Almond Pest Management Alliance
(Six and Seven Year)

Project Number:	05-MV-01
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Description

The Almond Pest Management Alliance plots were extended for two additional seasons in Kern and Butte Counties. The purpose was to collect extensive data on specific insect pest pressure on both reduced risks and conventional pest management programs. Also to extend the results to the almond growers of California.

Introduction

In 1998, The Almond Pest Management Alliance (PMA) was initiated by the Almond Board of California with funding from the California Department of Pesticide Regulation to evaluate the possibility of reducing the pesticide inputs in California Almonds. The PMA is a cooperative effort among the industry stakeholders including the Almond Board of California, the Board's Environmental Committee, the Almond Hullers and Processors Association, the University of California Statewide IPM Project, University of California Cooperative Extension, PCA's and growers, CA Department of Pesticide Regulation, and U.S. EPA Region 9. With increasing funding from the Almond Board, the PMA was continued for two additional years (six and seven) in Butte and Kern County.

Butte County Site 2004, Year 6

The Butte County site is an ongoing demonstration of the long-term effects on orchard pest management with reduced pesticide inputs. Intensive monitoring is used to track pest pressure over the years and to reduce the possibility of damage to the crop. Monitoring continues to show that reduced risk practices appear to be controlling the pests below economic damage levels.

The 49 acre orchard is divided into four treatment blocks which have been followed since 1999. in 2001, an untreated check was added. In 2004, three secondary treatments were added in an effort to avoid the worm damage seen in the 2003 crop. The treatment blocks are as follows:

Treatment Block	Materials Applied	Created
PMAI	No sprays	1999
PMA I + OFM pheromone	2 applications of pheromone	2004
OP Dorm	Diazinon + oil dormancy	1999
OP Dorm + OFM pheromone	Diazinon + oil at dormancy and 2 apps. Pheromone	2004
OP Dorm/Hullsplit	Diazinon + oil at dormancy and Imidan at hullsplit	1999
Hullsplit only	Imidan at hullsplit	2004
PMA II	No sprays	1999
Untreated Check	No sprays	2001

No insecticide treatments have been applied to the PMA I block since 2001 (except for a section treated with Clinch ant bait in 2003) and the PMA II block has been without insecticide sprays since 2002. The Oriental Fruit Moth pheromone was applied to the two blocks during the third and fourth flights, determined by trap catches and degree-day forecasting. The timing of the hullsplit and dormant treatments were determined by the grower. Fungicide treatment and weed management was the same across the whole orchard.

Monitoring

Traps: This trial has been monitored for peach twig borer, navel orangeworm, web spinning mites, San Jose scale adult males, and San Jose scale parasitoids *(Encarsia* and *Aphytis)* , and in 2004 Oriental Fruit Moth traps were added to each block. Degree days for each of these pests were calculated to determine biofixes and to provide treatment timing for those in the area who might need it. The weather data and degree day modeling available on the UC IPM website **http://www.ipm.ucdavis.edu/index.html,** used in conjunction with actual trap catches helps to identify the biofixes during the season.

Shoot Strikes: The upper portion of the canopy was inspected for shoot strikes (SS) at the beginning of the PTB generations. Shoots with damage were clipped with a pole pruner and split down the center to verify presence and identification of larvae. When larvae were present, they were identified, but if the strike was already vacated, no attempt was made to determine whether the damage was done by Peach Twig Borer or Oriental Fruit Moth. In most seasons, including 2004, few if any shoot strikes were ever found, making the high level of strikes found in 2003 unusual.

Dormant spur sampling: Spurs are collected before the growing season begins, most recently on Jan. 15, 2004. Spurs were taken from each treatment block and inspected for mite eggs, predatory mites, San Jose scale, parasitized SJS, and European Fruit Lecanium crawlers. Counts were tabulated to determine if levels are increasing or decreasing and if the treatment threshold for any of the listed insects had been reached. This orchard has had evidence found in the dormant spur sample of parasitism of the San Jose scale and also of the European Fruit Lecanium.

Mummy nuts: Twenty trees per treatment block are surveyed for mummy nuts. This can be done at the same time as dormant spur sampling. Mummy nuts are counted to make sure there are less than an average of two per tree. The Butte cooperator routinely shakes the entire orchard to remove mummies.

Damage At Harvest

At harvest, 100 almonds were randomly collected from each of the five trees in each of the treatment blocks for a total of 500 per treatment. Nuts were inspected for damage, and an attempt was made to identify the insect which had caused the damage. It is difficult to distinguish OFM from PTB worm damage to the nut, if no larvae is found, damage is classified as "PTB/OFM". Percent damage to each treatment block was calculated. The Harvest Damage Table is expressed in percent damage.

Percent Insect Damage at Harvest, 2004

Block	Ant	NOW	PTB/OFM	Stink Bug
PMA I	1.4	0.4	0.4	0.2
PMA I + OFM pheromone	1.2	0.2	0.0	0.0
OP Dorm	0.2	0.0	0.0	0.0
OP Dorm + OFM pheromone	0.4	0.0	0.0	0.2
OP Dorm/Hullsplit	0.2	0.0	0.0	0.0
Hullsplit only	0.2	0.4	0.6	0.0
PMA II	1.4	0.4	0.4	0.2
Untreated Check	0.6	1.0	0.4	0.0

The high levels of worm damage seen in 2003 were not repeated in 2004, even in the un sprayed treatments, which is encouraging. We will continue to monitor for these insects, including OFM, for 2 more years.

Kern County Site 2004, Year 6

The PMA project in Kern County continues with the following objectives.

1. To establish the economic damage due to San Jose Scale (SJS) in almonds.

2. To determine the effect of a barley cover crop on ant control.

3. To demonstrate the feasibility of mite control using predatory mite releases.

Objective 1: Determination of Economic Damage due to San Jose Scale. The orchard was divided into the following treatments: 1) dormant (six gallons of oil), 2) dormant (six gallons of oil plus Diazinon®)and 3) untreated control. These treatments were established in both reduced and conventional pesticide programs. They continued for four years. The purpose was to allow a high degree of SJS infestation on shoots and fruiting spurs. Heavy SJS infestation was found in the untreated control where spur and shoot dieback occurred. The most affected varieties were Sonora and Fritz. The data from this experiment (Table 1) has established spray guidelines based on level of infestation on dormant spur and shoot samples.

Table 1. Percent of dormant shoots and spurs infested with SJS and spray choices.

Threshold	Treatment
Below 20%	No spray
20% – 60%	Oil at 6-8 gals/acre
Over 60%	Oil with insect growth regulators

The experiment was terminated after spray threshold levels were determined. Then, to eliminate all SJS, the orchard was sprayed with six gallons of 415 oil and 5 oz. of Seize® per acre. Data was collected to determine the recuperation period due to SJS infestation. SJS population from all previous treatments continue to be monitored using double sided sticky tape and SJS pheromone traps. Death spurs and shoots were cut and weighed from seven trees in each SJS monitoring location. The death spurs and shoots were cut off from Nonpareil, Sonora and Fritz varieties. In addition, yields were taken from Fritz which appears to be the most susceptible to SJS.

Table 2. Effect of San Jose Scale on Fritz's yields due to different dormant sprays treatment.

Treatment	**Yields (lbs/acre)**
Oil only	1969
Oil- Diazinon®	2533
Untreated control	2303

The yields on the oil only treatment are lower than Oil-Diazinon® and untreated control. The reason for the lower yields are due to severe defoliation and nut drop in March. This was caused by zinc contamination of an oil spray which was applied for mite control.

Table 3. Shows weight (lbs per tree) of death spurs and shoots due to different dormant spray treatments on Nonpareil, Sonora and Fritz varieties.

Variety	**Dormant Treatment**		
	Oil-Diazinon®	Oil-only	Untreated
Nonpareil	0.22	1.03	1.89
Sonora	3.58	3.59	4.31
Fritz	1.34	1.29	8.30

Table 3 shows the effect of dormant spray treatments on death spur and shoots on the Nonpareil, Sonora and Fritz varieties. Oil plus Diazinon® in a dormant spray reduced the amount of death wood on the Nonpareil variety. However this treatment didn't make any difference in both Sonora and Fritz. The data also shows that a no dormant spray will increase the amount of death spurs and shoots in all tree varieties. Furthermore, based on the amount of death spurs and shoots, the Fritz variety is the most susceptible to S1S.

