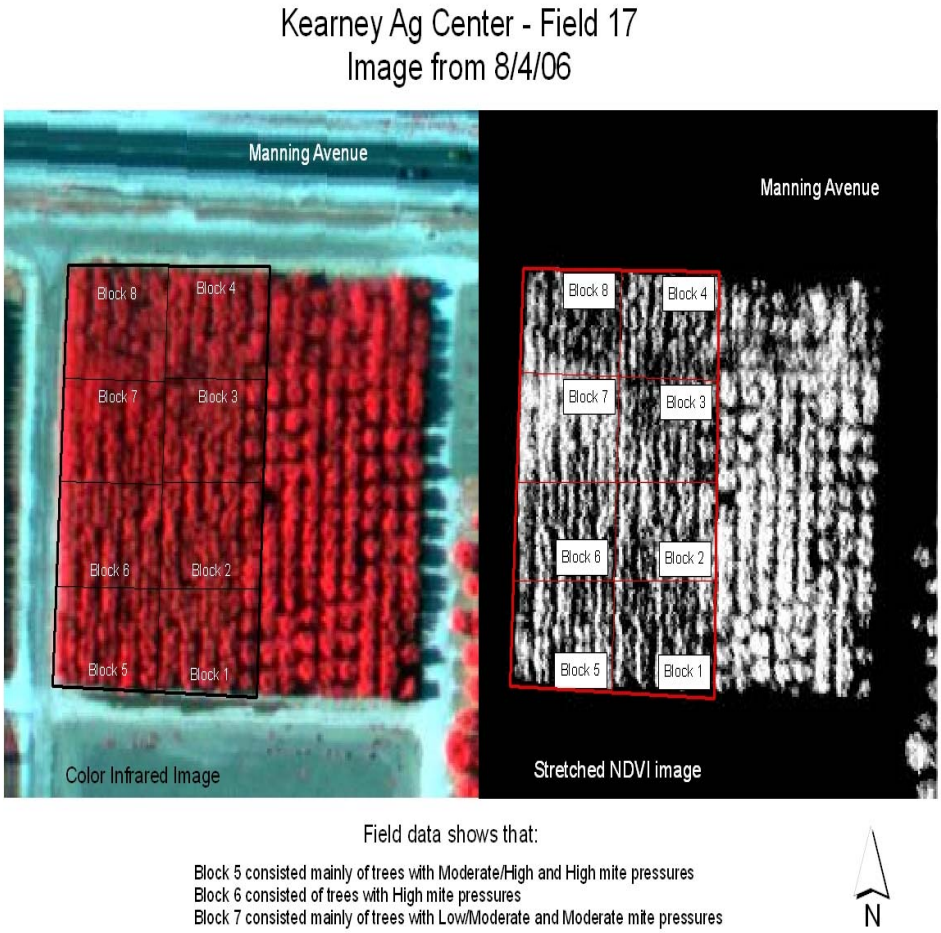


Figure 5. The project produced a seasonal IPM decision guide that complements UC IPM's Year-round IPM Programs for peaches and nectarines.

Remote sensing is being investigated by this project as a quick and potentially inexpensive way to monitor orchards for mites. A large-scale field study in nectarines is correlating manual mite counts, tree canopy reflectance data, and aerial images taken weekly from five 100-acre study sites in the Parlier area (Fig. 6). Preliminary results indicate that it may be possible to measure different levels of mite infestation in stone fruit orchards via remote sensing. Linking this technology to GIS/GPS-guided variable-rate application equipment could enable growers to adjust miticide dosage and to target applications within an orchard block on an as-needed basis, improving efficiency and reducing pesticide use.

Figure 6. Aerial image and corresponding mite population information from a nectarine orchard with a patchy infestation of webspinning spider mites, *Tetranychus* spp.



Regulatory support for reduced-risk pest management

DPR and UC IPM are developing a fumigant applicator subcategory for the Qualified Applicator License and Certificate. This should help ensure the use of appropriate application methods when fumigants are applied. Holders of a license or certificate in this category would be familiar with low-emission application methods and other mitigative measures to minimize VOC-related risks.

Initiatives related to this assessment

DPR has begun supporting two new reduced-risk pest management activities in response to opportunities highlighted by information and contacts gained in the course of this assessment.

Target-sensing sprayer collaboration with NRCS - USDA-NRCS provides technical and financial support to producers who wish to implement conservation practices on their land. As part of its U.S. EPA-funded stone fruit IPM project in the Parlier area, DPR helped NRCS initiate Environmental Quality Incentive Program (EQIP) co-payments to stone fruit growers who switch to target-sensing sprayers that increase efficiency (Fig. 7).

