U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION 9
Strategic Agriculture Initiative Program
Final Report

PROJECT TITLE: “Food Quality Protection Act Agricultural Initiative–Stone Fruit”

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PROJECT PERIOD: 10/01/04–06/30/08

GRANT RECIPIENT:
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GRANT AMOUNT: $142,000
NOTE: This report covers an existing EPA funded project EPA Assistance Number: X8-96903501-0 in the amount of $50,000), augmented on November 29, 2005 with an additional $92,000 for a total of $142,000. The total project budget was roughly $235,000.

COLLABORATING ORGANIZATIONS/PARTNERS:

California Tree Fruit Agreement (CTFA), stone fruit growers, University of California (UC) researchers, UC Statewide IPM, UC Cooperative Extension farm advisors, independent pest control advisors (PCAs), USDA Natural Resources Conservation Service (NRCS), Kings River Conservation District (KRCD) and Department of Pesticide Regulation (DPR) staff.

ABSTRACT:

The Department of Pesticide Regulation (DPR) initiated Food Quality Protection Act (FQPA) Stone Fruit project began in 2004 with USEPA Region IX Strategic Agriculture Initiative funds. The goal was to reduce use of five FQPA targeted organophosphate and carbamate insecticides, phosmet, chlorpyrifos, carbaryl, methidathion and diazinon, by 20% among fruit tree growers in the Parlier area of California. Key project components included 1.) Development and publication of a Seasonal Guide for reduced-risk pest management 2.) Baseline and follow-up surveys of grower knowledge and use of integrated pest management (IPM) practices 3.) Use of monitoring practices outlined in the Seasonal Guide 4.) Use of new technology, including target-sensing sprayers and remote sensing equipment (aerial imagery) to identify key pests and 5.) “Hands-on” outreach to the industry using the Seasonal Guide and Year-Round Plans developed by the University of California. Almost 17,000 acres of stone fruit were impacted by the project. Changes in IPM practice were identified in the survey and attributed to outreach efforts. Pest management changes included increased use of oil alone in the dormant season to control San Jose scale, a key stone fruit pest, and increased use of reduced risk pesticides and pheromone-mating disruption for Oriental fruit moth. The results of demonstration and research trials using target sensing spray technology showed reduced use and cost savings of almost 30% on average, with no negative effect on insect pest control. Between 2004 and 2007 use of the five FQPA pesticides in pounds per acre planted decreased 26 percent from the 2000-2003 baseline use. Through project efforts, USDA NRCS is now offering funds to help growers purchase target sensing sprayers and to use the IPM practices described in the Seasonal Guide.

LEVERAGED FUNDS:

Leveraged funds totaled $91,975, including $57,332 for a remote sensing component and $34,643 to purchase a target-sensing sprayer, SmartSpray® for grower demonstration and out reach. In addition, DPR contacted the USDA NRCS in early 2006 to discuss ways to collaborate. In particular, DPR was interested in finding ways to use Environmental Quality Incentive Program[1] (EQIP) funding as an incentive for tree fruit growers to continue to use the practices demonstrated by the project past the termination of grant funding. At the same time NRCS was interested in collaborating with the project, particularly in the area of volatile organic compounds (VOCs) in the Southern San Joaquin Valley. The goal was to have NRCS incorporate the Seasonal Guide and target-sensing sprayer into their ranking system for awarding EQIP funds. After review of available data on the effectiveness of remote sensing technology and after viewing the SmartSpray® equipment in operation and seeing the potential for cost savings first hand, NRCS had justification to put in place a form of cost sharing for growers ($ per acre) that use target-sensing sprayers in their operation. In addition, NRCS will give growers a per acre incentive payment for implementing a program that uses IPM practices in the seasonal guide and that follow practices identified in the University of California "Year Round Plan".

PROJECT GOALS AND OBJECTIVES:

The overall project goal was to assist growers in reducing their use of organophosphate (OP) and carbamate pesticides targeted by the Food Quality Protection Act (FQPA) through promotion and implementation of alternative pest management practices.

Objectives/Tasks:

Objective 1: Education and Outreach–Increase grower adoption of IPM by bringing the Seasonal Guide to the attention of all Kings River sub-watershed growers and particularly those growers near Parlier.

- Set up two grower orchards to use in hands-on demonstration of IPM practices
- Develop an IPM "seasonal guide" for growers detailing the alternative pest management systems developed through UC research and the Stone Fruit Pest Management Alliance
- Implement reduced-risk practices identified in the seasonal guide in several key growers orchards with assistance from pest control advisors
- Develop outreach information to explain to growers the need for making changes in production practices to reduce the use of OPs and carbamates. Conduct 4-6 meetings to disseminate information

[1] The Environmental Quality Incentives Program (EQIP) was reauthorized in the Farm Security and Rural Investment Act of 2002 (Farm Bill) to provide a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical assistance to eligible participants to optimize environmental benefits, including reductions in non-point source pollution (pesticides) and reduction of volatile organic compounds.

Objective 2: Evaluate and demonstrate alternative lower-risk technologies or practices to growers and PCAs.

- Provide new technologies (i.e., target sensing sprayers for hands-on use to reduce organophosphate and carbamate pesticide use in stone fruit and remote sensing using aerial imagery for early identification and build-up of mite pests).

Objective 3: Technology Transfer–Establish baseline practices and evaluate adoption of new practices.

- Conduct baseline survey of grower practices to define research needs, gaps and obstacles to change
- Evaluate grower adoption through a follow up survey. Compare survey results with PUR to identify trends

Objective 4: Environmental Impact–Evaluate (monitor) air and water quality in the Kings River sub-watershed and identify potential benefits of the project.

- Analyze phase II water sample test results from KRCD
- Review VOC monitoring data from Parlier–as part of DPR's Environmental Justice Pilot Project

EXECUTIVE SUMMARY:

The FQPA Stone Fruit project was established to continue work of the successful DPR funded Stone Fruit Pest Management Alliance (PMA)[2] providing support for the adoption of alternative pest management practices shown to be effective in stone fruit (i.e., peaches, plums and nectarines. The FQPA project identified stone fruit growing areas within the Kings River sub-watershed of the Southern San Joaquin River where pesticide use levels and orchard proximity to water pose significant environmental risk. The 2004 FQPA grant summarized effective reduced-risk practices identified by the PMA in an easy-to-use "Seasonal Guide to Environmentally Responsible Pest Management Practices in Peaches and Nectarines" (Attachment A). Copies of the guide were distributed to stone fruit growers statewide. The grant also funded a baseline survey of grower pest management practices (July, 2005 Attachment B) and extended information to growers and PCAs through meetings and field days in grower-cooperator orchards.

In 2006 DPR received additional funding to build upon work begun with the 2004 FQPA grant. The objective of this extended project was to use local grower experience, the Seasonal Guide, pesticide use report (PUR) information, survey data and hands-on workshops to inform peach and nectarine growers and PCAs that 1) most dormant applications of insecticides for

[2] The Stone Fruit Pest Management Alliance (PMA) demonstrated to peach and nectarine growers viable alternatives to currently used pesticides, such as methomyl, azinphos-methyl, methidathion, diazinon, chlorpyriphos, phosmet and other pesticides on the Food Quality Protection Act (FQPA) Priority Group One list. The PMA established a strategic partnership and developed a comprehensive pest management systems approach including: intensive field monitoring; use of mating disruption; use of biological agents; and use of reduced risk materials. After four years of the PMA project (1998-2001), use of FQPA pesticides went down, however, broad spectrum OP's and carbamates were still materials of choice for many growers.

San Jose scale are not needed, 2) mating disruption can replace traditional insecticides for some in-season pests, and 3) pesticide applications, when needed, can be more effectively applied using remote sensing technology. With additional funding for 2006-2008 the project goal was to realize a 20% reduction (from 2000-2003 levels) in the collective use of five FQPA pesticides[3] in stone fruit production among growers who met a set of pesticide use criteria[4] employed in the 2004 grant and are located within 30 miles of the town of Parlier[5] in the Kings River sub-watershed.

Approximately 16,945 acres of stone fruit were impacted by the project. To accomplish project goals a total of 25 orchards were monitored for Oriental fruit moth (OFM), peach twig borer (PTB), San Jose scale (SJS), Omniverous leafroller (OLR), Western flower thrips, katydid, web spinning mites and beneficial parasites and parasitoids. The orchards ranged in size from 5 to 10 acres. Fruit was examined for damage from each of the above pests. Several challenges were encountered during the project period and will be covered later in the report.

Between 2004 and 2007 use of four of the five FQPA pesticides in pounds per acre planted was down 26% based on the benchmark average (2000-2003). Use of carbaryl was down 47%, diazinon use was down 79%, phosmet was down 15% and chlorpyrifos was down 2%. Use of methidithion was up slightly at 1%, however, overall use of methidithion is low. Based on survey data and demonstration efforts growers are learning more about IPM alternatives and are more willing to change. For example, growers are beginning to apply dormant oil without insecticide. They know that oil alone will control low to moderate SJS levels and mite eggs and at the same time protect beneficial insects. Insecticides are added to control heavy levels of SJS, and if necessary, PTB and OLR. Pheromone mating disruption for oriental fruit moth (OFM) was shown to be an effective alternative to in-season insecticide sprays. Release of the parasitoid, *Macrocentrus ancylivorous* also helped control OFM. Use of reduced risk materials such as spinosad, diflubenzuron, methoxyfenozide and spirodiclofen, in-season, are replacing broad spectrum OP's and carbamates.

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[3] Diazinon, phosmet, chlorpyriphos, carbaryl and methidathion

[4] Growers who, on average, during 2000-2003: 1) use dgreater than 2 pounds of the five FQPA pesticides per planted acre, 2) treated every planted acre at least once and 3) farm more than 100 acres of tree fruit.

[5] The project area encompasses 18,884 acres and 54 growers. Generally these growers are located in the towns of Parlier, Reedley, Kingsburg and Sanger.

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OUTCOMES:

The combined project (2004–2008) had four major objectives including: Objective 1) Outreach and Education, Objective 2) Demonstrate alternative lower-risk techniques or practices to growers and PCAs, Objective 3) Technology Transfer and Objective 4) Environmental Impact.

Objective 1:

Education and Outreach

The Seasonal Guide was mailed to each fresh market stone fruit grower in the San Joaquin Valley. Two demonstration orchards with growers Bill Chandler and Ty Parkinson were used to demonstrate IPM practices to growers. Information about IPM practices was available to growers and PCAs through web page updates <http://www.uckac.edu/treefruitipm/>. Information was also presented by UCCE Farm Advisors and UCIPM Advisors at meetings set up by CTFA. There were a total of 36 individual Stone Fruit Pest Management presentations. Approximately 2000 growers and pest control advisors participated. Meetings extended from Sutter County in Northern California to Tulare County in the south. Presentations were made at two pesticide distributor locations, Gar Tootelian and Britz Ag Chem. Eight PCA's participated in the Gar Tootelian meeting and 11 PCA's in the Britz meeting. This is important because these are influential PCAs who work with a large number of growers in the project region.

Weekly monitoring was conducted in twenty-five additional orchards, following the Seasonal Guide. The objective was to familiarize growers with the seasonal guide and demonstrate the value of a reduced-risk program. Cooperating growers included Bill Tos, Jerry Surabian, Jay Scott (Reedley Farms) Jim Simonian (Simonian Farms), and Marko Rinaldi (Wawona Farms). Reduced risk practices were implemented, based on monitoring, in each of these locations. Only one site utilized a carbamate insecticide (Reedley Farms for Flower Thrips in 2007 on nectarine). Pest control advisors cooperating in the project included Kelley Morrow, Jim Mose, Les Nygrens, Marko Rinaldi, Greg Yamamoto, and Eric Olsen. These orchards were all in the Kings River Watershed Drainage.

The intent was to have the PCAs perform the monitoring but only one advisor was able to incorporate the additional time into their program. Time is a critical consideration for PCAs. As part of the project the average time for monitoring pheromone traps and fruit spurs for scale was calculated. This included travel time to different farms. The time required to monitor was 1.4 hours per orchard. Based on this information the PCA would be able to monitor about 10 orchards a day or 60 orchards per week (6 day work week) working at 12 hours per day. Time for grower consultation and recommendation writing was not calculated. Monitoring based on the Seasonal Guide was difficult for both independent and affiliated PCAs. As a result only one PCA took the time to monitor using the guide.

As a result, UC IPM Program Staff conducted monitoring for OFM, PTB, SJS, Omnivorous leafroller (OLR), Western flower thrips, katydid, and webspinning spider mite. The orchards ranged in size from 5 to 10 acres. Fruit was examined for damage from each of the key pests. A 1000 fruit harvest sample was taken at harvest.

During the four years of the project (2004–2008) arthropod infestation levels were very low based on monitoring and harvest sample results. Several orchards were augmented with the *Macrocentrus* parasitoid. Between 2006 and 2007 almost 10,000 parasitoids were released in seven separate peach and nectarine blocks. In 2008, six blocks were planted with sunflowers (2 rows ½ mile long) as refuge for the *Macrocentrus*. A separate block of late harvested peaches was also planted similarly with sunflowers and parasitoid releases were made on the same dates at that location. No OFM larvae were found in 2007.

Conclusions

- Use of a reduced-risk program did not increase damage by key pests
- Monitoring, following the Seasonal Guide, was difficult for both independent and affiliated PCAs because of the time required.
- The *Macrocentrus* parasitoid was used effectively as a biological control for OFM

Objective 2:

Alternative Technologies

A field experiment was established at Kearney Ag Center in 2008 to evaluate the efficacy of the SmartSpray® equipment. A description of the sprayer can be found at <http://www.durand-wayland.com/sprayers/smart_spray/smartspray.html>. The orchard used was four years old and 1.5 acres in size and planted to Fantasia Nectarines. It is flood irrigated planted on an 18 foot by 20 foot spacing. On February 15, the orchard was sprayed with 16 ounces of Dimilin 2L and 2 gallons of Petro Canada 455 dormant oil per acre in 300 gallons of water. The orchard was divided into 6, .2 acre blocks. Three of the blocks were sprayed with the SmartSpray® on and three with target sensing off. The sprayer was calibrated to deliver 200 gallons per acre in the conventional (target sensing off) mode. It was driven at 2 miles per hour. Evaluation of the two treatments included terminal strike counts caused by PTB and harvest infestation from Katydid, OFM, PTB, western flower thrips, and SJS. In addition the average gallons of spray material per acre was documented.

The two treatments resulted in 60 gallons of spray used for the SmartSpray® treatment and 100 gallons used for the standard treatment, a savings of 40 percent in material delivered. There was no significant difference in terminal limb injury, done by PTB, whether the SmartSpray® or conventional mode was used. Also, no significant difference, based on harvest samples, was noted for OFM, SJS, katydid, or western flower thrips.

A commercial target sensing spray control system (SmartSpray®), housed at the UC Kearney Ag Center, was made available to growers to try this approach. The technology uses ultrasonic sensors linked to an on-board computer and tractor-mounted controller to seek and target trees for spraying. When there isn't a tree present, the nozzles shut off and are not spraying the ground, the space between the tree or wasting material in the air. The Sprayer was tested at 4 locations in 2006 and 2007. On October 25, 2006 a six acre Laroda plum orchard was divided in half and half was treated with the SmartSpray® in target sensing mode and half in conventional mode. Seventy gallons of spray material was used with the SmartSpray® on and 83 gallons was used as a conventional spray with the target sensing mode off. A 16% savings was achieved with foliage on the tree. On February 2, 2007, an 8 acre plum orchard was sprayed, in the dormant season, in the same manner as the 6-acre orchard. A 47% saving in spray material was achieved with the SmartSpray® compared to the conventional.

Also on February 2, 2007, an 8-acre August Lady peach orchard was divided in half and treated the same as the plum orchard. Five hundred gallons of spray was used with the SmartSpray® on and 750 gallons was used as a conventional spray achieving a 33% savings with no foliage on the trees. On May 9, 2007, a 5-acre Spring Flame peach orchard was treated. The SmartSpray® treated portion received 60 gallons of spray and the conventional half received 75 gallons of spray, resulting in a 20% savings of spray material.

The results of these trials demonstrate a cost savings in material with no adverse effect on insect pest control. There were minor problems with equipment breakdown. The PTO shaft was damaged in transit, but this is not a problem unique to the SmartSpray®. A 3-week delay did occur due to loss of memory in the computer module control box. The box had to be reordered and calibrated. Operation of this equipment does require training that may be difficult for some users, particularly non English speakers. However, with care and proper training, it appears that the target-sensing sprayer technology will result in equal efficacy to that of conventional sprayers. Growers using target sensing spray technology are eligible for and using NRCS EQIP cost-share funding. Standards are outlined in Precision Pest Control Application 718 <http://www.ca.nrcs.usda.gov/programs/airquality.html>. In Fresno County over $100,000 in cost share dollars has been committed for 2008 to help defray the cost of this equipment. This represents almost 2000 acres. It is estimated that a minimum of $500,000 in equipment dollars will be available for 2009 in Fresno County.

A study (Attachment C) “Examining the Feasibility of Utilizing Remote Sensing Technologies to Track Mite Damage in Stone Fruit Orchards” was conducted in peach and nectarine orchards in Fresno and Kings Counties, during 2006 and 2007. Spider mites are an important pest affecting California’s stone fruit industry. Remote sensing, using aerial imagery, has been proven useful for controlling agricultural pests and reducing the impact of toxic pesticides to the environment. The objective of this study was to examine the feasibility of using remote sensing technology for early detection of mite infestations in stone fruit. The results could then be used for making more precise pest management decisions.