Objective 2. To Determine the Effect of a Barley Cover Crop on Ant Control Damage. This cover crop proved to be quite beneficial to the reduced risk pesticide program. Water infiltration rate was higher in the barley plots than in the natural vegetation plots. Spider mite populations were lower in the barley plots than on the natural vegetation. Insect damage however was higher in the barley plots.

To determine the effectiveness of Distance®, Clinch®, and Lorsban®, areas with barley and natural vegetation were sampled to determine ant population and ant damage at harvest time. Table 4 shows no differences in ant populations and ant damage between barley and natural vegetation.

Table 4. Ant population (ants per vial) and ant damage from areas with natural vegetation and from areas with barley as a cover crop.

Treatment	DATES			Damage (%)
	07-17	08-15	10-11	
Barley Cover Crop	94a	13a	8a	0.25a
Natural Vegetation	254a	97a	la	2.25a

Objective 3. To Demonstrate the Feasibility of Mite Control Using Predatory Mite Releases. The control of spider mite using predatory mites has been inconsistent. There has been good control some years but in other years the control has been poor. To continue testing the efficacy of predatory mite releases, the following treatments were established: 1) Agri-Mek® , 2) 415 oil, 3) Acramite® and 4) predatory mite releases.

The first application of 415 oil was done March 30, 2004 when mite infestation began to appear. The amount of oil was six gallons of oil in 200 gallons of water per acre. This oil application was repeated May 12 and June 9. Predatory mites were released April 15 and May 27. Agri-Mek® and Acramite® sprays were done May 5.

Figure 1. Percent mite infestation in the 415 oil, Agri-Mek®, Acramite® and predatory mite releases treatments during the 2004 season.

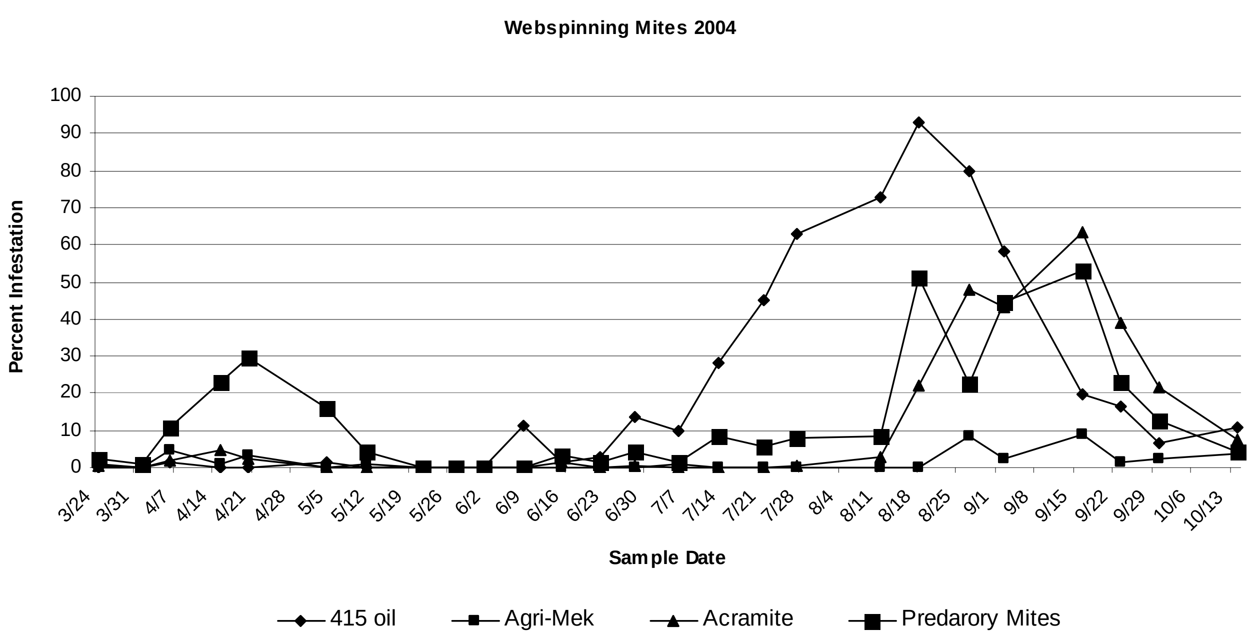
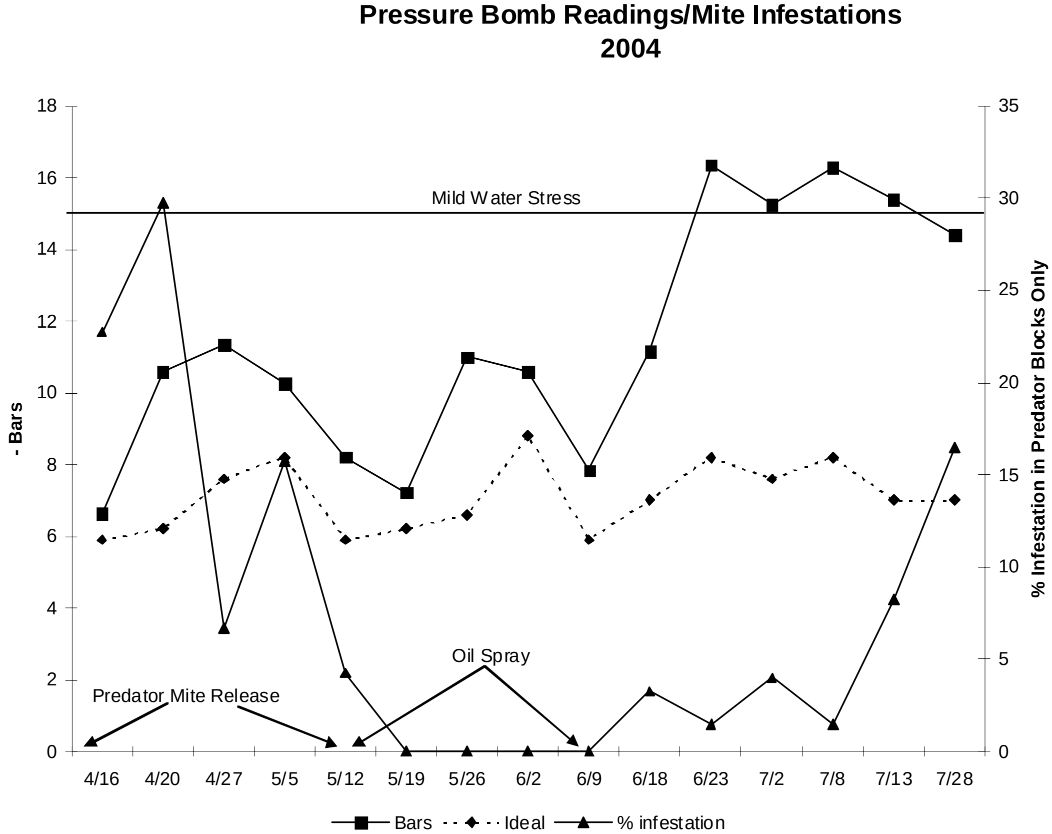


Figure 1 shows that 415 oil sprays were the least effective in controlling mites. The predatory mite releases were more effective than the oil sprays but less effective than Acramite®. Agri-Mek® was the most effective miticide. It maintained leaf infestation below 10%. Figure 1 also shows that oil sprays didn't control mites after June 30. Spider mite releases failed in mite control by July 14 and Acramite® failed after August 11.

The failure to control mites may be due to tree water stress. Figure 2 shows the relationships between mite infestation to ideal, mild and severe water stress. Pressure bomb reading showed that the trees were under water stress by mid-April. The pressure bomb readings (solid lines connecting solid squares) tree water potential. The water stress increased even more after June 9 and by June 23 it was in the severe water stress area.

Figure 2. The relationship between stem water potential (bars) and percent mite infestation during the 2004 growing season.



The reduced risk management program has not significantly reduced Nonpareil yields in five out of six years. Table 5 shows the yields of Nonpareil from 1999 to 2004. It was only in 2003 that reduced risk showed a yield reduction.

Table 5. Nonpareil yields (lbs/acre) from reduced and conventional pest management programs corresponding to the 1999-2004 period.

Treatment	Y E A R					
	1999	**2000**	**2001**	**2002**	**2003**	**2004**
Reduced	701a	716a	1737a	1758a	2473a	3098a
Conventional	794a	787a	1814a	1946a	2748b	3577a

Values followed by the same letters are not statistically different as measured by the LSD test PCO.05.