Figure 7. Target-sensing sprayer demonstration in a peach orchard, showing closed nozzles where there are no trees.[29]

The project purchased a target-sensing sprayer, demonstrated it during field days, and let growers try it out for free, providing they shared the pesticide application information recorded by the sprayer. NRCS subsequently broadened its program to include other SJV crops and additional types of target-sensing pesticide application equipment. In 2007, these EQIP contracts covered 3,250 acres belonging to 12 stone fruit and row crop growers (NRCS 2007).

Vine mealybug research - In May 2006 DPR awarded a two-year grant to Kent Daane and Walt Bentley of University of California Cooperative Extension for vine mealybug (VMB) pesticide studies in the Parlier area. Until recently, the recommended insecticide program for this invasive vineyard pest relied on the OP chlorpyrifos. The project includes laboratory and field efficacy testing of novel pesticides (oils, soaps, IGRs, neonicotinoids, botanical and/or bacterial insecticides) (Fig. 8). The study is evaluating

[29] The mention within this document of commercial products, their source, or their use is not to be construed as either an actual or implied endorsement. Mention is made of some representative products, but the Department of Pesticide Regulation does not recognize any product as superior to any other..

their cost-effectiveness as part of a VMB IPM system based on biological control and mating disruption with pheromones.

Figure 8. Novel pesticides are applied to vine mealybug cultured on miniature pumpkins, for evaluating pesticide toxicity and reproductive effects.

VIII. Recommendations for Further Action

Research

More economic and environmental data are required for comparing the cost-effectiveness and sustainability of different pest management practices. There is also need for ongoing development of innovative pesticide application technologies that reduce pesticide use. In addition, pest management scenarios are identified for which workable reduced-risk alternatives to soil fumigants or OPs are still needed.

Economic studies - Field budgets comparing the costs of conventional practices to those of alternative, reduced-risk pest management systems and practices need to be compiled and updated regularly. This information is essential for research guidance, effective outreach to growers, and the appropriate design of incentive programs to promote the adoption of improved practices.

Environmental benefits - of reduced-risk pest management systems and practices should be determined at least qualitatively. Quantitative comparison with conventional ones is

desirable, using field experiments or tools such as pesticide risk models and computerized pesticide application systems that measure amounts used. This information is being sought by commodity groups, food companies, "green" labeling organizations (certifiers of sustainable production practices), and government agencies, for deciding which growers qualify for commercial rewards or financial support for their conservation efforts.

Innovative pesticide application technology - continues to be a priority for research and development. For example, field surveillance systems based on remote sensing and GPS/GIS technology are in general use for measuring crop yield in different parts of a field and for need-based, variable-rate application of irrigation water and nutrients, but they are still under development in most crops as an efficient tool for pest and disease monitoring and decision making about pest management interventions.

Alternatives to pre-plant soil fumigation for trees and vines - All fumigants are subject to increased regulatory restrictions. Research is needed to increase the number of soil pest management tools and to integrate them into systems for managing replant disorder.

Scientists at the UC Kearney Agricultural Center have developed non-fumigant replant protocols for almond, stone fruit, and grapes that use improved rootstocks to avoid replant disorder while requiring only a one-year fallow. These protocols involve: 1) starving the existing soil ecosystem for a year by applying systemic herbicide to cut stumps, and waiting at least two months before stump removal; 2) soil ripping/scraping during the fallow period; 3) replanting with a substantial change in rootstock parentage; and 4) watering in small amounts of macro- and micronutrients just after planting. Many growers presently fallow for a year when they replant, so these options offer an alternative to soil fumigation with less economic loss. These protocols still need testing at a commercial scale, however. A similar protocol could be developed for walnuts and other perennial crops if rootstocks can be found that have the needed resistance to nematodes (McKenry 2007).

A number of innovative cultural and biological approaches are now under study and may increase growers' options in the future. Biological control using predators and parasites of nematodes and pathogens, perhaps in combination with pesticide treatments to protect plants from initial attack, appears promising but is still far from practical application (Becker 2007). Microbial inoculants (Halprin 2000) and novel biofumigants (Stapleton, Elmore and DeVay 2000) are also under investigation. Bionematicides are likely to become increasingly available. Further work is needed to screen natural products in order to weed out false claims, and to evaluate combinations of products offering multiple modes of action (Westerdahl 2007).