Data was collected weekly in nine orchards to document pest activity and plant health and to find both distribution and levels of infestation. Results showed that mite damage has a detectable effect on the spectral reflectance of peach leaves and canopies. However, due to the effects of other factors, such as desiccation and nutrient deficiency, detection of mite damage based solely on spectral readings remains difficult. Spatial mapping of relative mite damage is possible through the analysis of aerial images. With additional work remote sensing could become a useful tool for early detection of mite outbreaks in stone fruit orchards.

Objective 3:

Establish baseline practices and evaluate adoption of new practices

- Conduct baseline survey of grower practices to define research needs, gaps and obstacles to change
- Evaluate grower adoption through a follow up survey. Compare survey results with PUR to identify trends

Grower Survey Results

To establish baseline pest management and change in acceptance of IPM practices in stone fruit orchards, growers and pest control advisors (PCA) were surveyed in 2005 and 2008. Fresh-market peach, nectarine, and plum growers in California received surveys; 1200 in 2005 and 980 in 2008. Essentially 100% of growers were surveyed based on the membership lists of the CTFA. The CTFA estimates that only about 1% of growers were missed. Response rates were: 171/1200, and 174/980 for the two survey dates, 14 and 18 percent respectively. The lower number of surveys mailed in 2008 represents actual reduction in the number of growers with fruit tree orchards. The surveys included essentially the same questions both years in order to establish a baseline and provide a basis for evaluating change.

The survey consisted of five types or grouping of questions: pests problems–occurrence and importance (12 questions); pest management practices–monitoring, biological control, cultivation, and management with pesticides (19 questions); confidence using IPM practices (3 questions); considerations when choosing a pesticide (2 questions).

Grower demographics. In both 2005 and 2008, respondents were primarily owners who also managed pests themselves, 127/171 (74%) and 131/174 (75%) respectively, Table 1. Between 14% and 20% were managers but not owners or were owners who hired out pest management. Respondents listing themselves as “Other” were primarily PCA’s. No statistically significant changes in the number of respondent in each category were seen between survey dates. Despite a 12% decline in total acres of respondents from 61,608 acres in 2005 to 54,262 acres 2008, the relative contribution by owner-managers to total acres increased by 10%, from 25,078 to 27,510, 41% and 51% respectively. The percentage of acres managed PCAs declined by 15%.

Table 1 Position with regard to stone fruit management

Respondent categories	Respondents			Acres		
	2005	2008	% Change	2005	2008	% Change
Owner & pest manager	127	131	1%	25,078	27,510	10%
Pest manager but is not owner	20	17	-2%	15,402	14,505	2%
Owner but hires out pest management	14	17	2%	2,573	3,839	3%
Other (e.g., PCA)	8	6	-1%	18,530	8,298	-15%
Total	171	174	2%	61,608	54,262	-12%

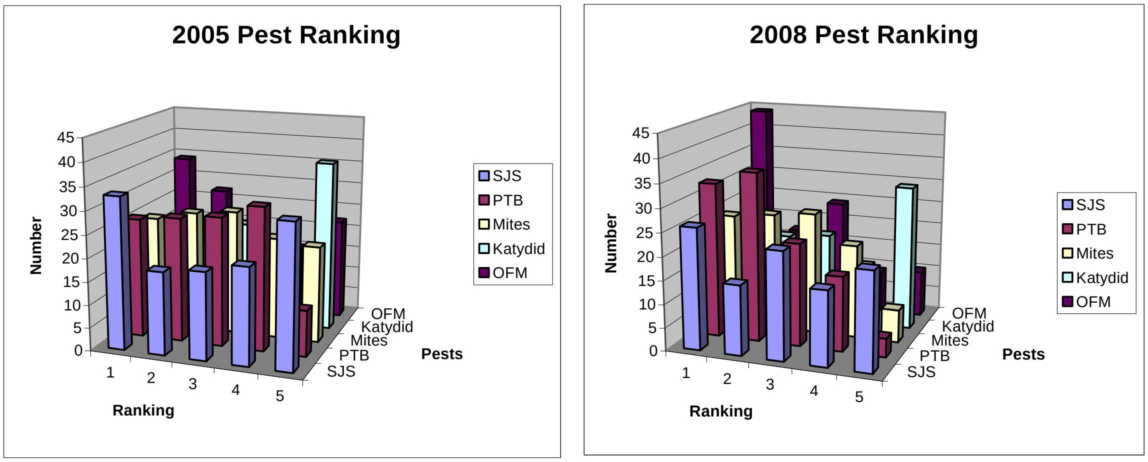
The proportion of respondents with less than 100 acres (small farms) increased in 2008 relative to those with greater than 100 acres (large farms), while the proportion of acres farmed by small growers versus large growers remained unchanged, Table 2. Respondents describing themselves as managing organic or organic transition acres increased by 5% from 15 % in 2005 to 20% in 2008. Total organic and organic transition acres managed by respondents increased by 1%, from 4% in 2005 to 5% in 2008. Management of late harvested varieties is of particular importance because late varieties generally require more pesticide applications for effective pest management. Respondents who owned or managed late harvested varieties increased by 9%, from 75% to 84% in 2008. The total acres of late harvested varieties increased by 2%, from 15,357 acres in 2005 to 15,867 acres in 2008.

Table 2 Orchard characteristics

Position	Respondents			Acres		
	2005	2008	% Change	2005	2008	% Change
Less than 100 acres	66	91	13%	3555	3044	0%
Greater than or equal to 100 acres	104	81	-15%	58053	51217	0%
Total	170	172	1%	61608	54261	-12%
Organic or organic transition	25	34	5%	2727	2888	1%
Conventional management	145	138	-5%	58881	51373	-1%
Total	170	172	1%	61608	54261	-12%
Having late harvested varieties	128	144	9%	15357	15867	4%
Having early harvested varieties	42	36	-9%	46251	38394	-4%
Total	170	172	1%	61608	54261	-12%

Relative importance of pests of stone fruit. Growers were asked to rank the principal pests in their operations on a scale of 1–5, 1 being most important. A tally of rankings reveals a complex pattern of pest problems that reflect crop losses and management cost to growers due to variations in pest incidence (Fig. 1). Many factors influence pest populations and crop damage including: stone fruit variety, past pest management practices, adjacent crops and other vegetation, soils, and weather.

Figure1. Ranking of pest importance in peaches and nectarines



Each of these pests ranked as the most important for at least some growers. More growers identified OFM as their number one pest in both 2005 and 2008, 25% and 30% respectively, Table 3. A slightly lower percentage of growers identified SJS or PTB as their most important pest, followed by growers who identified mites or katydids as their most important pest.

Table 3. Percent of growers ranking pest as the most important

Pest	2005	2008	Change
OFM	25%	30%	5%
SJS	24%	18%	-6%
PTB	19%	23%	4%
Mites	17%	17%	0%
Katydid	15%	12%	-3%
Total	100%	100%	

Based on mean ranking of all five pests, the most important is OFM followed by PTB, Table 4. Mites and SJS are of intermediate importance. Katydid is of lesser importance. This order was essentially the same in both 2005 and 2008, except that SJS appears to have increased slightly in relative importance.

Table 4. Mean Rank (Most important=5, Very important=4, Important 3, Somewhat important=2, Least important=1)

2005	OFM	PTB	Mites	SJS	Katydid
Mean	3.31	3.21	3.08	2.99	2.72
Std. Deviation	1.48	1.28	1.38	1.57	1.51
Variance	2.18	1.64	1.91	2.45	2.27
2008					
Mean	3.73	3.65	3.07	3.34	2.79
Std. Deviation	1.35	1.19	1.27	1.48	1.51
Variance	1.81	1.42	1.60	2.20	2.27

Growers were also asked to identify which pests were problems in the previous cropping year. About half of all respondents observed mites in both 2004 and 2007. OFM and SJS incidence increased by 5% and 1% respectively while mites, katydid, and PTB declined 3%, 3%, and 1% respectively, Table 5. Presence of a pest in the previous year correlated positively with importance of that pest, except for SJS. In 2005 importance of SJS appears to be independent of presence of the pest in the previous year.

Table 5. Pest problems in the previous year

Pest	2005	2008	Change
	Yes	Yes	
Mites	50%	47%	-3%
Peach Twig Borer	43%	42%	-1%
Oriental Fruit Moth	39%	44%	5%
Katydid	39%	36%	-3%
San Jose Scale	31%	32%	1%

IPM practices. IPM practices include: monitoring for pests and beneficials; biological control; cultural practices that exclude pests; and use of reduced-risk pesticides. This FQPA project particularly targeted growers through outreach and demonstration to increase use of monitoring as a guide to spraying decisions, use of biological controls, and replacement of high-risk chemicals such as organophosphates and carbamates with reduced-risk products. In the survey, growers were asked to identify pest management practices they used in the previous cropping season. Tabulations of positive responses are seen in Table 6. Nearly all respondents used the general appearance of trees to monitor pests. All monitoring practices examined in the survey increased between 2005 and 2008. The greatest increases in use of monitoring were seen in sampling for presence or absence of mites, monitoring of blossom and shoot strikes for PTB, monitoring emergence of PTB from overwintering sites, and monitoring PTB population changes with pheromone traps. These increased by 14%, 11%, 10% and 8%, respectively.

Table 6. Questions about monitoring

	2005	2008	Change
	Yes	Yes	
Look at general appearance of the trees	94%	95%	1%
Presence/Absence mite monitoring	65%	79%	14%
Use degree-days with monitoring	64%	67%	3%
Sample blossom and shoot strikes to determine if sprays are necessary for peach twig borer	54%	65%	11%
Place pheromone traps for peach twig borer	56%	64%	8%
Monitor emergence of peach twig borer at the overwintering hibernacula (hibernation site)	39%	49%	10%
Sample dormant spurs for San Jose scale	33%	34%	1%

Sanitation to remove mummies containing brown rot spores was used by about 67% of respondents, an increase of 7% over the 2005 rate, Table 7. Monitoring for beneficials, such as predatory mites and thrips was used by 61% of respondents in 2008, an increase of 6% over 2005. Release of predatory mites was little use by growers, 5% in both years. Considering the importance and high incidence of mites observed by growers, this IPM practice may be a good target in future outreach programs.

Table 7. Questions about use of cultural control and biological control

	2005	2008	Change
	Yes	Yes	
Perform annual winter sanitation to remove mummy fruits during winter	60%	67%	7%
Monitor for predatory mites and six spotted thrips	55%	61%	6%
Release predatory mites for spider mite control	5%	5%	0%

Use of reduced-risk pesticides increased for all pesticide types, Table 8. The most important increases were use of mating disruption with pheromones, biologicals, such as *Bacillus thurengiensis* and spinsosad to control PTB, and use of oil alone to control SJS. Reduction in the number of growers who used the organophosphates such as chlorpyrifos and diazinon for dormant sprays and in-season sprays was not statistically significant. However, based on the PUR data, the amount of FQPA targeted pesticides used by growers did decline in favor of reduced risk control methods. Although in-season spraying of miticides increased by 3%, use of alternatives to miticides increased 6%. Spring sprays for katydid based on monitoring increased. The general pattern of replacement of broad spectrum pesticides with reduced risk alternatives, use of alternatives to miticides, and spraying for katydid based on monitoring are all practices promoted by the is project. Increased use of in season applications of miticides is, however, not consistent with the practices promoted in this IPM program.

Table 8. Questions about pest management and pesticides

	2005	2008	Change
Question:	Yes	Yes	
Spray a dormant insecticide such as organophosphates (Chlorphyifos, Diazinon, Methidathion, Azinphos-methy), pyrethroids (Esfenvalerate), etc	80%	78%	-2%
Use Bt (i.e., Dipel, Biobit, Condor, etc.) or spinosad (i.e., Success) for control of peach twig borer at bloom	47%	63%	16%
Use pheromone mating disruption	46%	62%	16%
Apply an in-season spray of organophosphate (Chlorpyrifos, Azinphos Methyl), pyrethroid (Esphenvalerate), or similar product	58%	57%	-1%
Apply miticide in-season sprays	53%	56%	3%
Sprayed for katydid nymphs in April or May based on sample counts	40%	44%	4%
Use oil alone to control SJS	30%	39%	9%
Use alternatives to miticides, such as predatory mites, cultural practices, oils etc	29%	35%	6%

When asked to identify from a list all reduced-risk products growers had used, , statistically significant increases were seen for horticultural oil, Bt, Intrepid (methoxyfenozide) and Oniger (hexythiazox) in use between 2005 and 2008 Table 9.

Table 9. Questions about use of specific reduced risk products

Reduced Risk Products:	2005	2008	Change
Question: Circle all materials you have used from the list below.	Yes	Yes	
Success®	57%	67%	10%
Horticultural Oil	30%	52%	22%
Bacillus thurengiensis	30%	45%	15%
Intrepid®	20%	45%	25%
Acramite®	36%	44%	8%
Onager®	27%	37%	10%
Agrimek®	12%	22%	10%
Applaud®	13%	14%	1%
Entrust®	8%	14%	6%
Neemix®	4%	2%	-2%

Knowledge about IPM. Respondent self-assessment of knowledge of IPM did not improve in concert with increased use of IPM practices (Table 10). While those respondents considering themselves moderately knowledgeable increased 10%, those rating themselves as highly knowledgeable or somewhat knowledgeable each declined by 6%. One explanation may be that respondents in the two years may have sampled different grower populations. An alternative explanation for the observed inconsistency between self-assessment and reported IPM use may reflect modesty that comes from a recognition that the subject is perhaps more complex than they had originally supposed and adjustment for room to improve. This later interpretation is supported by the observation that this same overall response pattern was seen for the subgroup of 70 growers who responded in both survey years.

Table 10. Self-assessment of IPM knowledge

	2005	2008	Change
Not at all Knowledgeable	7%	7%	0%
Somewhat Knowledgeable	30%	26%	-6%
Moderately Knowledgeable	32%	42%	10%
Very Knowledgeable	30%	24%	-6%

Considerations for choosing a pesticide. Growers were asked to identify their three most important considerations when choosing an insecticide. Table 11 displays the options provided. By simple tabulation, the order of importance changed little from 2005 to 2008. The most important were efficacy and cost, followed by worker safety and selectivity to beneficials. Only worker safety and selectivity to benficials" switched places, as did environmental concerns" and resistance management. Efficacy decreased in the importance in favor of an increase in worker safety, environmental concerns, permit requirements, and processor requests.

Table 11. Considerations when choosing an insecticide

	2005	2008	Change
What are your three most important	Yes	Yes	
1 Efficacy	74%	65%	-9%
2 Cost	57%	59%	2%
3 Worker safety	38%	44%	6%
4 Selectivity to beneficials	43%	40%	-3%
5 Environmental concerns	24%	26%	2%
6 Resistance management	26%	23%	-3%
7 Permit requirement	18%	20%	2%
8 Processor request	8%	11%	3%
9 Urban issues	3%	2%	-1%

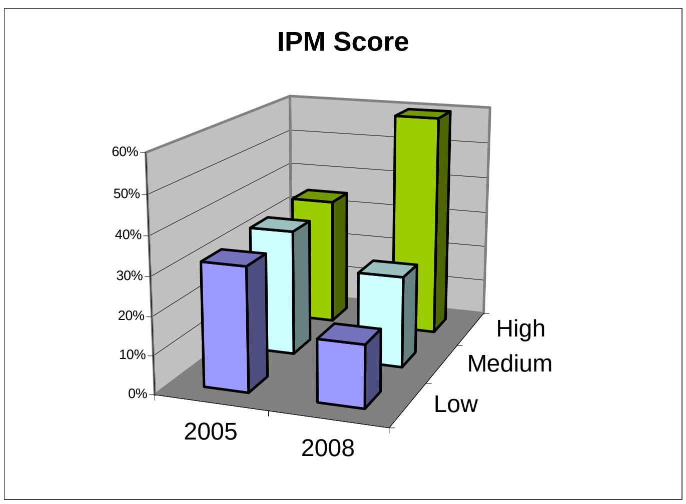
Growers were asked to rate their use of IPM for each of the pests in Table 12, “Not at All,” “A Little,” “Moderate,” “A Lot.” Growers rating their use of IPM “A Lot” increased between 2005 and 2008 for all pests.

Table 12. Percent of growers who reported “A Lot” of use of IPM for the following pests.

	2005	2008	Change
PTB	43%	57%	14%
OFM	46%	54%	8%
Katydid	46%	54%	8%
SJS	48%	52%	4%
Mites	49%	51%	2%

Overall IPM Score. Responses to the above questions concerning IPM practice and use of reduced risk pesticides were combined to create an IPM composite score for each respondent (Figure 3). Responses to these questions were weighted -2, -1, +1 or +2 for their relative contributions to effective IPM in stone fruit, positive weights were given to preferred IPM practices and negative weights were given for use of standard practice where a preferred IPM practice is available. The IPM composite scores of all respondents in 2005 were then grouped into Low (less than 1), Medium (1 to 6), and High IPM (7 and above). These cutoff values were arbitrarily chosen for 2005 such that about one third of respondents fell into each group. These groupings of scores allow comparison between groups and evaluation of change over time. They are not intended to describe an absolute value of IPM use by respondents. By using the same scoring procedure and the same cutoff values for Low, Medium, and High IPM for the 2008 respondents, we see a dramatic increase in the percentage of High IPM respondents, from 35% in 2005 to 60% in 2008. This increase in the percentage of High IPM respondents in 2008 reflects a significant reduction in both Low (from 32% to 16%) and Medium IPM respondents (from 33% to 24%).

Figure 3. Percents of overall IPM Scores



Question weights. Questions 3c, 4c, 4d, 4f, 4g, and 4h, yes answers scored +2. Sum of question 7 if >2 reduced risk pesticides then scored +2. For questions 4a, 4b, and 4e, yes answers scored –2. Sum of all yes answers to question 7 if not > 2 then scored -2. All other yes answers to questions 2 through 4 scored +1. No or "Don't Know" answers scored 0 (see appendix xxx).

Survey conclusions.