Butte County Site 2005, Year 7

The Butte County site is an ongoing demonstration of the long-term effects of reduced risk pest management compared to using conventional pesticides. Local growers continue to be interested in reducing use of broad spectrum pesticides while maintaining economic viability. A dormant season seminar in Chico attracted about 100 and about 80 people came to the orchard for a field meeting in June.

The 49 acre orchard is divided into six main treatment blocks, four of which have been followed since 1999. In 2001, an untreated check was added, and in 2004 a "Hull split only" treatment block was added. Also in 2004, two subplots were created for using OFM pheromone mating disruption. The additional treatments were added in response to the high level of worm damage seen in the 2003 crop. The treatment blocks are as follows:

Treatment Block	Hullsplit Treatment July 18,2005	Dormant Treatment Jan. 20,2005	Pheromone Mating Disruption (Jun. 22 & Jul. 23, 2005)	Created
Untreated Check	None	None	None	2001
HS only	Imidan	None	None	2004
PMAI	None	Oil only	None	1999
PMA I + OFM-F	None	Oil only	2x sprayable OFM pheromone	2004
PMA II	None	Oil only	None	1999
OP Dorm	None	Imidan + Oil	None	1999
OP Dorm + OFM-F	None	Imidan + Oil	2x sprayable OFM pheromone	2004
OP Dorm/HS	Imidan	Imidan + Oil	None	1999

Dormant treatment was based on the results of a spur sample collected in late January 2005. The Oriental Fruit Moth pheromone was applied to the two blocks during the third and fourth flights, determined by trap catches and degree-day forecasting. The timing of the hullsplit and dormant treatments were determined by the grower. No insecticides have been applied to the PMA I block since 2001 (except for a section treated with Clinch ant bait in 2003) and the PMA II block has been without insecticide sprays since 2002. Fungicide treatment and weed management was the same across the whole orchard.

Monitoring

Traps are placed in each treatment blocks to monitor for peach twig borer, naval orangeworm, oriental fruit moth, San Jose scale adult males, and San Jose scale parasitoids *(Encarsia* and *Aphytis).* Degree days for each of these pests were calculated to determine biofixes and to provide treatment timing for those in the area who might need it. The weather data and degree day modeling available on the UC IPM website http://www.ipm.ucdavis.edulindex.html, used in conjunction with actual trap catches helps to identify the biofixes during the season.

A dormant spur sample is collected before the growing season begins, most recently on Jan 6, 2005. Spurs were taken from each treatment block and inspected for mite eggs, predatory mites, San Jose scale, parasitized SJS, and European Fruit Lecanium crawlers. Counts were tabulated according to the guidelines in the UC publication "Seasonal Guide to Environmentally Responsible Pest Management Practices in Almonds" to determine if the treatment threshold for any of the listed insects had been reached. Two of the blocks, the PMA I and the PMA II, were above the treatment threshold for San Jose scale and were treated with an oil spray. This orchard has had evidence found in the dormant spur sample of parasitism of the San Jose scale and also of the European Fruit Lecanium.

Additional monitoring includes shoot strike surveys, with the damaged shoots removed from the tree and split down the center to verify presence and identification of larvae. When larvae were present, they were identified, but if the strike was already vacated, no attempt was made to determine whether the damage was done by Peach Twig Borer or Oriental Fruit Moth.

Beneficial Insect Releases

Beneficial insects were released through the entire orchard in all the treatment blocks. Lacewings were released each week beginning April 7 and continuing through June 2. Each week, lacewings were released to one-half of the orchard, then released in the other half the next week. *Trichogramma* were also used, the release dates calculated using degree days based on a PTB biofix of April 14. The *Trichogramma* were released on May 19, May 25, and June 2, with twice as many released on May 25th. The beneficial insect releases were done independently of the Almond Pest Management Alliance project in an agreement between the grower and his Pest Control Advisor.

Damage At Harvest

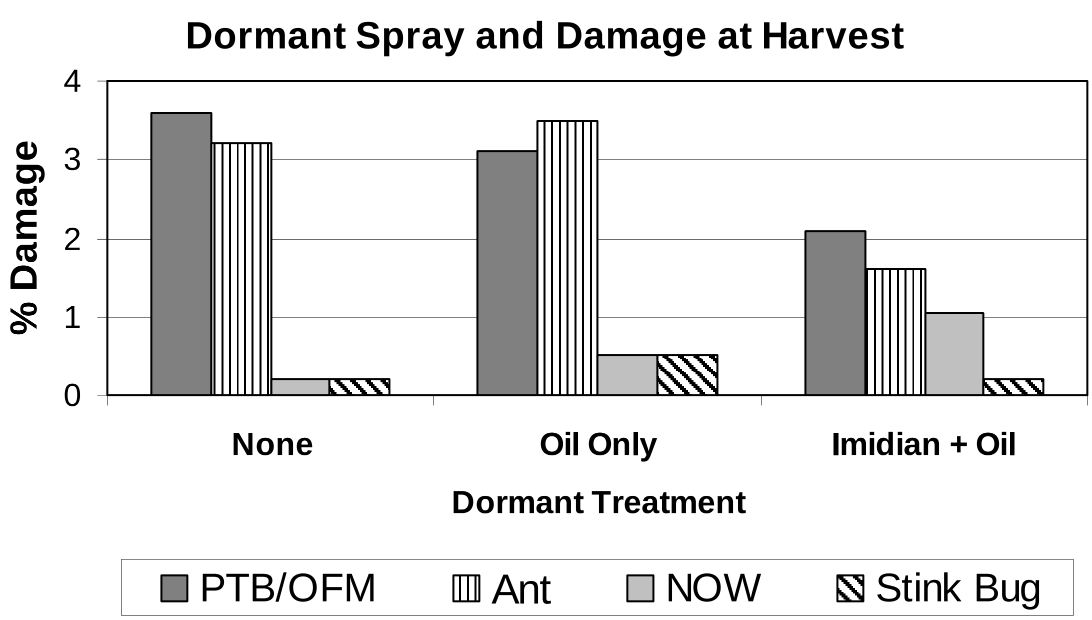
At harvest, 100 almonds were randomly collected from each of five trees in each of the treatment blocks for a total of 500 per treatment. Nuts were inspected for damage, and an attempt was made to identify the insect which had caused the damage. It is difficult to distinguish OFM from PTB worm damage to the nut, so damage is classified as "PTB/OFM". Percent damage to each treatment block was calculated. The Harvest Damage Table is expressed in percent damage.