Cost-effective ant bait systems for citrus and grapes - are needed to control ants that harm trees or interfere with natural control of pests in citrus orchards and vineyards (Tollerup et al. 2004). Additional bait products and practical and cost-effective ways to deploy ant bait systems require research. Considerations include: ant biology and

foraging behavior; optimal bait station design and placement; effective use of broadcast formulations; required frequency of bait renewal; and timing for greatest efficacy (Klotz, Rust and Phillips 2004, Daane et al. 2006).

Citricola scale management in SJV citrus - It may be possible to mass produce citricola scale parasitoids using brown soft scale as an insectary host, and release the parasitoids during the growing season when resident parasitoid populations decline (Kapranas et. al. 2007). An international search might discover additional predators and parasitoids that could be established or released in the SJV to improve natural control. Alternative, reduced-risk pesticides are also a possibility. For example, oil is being used to manage citricola scale in Australia.[30]

Leaffooted bug and other "true bugs" - (Order Hemiptera) that occasionally invade orchards appear to have population cycles and to attack if host vegetation in the surrounding habitat becomes less attractive. Improved systems are needed for monitoring and management of these pests on a landscape scale, as well as reduced-risk control measures.

Tenlined June beetle - is a significant problem in orchards with sandy soil in the SJV, such as many of those around Parlier. Possible research avenues include: biological control by parasitic wasps, pathogens, or nematodes; tolerant or non-preferred rootstocks; orchard floor and irrigation management; trapping or mating disruption using pheromones; and insecticides applied to soil (Johnson et al. 2003, Johnson and Wang 2007).

Outreach to growers

Outreach to growers is a constant necessity for all crops because pest management needs and tools change, and for increasing adoption of reduced-risk practices. Citrus is highlighted below because implementing biologically-based pest management for citrus is particularly challenging now. Unlike for table grapes, peaches, and nectarines, there is currently no crop-specific multi-stakeholder outreach project for reduced-risk pest management in SJV citrus.

Programs in all crops should be designed keeping in mind that most growers in the project area are small-scale producers (Table 1). Wider adoption of some reduced-risk practices and systems (including crop monitoring and threshold use in place of calendar pesticide application) is likely to require strong outreach because they are knowledge- and management-intensive, and/or require changed grower attitudes and habits. Grower-to-grower outreach and mentoring for learning-by-doing might be a useful approach for adapting reduced-risk practices to fit the needs of individual operations, while lessening perceived risk (Getz and Warner 2006, Warner 2006).

[30] South Australian Research and Development Institute, http://www.sardi.sa.gov.au:82/pages/horticulture/citrus/hort_citp_groinsect.htm:sectID=302&tempID=98

Certain themes, while not necessarily new, are still important to emphasize in outreach programs:

Crop monitoring and the use of pesticide application thresholds - should generally replace routine calendar pesticide applications. These practices allow pest control interventions to be timed for greatest effectiveness, and help eliminate unnecessary treatments. UC scientists have developed reliable monitoring and threshold decision making guidelines for most significant California crop pests. In the case of quarantine pests, or when pest damage to the marketable commodity is direct and severe, crop monitoring allows the grower to act as soon as the pest is detected. Many growers are willing to switch to reduced-risk pesticides, but are not inclined to rely on monitoring and thresholds, even when their use is appropriate (Walt Bentley, UC IPM Entomologist, personal communication, 6/11/07). Outreach should emphasize that better timing of pest control interventions and fewer of them may increase marketable yield while reducing costs.

The importance of pest control adviser services - Guidance and advice from PCAs who practice IPM (see *New partnerships* below) are important for helping growers adopt new practices with confidence, especially replacing calendar sprays with crop monitoring and threshold use (Shennan et al. 2001, Brodt et al. 2006). Moreover, there is likely to be increasing need for PCA advice in complex pest management scenarios; in citrus, for example, or for choosing optimal alternatives to pre-plant soil fumigants.

Pesticide resistance management - has not lost any importance for PCA and grower education (see section V above). An important aspect is decision making about whether and when the use of OPs and other broad-spectrum materials is appropriate in pesticide rotations to prevent the development of resistance to reduced-risk pesticides. Good education will help ensure that broad-spectrum pesticides are used only if necessary.

Decision making about alternatives to soil fumigants - is challenging. Whether effective alternatives are available, and the best choice and management of alternatives, are likely to be site- and situation-specific decisions. Factors to consider include the crop, field history, soil type, and information about the kinds and population levels of weeds, soilborne pathogens, and soil pests present. Growers or their PCAs must be capable of analyzing these complexities to identify optimal practices.