1. Respondents were mostly owners who manage pests themselves
2. 94% of all acres were held by large growers (greater than 100 acres)
3. Relative importance of stone fruit pests based on mean rank: OFM> PTB> Mites> SJS> Katydid

4. Monitoring increased, especially for
    a. Mite presence/absence
    b. PTB blossom & shoot strikes
    c. PTB emergence from winter hibernation sites
5. Biological/cultural control increased, especially
    a. Sanitation by removal of mummy fruits to remove overwintering brown rot spores
    b. Monitoring of predatory mites & six-spotted thrips
6. Use of reduced-risk pesticides increased, especially
    a. Biological pesticides
    b. Pheromone mating disruption
    c. Oil alone (no organophosphates) in the dormant season to control SJS
7. Overall IPM use greatly increased as exemplified by IPM composite scores

Objective 4:

Environmental Impact

Water Quality Evaluation–Pursuant to requirements of the Irrigated Lands Conditional Waiver Program, Kings River Conservation District conducts water monitoring under guidelines established in a Quality Assurance Project Plan developed for the California Regional Water Quality Control Board. Water samples were tested for a range of constituents including pesticides. In particular, samples were tested for the five FQPA targeted pesticides: diazinon, phosmet, chlorpyrifos, carbaryl and methidithion. Analysis of the test results from samples taken over a two-year period (5/18/06 to 5/20/08), showed residues for carbaryl, diazinon, methidithion and phosmet below analytical detection limits. Analysis for chlorpyrifos (3 samples) showed residues at the trace detection level.

Air Quality Evaluation–The project was not actively involved in ambient air monitoring for pesticides. However, air-monitoring data from Parlier, as part of the DPR's Environmental Justice Pilot Project (Attachment D) was available for review. Three of the FQPA targeted pesticides, diazinon, chlorpyrifos and phosmet were detected during ambient air sampling. Diazinon exceeded DPRs health screening level for acute exposure on one day (one of 468 samples).[6] As a result diazinon has been prioritized for risk assessment. Chlorpyrifos and phosmet did not exceed DPR established screening levels

POSSIBLE LONG TERM OUTCOMES:

Surface Water and Air Quality–Using IPM practices identified in the seasonal guide and the UC Year-Round Plan will help provide long-term protection of surface water and air quality

[6] Enforcable state or federal health standards have not been established for most pesticides in air. For the EJ 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 detection above a screening level points to a need for further evaluation.

from pesticides. These practices ensure a systematic approach to pest prevention, with the use of pesticides as a last resort. Reduced-risk pesticides are becoming more prevalent in the market and recognized by growers as a plausible alternative.

SUCCESSFUL PRACTICES THAT COULD BE MORE BROADLY IMPLEMENTED:

Lessons learned from this project could be applied to other crops. For example, during the project a very good monitoring threshold that could be used for other crops was developed for San Jose scale. The use of pheromone monitoring traps for PTB was expanded along with pheromone mating disruption for OFM. The *Macrocentrus ancylivorous* wasp was introduced providing a new biocontrol practice for OFM. Use was improved by planting sunflowers as a refuge for the wasp.

OUTREACH/OUTPUTS AND DELIVERABLES:

Two demonstration orchards were established following the Seasonal Guide. A total of 25 orchard locations were monitored based on practices outlined in the Guide. Outreach meetings were held in conjunction with the CTFA, UCCE and UC IPM. Between 2006 and 2008 target sensing spray equipment (SmartSpray®) was demonstrated at spring field days. In addition, the spray equipment was used by four growers as part of their standard pest management program. Applications were made during the dormant season and in-season. Savings in spray material ranged from 16% to 40%. There were a total of 36 individual Stone Fruit Pest Management presentations. Approximately 2000 farmers and pest control advisors were reached. Meetings extended statewide from Yuba City to Dinuba. Of special importance were meetings at two pesticide distributors, Gar Tootelian and Britz Ag Chem. A total of 19 PCAs attended resulting in a good exchange of information on pest monitoring practices. These meetings were important because the PCAs with these two companies influence a large number of growers in the project region.

The “Seasonal Guide to Environmentally Responsible Pest Management Practices in Peaches and Nectarines” was published and mailed to each fresh market stone fruit grower in the San Joaquin Valley. Although not part of this project, a similar guide for prunes was published. Plum growers can utilize the prune guide for pest management practices because they are virtually identical to peaches and nectarines.

The grower survey noted changes in IPM practice. The biggest were use of oil alone without organophosphate pesticides for control of San Jose Scale, use of Bacillus thuriengensis and spinosad as well as use of other reduced risk pesticide products and increased use of pheromone mating disruption. In addition, as a result of project work *Macrocentrus ancylivorous* has been identified as an effective biocontrol for OFM.

NEW TECHNOLOGIES:

Target sensing spray technology (SmartSpray®) and remote sensing using aerial imagery to pin-point web spinning mite infestations.

TECHNOLOGIES TRANSFERABLE:

Target sensing spray technology could be adopted by other commodities, and/or in other regions.

IF BIOPESTICIDES/REDUCED RISK ALTERNATIVES WERE USED, WERE THEY EFFICACIOUS?

All of the biopesiticides (biological pesticides such as Bacillus thurengiensis and spinosad) used in the project were exceptionally effective. Dormant oil alone is very effective for low to moderate levels of SJS. Efficacy is enhanced with the addition of reduced risk growth regulators pyriproxyfen (Esteem®) or buprofezin (Applaud®). By utilizing these products, scale does not need to be treated each year. There were no failures with the reduced risk approach. In addition to alternative pesticides, *Macrocentrus ancylivorous*, Rowher, a parasitoid effective against OFM was released in stone fruit orchards. The natural host of this native parasitoid is the sunflower moth *Homeosoma electellum*. As a result of sampling it was found that sunflower moth is widely present in wild sunflowers. This provides a natural over wintering host for *Macrocentrus.*

ECONOMIC VIABILITY:

TACTIC / PRACTICE	ADOPTION COST	SAVINGS / ACRE
Reduced-Risk Insecticides	$189.00*	
Target Sensing Spray Equipment	$34,000**	
Pheromone Mating Disruption	$100.00 /Acre***	$10.00
Biocontrol (*Macrocentrus)*	No additional cost	

**Cost data from Stone Fruit PMA (2000-2003). Cost was identical for reduced-risk and conventional treatment*
***Cost for new SmartSpray® equipment*
****Mating disruption for OFM costs less than conventional spray treatment*

STATE(S) IMPACTED: California

KEY CROPS: Peaches, Nectarines and Plums

KEY PESTS:

COMMON NAME	SCIENTIFIC NAME
Oriental Fruit Moth	*Grapholita molesta*
Peach Twig Borer	*Anarsia lineatella*
San Jose Scale	*Quadraspidiotus perniciosus*
Omniverous Leafroller	*Platynota stultana*
Web Spinning Mites	*Tetranychus* spp.
Western Flower Thrips	*Frankliniella occidentalis*
Forktailed Bush Katydid	*Scudderia furcata*

THE PROJECT IMPACT ON THE FOLLOWING? Groundwater, Surface Water, Soil, and Air

Increased use of target sensing spray technology will have an immediate impact by increasing IPM strategies and reducing pesticide run off, leaching and air contamination.

WHAT PRACTICES WERE ADOPTED/WHAT CHANGED ON THE GROUND AS A RESULT OF THE PROJECT AND WHY DID GROWERS ADOPT THIS PRACTICE?

Growers are now more comfortable using oil alone to control SJS in the dormant season. This is a big change for stone fruit growers. Insecticides are added only when pest levels are high or problems maintaining control were encountered the previous growing season. Demonstration of pheromone mating disruption as an effective control for OFM has increased grower confidence and subsequent use of mating disruption. Release of the *Macrocentrus* parasitoid and demonstration of its effectiveness in controlling OFM has helped to further increase grower confidence. Information in the Seasonal Guide has resulted in increased interest and use of reduced-risk insecticides such as spinosad, diflubenzuron, methoxyfenozide and spirodiclofen replacing broad spectrum OP’s and carbamates.

WHAT, IF ANY, WORKER SAFETY ISSUES DOES THIS PROJECT ADDRESS?

Worker safety is important to growers as documented in the survey. OPs and carbamates present a potential hazard to workers assigned to handle (e.g., mix/load and apply), and reenter treated areas.

WHAT, IF ANY, ENDANGERED SPECIES DOES THIS PROJECT ADDRESS?

COMMON NAME	**SCIENTIFIC NAME**
San Joaquin Kit Fox	*VULPES MACROTIS MUTICA*
Valley Elderberry Longhorn Beetle	*DESMOCERUS CALIFORNICUS DIMORPHUS*

PROJECT WEB ADDRESSES:

<http://www.cdpr.ca.gov/docs/pestmgt/ipminov/ipmmenu.htm>
<http://www.ipm.ucdavis.edu/IPMPROJECT/otherpubs.html>
<http://www.ipm.ucdavis.edu/PMG/selectnewpest.peach.html>
<http://www.ipm.ucdavis.edu/PMG/selectnewpest.prune.html>

RESULTS OF DIRECT ENVIRONMENTAL MEASURES:

Water Quality Evaluation–Pursuant to requirements of the Irrigated Lands Conditional Waiver Program, Kings River Conservation District conducts water monitoring under guidelines established in a Quality Assurance Project Plan developed for the California Regional Water Quality Control Board. Water samples were tested for a range of constituents including pesticides. In particular, samples were tested for the five FQPA targeted pesticides: diazinon, phosmet, chlorpyrifos, carbaryl and methidithion. Analysis of the test results from samples taken over a two-year period (5/18/06 to 5/20/08), showed residues for carbaryl, diazinon, methidithion and phosmet below analytical detection limits. Analysis for chlorpyrifos (3 samples) showed residues at the trace detection level.

Air Quality Evaluation–Air-monitoring data from Parlier, as part of the DPR's Environmental Justice Pilot Project was available for review. Three of the FQPA targeted pesticides, diazinon, chlorpyrifos and phosmet were detected during ambient air sampling. Diazinon exceeded DPRs health screening level for acute exposure on one day (one of 468 samples). As a result diazinon has been prioritized for risk assessment. Chlorpyrifos and phosmet did not exceed DPR established screening levels.

RESULTS OF SURROGATE ENVIRONMENTAL MEASURES:

To establish baseline pest management and change in acceptance of IPM practices in stone fruit orchards, growers and pest control advisors (PCA) were surveyed in 2005 and 2008. In 2005 approximately 1200 fresh-market peach, nectarine, and plum growers in California received surveys and 980 growers received surveys in 2008. Essentially 100% of growers were surveyed based on membership information from CTFA. Its estimated that only about 1% of growers were missed. Response rates were: 171/1200, and 175/980 for the two survey dates. The lower number of surveys mailed in 2008 represents actual reduction in growers. The surveys included essentially the same questions both years in order to establish a baseline and provide a basis for evaluating change.

Conclusions

- Respondents were mostly owners who manage pest themselves
- 94% of all acres were held by large growers (greater than 100 acres)
- In 2005 most growers had greater than100 acres, but in 2008 most had less than 100 acres
- Relative importance of stone fruit pest: PTB > OFM > Mites > SJS > Katydid
- Monitoring increased, especially
    - Mites presence/absence
    - PTB blossom & shoot strikes
    - PTB emergence from winter hibernation sites
- Biological/cultural control increased, especially
    - Sanitation by removal of mummy fruits to remove overwintering brown rot spores
    - Monitoring of predatory mites & six-spotted thrips
- Use of reduced risk pesticides increased, especially
    - Biological pesticides
    - Pheromone mating disruption
    - Oil alone (no organophosphates) in the dormant season to control SJS
- Overall IPM use greatly increased as exemplified by growers IPM composite scores

NUMBER OF DOCUMENTED ACRES WHERE NEW TACTICS ARE BEING IMPLEMENTED:

Acres	Year
18,884	2004 - 2008

POTENTIALLY IMPACTED ACRES:

The project potentially impacted approximately 200,000 acres. This includes statewide acreage for peaches (freestone and clingstone), nectarines and fresh and dried plums.

NUMBER OF PARTICIPATING FARMERS:

Over 2,350 growers and PCAs participated in the project. Six growers and five PCAs participated in the demonstration phase of the project. In 2005, 171/1200 growers returned a survey and in 2008, 174/980* returned a survey. Approximately 2,000 growers and PCAs participated in one or more of the field days, meetings or other project outreach events.

**A total of 67 growers returned both surveys*

HOW MANY GROWERS INDICATE THEY WILL CHANGE THEIR BEHAVIOR AS A RESULT OF THIS PROJECT?

The percentage of growers who responded to the survey indicated a willingness to change. For example, in 2005, when asked if they used IPM 35% of the respondents said yes. In 2008, 60% of the respondents said they used IPM practices.

PESTICIDES TRANSITIONED FROM:

ACTIVE INGREDIENT	APPLICATION (LBS / ACRE)	PRECENT REDUCTION
Carbaryl	0.20	47%
Diazinon	0.26	79%
Chlorpyrifos	1.13	2%
Phosmet	1.84	15%
Methidathion	0.57	0%

Between 2004 and 2007 use of the five FQPA pesticides in pounds per acre planted was down–26% based on the benchmark average (2000-2003).

PESTICIDES TRANSITIONED TO:

Alternative reduced-risk insecticides include horticultural oil, spinosad, diflubenzuron, methoxyfenozide and spirodiclofen.

ALTERNATE TACTICS USED:

Target sensing spray technology to reduce amount of pesticide applied, pheromone mating disruption, and biocontrol agents.

NEW TECHNOLOGY:

Target sensing spray technology and remote sensing aerial imagery to track pest damage.

IS THE PROJECT COMPLETE?

Project work is still on-going. Additional work, using knowledge gained, is being extended to the Central San Joaquin Valley through the Canning Peach Pest Management Alliance project funded by DPR. This project is designed to reduce OP insecticide use in the canning peach industry an additional 20 percent, by 2011. Based on successes in the fresh fruit industry, canning peach growers will be encouraged to adopt new monitoring methods for key pests, to use pheromone-mating disruption, and to enhance existing biological control by planting sunflowers as a refuge for the *Macrocentrus ancylivorous* parasitoid shown to be effective in controlling OFM, a key pest in canning peaches.

WHAT IS THE ENDING SCORE ON THE SAI TRANSITION GRADIENT?

The project moved growers from the Strategic Agriculture Initiative IPM transition gradient score 1 to score 3. After moving to 1 as a result of work by the California Tree Fruit Agreement and UC researchers through a DPR Pest Management Alliance (PMA) grant. The Stone Fruit FQPA grant provided continuation that allowed education, training, and experience using workshops, the Seasonal Guide, and target-sensing sprayer (SmartSpray®) to decrease pesticide use and increase grower reliance on IPM practices as well as increased reliance on reduced-risk pesticides and practices. Evidence of this transition are changes in actual pounds of pesticide used as recorded in the Pesticide Use Report database, the grower survey, and other project data. The Stone Fruit FQPA project also allowed identification, refinement, and incorporation of the parasitoid *Macrocentrus sp*. as an effective addition to the initial IPM program. The project has been so successful that it is being used as a model through $585,000 in new DPR PMA grants to support IPM outreach and demonstration for canning peach, almond and grape growers. In addition, new funding $160,000 through an EPA-PRIA II grant will support continued outreach to the above commodities and expand to include Walnuts as well. This new project will emphasize expanding the cooperative alliance to include other agencies, e.g., USDA-National Resources Conservation Service, California Resource Conservation Districts, and California County Agricultural Commissioners to aid growers to move toward SAI transition gradient 5.

COMPLETION DATE:

The project completion date was June 30, 2008.

LESSONS LEARNED:

What Worked

- Good team effort
- Survey provided useful information on grower attitudes and use of IPM
- Publication of the Seasonal Guide provided a reduced-risk pest management standard for growers and PCAs
- Targeted outreach with two major pesticide distributors in the region
- Demonstration of the SmartSpray® equipment created interest in target sensing spray technology
- Created an opportunity to collaborate with USDA NRCS to provide cost-share opportunities for growers who follow the guide or UC Year-Round Plan
- Examined feasibility of using remote sensing technology as a pest management tool
- The *Macrocentrus* parasitoid was identified as an effective biological control program for OFM

What Did Not Work

- PCA's did not have time to conduct all the critical pest management activities identified in the Seasonal Guide
- Loss of data from computer module on SmartSpray® due to equipment breakdown
- Outreach with Coalition for Urban/Rural Environmental Stewardship was not accomplished
- Remote sensing for mites (needs additional work)

WERE PROJECT GOALS MET AND DO YOU CONSIDER IT A SUCCESS?

The overall project goal was to assist growers to reduce, by 20 percent, their use of organophosphate (OP) and carbamate pesticides targeted by the FQPA. Pesticide use among the large growers in the project area deceased by 26 percent. This was accomplished by increasing grower outreach and education of IPM and by producing and making available to growers an easy to use and understand Seasonal Guide. This Guide was the key to project efforts. The Seasonal Guide will be used in USDA-NRCS efforts to assist growers to adopt IPM through implementation and funding provided by the EQIP program, thereby extending the successes of the grant into the future. Growers were able to see an effective target-sensing sprayer at project field days and were able to test its effectiveness in their own fields. This component of the program showed growers that these new sprayers could reduce spray volumes from 20–47 percent without affecting pest damage. Again, project efforts to leverage grant funds with USDA-NRCS should keep this program active into the future. Over 2,000 growers and PCA's attended one or more of the various field days or project meetings. The value of smaller meetings at pest control company headquarters was established, allowing one-on-one discussion to take place that benefited the PCA and UC researchers. The use of remote sensing technologies for early detection of mite infestations in stone fruit provided usable data. Results showed that mite damage has a detectable effect on the spectral reflectance of peach leaves and canopies. However, due to the effects of other factors, such as desiccation and nutrient deficiency, detection of mite damage based solely on spectral readings remains difficult.