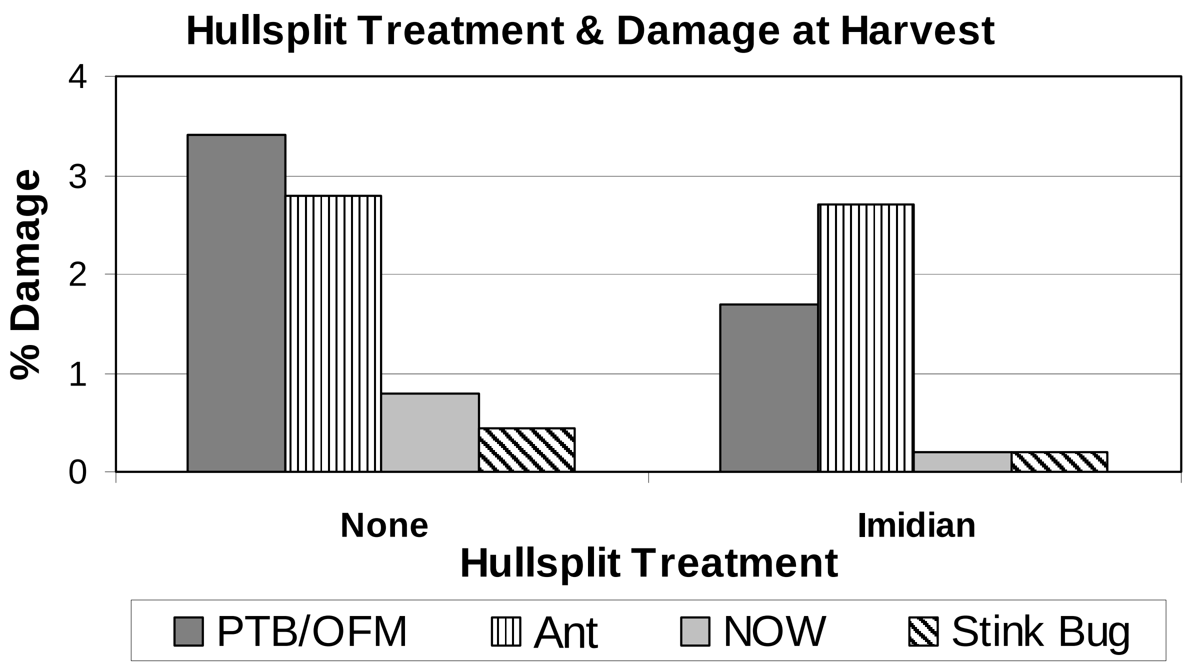
PERCENT HARVEST DAMAGE, 2005

Treatment Block	PTB/ OFM	Ant	NOW	Stink Bug	TOTAL INSECT DAMAGE
OP Dorm/HS	1	0.2	0.4	0	1.6
OP Dorm + OFM-F	2.4	1	1.4	0.2	5.0
PMA I + OFM-F	1	3.4	0.6	0.2	5.2
Untreated Check	5	1.6	0.6	0.2	7.4
HS only	2.4	5.2	0	0.4	8.0
PMA I	5.6	1.4	0.6	1.2	8.8
OP Dorm	3.2	3.6	1.4	0.8	9.0
PMA II	3	6	0.4	0	9.4

The treatment blocks that received the OFM pheromone (OFM-F) had some of the lowest levels of damage, especially in the PTB/OFM category. The OFM-F was applied twice, with the intention of disrupting the flights that occurred during hullsplit. It is a reduced risk material, and the cost per application is about $10.00/acre.

The hullsplit spray reduced damage to the crop more than the dormant applications as shown by the following two charts.





The harvest samples were collected over two days, the second and third days after the shaking was completed. The samples collected on the second day were from the HS only, the PMA II, and the PMA I + OFM-F blocks. These three blocks also have some of the highest ant damage. It is possible that the elevated ant damage found in these samples were due to the extra day the nuts were on the ground.

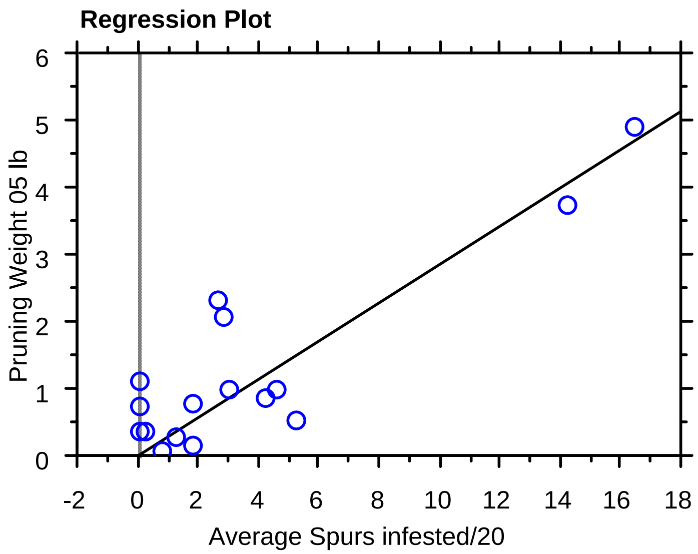
Kern County Site 2005, Year 7

Objective 1: To establish economic damage due to San Jose Scale (SJS).

In year six weights (lbs per tree) of dead spurs and shoots due to SJS infestations were determined. In the same year, yield losses from the Fritz variety were established. These led to the establishment of spray threshold levels.

The analysis of dead wood and SJS spur infestation can be found in Figure 1. This figure shows a direct relationship between dead wood across all varieties and spur infestation with SJS. This means that SJS infestation causes the death of fruiting spurs and therefore yield losses.

Figure 1. Regression line showing the relationship between the total number of SJS found on 20 spurs and the amount of dead wood per tree.



Y = .374 + .246 * X; R^2 = .771

Objective 2: To determine the effect of a barley cover crop on ant control.

The 2004 data showed that barley didn't interfere with ant control. The same results were obtained in 2005. Table 1 shows the results of the following treatments: 1) Clinch® at one lb per acre, 2) Distance® at two lbs per acre, Lorsban® at 4 pt per acre and untreated control. There were no statistical differences between barley and no barley in any of the treatments.

Table 1. Percent of rejects due to ant damage between barley and no barley among different ant treatments.

Treatment	Barley	Percent Ant Damage
Clinch®	No	0.40 a
Clinch®	Yes	0.20 a
Distance®	No	1.10 a
Distance®	Yes	0.50 a
Lorsban®	No	1.00 a
Lorsban®	Yes	0.20 a
control	No	1.70 a
control	Yes	1.90 a

Data followed by the same letters are not significantly different as measured by the Duncan's Multiple Range Test ($P \geq 0.05$).

Objective 3: To determine the feasibility of mite control using predatory mite releases.

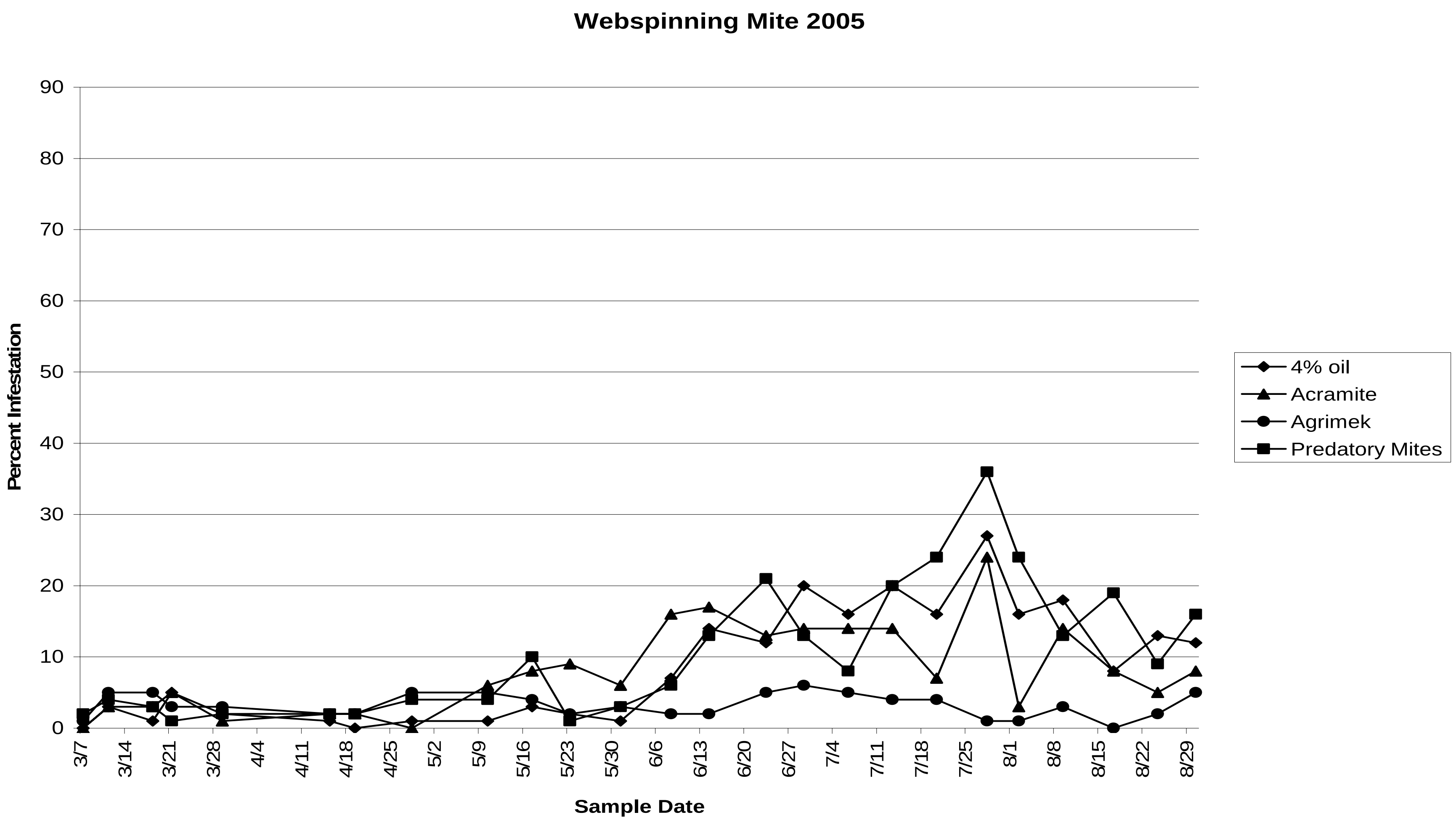
Predatory mite releases for the control of mites gave us mixed results during the first five years of the PMA project. In some years, the mite control was excellent to good but in other years the control was poor. The reason for the wide range in control was due to high mite pressure brought about by high temperatures and/or water stress.