Adoption of ant bait systems - may be a difficult outreach goal because these systems are so different from spraying and are perceived as labor-intensive (E. Grafton-Cardwell, Director, UC Lindcove Citrus Research and Extension Center, personal communication, 9/20/07). Educational themes should include the greater effectiveness of baiting, minimal environmental contamination and risk to non-target species, and enhancement of biological control, which may reduce pest control costs (Tollerup et al. 2004).

Adoption of reduced-risk pesticide application technology - is an important outreach thrust. Many growers do not buy new equipment frequently. Opportunities to try out new equipment and financial support for its purchase can facilitate the adoption of target-

sensing equipment. Growers must be convinced that new equipment will be effective, will not slow operations, and will pay for itself quickly. Training or mentoring may be especially helpful for optimal use of computerized systems and the application information they generate (Giles and Downey 2003; K. Giles, UC Davis Professor of Agricultural Engineering, personal communication 7/19/07).

Citrus IPM - outreach in the SJV is especially important because conditions have become increasingly challenging for biologically-based pest management. That reduced-risk approach requires close crop monitoring and information-intensive management decision making, including anticipation of pesticide resistance and the status of invasive pests. Growers should also be encouraged to use bait systems for managing ants. Many growers perceive biological control as riskier and harder to employ than a traditional chemical control program (Morse, Luck, and Grafton-Cardwell 2007). The Positive Points grower self-assessment system for sustainable citrus management (UC ANR 2007) provides a vehicle for outreach and follow-up. Area-wide implementation improves the effectiveness of biologically-based systems by enhancing protection of the natural enemies of pests. Effective collaboration like that achieved for red scale control with parasitoids by the Fillmore Protective District in Ventura County during the 1980s might be an appropriate long-term objective (Luck, 2007).

New partnerships for research and outreach

New sources of funding - For decades, pest management specialists have relied chiefly on agricultural funding sources for research and outreach. They should be made aware of new sources of funding earmarked for activities to protect human health and the environment. Examples include Cal/EPA's Environmental Justice Small Grants Program,[31] project funding from the U.S. EPA Environmental Justice Collaborative Problem-Solving Cooperative Agreements Program,[32] NRCS Conservation Innovation Grants,[33] U.S. EPA Food Quality Protection Act grants,[34] Water Board grants,[35] and DPR's Alliance Grant program.[36] Alliance Grant projects support broad-scale implementation of reduced-risk pest management by developing lasting partnerships for IPM demonstration and outreach in agricultural or urban settings. Current priorities include IPM strategies that reduce VOC emissions, protect air and water quality, reduce worker exposure to pesticides, and address urban pesticide uses.

DPR's pest management program maintains a longstanding fruitful collaboration with growers, commodity groups, UC scientists, the UC Statewide IPM Program, county Agricultural Commissioners, and the U.S. EPA. It has worked with other partners of many types, especially through the Alliance Grant program. The following are examples of additional agricultural stakeholder partners that DPR and others might consider for

[31] http://www.calepa.ca.gov/EnvJustice/Funding/
[32] http://www.epa.gov/compliance/environmentaljustice/grants/ej-cps-grants.html
[33] http://www.ca.nrcs.usda.gov/programs/cig/
[34] http://www.ctahr.hawaii.edu/vincent/EPA_2007_FQPA_RFP.pdf
[35] http://www.swrcb.ca.gov/funding/index.html
[36] http://www.cdpr.ca.gov/dprgrants.htm

strengthening existing pest management partnerships and establishing new ones. Several of these potential partners offer EJ experience and expertise:

Community and public interest organizations - are potential collaborators in EJ and Alliance Grant projects and other initiatives in agricultural, periurban, and urban settings.

Community Outreach for Research and Education - Part of the UC Davis Western Center for Agricultural Research and Safety, this program promotes health and safety among agricultural populations. Possibilities: stakeholder networking, participatory research, training and educational materials.[37]

Environmental Justice Project, UC Davis John Muir Institute of the Environment - encourages and develops interdisciplinary research on EJ in the Central Valley. Possibilities: stakeholder networking, participatory research, training and educational materials.[38]

Roots of Change - is a foundation-led, multi-stakeholder initiative for creating a sustainable food system in California, from the ground to the store shelf. Through Alliance Grant agreements or other partnerships, DPR could work under this umbrella with commodity groups, nonprofits, and others to help develop sustainable farming systems and further advance the use of reduced-risk pest management practices.[39]

Ag Futures Alliance - is a statewide alliance of county-based consensus building policy roundtables. It is committed to preserving viable agriculture, particularly at the heavily challenged agriculture/urban interface. The alliance promotes sustainable farming practices and increased understanding and collaboration among environmental and farm labor advocates, farmers and ranchers, governments, and other civic leaders. Policy roundtables could broaden participation and enhance EJ, outreach, and public education.[40]

USDA-NRCS and county Resource Conservation Districts (RCDs) - NRCS is increasing its technical and financial support for pest management-related conservation practices in California.[41] Outreach to RCD members,[42] who are growers and ranchers, is important for promoting NRCS pest management conservation practices because RCDs help set local NRCS funding priorities. Possibilities: Alliance Grant and other partnerships, technical and regulatory information sharing, and EJ collaboration with NRCS program enhancements for American Indians and beginning or limited-resource producers.