The grower survey was particularly successful in assessing growers awareness and attitudes toward reduced-risk pest management and IPM. The project used outreach and demonstration to increase use of monitoring as a guide to spraying decisions, use of biological controls, and replacement of high-risk chemicals such as organophosphates and carbamates with reduced reduced-risk products. All monitoring practices examined in the survey increased. The greatest increases in use of monitoring were seen in sampling for mites, monitoring of blossom and shoot strikes for PTB, monitoring emergence of PTB from overwintering sites, and monitoring PTB population changes with pheromone traps. These increased by 14, 11, 10, and 8 percent, respectively. Sanitation to remove mummies containing brown rot spores was used by about 67 percent of growers, an increase of 7 percent over 2005. Monitoring for beneficials increased by 6 percent over 2005.

The survey indicates that use of reduced-risk pesticides increased among growers. Most important increases were the use of mating disruption with pheromones, biologicals such as *Bacillus thurengiensis* and spinsosad, and use of oil alone. These reductions are supported by the PUR data—the amount of FQPA targeted pesticides used by growers did decline in favor of reduced-risk pesticides.

Perhaps a collateral result of project outreach involved grower's considerations when choosing a pesticide. The survey showed a significant increase for "worker safety" as a consideration. Overall the survey indicated that in terms of IPM awareness there was a dramatic increase in the percentage of growers, from 35% in 2005 to 60% in 2008, that use a suite of IPM-related practices in their orchards.

OTHER COMMENTS:

This project is a success story that grew out of the cooperative effort and vision of dedicated growers, PCAs, Farm Advisors, university researchers, and commodity board leaders. In 1998 and 1999, two DPR grants of $30,000 each, provided resources to evaluate and implement reduced-risk IPM practices for SJS, PTB, and OFM in stone fruits orchards. Organophosphate pesticides, which at that time accounted for greater than 80% of pesticide use in stone fruit orchards greatly reduced the effectiveness of natural enemies of these pests. San Jose Scale in particular had become such a serious pest in the San Joaquin Valley that growers were removing orchards. These first projects allowed efficacy trials of key components of the IPM plan that were effectively promoted later in this FQPA project.

Between 1999 and 2003 with the aid of four additional DPR Alliance grants totaling $251,365, the California Tree Fruit Agreement (CTFA) and the Cling Peach Advisory Board (CCPA) combined forces to develop a model IPM system incorporating IPM approaches developed by the University of California. Broader use of the IPM system of intensive field monitoring, use of mating disruption, use of biological agents, and implementation of reduced risk materials allowed economic studies to be included as well. Through these demonstration and outreach projects by CTFA and CCPA, hundreds of PCAs and growers observed reduced-risk practices that effectively control pests of stone fruit. By 2003, although the IPM system showed great potential, only modest reductions in use of broad-spectrum pesticides were as yet observed.

CTFA continued promoting an IPM system using its own funds until FQPA funding became available in 2004. As can be seen from project results during the past four years, this long effort has borne out the vision of early leaders, notably Jonathan Field, Blair Richardson, and Gary Van Sickle of the CTFA, the many researchers, grower cooperators, PCAs, and funding agencies. Worthy of particular mention is Walt Bentley, UCIPM Entomologist, UC Kearney Agricultural Center for his many years of hard work, exceptional insights, and dedication to this project. Although the FQPA grant which focused primarily on fresh-market tree fruits has come to an end, the project continues with a new Canning Peach Pest Management Alliance grant of $195,000 from DPR. The support provided by the US EPA-FQPA grant provided the means to bring this visionary work to fruition. The project was not only a success but is a model for future IPM development and outreach programs.

Attachment A: Seasonal Guide to Environmentally Responsible Pest Management Practices in Peaches and Nectarines

Seasonal Guide to Environmentally Responsible Pest Management Practices in Peaches and Nectarines

Walter Bentley, IPM Entomologist, UC Kearney Agricultural Center • **Carolyn Pickel**, UC Cooperative Extension Area IPM Advisor, Sacramento Valley • **Janine Hasey**, UCCE Farm Advisor, Sutter-Yuba Counties **Richard Coviello**, UCCE Farm Advisor Emeritus, Fresno County • **Mario Viveros**, UCCE Farm Advisor, Kern County • **Brent Holtz**, UCCE Farm Advisor, Madera County • **Harry Andris**, UCCE Farm Advisor, Fresno County **Roger Duncan**, UCCE Farm Advisor, Stanislaus County • **Marshall Johnson**, IPM Entomologist, UC Kearney Agricultural Center • **Barbara Ohlendorf**, Pest Management Guidelines Coordinator, UC Statewide IPM Program **Gary Van Sickle**, Research Director, California Tree Fruit Agreement

University of California
Agriculture and Natural Resources
Publication 21625

The Stone Fruit Pest Management Alliance (PMA), a public-private partnership, is dedicated to the demonstration of environmentally responsible pest management practices for managing economic pests in peaches and nectarines. The partnership includes the California Tree Fruit Agreement, the California Cling Peach Board, UCCE Farm Advisors and IPM Advisors, the California Department of Pesticide Regulation, and the U.S. Environmental Protection Agency (EPA) Region 9.

The information in this publication is based on research findings of University of California Cooperative Extension (UCCE) Farm Advisors working with peach and nectarine farmers in California. It is designed to be a readily accessible resource to assist in making environmentally responsible pest management decisions that do not result in decreased crop value or increased production costs. The peach industry in California has many alternatives to broadly toxic pesticides, which have been linked to surface water contamination and worker safety concerns. Because circumstances exist when these materials may be necessary, we have designed this program to use them only when necessary and as a last resort.

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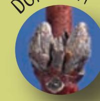
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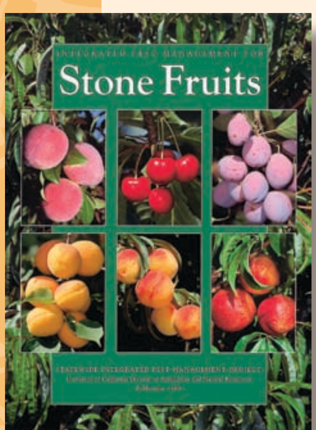
YOUR PEST MANAGEMENT PROGRAM IS ENVIRONMENTALLY RESPONSIBLE IF IT RELIES UPON:

- **Monitoring key pests and beneficial arthropods, diseases, and weeds on a regular basis.**
- **Using sprays only when monitoring information shows the potential for crop damage.**
- **Using mating disruption for oriental fruit moth and effective, environmentally friendly, and less-toxic pesticides or pesticide timing whenever possible.**
- **Integrating cultural and biological controls as a regular practice.**
- **Using broad-spectrum insecticides as a last choice when environmentally friendly materials are not available.**

A SEASONAL APPROACH TO PEACH PEST MANAGEMENT

This guide takes you through the year based on the stages of peach tree growth, providing for an easily understood approach to environmentally friendly pest management in peaches (see table 1). It indicates the best times to monitor specific pests and, when available, gives treatment thresholds and appropriate pesticides to use.



Detailed year-round integrated pest management (IPM) plans for peaches and nectarines that complement this publication can be found on the UC IPM Web site at http://www.IPM.ucdavis.edu/PMG/crops-agriculture.html. These online documents include downloadable monitoring protocols, recordkeeping forms, pest identification screens, and specific treatment suggestions. Additional information can be found in other UC publications such as *Integrated Pest Management for Stone Fruits* (ANR Publication 3389), the UC IPM pest management guidelines for peach (see http://www.ipm.ucdavis.edu/PMG/selectnewpest.peach.html) and nectarine (see http://www.ipm.ucdavis.edu/PMG/selectnewpest.nectarine.html), and the *Tree Fruit Pest Identification Monitoring Cards* (ANR Publication 3426).

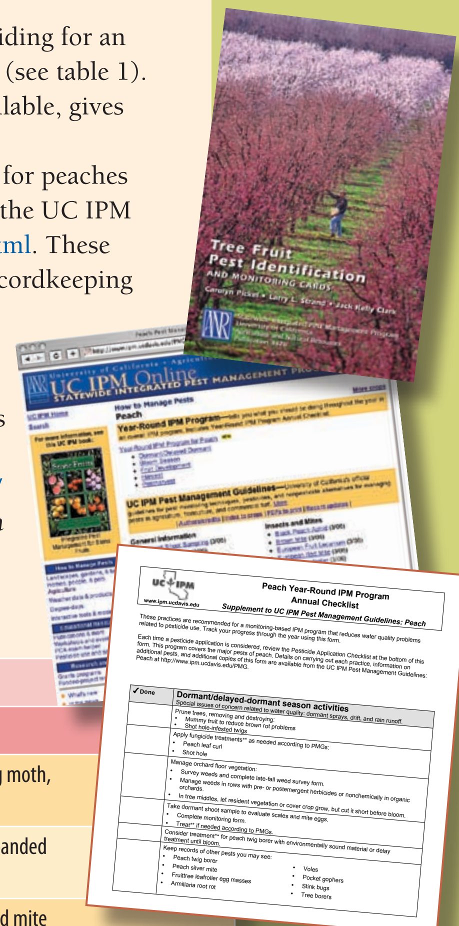


Table 1. Environmentally friendly insecticides and targeted pests

Insecticide class	Trade name examples	Target pests
mating disruption	Isomate M-Rosso, CheckMate OFM-F and OFM-SL, NoMate OFM, Isomate C TT, Isomate OFM TT	oriental fruit moth, omnivorous leafroller, codling moth, peach tree borer
microbials	Dipel, Condor, Javelin	peach twig borer, omnivorous leafroller, obliquebanded leafroller, fruit tree leafroller
miticides	Acramite, Apollo, Savey, Onager	Pacific mite, twospotted spider mite, European red mite
horticultural mineral oils	Gavicide, Omni oil, Volck supreme oil	San Jose scale, European red mite, European fruit lecanium scale
naturalyte	Success, Entrust	katydid, peach twig borer, omnivorous leafroller, obliquebanded leafroller, fruit tree leafroller, western flower thrips
insect growth regulators	Intrepid, Dimilin, Esteem, Seize, Centaur	oriental fruit moth, peach twig borer, omnivorous leafroller, obliquebanded leafroller, fruit tree leafroller, San Jose scale, katydid
neonicotinoids	Provado	black peach aphid

DORMANT PERIOD

DORMANT SPRAYS

What are dormant sprays and what do they control?

Any insecticide or fungicide applied during the dormant season is a dormant spray. Dormant oils alone control the wintering egg stage of European red mite and brown mite eggs, the black cap stage of San Jose scale (about 80 to 90% of the wintering population), and European fruit lecanium scale.

Traditional dormant oil sprays that include a pyrethroid or organophosphate insecticide control peach twig borer and obliquebanded leafroller. Environmentally friendly materials such as Success or Dimilin applied at the dormant period also control peach twig borer and obliquebanded leafroller. Green peach aphid does not plague Central Valley peach growers. Where green peach aphid is a problem, the inclusion of an insecticide is necessary for control. In some areas black peach aphid populations are becoming an increasing problem; dormant sprays do not control this pest. These insecticides reduce predatory mites but are less harmful in the dormant period than they are during the growing season. If insecticides are added to the dormant spray they do not control oriental fruit moth, codling moth, or webspinning spider mites.

Peach growers should also apply a dormant fungicide to control shot hole and peach leaf curl. The best program combines applications for insects and diseases. Most California peach farmers combine the pesticides for dormant insect control and dormant disease control into one dormant spray in winter. However, where peach leaf curl and shot hole disease are severe problems, an earlier dormant disease spray may be required in late fall, after leaf fall. If this is the case, choose a fungicide that controls both shot hole disease and peach leaf curl.

The dormant shoot sample will indicate whether San Jose scale or European red mite is a problem. Supreme or Superior dormant oil controls San Jose scale and overwintering mite eggs. Growers can control peach twig borer and leafrollers by adding environmentally friendly insecticides listed in table 1 during bloom along with fungicides for brown rot and eliminate the dormant spray that has been identified as a major contributor to pesticides in the rivers in February.

What pests are managed during the dormant stage?

- San Jose scale
    - During the dormant period, 80 to 90 percent of the population is in the black cap stage and is quite susceptible to oil applications.
- European red mite
    - European red mite overwinters in the egg stage and is also susceptible to dormant oil applications.
- European fruit lecanium
    - European fruit lecanium scale winters as a nymph exposed on twigs and branches. Dormant oil spray is most effective on this stage.
- Shot hole
    - Management of shot hole disease focuses on protecting buds and twigs from infection. Remove shothole–infested twigs when trees are pruned. If shot hole disease has been severe in the past, treat from November 15 to December 1 before winter rains begin.
- Brown rot
    - Remove mummy fruit during pruning to reduce brown rot problems.
- Peach leaf curl
    - Choose a fungicide for the shot hole spray that controls peach leaf curl.

Dormant spur.

Most San Jose scales will be in the black cap stage during the dormant season.

Remove mummy fruit during the dormant season to reduce brown rot problems.

How do you know whether your orchard needs a dormant spray for insects?

Use dormant shoot sampling for San Jose scale, European red mite, and European fruit lecanium scale. Collect 100 shoots (5 shoots along the primary and secondary scaffold limbs on 20 trees per block) anytime from early November through early January. The shoot samples should be about 3 inches (7.5 cm) long and should include both 1- and 2-year-old wood. If you collect samples from known hot spots you will be able to tell whether you need to spray for San Jose scale, European red mite, or European fruit lecanium scale. Treatment thresholds are given in table 2, which also indicates whether to add an insecticide to the dormant oil.

Using a hand lens or binocular microscope, examine the 3-inch basal section of the shoot and note the presence or absence of scales and parasitized scales and mite eggs. It is not necessary to count the number of individual insects or mite eggs present, just identify the pest and record that it is present. Note if parasitized scale are present.

A dormant sampling program is not available for peach twig borer or obliquebanded leafroller. Dormant oils alone do not manage these two pests, but bloom and spring sprays do manage them.

Clip off 3-inch (7.5-cm) shoot sections that contain both 1- and 2-year-old wood for the dormant shoot sample. *Photo by Barbara Ohlendorf.*

Dormant spray options

- For San Jose scale use a minimum of 6 gallons of oil per acre (56 l/ha). Dilute treatments at 300 gallons per acre (2,800 l/ha) provide better spray coverage for heavy populations. Insect growth regulators combined with oils can provide good control of severe scale populations. See the UC IPM pest management guidelines for peach and nectarine for more information on specific pesticides and application rates.

Alternatives to dormant spray for peach twig borer and leafrollers

Effective in-season treatment timings include bloom and May applications for peach twig borer, omnivorous leafroller, and obliquebanded leafroller. The environmentally safe insecticides listed in table 1 are not toxic to beneficial predators and parasites and can be used during bloom.

Special mitigation measures

If you still feel it necessary to use organophosphates or pyrethroids during the dormant season, take the following precautions to prevent contamination of waterways.

- Monitor weather forecasts and avoid spraying when soil is saturated and rain is likely.
- Do not spray just before rain is forecast.
- Make dormant applications before January 1. (Earlier applications allow the pesticides to degrade before the first rains in the season can cause runoff.)
- Mix, load, and clean equipment away from areas where wastewater or residues might run off into surface water. Take care to avoid contamination of surface water when rinsing the sprayer and attempt to work in a contained area.
- Minimize spray drift by shutting the sprayer off while turning at end of row and when near any body of water.
- Avoid spraying in foggy weather.
- Do not use organophosphates or pyrethroids when spraying adjacent to ponds, lakes, or rivers.

MANAGING ORCHARD FLOOR VEGETATION IN THE DORMANT PERIOD

Apply preemergent herbicides in tree rows or consider applying a postemergent herbicide in January. In tree middles, let resident vegetation or a cover crop grow, but mow it before it blooms.

Table 2. Dormant treatment decision table based on the percentage of infested shoots

Pest	Threshold (% infested shoots)	Treatment
San Jose scale		
harvested before June 15	below 20%	no treatment
	20–60%	oil at 6 gal/acre (56 l/ha)
	over 60%	oil at 6 gal/acre (56 l/ha) plus insect growth regulator
harvested after June 15	below 5%	no treatment
	5–10%	oil at 6 gal/acre (56 l/ha)
	over 10%	oil at 6 gal/acre (56 l/ha) plus insect growth regulator
European fruit lecanium	24% and below	no spray
	over 24%	oil only
overwintering mite eggs (brown mite and European red)	below 20%	no spray
	20% and over	oil only

BLOOM TO PETAL FALL

CRITICAL PEST MANAGEMENT ACTIVITIES

- Place pheromone traps for oriental fruit moth, omnivorous leafroller (San Joaquin Valley), and San Jose scale (see table 3).
- Monitor flowers for peach twig borer and manage with reduced-risk pesticides that are not toxic to honey bees.
- Manage obliquebanded leafroller using the same materials and timing as for peach twig borer.
- Monitor oriental fruit moth with pheromone traps and manage with mating disruption.
- Monitor thrips in nectarine orchards and treat, if necessary, before calyx tightens around the developing ovary.
- Monitor leaves and ground cover for katydid nymphs.
- Manage fungus diseases during the most susceptible period for each disease. Diseases managed during this period include brown rot, jacket rot, powdery mildew, rust, and shot hole.

Place pheromone dispensers in orchard to manage oriental fruit moth in early bloom stage. *Photo by Janine Hasey.*

Larva of peach twig borer on bloom.