The approach of mite management after successes and failures with predatory mite releases was changed in 2005. Four miticides were used in 32 ten acre plots. Each miticide was replicated eight times. The miticides and rates were as follows: 1) two predatory mite releases at 2500 mites per acre, 2) 415 oil at four percent in 200 gallons of water per acre, 3) Acramite® 16 oz. in 200 gallons of water per acre and 4) Agrimek® 12 oz. in 200 gallons of water per acre. The first predatory mite release was done when the level of mite infestation was four percent and the second release was done seven weeks later when the level of mite infestation was 10 percent. The four percent oil was applied when the level of mite infestation was four percent. Agrimek® and Acramite® were applied when the level of mite infestation reached 10 and 17 percent respectively.

Mite infestation reached treatable levels by June 24. At this time, two percent 415 oil in 200 gallons of water were used to retreat three predatory mite plots, two 4% 415 oil and one Acramite® plot. Five weeks later some of the plots were treated again because of high mite infestation. At this time, five predatory mite plots, two 4% 415 oil plots and two Acramite® were retreated with a two percent 415 oil. In the first week of August mite infestation again reached treatable levels. At this time, three predatory, two 4% 415 oil and one Acramite® plot were retreated with a two percent 415 oil spray.

Predatory mite releases were capable of maintaining webspinning mites at a reasonable level in 2005, which was a high mite pressure year. This was accomplished due to supplemental oil sprays. Some plots were treated twice at three different times. The 4% 415 oil and Acramite® were also effective in controlling mites but they also require supplemental oil sprays. The best treatment was Agrimek® (Figure 2).

Figure 2. Webspinning mite infestations (presence/absence) on 30 leaf samples.



Objective 4: To determine the effect of a reduced input management program on yields.

Table 2 shows the impact on yields due to conventional/dormant and conventional/no dormant versus reduced risk/dormant and reduced risk/no dormant in both Nonpareil and Butte varieties. The Nonpareil yields were better in the conventional/dormant and no dormant than on the reduced risk/dormant and no dormant sprays. The differences in yields were significant in 2001, 2003 and 2005. However, there was no significant differences between these two management systems in the Butte variety.

Table 2. Yield effect (meat lbs/acre) from 1999-2005 due to conventional and reduced risks management system in both Nonpareil and Butte varieties.

Nonpareil							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Conventional/Dormant	794 a	716 a	1737 a	1759 a	2748 bc	3577 a	3043 b
Conventional/No Dormant	–	–	2116 b	1986 a	2795 c	3399 a	–
Reduced Risk/Dormant	701 a	716 a	1737 a	1758 a	2473 ab	3462 a	2699 a
Reduced Risk/No Dormant	–	–	1422 a	1754 a	2393 a	3098 a	–
Butte							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Conventional/Dormant	804 a	832 a	2747 a	2784 a	3397 a	3157 a	2894 a
Conventional/No Dormant	–	–	2603 a	2594 a	3437 a	3060 a	–
Reduced Risk/Dormant	760	896 a	2562 a	2401 a	3321 a	3028 a	3131 a
Reduced Risk/No Dormant	–	–	2368 a	2606 a	3325 a	3029 a	–

Data followed by the same letters are not significantly different as measured by the Duncan's Multiple Range Test ($P \geq 0.05$).

Summary

The data shows that San Jose Scale does kill fruiting wood. This explains the low yields of Nonpareil in the reduced risk plots where no dormant or in season sprays were applied for the control of San Jose Scale. There were no significant differences in ant control between barley and no barley plots. It is possible to control webspinning mites using predatory mite releases. However, under high mite pressure supplemental oil sprays are needed to keep mites under control. Agrimek® gave the best mite control in the PMA orchard. Nonpareil's yields were higher on the conventional than on the reduced risks management system. However, Butte's yields were not significantly different between the two systems.

Butte County Summary 2006

In 2006, the Butte almond PMA discontinued the treatment blocks at the orchard, and put the emphasis on outreach and education. However, because the grower/cooperator rarely uses insecticides, the site is still a demonstration of the long-term effects of using reduced pesticide inputs. Summary data was shown in "Lessons Learned in the Almond Pest Management Alliance Project", Carolyn Pickel's presentation at the Walnut Day and Almond Institute Feb. 1, 2006 in Chico. The years of the Butte PMA showed that harvest quality did not decline in blocks where no insecticides were used. Using treatment thresholds from "Seasonal Guide to Environmentally Responsible Pest Management Practices in Almonds", pests were managed with materials such as a dormant oil-only spray or pheromone mating disruption.

The Butte PMA continues to monitor the orchard with traps to follow the insect activity, and to provide treatment timing information to local-area growers. The last three years, the traps have shown there is a healthy population of Oriental Fruit Moth, not usually considered an important pest of almonds. Monitoring also shows a very low level of San Jose scale, even without any dormant treatment. The long-term nature of this project has also shown us that the total trap catches of Peach Twig Borer do not correlate with the level of damage at harvest. We continue to extend the information collected from this multi-year project to growers who are interested in reducing their use of pesticides.

RESEARCH ARTICLE

Almond growers rely on pest control advisers for integrated pest management

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A comprehensive survey of full-time almond growers in the three primary almond-producing regions of California showed that growers rely substantially on pest control advisers (PCAs) for pest management decision-making. Independent PCAs communicated more frequently with growers than PCAs who are employed by agricultural product suppliers. Growers who use independent PCAs tend to feel more knowledgeable about integrated pest management (IPM) and report the use of more complex pest-monitoring techniques and control practices. The use of insecticide sprays, however, is independent of the type of PCA employed, and the percentage of growers using them has declined substantially since a 1985 survey.

Jack Kelly Clark

UC IPM entomologist and co-author Walt Bentley demonstrates the use of a hand lens to monitor for arthropod pests of almonds. Almonds cover about 540,000 acres in California, making them a significant focus of UC integrated pest management (IPM) outreach and extension. A survey found that pest control advisers (PCAs) also play an important role in providing information to almond growers about IPM.

The goals of the UC Statewide Integrated Pest Management Program include increasing the adoption of integrated pest management (IPM) practices to improve pest control, and reducing growers' need for broad-spectrum pesticides. With more than 6,000 almond farms covering approximately 540,000 acres statewide, almond growers and their consultants are a major focus of UC research and extension (Zalom et al. 2005). The almond industry has worked closely with UC for more than 25 years to implement new IPM practices, most recently utilizing the partnership framework of the Almond Pest Management Alliance (Looker 2005).

Many complex factors affect pest management decisions, including the decision-maker's knowledge about and attitudes toward practices that are continually changing. Furthermore, the practices chosen must interact with multiple biophysical and economic variables. In California, state-licensed pest control advisers (PCAs) play a substantial role in helping growers work through these management decisions and are among the most important clientele for UC educational efforts. How these PCAs influence the adoption of IPM practices is a much-debated topic among academics and government agencies.

In particular, some PCAs are affiliated with agricultural product suppliers and so appear to have a conflict of interest. While these supplier-affiliated PCAs provide pest monitoring and consulting services for free, their employers stay in business by selling pest control products. Independent PCAs, on the other hand, are not on the payroll of a supply company and charge a per-acre fee for their services. Whether supplier-affiliated or independent, a PCA's reputation depends on his or her ability to help growers produce quality crops in the most cost-effective manner.

IPM mail survey

In 2000, the UC Statewide IPM Program and the Almond Pest Management Alliance conducted a comprehensive mail survey of almond growers intended to measure their use of specific pest-management practices and to learn more about factors that influence their decisions. We present a portion of the survey results, highlighting declining trends in the use of broad-spectrum insecticides, examining how growers' interactions with PCAs may be affecting these trends and exploring the impact of PCA affiliation on the adoption of IPM tactics.