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[37] http://agcenter.ucdavis.edu/Training/Outreach.php
[38] http://ej.ucdavis.edu
[39] http://www.rocfund.org/
[40] http://agfuturesalliance.net/
[41] http://www.ca.nrcs.usda.gov/
[42] http://www.carcd.org/yourdistrict/rcdabout.htm

Center for Agricultural Partnerships - is a nonprofit that spearheads collaborative programs to bridge the gap between agricultural research and practical field implementation of innovations, including facilitation of greater NRCS support for sustainable pest management practices in many states.[43]

Organic growers and organic agriculture organizations - such as California Certified Organic Farmers,[44] the Organic Farming Research Foundation,[45] and the National Center for Appropriate Technology[46] and its National Sustainable Agriculture Information Service, known as the ATTRA project,[47] offer information, experience, and sometimes mentoring in the use of pest management practices other than the application of synthetic pesticides. Organic growers have had to learn how best to manage and combine reduced-risk pest management tools for reliable efficacy, and they know about costs. They could be a valuable technical and outreach partner because many scientists and mainstream growers are unfamiliar with, and lack confidence in, unconventional practices and products.

"Green" labeling and certification organizations - such as Protected Harvest[48] and the Food Alliance[49] motivate and reward growers who adopt reduced-risk pest management practices. They are potential partners in Alliance Grant projects and other sustainability initiatives.

"Green" food wholesalers and retailers - have become a significant proportion of the market for some California commodity groups and packers. Some have begun to set a high bar for sustainability and to demand proof of grower compliance, including for pest management. The market access they can offer, and sometimes the price premiums, can reward growers for improving their operations. In such cases, the participation of these companies would be an asset in sustainable pest management initiatives.

Pest control advisers - Providing that PCAs practice IPM by monitoring crops frequently, using thresholds when appropriate for deciding whether pest control action needs to be taken, and giving preference to reduced-risk practices, their services help growers break the calendar spraying habit and switch to reduced-risk practices with confidence (Brodt et al. 2006). Written monitoring data and recommendations provided to the grower after each field visit can satisfy recordkeeping requirements of "green" food companies, "green" labeling or organic certification programs, and NRCS conservation contracts. The expertise and local experience of PCAs make them potential partners for Alliance Grant projects and other sustainable pest management initiatives. PCAs may also facilitate and supervise conservation contracts as NRCS Technical Service Providers.

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[43] http://www.agcenter.org/
[44] http://www.ccof.org/
[45] http://ofrf.org/index.html
[46] http://www.ncat.org/
[47] http://www.attra.ncat.org
[48] http://www.protectedharvest.org/
[49] http://www.foodalliance.org/

IX. Key to Pesticide Names

Active ingredient	Commercial product names[50]
1,3-dichloropropene (1,3-D)	Telone®, Inline® (combination with chloropicrin)
abamectin	Agri-Mek®, Clinch® ant bait
acetamiprid	Assail®
borax	Gourmet® ant bait
buprofezin	Applaud®, Centaur®
carbofuran	Furadan®
chloropicrin	Chloropicrin, Inline® (combination with 1,3-D)
chlorpyrifos	Lorsban®
cryolite	Kryocide®
diazinon	Diazinon
diflubenzuron	Dimilin®
dinotefuran	Venom®
imidacloprid	Admire®, Provado®, Vitis® ant bait
kaolin clay	Surround®
metalaxyl	Ridomil®
methidathion	Supracide®
methoprene	Tango® ant bait
methoxyfenozide	Intrepid®

[50] This list contains names of some of the products used on major crops in the EJ Pilot Project area. It is meant to assist readers who are not familiar with pesticide active ingredients, and is not exhaustive.

The mention within this assessment of commercial products, their source, or their use is not to be construed as either an actual or implied endorsement. Mention is made of some representative products, but the Department of Pesticide Regulation does not recognize any product as superior to any other.

oxamyl	Vydate®
phosmet	Imidan®
pyriproxyfen	Esteem®
spinosad	Entrust®, Success®
tebufenozide	Confirm®
thiamethoxam	Actara®

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