FUNGUS DISEASE CONTROL, BLOOM TO PETAL FALL

- **Brown rot**
  - Bloom sprays reduce both blossom and twig blight as well as ripe fruit rot.
  - Treat at 20 to 40% bloom and again at full bloom.
  - Remove fruit remaining on trees after harvest to reduce inoculum the following spring.
- **Jacket rot**
  - Can be managed with the second brown rot spray at full bloom if appropriate fungicides are chosen.
- **Powdery mildew**
  - Management focuses on preventing infections. Rainy weather and warm temperatures promote powdery mildew.
  - Treat from bloom until pit hardening.
  - If nearby apples are expected to cause mildew problems on peaches, control the disease on apples or apply a fungicide to peaches at jacket split.
  - Alternate fungicides to prevent development of resistance to the fungicide.
- **Rust**
  - If rust was severe the previous year, treatment may be required as soon as trees leaf out.
  - Examine 1-year-old fruiting wood for small blisters or longitudinal splits.
  - Treat if cankers are found and rain is forecasted.
  - Additional applications may be necessary if wet weather persists.
- **Shot hole**
  - Treat in spring during bloom to prevent fruit and leaf infection.

Table 3. Placing traps for insect pest monitoring

Insect pest	Trap placement date	Purpose
obliquebanded leafroller	April 15	Monitor populations to better plan for next year's management.
omnivorous leafroller	February 20	Establish biofix.
oriental fruit moth	February 15 (San Joaquin Valley) February 25 (Sacramento Valley)	Establish biofix and determine mating disruption application.
peach twig borer	March 20 (San Joaquin Valley) April 1 (Sacramento Valley)	Establish biofix if bloom spray not used.
San Jose scale	traps: February 25 tape: April 1	Establish biofix and determine efficacy of dormant oil and parasitoid abundance.

ORCHARD FLOOR VEGETATION, BLOOM TO PETAL FALL

- Mow ground cover before bloom.

Rust lesion on second-year wood.

Peach buds in full bloom.

FRUIT DEVELOPMENT

CRITICAL PEST MANAGEMENT ACTIVITIES

- Place pheromone traps to monitor peach twig borer and obliquebanded leafroller (see table 3).
- Monitor shoot strikes for evidence of oriental fruit moth mating success and excessive peach twig borer populations. This entails looking for branch terminals that are wilted due to feeding by oriental fruit moth or peach twig borer.
- Monitor leaves and orchard weeds for presence of katydids, plant bugs, and stink bugs.
- Examine fruit for plant bugs and stink bugs by evidence of curling gum exudates.
- Monitor for powdery mildew until pit hardening.
- Monitor for rust twig cankers if rain occurs during April and May.
- Begin leaf examination for webspinning spider mites in June using timed searches to determine presence or absence.
- Use environmentally safe insecticides if sprays are needed. Fruit harvested after August 1 may require supplemental sprays if shoot monitoring indicates.

Peach fruit after pit hardening.

ENVIRONMENTALLY RESPONSIBLE PEST MANAGEMENT PRACTICES DURING THE GROWING SEASON

- **Orchard floor vegetation**
  - In mid-April to early May when summer annuals have germinated, conduct a weed survey to identify annual and perennial weeds that escaped the fall or winter treatments and to help plan next fall's management strategy.
- **Ripe fruit rot**
  - Apply preventive sprays during the last 4 weeks before harvest if rain is forecast.
  - Wetness, injury, or fruit cracking increases the chance of infection.
  - Controlling oriental fruit moth and peach twig borer reduces fruit injury.
- **Powdery mildew**
  - Monitor for powdery mildew until pit hardening, especially if apples, which can be a major source of inoculum, are grown nearby.
  - Treatment may be necessary in seasons when there is cool weather with occasional rain, but early treatments (at jacket split) are the most important and most effective.
- **Oriental fruit moth**
  - Oriental fruit moth is best managed with mating disruption. At times, mated moths may move from untreated neighboring orchards. If mating disruption is working properly, no moths should be trapped in pheromone traps.
  - Insecticides may be needed to supplement mating disruption, especially in orchards where fruit is harvested in late summer. Shoot strike sampling described in the year-round plan is used to determine whether supplement sprays are needed. If a block averages 3 shoot strikes, insect growth regulators can be used to supplement mating disruption. If a block averages 5 or 6 shoot strikes per tree, more then one spray may be needed. Refer to table 1 and review the UC IPM pest management guidelines for peach and nectarine for treatment timing if sprays are needed.
  - *Macrocentrus ancylivorus*, a parasitoid of oriental fruit moth, can also aid in control and can be preserved by using environmentally safe pesticides for oriental fruit moth and peach twig borer.

Powdery mildew on young peach fruit.


Shoot strike damage caused by peach twig borer or oriental fruit moth. *Photo by Walter Bentley.*

- **San Jose scale**
  - If horticultural mineral oil was applied properly during the dormant season, San Jose scale will not typically be a problem. Both narrow range oils for crawlers found in-season and environmentally sound insecticides such as buprofezin (Centaur) and pyriproxyfen (Esteem, Seize) are effective.
  - Monitor scale crawlers on main scaffolds and movement of crawlers on fruit by examining wood and fruit throughout the season. Optimal timing for sprays can be found in the UC IPM pest management guidelines for peach. Fruit harvested before July is seldom infested with this pest.
- **Peach twig borer**
  - Monitor peach twig borer pheromone traps at least weekly.
  - In the process of monitoring shoot strikes for oriental fruit moth, attempt to determine whether the strikes may be caused by peach twig borer by identifying larvae (see the UC IPM pest management guidelines for peach).
  - If more than 3 strikes per tree are found, a treatment may be needed. Methoxyfenozide (Intrepid) or spinosad (Entrust, Success) are environmentally sound insecticides.
  - Review the UC IPM pest management guidelines for peach for treatment timing if sprays are needed.
- **Katydids**
  - Monitor leaves and fruit for presence of katydid feeding.
  - If katydids have caused damage it is critical that treatment be made before katydids reach the adult stage.
  - An environmentally safe insecticide is spinosad (Success).
  - Adult katydids are very difficult to kill; make treatment decisions before June 1.
- **Plant bugs and stink bugs**
  - Monitor the ground cover with a sweep net in spring for these insects, and treat, if necessary, to prevent them from moving into the tree.
  - As fruit develop, check for damaged fruit. Look for gumming and sappy exudate; small, bluish green spots; pithy or corky areas under the skin; and dead areas.


Forktailed katydid and damage. *Photo by Walter Bentley.*

- **Rust**
  - Rust will develop if sporulating twig cankers are present and rain falls during April and May.
  - Monitor for twig cankers in April and apply protective fungicides if cankers have spores and rain is predicted through early June.
  - Sprays should be applied before leaf symptoms occur.
  - Rust occurs mainly in the Sacramento Valley and Kingsburg growing areas.
- **Scab**
  - If the orchard has a history of scab, treat 3 weeks after full bloom.
  - Treat again 2 weeks later if scab was severe the previous year.
- **Webspinning spider mites**
  - Begin monitoring for spider mites between June 15 and July 1, depending on where fruit is being grown. In the Sacramento Valley, begin monitoring in early July. A timed search method based on a rating system is available.
  - Environmentally safe miticides include bifenazate (Acramite), clofentezine (Apollo), and hexythiazox (Savey and Onager). Each of these is less toxic to the western predator mite than are other miticides. Low rates of summer oils can also be effective in the late spring and early summer.
  - Minimize water stress and dusty conditions.
  - Avoid applying pyrethroid insecticides aimed at other pests.
  - If predator mite populations are not present, consider releasing predators for long-term management.

HARVEST PERIOD

CRITICAL PEST MANAGEMENT ACTIVITIES

- As fruit is picked, sample a minimum of 500 fruit before sorting and identify pest damage. Keep records of damage to follow long-term pest trends.

Sampling fruit at harvest.

POSTHARVEST ACTIVITIES

- In early-harvest orchards, continue to monitor and treat, if necessary, San Jose scale and webspinning spider mites.
- Monitor shoot strikes to determine if oriental fruit moth populations are building.
- Treat for peach leaf curl and shot hole just after leaf fall.
- Conduct a late-fall weed survey to identify winter annuals and perennials that are present in the orchard; consider planting a cover crop if the resident vegetation is sparse.
- Look for dead and dying limbs caused by wood borers. Apply whitewash or interior latex paints to bark, if needed.

Brown rot developing on a fruit injured by peach twig borer or oriental fruit moth.

You'll find more information on peach and nectarine production and other topics in the many slide sets, CD-ROMs, and videos from UC ANR. Visit our online catalog at http://anrcatalog.ucdavis.edu, place orders by mail, phone, or FAX, or request a printed catalog from

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Attachment B: Study of Pest Management Practices in Stone Fruits

Study of Pest Management Practices in Stone Fruits

Cooperators and Sponsors:

California Tree Fruit Agreement
University of California

The purpose of the survey is to better understand the pest management decisions stone fruit growers make, characterize the adoption of Integrated Pest Management practices and to help direct further research of IPM practices by the University of California.

Please answer the questions to the best of your ability.

Q1. What insect and mite problems did you have in your bearing stone fruit acres within the last crop year, postharvest season through harvest (November 2004-current)? "Problem" means that if no control measures were taken, you believe the pest would have resulted in economic damage in your stone fruit.

NOTE: If you are unsure what pests you had, just mark your response as DK for "Don't Know".

Insect Pests	**Rank each pest in your operation (1 - 5), 1 being most important, 5 least important**	**Was the pest a problem within the last crop year?** *Circle NO or YES or DK (don't know)*
San Jose scale (SJS)		NO YES DK
Peach twig borer (PTB)		NO YES DK
Mites		NO YES DK
Katydid		NO YES DK
Oriental fruit moth (OFM)		NO YES DK
Other		

Q2. For each practice listed in the table below, please indicate if **you or someone on your farm** used the practice within the last stone fruit crop year, postharvest season through harvest (Nov. 2004-current).

Insect and Mite Monitoring Practices	**Was the practice used within the last crop year?**
	Circle NO or YES or DK (don't know)
Look at general appearance of the trees	NO YES DK
Sample dormant spurs for San Jose scale	NO YES DK
Monitor emergence of peach twig borer at the overwintering hibernacula (hibernation site)	NO YES DK
Sample blossom and shoot strikes to determine if sprays are necessary for peach twig borer	NO YES DK
Place pheromone traps for peach twig borer	NO YES DK
Use degree-days with monitoring	NO YES DK
Presence/Absence mite monitoring	NO YES DK

Q3. Think about the **cultural and biological insect management practices** in your stone fruits. For each practice listed in each row of the table below, please indicate **if you or someone on your farm** used the practice within the last stone fruit crop year, postharvest season through harvest (Nov. 2004-current).

Cultural and Biological Insect Management Practices	**Was the practice used within the last crop year?**
	Circle NO or YES or DK (don't know)
Perform annual winter sanitation to remove mummy fruits during winter	NO YES DK
Monitor for predatory mites and six spotted thrips	NO YES DK

Q4. Think about **insect management practices that involve the use of insecticides** in stone fruits on your farm. For each practice listed in each row of the table below, please indicate **if you or someone on your farm** used the practice within the last stone fruit crop year, postharvest season through harvest (Nov. 2004-current).

Management Practices Involving the Use of Pesticides	**Was the practice used within the last crop year?**
	Circle NO or YES or DK (don't know)
Spray a dormant insecticide such as *Lorsban, Diazinon, Asana, Supracide, or Imidan*	NO YES DK
Apply an in-season spray of *Lorsban, Guthion, Imidan, Asana* or similar product	NO YES DK
Use oil alone to control SJS	NO YES DK
Use Bt (i.e., *Dipel, Biobit, Condor*, etc.) or *spinosad* (i.e., *Success*) for control of peach twig borer at bloom	NO YES DK
Apply miticide in-season sprays	NO YES DK
Use alternatives to miticides, such as predatory mites, cultural practices, oils etc	NO YES DK
Use pheromone mating disruption	NO YES DK
Sprayed for katydid nymphs in April or May based on sample counts	NO YES DK

In this section of the questionnaire, we would like to know more about stone fruit grower impressions of IPM or Integrated Pest Management.

Q5. Overall, how knowledgeable do you feel you are about IPM in stone fruit? *Circle the number corresponding to your response.*

1. Not at all Knowledgeable
2. Somewhat Knowledgeable
3. Moderately Knowledgeable
4. Very Knowledgeable

Q6. Do you feel you have adequate pest management options to replace Lorsban and diazinon in your stone fruit production?

NO YES DK

Q7. Are you using more reduced risk practices or chemicals in your pest control/management program as some traditional materials have been removed from the market? If yes, please list material and target pest.

NO YES DK

If yes, please circle a material you have used from the list below.

Intrepid® Success® Horticultural Oil Onager® Agrimek®

Entrust® Applaud® *Bacillus thurengiensis* Acramite® Neemix®

Other____

Q8. What are your three most important considerations in choosing an insecticide? *Circle three.*

Cost Efficacy Environmental concerns Permit requirement Processor request

Resistance management Selectivity to beneficials Urban issues Worker safety

Q9. How would you rate your **use** of IPM for each of the pests listed below? *Place a check mark or X in the appropriate box for each pest area:*

Pest	Not at All	A Little	Moderate	A Lot
San Jose scale				
Peach twig borer				
Mites				
Katydids				
Oriental fruit moth				

Last, we need some background information.

Q10. What is the total number of bearing stone fruit acres you have this year, November 2004-current?

____

Q11. What is the approximate percentage of your stone fruits acreage harvested after August 1 last year?

____

Q12. What is the total number of your bearing stone fruit acres that were organic or in transition last year, November 2004-current?

____

Q13. Which of the following categories BEST describes your position with regard to stone fruit management? *Circle the number corresponding to the category that describes you.*

1. Owner; Hire someone to manage stone fruit
2. Manager, but not owner
3. Both Owner and Manager
4. Some other arrangement; Please explain:

Q14. Name: ____

Q15. Farm Name:____

COMMENTS:

We would appreciate any comments you would like to make relative to your insect control programs which may not have been addressed in this survey. Particularly, what tools do you need to reduce the use of organophosphate pesticides and move to reduced-risk pest management practices?

Attachment C: Examining the Feasibility of Utilizing Remote Sensing Technologies to Track Mite Damage in Stone Fruit Orchards

Examining the Feasibility of Utilizing Remote Sensing Technologies to Track Mite Damage in Stone Fruit Orchards

Project report

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EXECUTIVE SUMMARY

Scope and Objectives

To assess the feasibility of using remote sensing techniques to detect spider mite damage in peach orchards, a study was conducted in ten peach and nectarine orchards in Fresno and Kings Counties, California, during the field seasons of 2006 and 2007. Spider mites are an important pest affecting California's stone fruit industry, which uses large amounts of some of the most toxic agrochemicals permitted in California to control these pests. Due to the long periods of restricted orchard entry following these applications, spider mite damage can substantially disrupt the workflow. Remote sensing has been shown to reduce pest monitoring costs in agricultural operations and to allow a more thorough spatial identification of pest hotspots than conventional monitoring techniques. Successful applications in orchards, however, are rare to date, and no studies on the feasibility of remote sensing for detecting spider mite damage are currently available.

Study sites

Of the ten sampled orchards, seven were privately managed by a total of four growers, whereas the remaining three orchards were at Kearney Agriculture Center (KAC), a University of California research facility. Half of one orchard at this site was treated with a broad spectrum pesticide early in the season to ensure varied levels of mite damage in the orchard. Not all orchards were sampled in both years.

Sampling and analysis

During the field season of 2006, 50 leaves were collected from each of the five orchards investigated in that season, on 6 occasions throughout the season. At KAC, 25 leaves were taken from each of the eight blocks of the experimental design, resulting in 200 leaves per sampling date. Under a microscope, spider mites, spider mite eggs, predatory mites and eggs of predatory mites were counted, and the numbers averaged to monitor mite and predator dynamics over the season.

In the same season, mite damage of 392 peach canopies was assessed visually, assigning one of six damage classes to each canopy, ranging from 'no damage' to 'highly affected'. For each canopy, spectral reflectance was measured using an ASD FieldSpec Spectroradiometer (Analytical Spectral Devices, Boulder, CO, USA). This device measures leaf or canopy reflectance at wavelengths between 350 and 2500 nm, at 1-nm intervals, covering all visible and most Near Infrared regions of the electromagnetic spectrum. Measurements were taken from 1 m above the canopy as averages of triplicate spectral reading taken at two locations above the canopy.

In 2007, mite damage at the canopy scale was very low, so that the scale of the study was changed to the leaf level to obtain detectable differences in damage levels. For each of 1153 leaves, mite damage was estimated as the percentage of a circular area of 24-mm diameter centered on the middle rib of the leaf that showed visible signs of mite damage. Spectral reflectance was assessed for the same area using the ASD FieldSpec instrument and a leaf sampling device, which provided controlled light conditions.

The effect of different levels of mite damage estimates on spectral signatures was determined using Partial Least Squares regression, a technique that allows identifying spectral regions that are significantly correlated with leaf or canopy attributes. From the central bands of these significant regions, normalized difference reflectance indices were calculated. The potential of these indices, as well as nine previously published vegetation indices, to predict mite damage was tested by linear regression with the damage ratings.

After identifying the most promising spectral indices, the applicability of these findings was tested on aerial images obtained of all orchards during the field seasons of 2006 and 2007. Images were acquired from two different providers. For reasons outlined below, only images for 2006 could be used for calculating spectral indices. For assessing the usefulness of the derived index, trees corresponding to 265 canopy assessments at KAC, were georeferenced, and the assigned ratings were correlated with mean canopy index values derived from the aerial images.

Results and discussion

Mite and predator counts under the microscope revealed that the pesticide treatment at KAC promoted spider mites due to decimation of natural enemies of the pests. Nevertheless, mite counts increased throughout the season, except where miticides were applied.