Our sampling was based on the three major almond-production regions in California: the central and southern San Joaquin Valley (Fresno, Kern, Tulare and Madera counties), the northern San Joaquin Valley (Merced, San Joaquin and Stanislaus counties) and the Sacramento Valley (Butte, Glenn and Colusa counties). In order to focus on full-time growers, we sampled those with more than 20 bearing almond acres. Samples were drawn from lists of growers obtained from the agricultural commissioner's offices in eight counties, and from Cooperative Extension mailing lists in the remaining two counties.

The survey included five main sample groups. In each of the three growing regions, we systematically drew approximately equal-sized samples. For each region, we started with a random grower on the list and then drew every nth grower, defining "n" as the total number of growers on the list divided by the final desired sample size. Then, to also include growers with smaller almond farms, we similarly drew a fourth sample from almond growers with 20 or fewer acres across the three regions. Finally, we mailed surveys to a fifth group of almond growers, who were from the same almond-production regions and represented all farm sizes, and had participated in an earlier telephone survey phase of this project (table 1).

The survey was mailed in spring 2000. In order to encourage responses, mailings were personalized as much as possible, used first-class postage and included a postage-paid return envelope, and there were three follow-up mailings. Due to length considerations, half of those surveyed in each sample group received the insect and mite management version of the questionnaire while the other half received the disease and weed management version. Both versions included a set of identical questions pertaining to information sources, attitudes toward IPM and general decision-making factors (including reliance on PCAs for the control of insects/mites, weeds, diseases and nematodes).

A completion rate of 39% resulted in a final response set of 453 growers (table 1). Three hundred and twenty-two of the responding growers had more than 20 acres of bearing almonds in 1999, and 168 of these completed the insect and mite management version of the questionnaire. The results discussed in this article are based either on the larger set of 322 growers with more than 20 acres or on the subset of 168 growers who completed the insect and mite questionnaire.


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Air blast sprayers are used for ground applications of pesticides in orchards. Almond growers reported applying dormant season, May and hullsplit insecticide sprays less frequently in the current survey than in a 1986 study.

We used nonparametric statistical tests for two reasons: first, in some instances the groups being compared had different variances; and second, in many cases the variables being tested were categorical (such as yes/no/don't know responses to questions about the use of a practice). We used the Wilcoxon 2-sample test to assess differences in a continuous variable (such as farm acreage) between two groups with unequal variances. Similarly, we used the Kruskal-Wallis test to assess differences in a continuous variable among more than two groups. We used the chi-square statistic to assess differences between two or more groups when categorical variables were involved. Finally, we used Fisher's exact test in cases when sample sizes were too small to allow the appropriate use of chi-square.

Role of PCAs

Grower use of PCAs. Nearly all (97%) of the survey respondents used PCAs for pest management advice,

TABLE 1. Sample groups for 2000 mail survey* of California almond growers

Sample group	Eligible respondents sampled	Completed surveys
	.... *number*	
Central/South San Joaquin Valley (> 20 acres)	185	75
North San Joaquin Valley (> 20 acres)	193	71
Sacramento Valley (> 20 acres)	234	80
Small growers across three regions (≤ 20 acres)	185	55
Growers across regions and farm size who participated in earlier telephone survey	354	172
Total sample	1,151	453

*Survey completion rate = 39%.

showing that this is a nearly universal practice. About 73% used only one PCA, 21% used two PCAs and 3% used three or more. The degree of PCA influence on decision-making, however, varied with different kinds of pests. For example, 80% of growers reported following their primary PCA's recommendations for insect pest-management actions at least 80% of the time, and 78% of growers followed recommendations for disease management at least 80% of the time. In contrast, only 60% of growers followed their primary PCA's recommendations for weed management at least 80% of the time. Moreover, more than one-quarter (28%) of growers followed their primary PCA's recommendations for weed management only half of the time at most.

These differences in reliance on PCAs are likely due to the fact that for weeds, almond growers tend to follow a set pattern of management practices from year to year. In addition, weeds may not have as direct an impact as other pests on yield and quality, especially in mature orchards. On the other hand, insect/mite and disease management in almonds typically involves more complex monitoring techniques, treatment thresholds (especially for insects and mites) and timings, as well as the consideration of variable weather factors, which facilitates strategic decision-making. Expert input to such decisions can substantially affect pest control efficacy and cost. In addition, insects, mites and diseases directly influence crop quality and tree longevity, and therefore directly affect returns to the grower.

Independent vs. supplier-affiliated. Of all responding growers who used a PCA, nearly two-thirds (64%) worked primarily with a PCA affiliated with an agricultural products supplier, while almost a third (31%) worked primarily with an independent PCA. An additional 5% reported having an in-house or employee PCA.

Statistical tests show that growers with smaller acreage were less likely to use independent PCAs than those with larger acreage. Growers with supplier-affiliated PCAs managed a mean of 233 almond-bearing acres, while those who primarily used independent PCAs managed a mean of 307 almond-bearing acres (Wilcoxon 2-sample, $P < 0.001$). This difference may be due to the economies of scale afforded to PCAs by larger orchards. The practice of compensating independent PCAs on a per-acre basis provides a disincentive for the PCAs to accept contracts on small farms, where the compensation is smaller relative to fixed costs associated with traveling to and from the orchard regularly.

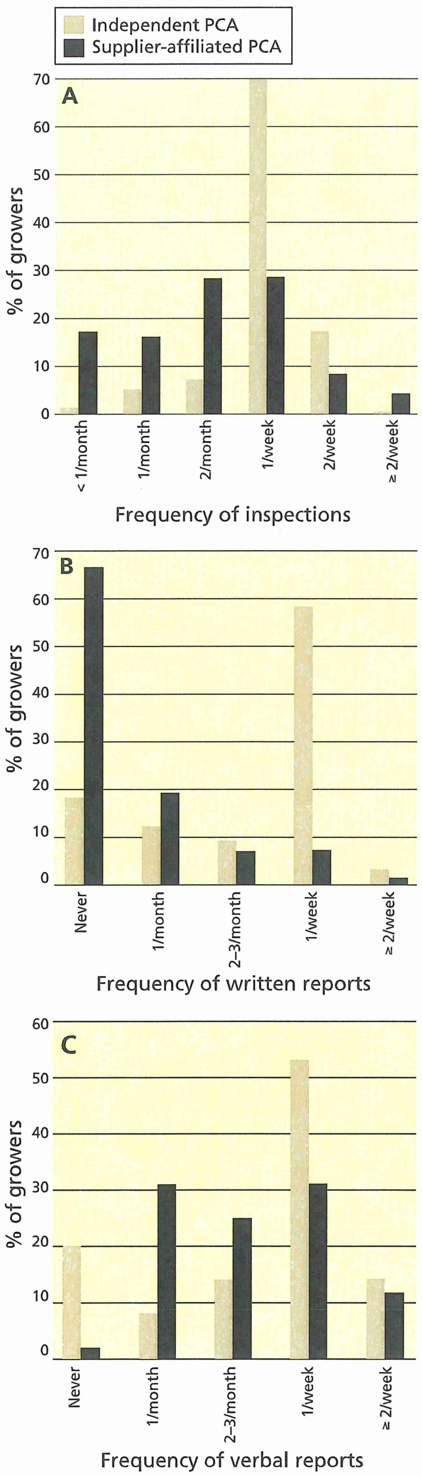

Fig. 1. Frequencies of (A) orchard inspections, (B) written reports and (C) verbal reports by primary PCA during peak season, as reported by surveyed almond growers.

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Strip weed control is used by many almond growers to manage orchard floors. Among the benefits of this approach is reduced pesticide runoff.

TABLE 2. Significance of differences in frequency of PCA orchard inspection and reports for growers with independent versus supplier-affiliated PCAs, by acreage

	Frequency of		
Acreage quartile	Inspection	Verbal reports	Written reports
	Fisher's exact test P *value (n)*		
21–45 acres	NS (53)	NS (34)	0.003 (12)
46–96 acres	0.024 (60)	NS (41)	NS (23)
97–250 acres	< 0.001 (71)	NS (53)	< 0.001 (27)
251–9,000 acres	0.003 (69)	NS (58)	0.005 (42)

Growers who reported primarily consulting an independent PCA also had a significantly greater tendency to follow their recommendations for insect/mite and disease management (Wilcoxon 2-sample, $P = 0.001$ for insect/mite and $P = 0.033$ for disease) than those who primarily used a supplier-affiliated PCA. The growers with independent PCAs also received more frequent orchard visits (chi-square, $P < 0.001$) (fig. 1A) and written status reports (figs. 1B and 1C) than growers using supplier-affiliated PCAs. About three-fifths (61%) of the growers employing independent PCAs indicated receiving written reports as often as once per week or more, a significantly higher percentage than the 8% of growers with supplier-affiliated PCAs (chi-square, $P < 0.001$). Furthermore, most growers (66%) using supplier-affiliated PCAs indicated receiving no written reports at all (fig. 1B). IPM is information intensive, so frequent written reports facilitate the grower's ability to implement least-toxic pest control approaches.

In contrast to independent PCAs, supplier-affiliated PCAs favored verbal reports and most (87%) gave these from once per week to once per month (fig. 1C). Even so, significantly more growers with independent PCAs received verbal reports once per week than growers with supplier-affiliated PCAs — more than half versus less than a third (chi-square, $P = 0.001$). We can only hypothesize the reasons that supplier-affiliated PCAs favor verbal over written reports. Written reports may take longer to complete, and supplier-affiliated PCAs may be more reluctant to take the extra time due to different compensation structures. Verbal interaction with the grower may also allow more opportunities for supplier-affiliated PCAs to promote the company's products.

Acreage. Since growers using independent PCAs also tended to have larger orchards, we performed the above tests on smaller subcategories of growers to determine whether total acreage affected the frequency of PCA orchard visits as well as of verbal and written reports. The four subcategories were selected by taking quartiles of the acreage variable: the first quarter of the sample had 21 to 45 acres, the second had 46 to 96 acres, the third had 97 to 250 acres, and the fourth had 251 to 9,000 acres. In all 12 cases, growers who used independent PCAs tended to report both more inspections and more frequent PCA reports than growers who used supplier-affiliated PCAs (table 2). Six out of the 12 tests resulted in significant P values ($P \leq 0.05$), suggesting that farm size may not be a substantial factor in determining the frequency of some PCA activities, while PCA type is an important factor.

The higher frequencies of communication and field visits provided by independent PCAs may be partly responsible for the fact that they reportedly had more influence over grower decisions. Growers may also follow independent PCA recommendations more closely because they pay for them directly. In addition, the reports of PCA activity in this study were based on growers' perceptions rather than empirical measurements. It is possible that growers who pay their PCAs for services also pay more attention to them and therefore are more likely to remember what they did than growers receiving unpaid services from supplier-affiliated PCAs.

Trends in pest control practices

Pesticide use. In debates about the significance of PCA affiliation, an issue that is often raised is whether supplier-affiliated PCAs promote more chemical use. It is often assumed that independent PCAs are more likely than supplier-affiliated PCAs to recommend fewer sprays and to promote IPM. We tested this assumption by examining growers' responses about applying insecticides during the three most common insecticide-treatment timings for almonds: the dormant season, in December and January for almond growers; in May, when susceptible stages of navel orangeworm, peach twig borer, oriental fruit moth and San Jose scale may be present; or at hull-split, which typically occurs in early July.

Two-thirds (66%) of responding growers reported spraying insecticides during the 1998 to 1999 dormant season (n = 154), about one-fifth (22%) applied a May spray (n = 156), and more than half (59%) applied a hull-split spray (n = 158); for each practice, the percentage who answered "don't know" was less than 2%.

We found that the affiliation of PCAs did not have a significant effect on responding almond growers' use of common chemical controls for insect and

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Winter mummy-nut removal is critical to managing navel orangeworm. Growers with independent (non-supplier-affiliated) PCAs were more likely to perform winter-sanitation measures such as poling (shown), which helps to prevent overwintering of the pest's larvae.

Trends in pest control for almonds

Photos: Jack Kelly Clark

Between 1985 and 1999, there was a large increase in survey respondents who perceived mites and ants as control problems in almond orchards. *Left, Tetranychus* spider mites produce webs; *right,* the southern fire ant feeds on almond nut meats.

California's almond IPM program was chosen as a case study for the 1985 USDA National Evaluation of Extension IPM Programs (Klonsky et al. 1990). The 1985 mail survey was conducted by UC Davis agricultural economist Karen Klonsky and UC IPM director Frank Zalom in collaboration with the Almond Board of California, which provided mailing lists of growers affiliated with both the Blue Diamond Growers Cooperative and independent handlers from which names of growers were drawn at random.

Although less comprehensive than the 1999 survey, several questions — including the perceived importance of different pests, use of various IPM practices, and use of specific seasonal spray timings — were asked in both surveys. Comparing the 1999 mail survey of IPM use with the 1985 survey shows that almond growers continue to perceive the navel orangeworm and peach twig borer to be key insect pest problems, while the relative importance of mites and ants increased during this time (table 3). The navel orangeworm is a target of two spray timings (May and hull-split), while the peach twig borer is a target of all three spray timings (dormant season, May and hull-split).

Despite the continuing importance of key insect-pest problems in growers' perceptions, the reported use of insecticide sprays declined substantially during all three timings. From 1985 to 1999, May sprays declined from 78% to 22%, dormant-season sprays declined from 93% to 61%, and hull-split sprays declined from 82% to 59%. The reduction in dormant sprays — especially organophosphates — during the 1990s has been documented by other researchers analyzing pesticide-use reports submitted by almond growers statewide, as required by the California Department of Pesticide Regulation (Epstein and Bassein 2003; Zhang et al. 2004).

The decline in use of dormant and in-season sprays reflects to some extent the history of UC's almond pest management guidelines. In the 1970s and 1980s, UC guidelines preferred the use of dormant-season insecticide sprays to control peach twig borer, San Jose scale and the eggs of both brown almond mite and European red mite. Spraying during the dormant season reduces overwintering populations of these pests while minimizing insecticide exposure of biological control agents, nontarget organisms, and workers in orchards during the growing season.

TABLE 3. Grower perception of pests as problems requiring management in their orchards, 1985 and 1999

Pest	Growers who perceived pest as a problem 1985*	1999
	.... %	
Navel orangeworm	70	61
Peach twig borer	50	62
Mites	27	65
Ants	13	57
San Jose scale†	—	2
Oriental fruit moth	4	19

* 1985 sample includes all farm sizes; 1999 sample includes only farm sizes > 20 acres.

† Questions about San Jose scale were not included in the 1985 survey.

During the 1990s, however, the UC guidelines were revised to reflect the availability of new commercial products that control target pest species, new research findings on alternative pest-control practices and increasing environmental concerns. The new UC guidelines more strongly emphasize monitoring for the appropriate pests before applying sprays during any of the three timings, and also suggest alternative controls and treatment timings (Zalom et al. 2005). For example, monitoring for peach twig borer and navel orangeworm was recommended as a prerequisite to using in-season sprays, and the May spray was only suggested if warranted by monitoring and if a dormant spray and winter mummy-nut removal had not been performed.

While our study does not support the notion that supplier-affiliated PCAs encourage more chemical insecticide use, it does point toward possible increases in knowledge and use of IPM practices by growers employing independent PCAs.

mite pests. Whether or not they used an independent or supplier-affiliated PCA, growers were statistically as likely to use insecticide sprays during the 1998 to 1999 dormant season (62% and 70%, respectively, chi-square, NS), in May (19% and 27%, chi-square, NS) and at hull-split (56% and 65%, chi-square, NS) to control peach twig borer, San Jose scale or navel orangeworm.

There was also no difference in the use of two IPM practices without insecticides, dormant oil (33% and 27% respectively, chi-square, NS) and summer oil alone without insecticides (16% and 10%, chi-square, NS) to control scale, spider mites or leafhoppers. The reported use of biopesticides — those toxins derived from microbial or botanical sources, such as *Bacillus thuringiensis* (Bt) and spinosad — was also similar by growers using either independent or supplier-affiliated PCAs (50% and 46%, respectively, chi-square, NS). "Don't know" responses for all of these practices were 7% or fewer.

Grower knowledge. Almond growers using independent PCAs reported feeling more knowledgeable about IPM than those using supplier-affiliated PCAs (chi-square, $P = 0.009$). While the majority of growers in both groups reported feeling either somewhat or moderately knowledgeable about IPM (74% of those with independent PCAs and 83% of those with supplier-affiliated PCAs), considerably more growers with independent PCAs reported feeling very knowledgeable than did those with supplier-affiliated PCAs (19% versus 5%, respectively). It is possible, however, that almond acreage influences these results. We conducted the same statistical tests for differences within the four subcategories of growers as defined by acreage quartiles, and the results were nonsignificant in all four cases ($P > 0.05$).