On the leaf level, eight spectral regions were identified as significant, with several indices calculated from these bands, as well as the previously published indices NDVI, CTVI and SAVI, showing highly significant correlations with mite damage. The significant regions were located in the blue, green and red parts of the spectrum, at the red edge and in four parts of the adjacent Near Infrared region. Probably due to interference by water vapor and dust in the air between the sensor and the tree canopy, most of these regions were not significantly correlated with mite damage on the canopy level. However, a normalized difference index calculated from the only two significant regions, in the red and blue parts of the spectrum, showed potential for mite damage detection. This red-blue index reflects the visible color change of mite-affected leaves from dark green to reddish yellow.

Transferring these findings to some of the aerial images was impossible, because images obtained from one provider did not contain a blue band. Analyses were thus restricted to six images of each orchard obtained in 2006. For these images a normalized difference index was calculated from the red and blue bands of the images. A further impairment to the analysis was a large variation in image brightness, caused by atmospheric and focal effects during image acquisition, which concealed much of the subtle variation in spectral reflectance caused by spider mites. Subtracting the minimum pixel value from each index image removed some of this variation, but could not account for all confounding effects.

Nevertheless, relative mite damage variation in the orchards was clearly visible, and rough tracing of mite damage progression throughout the season was possible for the KAC experimental orchard. The ground-control procedure showed correspondence between index values derived from the aerial images and damage ratings assigned in the field, with a coefficient of determination of 0.47.

Conclusions

The study showed that mite damage has a detectable effect on the spectral reflectance of peach leaves and canopies. Due to the effects of confounding factors, such as desiccation and nutrient deficiency, on the spectral reflectance of peach trees, unequivocal detection of mite damage based solely on spectral readings remains difficult. Aerial images were not sufficiently standardized to detect the fine shifts in the spectral reflectance that accompany mite damage. Damage detection was most successful on the leaf level, indicating a higher potential for detecting mite damage using ground-based low-range spectral sensors than using aerial imagery.

Outreach and dissemination of results

Throughout the duration of the project, results were presented to peach growers on three occasions, in 2006, 2007 and 2008, at Kearney Agriculture Center in Parlier, CA. The results of this project will also be presented as a poster, an extended abstract and a full paper at the IEEE International Geoscience & Remote Sensing Symposium (July 6-11, 2008, Boston, MA) and in a journal article that is currently under review in Remote Sensing of Environment.

Scope and objectives

The objective of this project was to determine whether remote sensing could be successfully implemented to monitor peach orchard infestations with web-spinning spider mites. Spider mites are a widespread problem in California orchards and their control typically requires spraying of some of the most toxic pesticides commonly used in California. These applications are costly for farmers (Day et al., 2004) and, due to the long Restricted Entry Intervals of some of the chemicals used (Fouche et al., 2000), can substantially disrupt the workflow in stonefruit operations. Using remote sensing could help determine whether pesticide applications are necessary and aid in optimizing the timing of such applications. The feasibility of remote sensing for detecting mite damage has been demonstrated for field crops (Fitzgerald et al., 2002; Fitzgerald et al., 2004), but so far, data for achieving the same in stonefruit orchards is lacking.

In this project, the detectability of spider mite damage by multispectral techniques was tested on three levels of scale, by analyzing the spectral signatures of peach leaves, peach canopies and peach orchards and correlating these readings with mite damage observed on the ground.

Sampling and analysis

Study sites

Samples were taken from a total of ten late-harvest peach and nectarine orchards, covering approximately 74 acres in Fresno and Kings Counties. Most of the sampled area (~68 acres) belonged to commercial orchards, managed by four different growers (Fig. 1; Tab. 1). One of these growers followed organic management practiced. Three orchards belonging to Kearney Agriculture Research Center (KAC), a University of California research facility in Parlier, made up the remaining 6 acres. To ensure different levels of mite infestation in one of the orchards at this site, half of the orchard was treated with a pyrethroid (Pounce) several weeks before sampling. This treatment, which was applied to four of eight blocks of a randomized block design with ~37 trees per block, reduced populations of natural mite predators, facilitating rapid buildup of mite populations.
Two commercial orchards were only sampled in 2006, whereas the organic orchards were only sampled in 2007. At KAC, two small additional orchards were sampled in 2007.

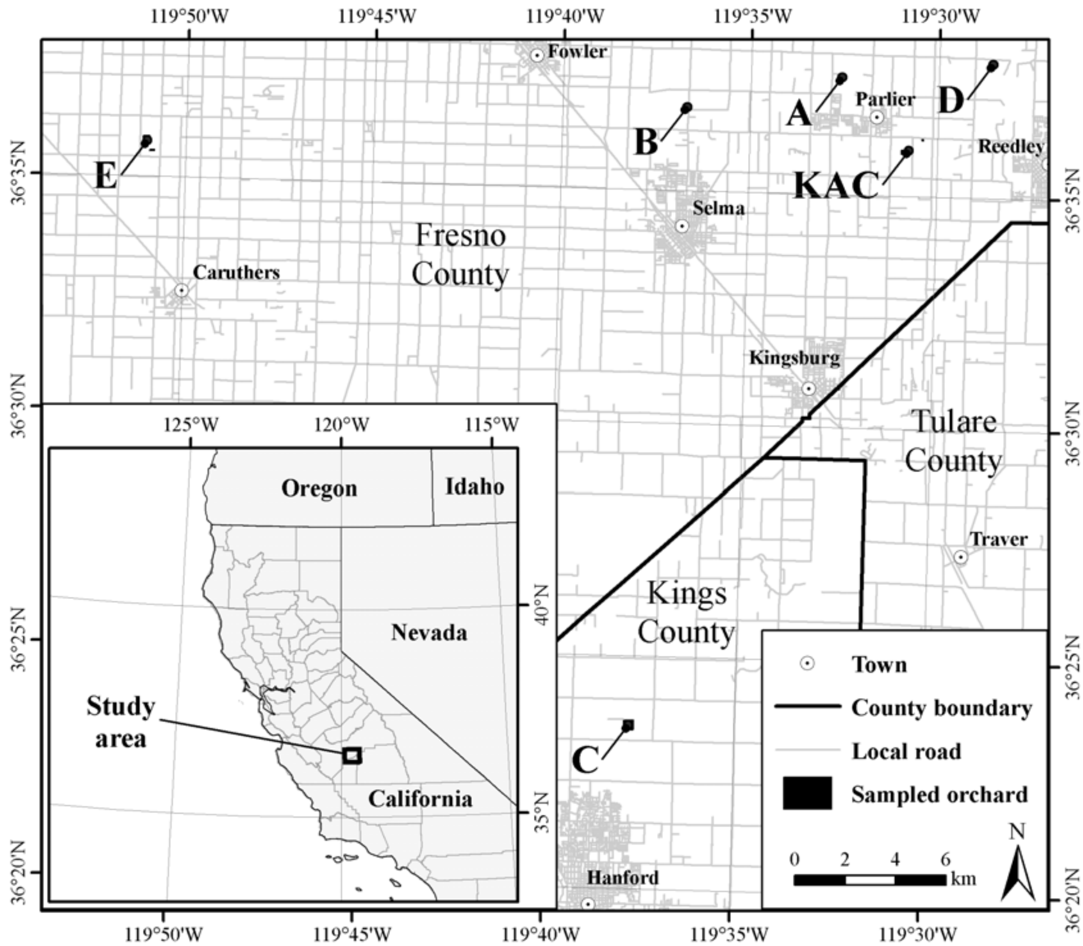

Figure 1. Map of orchards sampled in this project.

Table 1. List of sampled orchards.

Field Name	Lat./ Long.	Management	Area (acres)	Ownership	Years
KAC1	36°36’14”N / 119°30’23”W	Conventional	1	Public	Both
KAC5	36°35’56”N / 119°30’44”W	Conventional	2.7	Public	2007
KAC6	36°35’58”N / 119°30’56”W	Conventional	1.7	Public	2007
Chan	36°37’34”N / 119°32’35”W	Conventional	8	Private	Both
Chan2	36°36’48”N / 119°36’42”W	Conventional	5.8	Private	Both
Parkinson	36°37’50”N / 119°28’35”W	Conventional	10	Private	2006
Tos	36°23’30”N / 119°37’50”W	Conventional	39	Private	2006
Nak1Gp1	36°35’52”N / 119°51’4”W	Organic	2	Private	2007
Nak1Gp2	36°35’50”N / 119°51’4”W	Organic	2	Private	2007
Nak1Gp3	36°35’48”N / 119°51’4”W	Organic	2	Private	2007

Sampling and mite damage assessment

During the growing season of 2006, mite infestation in most orchards was relatively high, allowing sampling at the tree canopy level. Mite damage was assessed on a total of 392 tree canopies, distributed among all orchards investigated in that year (Tab. 1). Mite damage was quantified using the standard procedure of the University of California Integrated Pest Management (UCIPM) program (Pickel et al., 2006), assigning damage ratings on a six-point scale ranging from ‘no damage’ to ‘highly affected’. Among the trees sampled in this manner were the center nine trees of each treatment block at KAC. Samples were taken at two-week intervals between 18 July and 22 August, 2006.

In 2007, mite infestation in all orchards was very low, so that sampling whole canopies would have classified all trees into the two lowest mite damage classes, which would not have been informative. Sampling was thus scaled down to the leaf level, and 1132 leaf samples were collected on six occasions between 17 May and 2 August, 2007. On the leaf level, mite damage was quantified based on a circular area with a diameter of 24 mm centered on the middle rib of the leaf. For this area, the percentage of the area that showed visible signs of mite damage was estimated in increments of 5 percentage points. For very minor damage, a rating of 1% was assigned.

Mite counts

At weekly intervals between 13 June and 6 August, 2006, 50 leaves were collected from each commercial orchard analyzed, and an additional 25 leaves from each block of the experimental orchard at KAC. All leaves were stored on ice until analysis. Spider mites, spider mite eggs, as well as predatory mites and their eggs were counted under the microscope.

Spectral measurements

Spectral measurements were conducted using an ASD FieldSpec Pro Field Spectroradiometer (Analytical Spectral Devices Inc., Boulder, CO, USA). This device measures spectral reflectance in the visible and near infrared regions of the electromagnetic spectrum. The range of wavelengths covered is between 350 and
2500 nm, at a 1-nm resolution. All spectral measurements were taken as averages of three readings. For spectral analysis of tree canopies, the sensor of the spectroradiometer was held at nadir at approximately 1 m above the tree canopies. The spectral signature of a canopy was calculated as the average of triplicate measurements at two locations above the canopy. For analyses at the leaf level, the device’s leaf clip device was used to measure reflectance of a defined area of the leaf, which was similar to the area, for which mite damage had been assessed.

Aerial imagery

Multispectral aerial images were obtained from two providers, with one provider supplying two slightly different datasets (Tab. 2). The image providers were InTime Inc.

(Cleveland, MS, USA) and AgriData Inc. (Grand Forks, ND, USA). Unfortunately, the availability of spectral bands, as well as the range of wavelengths included in each bands varied between the three sets of images. As will be outlined later in this report, mite detection on aerial photographs requires a blue band, which was not available in the InTime datasets. These images could thus not be used. The AgriData images showed all orchards sampled in 2006 on 21 and 29 June and on 4, 12, 16 and 21 August, 2006.

Tab. 2. Properties of the aerial images obtained for this study.

Provider	Year	#	Blue	Green	Red	Near Infrared	Spatial res.
InTime	2006	1	n.a.	530-570 nm	640-680 nm	768-832 nm	1 m
AgriData	2006	6	410-490 nm	510-590 nm	610-690 nm	800-900 nm	0.5 m
InTime	2007	4	n.a.	530-570 nm	640-680 nm	772-828 nm	0.5 m

Analysis methods

Partial Least Squares regression was used to correlate the wavelengths of the spectral datasets with the mite damage ratings (Wold et al., 2001; Min and Lee, 2005), allowing the identification of significant wavelengths. From all possible pairs of two significant wavelengths, normalized difference reflectance indices were calculated (Tucker, 1979; Hansen and Schjoerring, 2003). Additionally, nine published vegetation indices were also calculated for comparison (NDVI, TCARI, OSAVI, SIPI, CTVI, MCARI, SAVI, PRI and RVSI).

For evaluating the suitability of the indices for estimating mite damage, linear regressions were computed between the values of each index and the damage ratings corresponding to the respective leaves or canopies. The F statistic of the linear regression was interpreted to indicate the goodness of fit.

From the results obtained at the leaf and canopy scales, an algorithm was developed to compute a mite damage index from the spectral bands included in the aerial images. For the experimental orchard at Kearney Agriculture Center, a total of 265 canopy damage ratings taken within three days of the aerial photographs were georeferenced and used as ground control of the image classification algorithm. Mean index values of the canopies of these trees were correlated with tree damage ratings, and the coefficient of determination interpreted to assess the goodness of the prediction.

Grower outreach and project management meetings

On three occasions, in the spring of 2006, February of 2007, and on 3 April, 2008, oral presentations were given to California peach growers to inform them about the progress of the project. To coordinate efforts with project partners outside the Remote Sensing component of the project, ~10 project management meetings were held between 2006 and 2008.

Results and Discussion

Mite counts

The pre-season pesticide treatment clearly affected the levels of spider and predatory mite individuals and eggs at Kearney Agriculture Center (Fig. 2). After mite populations had built up at the beginning of the sampling period, spider mite levels were consistently higher in the treated plots than in the untreated blocks. Predatory mite populations were largest in the untreated blocks, with very small numbers of individuals found in the treated blocks. The increase in predatory mite eggs in mid July in both treatments, however, indicates that a certain base population must have been present.

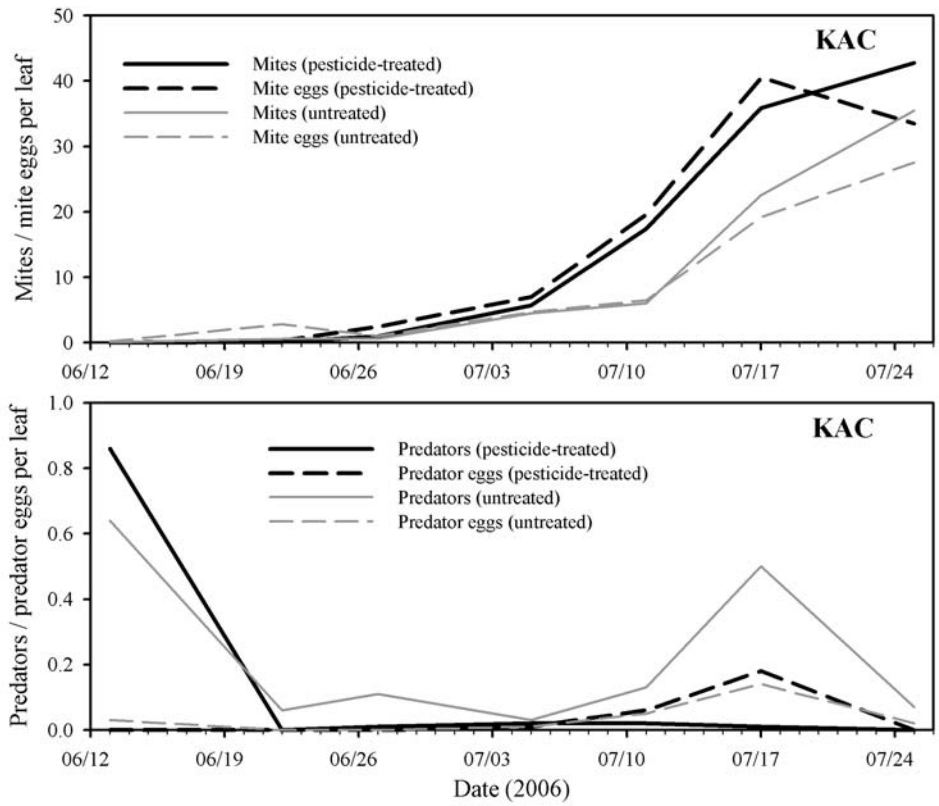

Figure 2. Counts of individuals and eggs of spider mites (top) and predatory mites (bottom) on leaves taken from the experimental orchard at Kearney Agriculture Center, with (black bold lines) or without (gray lines) pre-sampling treatment with a broad spectrum pesticide.

Because of the effective pest management strategies used in all commercial orchards, spider mite levels were substantially lower there than at KAC. At orchard Chan, mite populations and egg numbers peaked on 3 July, but were kept in check by a subsequent miticide application (Fig. 3a,b). Since the respective grower did not apply miticides after 26 June, mite populations and egg numbers at Park increased steadily over the entire sampling period. At Tos, almost no spider mites or eggs were present. Numbers of predatory mites were similar among all commercial orchards, peaking on 3 July, decreasing during the following two weeks and rising after that (Fig. 3c). Predatory mite eggs showed similar dynamics, except at Chandler, where temporarily high egg counts were substantially reduced following the miticide application (Fig. 3d).