In any case, even a discernible difference between growers using different types of PCAs does not mean that consulting with independent PCAs is in itself responsible for growers' greater confidence in their IPM knowledge. Rather, such results may only indicate that growers who are more knowledgeable and perhaps more interested in IPM also have a higher tendency to use independent PCAs. On the other hand, half of the surveyed growers with independent PCAs reported that they first heard about IPM from a private consultant or PCA, as opposed to only a fifth of the growers with supplier-affiliated PCAs. These results suggest that independent PCAs might be somewhat more likely to introduce growers to IPM.

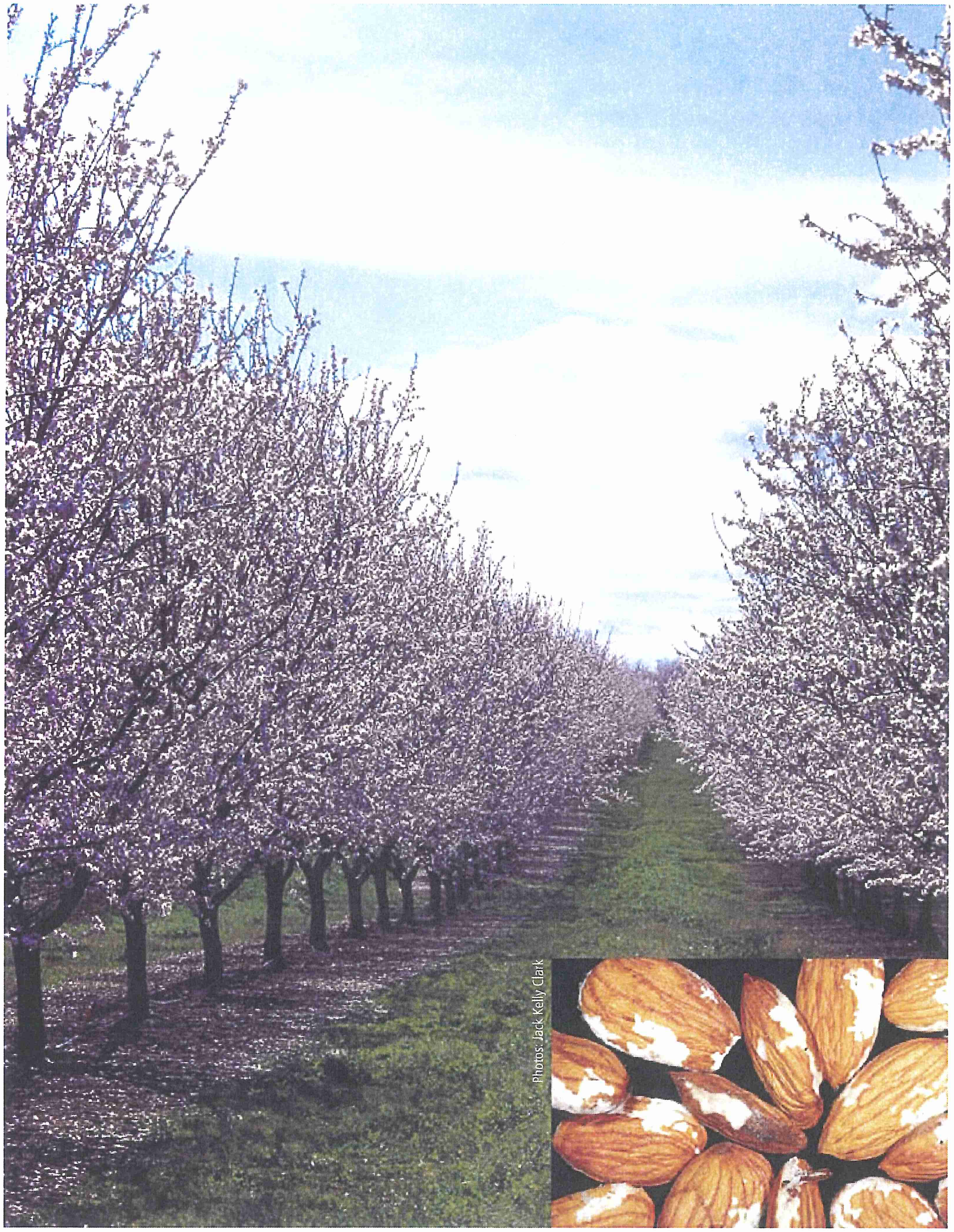
Use of IPM. Growers using different types of PCAs varied significantly in the use of several cultural controls and monitoring techniques (chi-square, $P < 0.05$). For example, responding growers with independent PCAs were more likely than growers with supplier-affiliated PCAs (90% versus 65%, respectively) to perform winter sanitation by knocking mummies from trees by hand with poles or by shaking mummy nuts — the overwintering site of navel orangeworm larvae — from the trees with mechanical shakers. Winter sanitation is one of the most important means for controlling navel orangeworm and can reduce the need to apply insecticide sprays during spring and summer. Similarly, growers with independent PCAs were more likely to determine the effectiveness of sanitation by counting mummy nuts than growers using supplier-affiliated PCAs (78% versus 40%, respectively). However, both winter sanitation and counting mummy nuts also varied significantly by acreage (chi-square, $P < 0.001$ and $P = 0.032$). Growers with larger acreage were more likely to perform winter sanitation and count mummies than those with smaller acreage, suggesting that the role of farm size should be examined more critically.

Almond growers with independent and supplier-affiliated PCAs also reported significant differences in the use of IPM monitoring practices (chi-square, $P < 0.06$) (table 4). Notably, growers with independent PCAs were also more likely to respond "don't know" to monitoring questions than growers with supplier-affiliated PCAs ("don't know" responses ranged from 5% to 24% for the former,

TABLE 4. Differences in monitoring practices between surveyed growers using independent and supplier-affiliated PCAs

	Responding growers with	
Monitoring practice*	**Independent PCAs**	**Supplier-affiliated PCAs**
	.... %	
Monitor emergence of peach twig borer at overwintering hibernaculae	71	49
Sample blossom and shoot strikes to determine if sprays necessary for peach twig borer	70	62
Place pheromone traps for peach twig borer†	81	51
Use degree days with monitoring†	67	43
Place double-sided sticky tape to monitor San Jose scale crawler	36	9
Place pheromone sticky traps for San Jose scale males	24	8
Sample dormant spurs for San Jose scale†	55	30
Sample dormant spurs for mite eggs†	55	35
Use presence/absence spider mite monitoring	71	59
Brush or count mites per leaf	71	54
Place navel orangeworm egg traps†	76	36
Monitor navel orangeworm eggs or larvae on mummy nuts or hull-split nuts†	80	51
Count number of ant hills per orchard area	45	28
Monitor for predatory mites and six-spotted thrips†	88	66
Monitor sticky traps for San Jose scale parasites	32	10

* All practices chi-square $P < 0.06$.
† Performance of these practices varies significantly (Fisher's exact test $P < 0.03$) by acreage quartiles.



◀ **Almond growers with independent PCAs appeared to be more knowledgeable about IPM practices. *Left,* almond bloom is a preferred timing for some alternatives to organophosphate insecticides, to control peach twig borer. *Inset,* feeding by peach twig borer larvae on almond nutmeats causes shallow channels and surface grooves on the kernels.**

compared to 1% to 14% for the latter), suggesting that growers using independent PCAs rely more heavily on them to carry out monitoring activities and that the growers may not understand the PCA's specific methodology.

Linking growers to IPM extension

This survey shows that PCAs are important to almond growers as sources of information on IPM practices, especially for insect and mite pests and diseases. Furthermore, some of the findings suggest that greater contact between growers and PCAs, in person and through written reports, might help growers become better informed about IPM practices in general and more specifically about pest problems on their own farms.

Our study found a high degree of self-reported grower reliance on PCAs for assistance in pest management decision-making, supporting the assertion that PCAs can make a substantial difference in grower understanding and approaches to pest management. Moreover, the influence of PCA affiliation on grower knowledge and the use of different practices should be reconsidered and studied further. While our study does not support the notion that supplier-affiliated PCAs encourage more chemical insecticide use, it does point toward possible increases in knowledge and use of IPM practices by growers employing independent PCAs. However, this study does not show whether this association occurs due to PCA influence on growers or because growers who hire independent PCAs are already predisposed toward IPM.

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