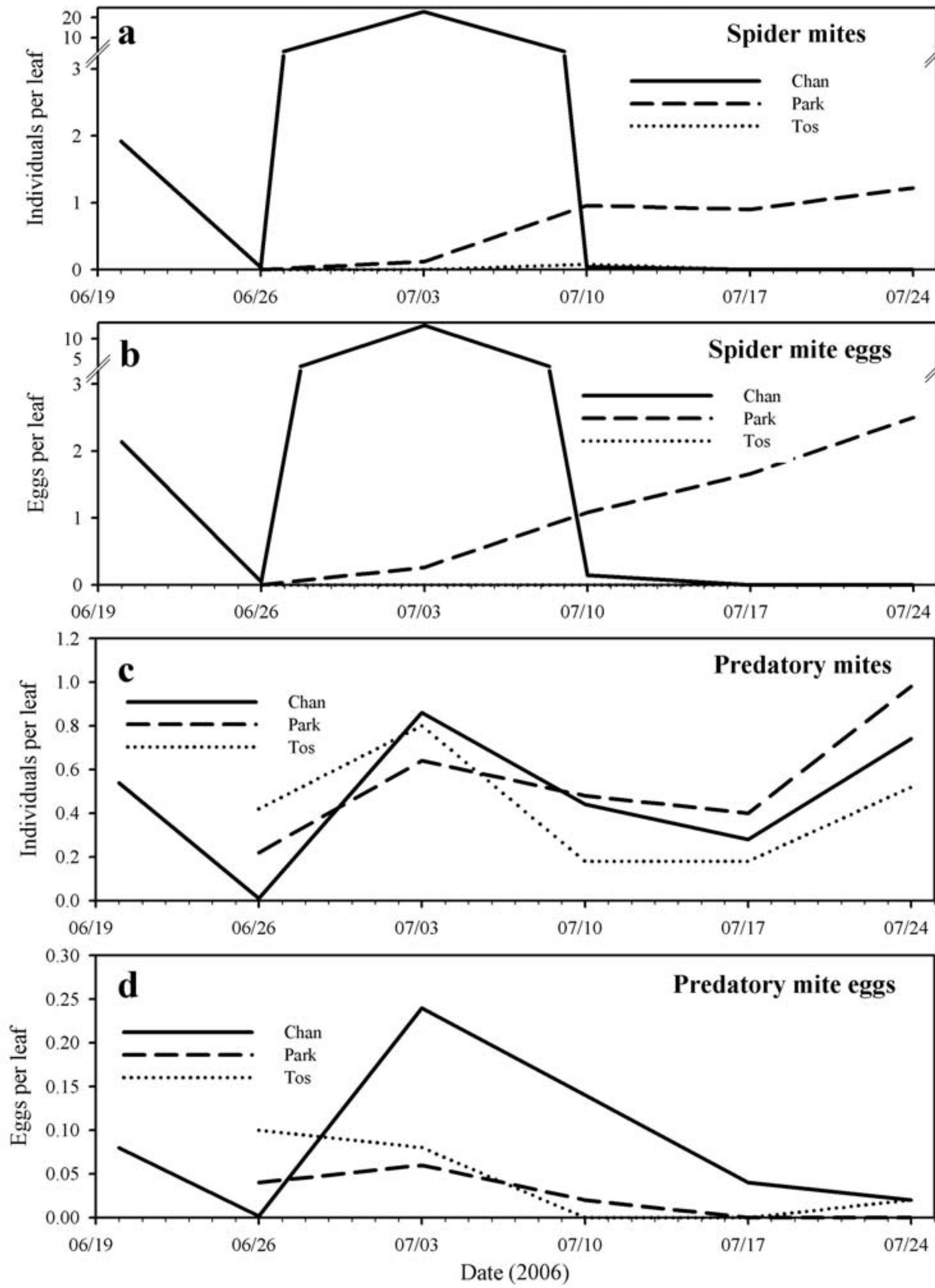

Figure 3. Temporal dynamics of counts of spider mite individuals (a), spider mite eggs (b), predatory mite individuals (c) and predatory mite eggs (d) at all commercial orchards sampled in 2006. Note the axis break in figures a and b.

Leaf level analyses

Eight regions of the electromagnetic spectrum contained wavelengths that were significantly correlated with mite damage on the leaf level (Fig. 4). These regions were located at wavelengths of visible light (365, 497 and 687 nm), at the border between red and near infrared (744 nm), and in the near infrared (1405, 1761, 1888 and 2500 nm). Several indices calculated from these bands, as well as the published indices CTVI, NDVI, OSAVI and SAVI were highly significantly correlated with mite damage (Fig. 5).

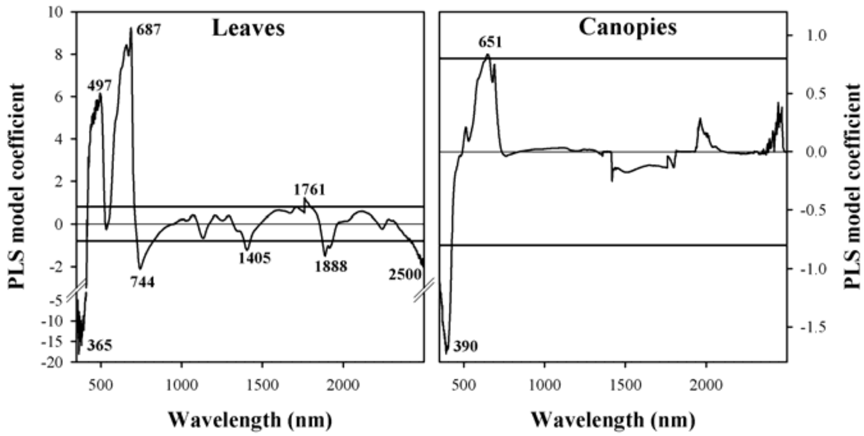

Figure 4. Regions of the electromagnetic spectrum of peach leaves (left) and canopies (right) that were identified as sensitive to mite damage by Partial Least Squares regression. The bold horizontal lines at -0.8 and 0.8 indicate the thresholds, below and above which wavelengths were considered significant.

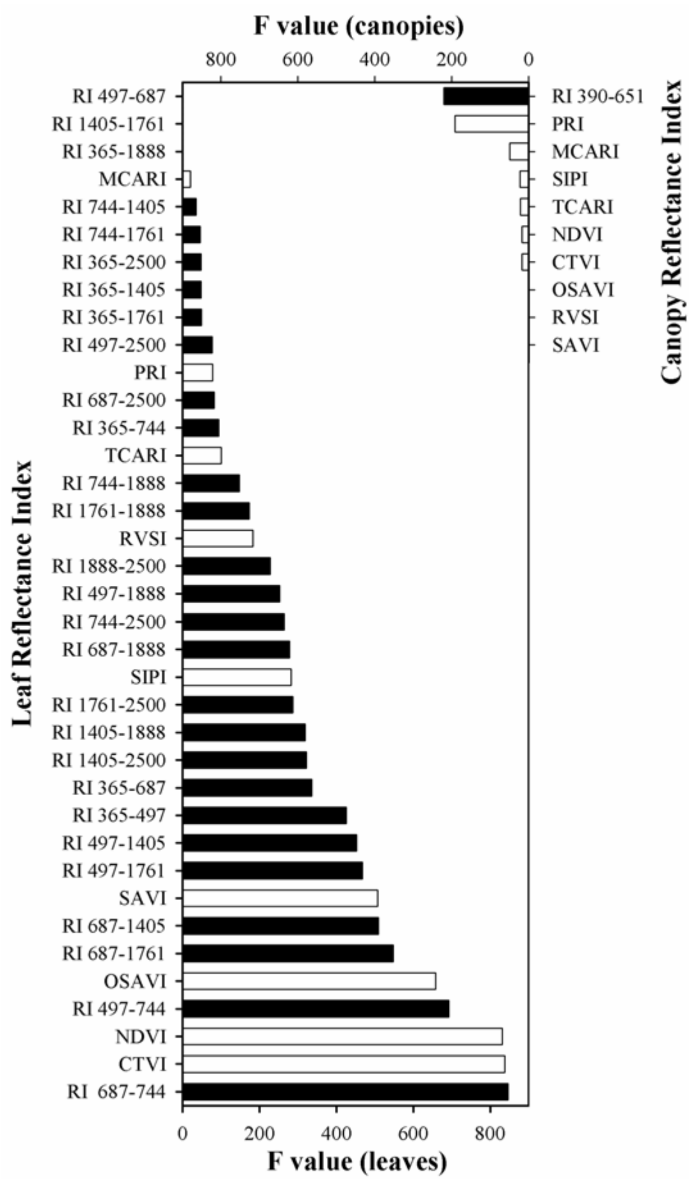

Figure 5. F values of the linear regression between the values of all calculated indices and mite damage ratings.

Canopy level analyses

On the canopy level, only two spectral regions were significantly correlated with mite damage (390 and 651 nm; Fig. 4). The loss of the other six bands when scaling up to the canopy level appeared to be due to the absorption of radiation by water vapor or particles in the air between canopy and sensor and due to interference by diffuse radiation from surrounding canopies. Nevertheless, the normalized difference reflectance index calculated from these bands was significantly correlated with mite damage (Fig. 5). The spectral bands involved in this index are in the blue (390 nm) and red (651 nm) parts of the spectrum, and variation in these bands reflects the change in color, from dark green towards orange and yellow, that is typical of mite damage.

Analyses of aerial images

Based on the significant spectral regions identified on the canopy level, the algorithm to estimate mite damage based on aerial photographs included calculation of a normalized difference index from the red and blue bands of the images. Analyses were restricted to the vegetated area of each image. Unfortunately, the images were poorly standardized, so that the overall brightness level and the relative brightness of the different spectral bands varied substantially among images (Fig. 6).

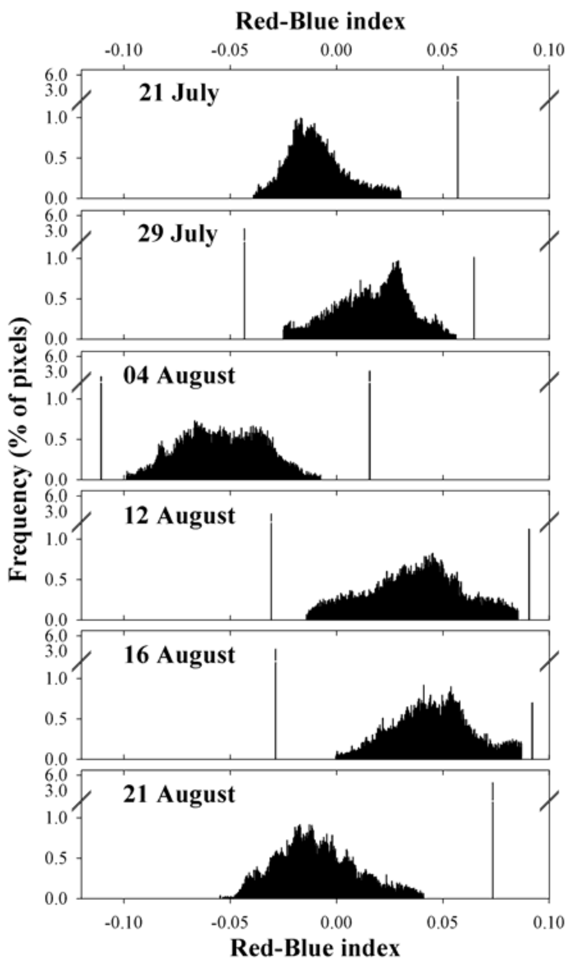

Figure 6. Calculated normalized difference red-blue indices for aerial images taken on six dates throughout the field season of 2006. The substantially different pixel value distributions among images complicated image interpretation.

Only six aerial images were useful for spectral analysis, because all photographs obtained from InTime Inc. lacked the blue band that was necessary for calculating the red-blue index. For the remaining images, the brightness variation was standardized by subtracting the minimum index value of each image from each pixel of the image. While this procedure removed some of the image-specific bias, it cannot be expected to completely account for the unsystematic variation in the dataset. The inconsistency in the aerial data precluded the establishment of an objective mite damage scale for the aerial photographs that could be used to reliably monitor mite damage progression over time. More efforts to standardize the way aerial photographs are obtained are necessary to remove these inconsistencies. Nevertheless, assessment of relative mite damage within one image and tentative analysis of damage progression over time among selected images was possible. Some postprocessing steps were carried out to remove some random scatter in the dataset and improve visualization (Fig. 7). The mite damage distributions on the index images corresponded roughly to the mite infestation levels observed on the ground, even though the coefficient of determination for the regression between index values and damage ratings was relatively low at 0.47 (Fig. 8).

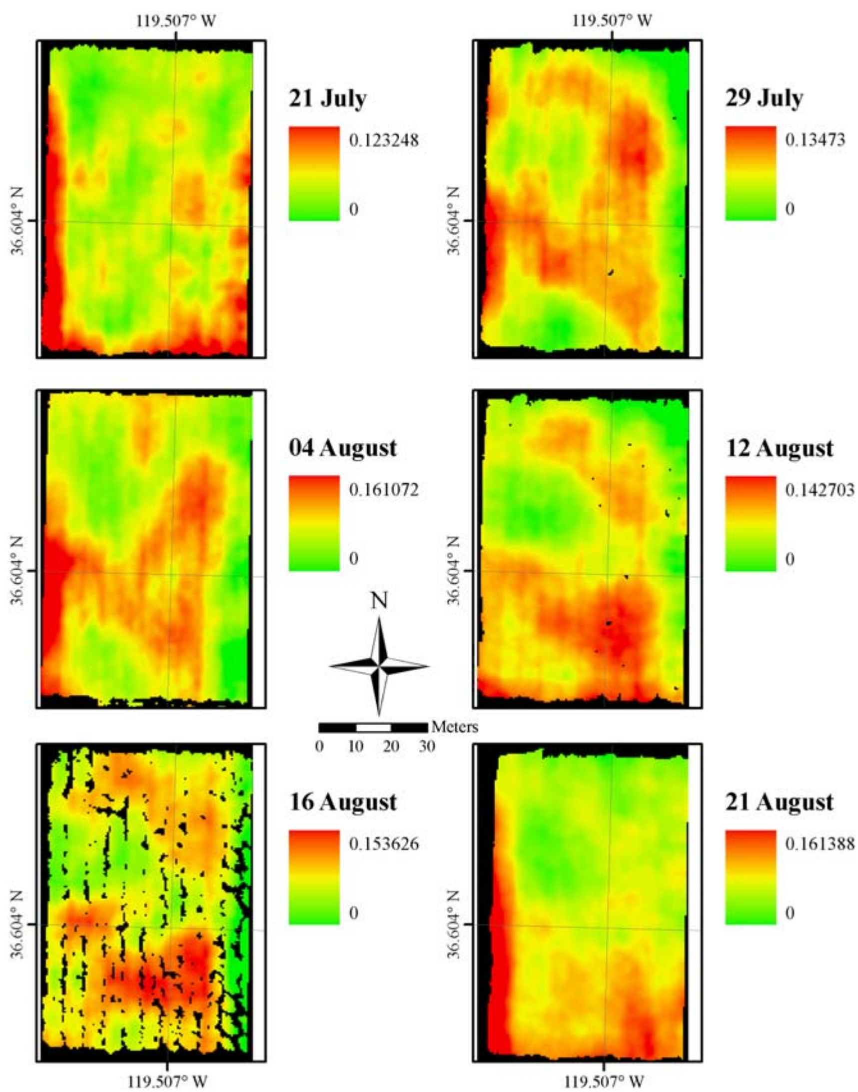

Figure 7. Mite damage monitoring using the normalized difference Red-Blue index. The image shows indices calculated for the experimental orchard at Kearney Agriculture Center for six dates throughout the field season of 2006.

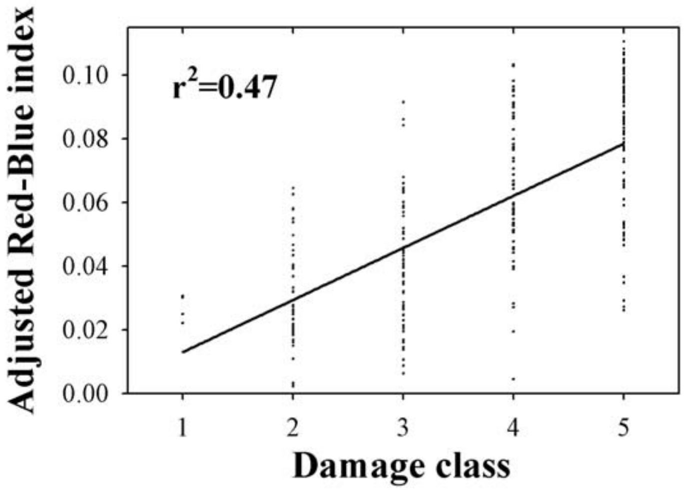

Figure 8. Correlation between mite damage ratings assigned to georeferenced peach canopies and Red-Blue index values (adjusted by subtracting the minimum pixel value of each image). Calculations are based on aerial images of the experimental orchard at Kearney Agriculture Center taken on six dates during the field season of 2006.

Conclusion

Even though highly significant correlations between mite damage and spectral readings were obtained in many cases, predicting mite damage unequivocally based on such indices seems difficult. Many processes affect peach trees, and the effects of desiccation, nutrient deficiency or certain plant diseases is likely to affect spectral reflectance in a similar manner as mite damage. Whether these techniques can be successfully implemented on the canopy or aerial image scale thus seems questionable. More potential appears to exist for developing ground-based sensors for mite damage detection, exploiting the larger number of significant wavelengths on the leaf level.

Dissemination of project results

The results of this research were presented to peach growers in three oral presentations at Kearney Agriculture Center in Parlier, CA in spring of 2006, on 2/14/2007 and on 4/3/2008. They will also be presented as a poster, an extended abstract and a full paper at the 2008 IEEE International Geoscience & Remote Sensing Symposium (July 6-11, 2008, Boston, MA) and in a peer-reviewed journal article that is currently under review in Remote Sensing of Environment. All articles, as well as two of the presentations to growers, are attached to this report.

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List of attached files

Folder name	**Description**
Aerial_images	All aerial images that were obtained during the summer seasons of 2006 and 2007
Canopy_spectral_data	Reflectance readings, damage ratings and indices calculated for all canopies during the season of 2006, combined in a comma-delimited values (.csv) file
Leaf_spectral_data	Reflectance readings, damage ratings and indices calculated for all leaves during the season of 2007, combined in a comma-delimited values (.csv) file Separate .csv filed for each date of reflectance readings of leaves in 2007
Mite_counts	File containing all mite counts from all four orchards, where mites were counted in 2006 (.xls file)
Resulting_publications	Extended abstract and full paper to be presented at the International Geoscience and Remote Sensing Symposium in Boston, 2008 (.pdf files) Manuscript of research results submitted to the International Journal of Applied Earth Observation and Geoinformation (.pdf file) Powerpoint file of the presentation given to growers at Kearney Agriculture Center on February 14, 2007 (.pps file) Powerpoint file of the presentation given to growers at Kearney Agriculture Center on April 3, 2008 (.pps file)

Attachment D: Environmental Justice Pilot Project Pest Management Assessment: Soil Fumigant and Organophosphate Insecticide Use and Alternatives–Parlier, Fresno County California

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

October 2007

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PML-07-01

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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).

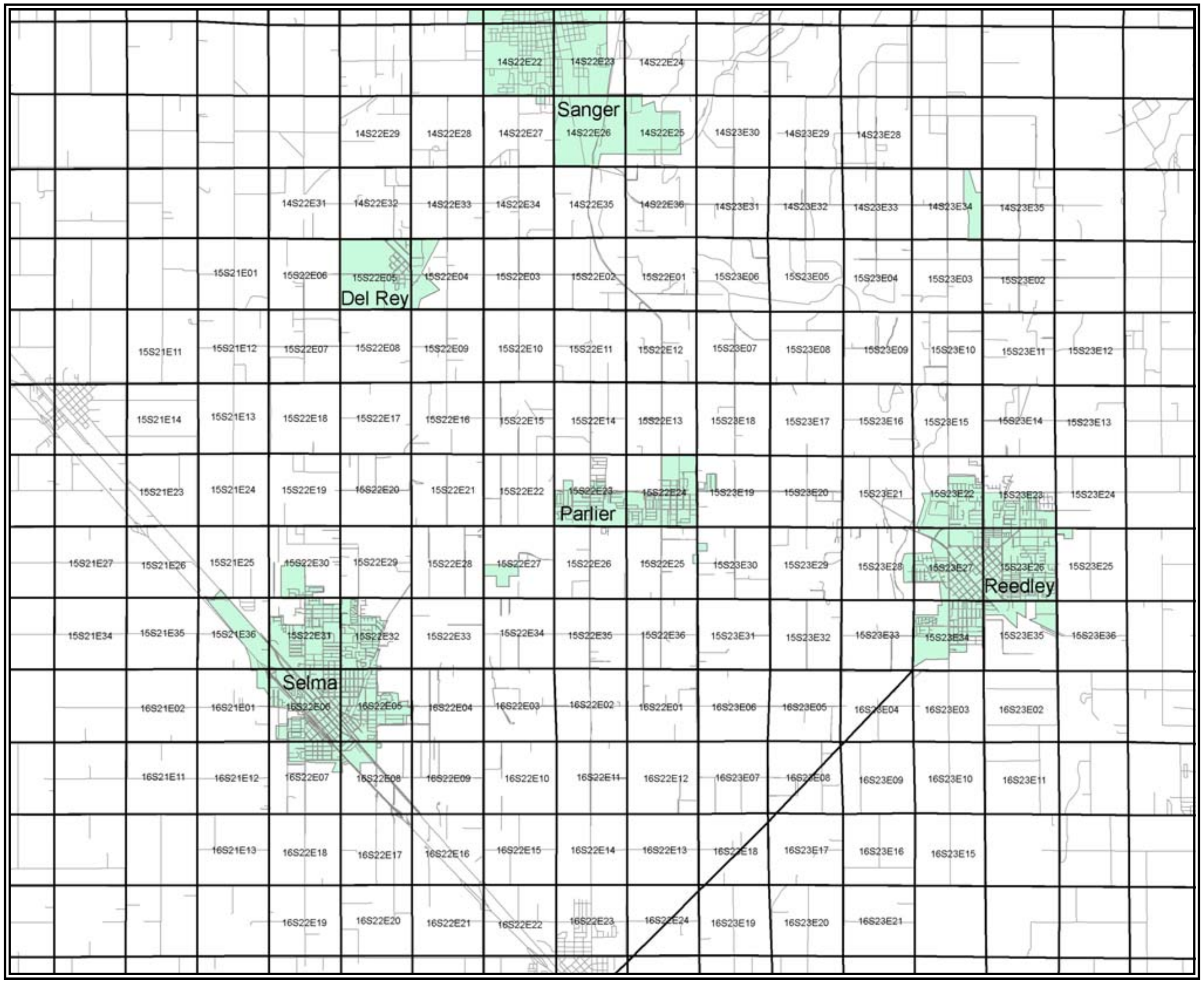
Table 1. Grower acreages, Parlier EJ Pilot Project area major crops 2006.

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 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.*

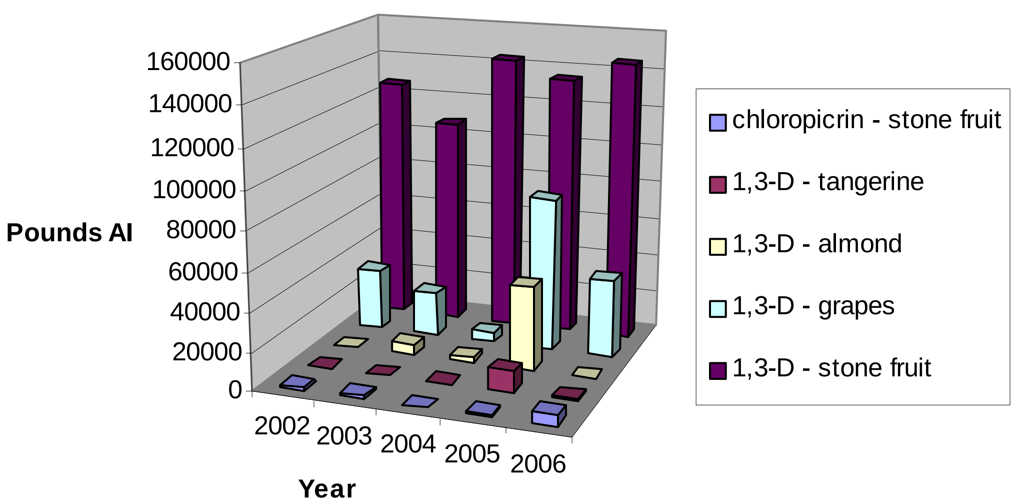
[2] Except for referenced items, pest management information in this report is from the University of California Statewide IPM Program's Pest Management Guidelines, <www.ipm.ucdavis.edu/PMG>, and the 2002 California Department of Food and Agriculture report *The Economic Importance of Organophosphates 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.

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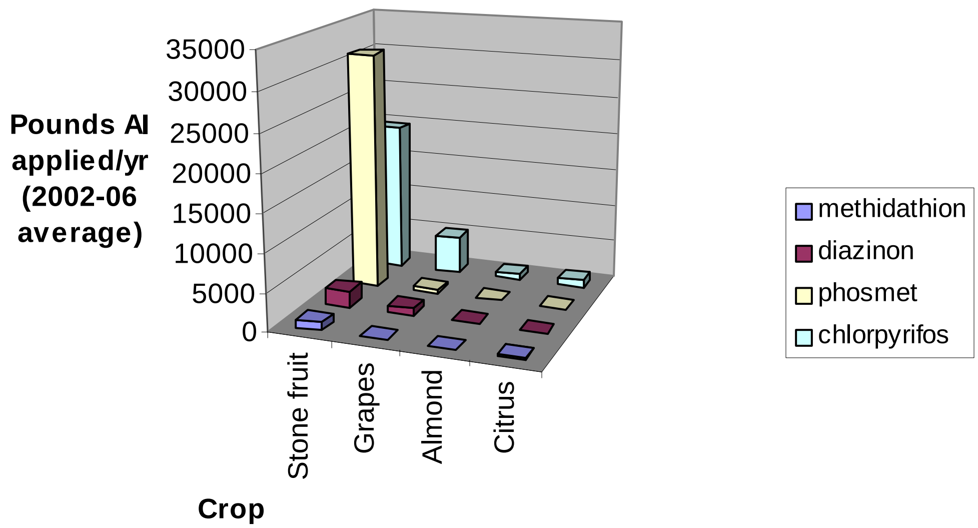
[3] <http://ozone.unep.org/Ratification_status/evolution_of_mp.shtml> and <http://ozone.unep.org/pdfs/Montreal-Protocol2000.pdf>
[4] <http://www.cdpr.ca.gov/docs/emon/vocs/vocproj/voc_reg_issues.htm>

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

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[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.

[7] <http://www.cdpr.ca.gov/docs/risk/final_notice.pdf>

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.

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.

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[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>

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 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

[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.

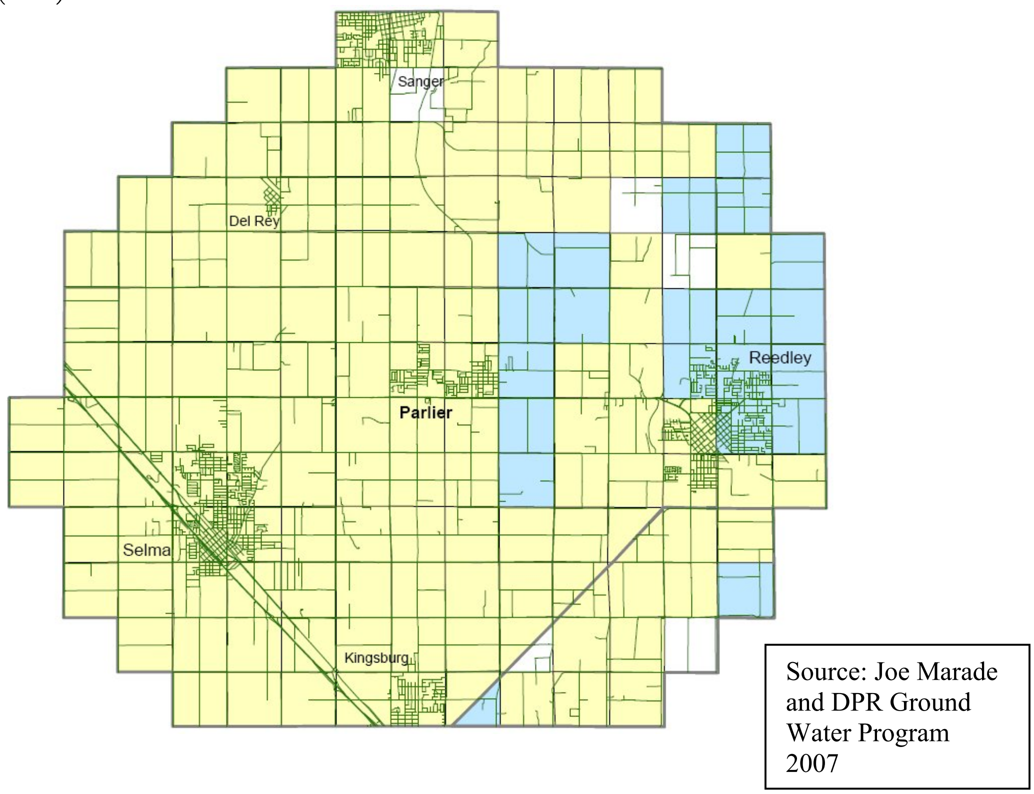
[12] <http://www.ipm.ucdavis.edu/PMG/r107301611.html>

[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).

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).



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.

Alternatives to Soil Fumigation in Orchards and Vineyards

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-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.

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

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 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	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

16 <http://www.cdpr.ca.gov/docs/pestmgt/grants/alliance/01-02/01-0194C.pdf>
17 <http://www.lodiwine.com/lodirules_home1.html>
18 <http://www.ipm.ucdavis.edu/PMG/C302/m302yi01.html>
19 <http://news.ucanr.org/newsstorymain.cfm?story=657>

fruit injuries that promote rot. These are often treated with broad-spectrum chemicals including OPs, especially phosmet and diazinon.	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 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.	Delayed-dormant and/or summer treatment with buprofezin or drip-applied imidacloprid at bloom will control these pests, but are more expensive than chlorpyrifos.
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	1) Mating disruption with pheromones is an effective control measure.

[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>

tips and fruit of peaches and nectarines. Management relies on multiple in-season applications of OPs (diazinon, phosmet) or other broad-spectrum insecticides.	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.
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.

[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>

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 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.
<u>Citricola scale</u>, *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.
<u>Ants</u>: 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	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.

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).	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*

[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>

Pest Management Practices in Almonds[28] (Pickel et al. 2004) provide growers with detailed guidance for every stage of the crop.

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.

[28] <http://www.ipm.ucdavis.edu/IPMPROJECT/seasonalguidealmonds.html>

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.

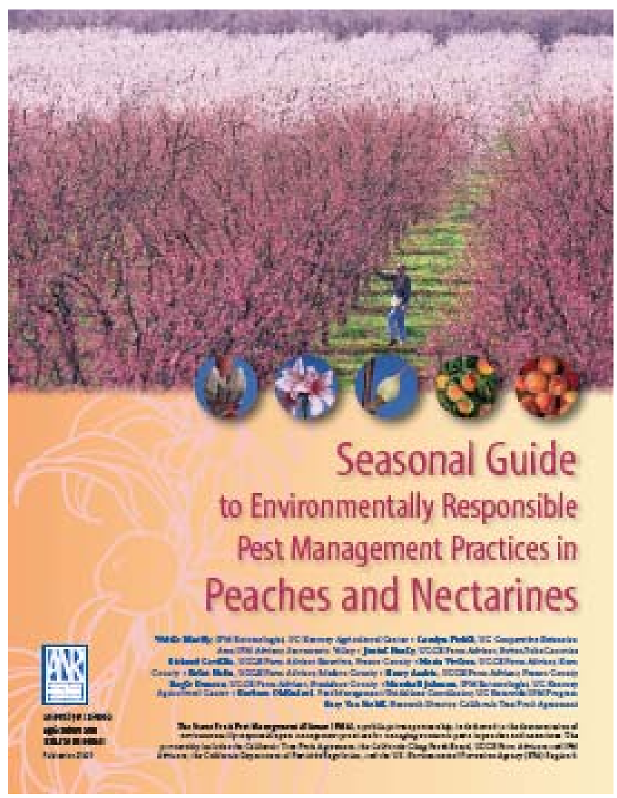
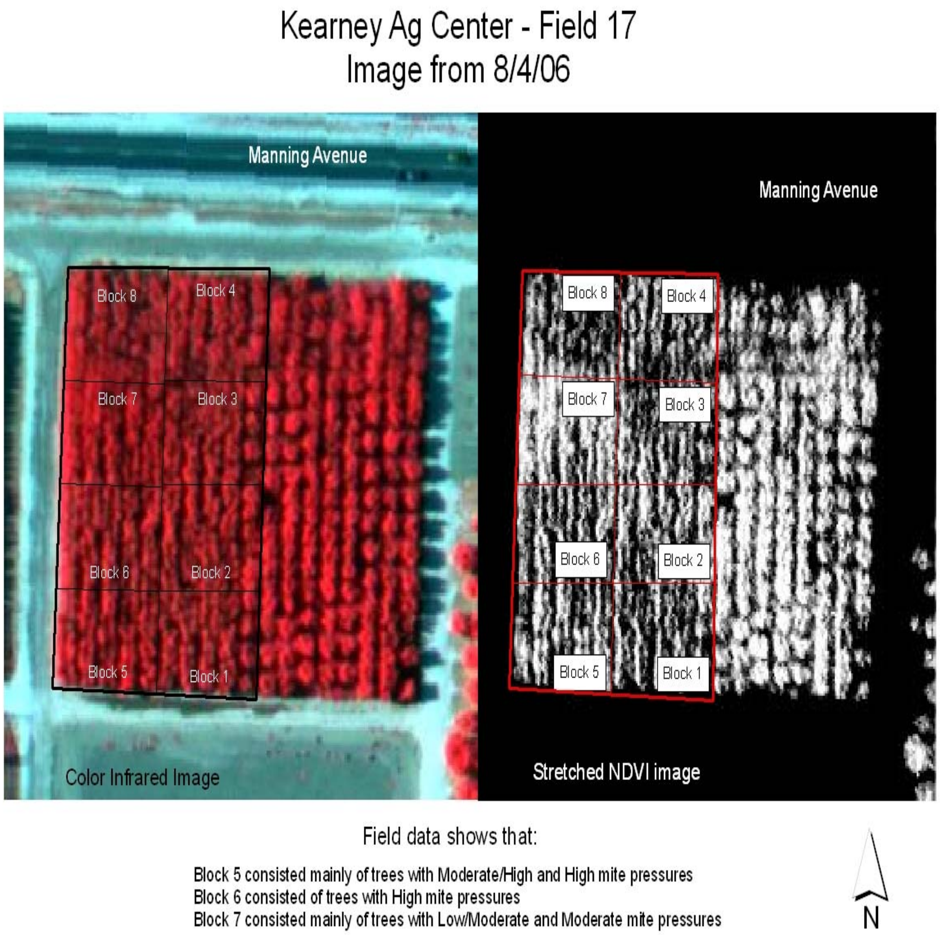


Figure 5. The project produced a seasonal IPM decision guide that complements UC IPM's Year-round IPM Programs for peaches and nectarines.

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

[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.

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).

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.

[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

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 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]

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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.html>
37 <http://agcenter.ucdavis.edu/Training/Outreach.php>
38 <http://ej.ucdavis.edu>

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.

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.

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[39] <http://www.rocfund.org/>
[40] <http://agfuturesalliance.net/>
[41] <http://www.ca.nrcs.usda.gov/>
[42] <http://www.carcd.org/yourdistrict/rcdabout.htm>
[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>

“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.

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®

[48] <http://www.protectedharvest.org/>
[49] <http://www.foodalliance.org/>
[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.

Active ingredient	Commercial product names
metalaxyl	Ridomil®
methidathion	Supracide®
methoprene	Tango® ant bait
methoxyfenozide	Intrepid®
oxamyl	Vydate®
phosmet	Imidan®
pyriproxyfen	Esteem®
spinosad	Entrust®, Success®
tebufenozide	Confirm®
thiamethoxam	Actara®

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