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Annual Report to
Almond Board of California
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Correct Project Number: 01-FZ-00
Project No.: 2001-FZ-o0 Insect and Mite Research

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Project Participants: UC Farm Advisors in 9 counties for Objective 1; Walt Bentley, Brian Ribiero and Lee Martin (UC Kearney Agricultural Center), Mario Viveros (UCCE Kern Co.) and Francisco Badenes-Perez (M.S. student, UC Davis) for Objective 2; Roger Duncan and Mike Oliver (both UCCE Stanislaus Co.) and Walt Bentley for Objective 3; Darren Van Steenwyk (B.S. Student, UC Davis), John Edstrom (UCCE Colusa Co.) and Beth Teviotdale (UC Kearney Agricultural Center) for Objective 4.

Objectives:

1. Purchase pheromone traps and lures, and other monitoring supplies for UC Cooperative Extension Farm Advisors as part of their ongoing monitoring efforts.

2. San Jose Scale - Continue to monitor specific orchards in Kern Co. to determine the possible influence of different pest management practices on San Jose scale and parasite population dynamics. Attempt to improve monitoring of San Jose scales by correlating male abundance in pheromone traps to scale crawlers. Conduct field trials to test the efficacy of different dormant sprays and timing for control of San Jose scale.

3. Oblique-banded leafroller/ peach twig borer – Determine the relationship between dormant sprays and OBLR incidence. Attempt to determine pest status of OBLR. Determine affect of treatment timings on peach twig borer.

4. Spider mite/ predator mite bioassays – Determine impact, if any, of fungicides and new miticides used in almonds on spider mites and the predator mite *Galandromus occidentalis*.

Summary of Results:

Objective 1, Monitoring supplies. Each year through this project, trapping supplies are purchased for use by participating UC Cooperative Extension Farm Advisors to help them to monitor the phenological activity of specific insects in their counties. The advisors use the data gathered from these traps to update local growers and PCA's in the status of various almond insect pests in their counties, and the information is disseminated in local meetings and newsletters often come from traps and lures purchased through this project. Trapping records are solicited from the Advisors at the end of each season, and serves as a database for research and validation. Table 1 provides a summary of lures purchased through this project for use for monitoring and applied research. Totals for 2001 included 1728 traps and trap liners, 1939 pheromone lures and 11 lbs of navel orangeworm bait at a cost of about $5400.

Table 1. Trapping supplies purchased for monitoring insect pests in almonds, 2001.

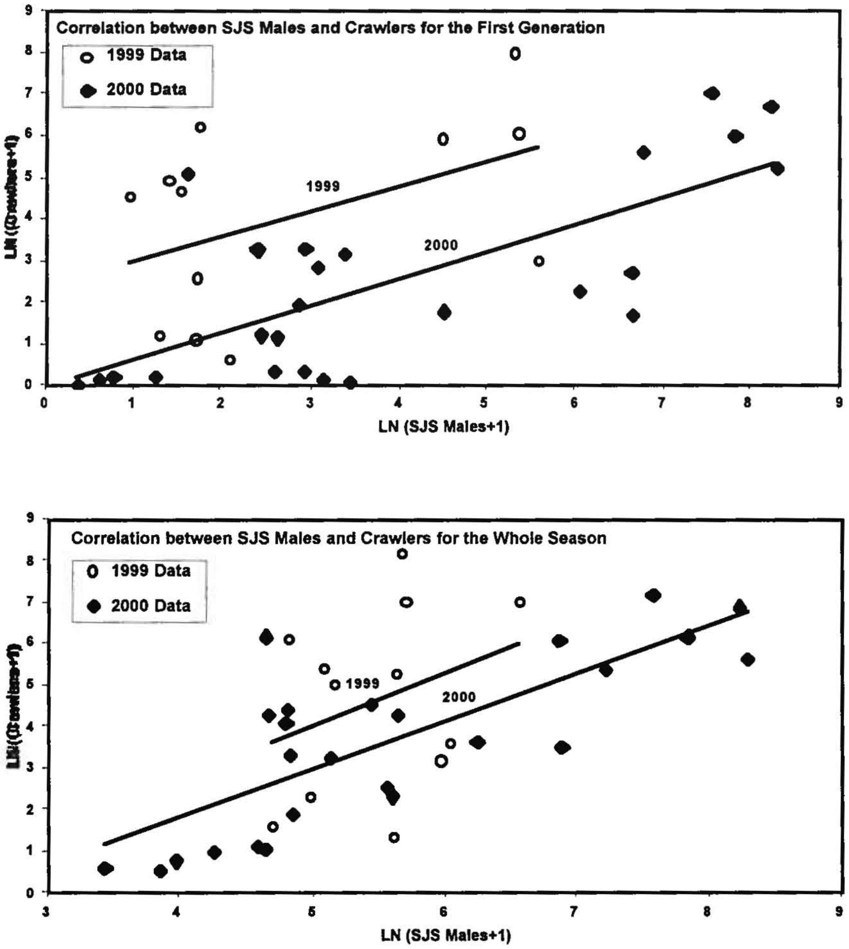
Name	Location	Wing Traps	Trap Liners	NOW Traps	SJS Traps	PTB Lures	OFM/ OBLR Lures	SJS Lures	NOW Bait (lb)
R. Coviello	Fresno Co.	24	354	8	88	266	88	80	2
L. Hendricks	*Merced Co.*				*100*			*100*	
J. Edstrom	*Colusa Co.*	*8*	*40*	*4*	*8*	*28*		*8*	*1*
R. Buchner	*Tehama Co.*	*12*	*36*	*4*	*16*	*64*	*32*	*16*	*1*
M. Oliver	Stanislaus Co.	60	100		75	50	75	75	
W. Krueger	*Glenn Co.*	*8*	*24*	*4*	*25*	*40*	*20*	*25*	*1*
W. Reil	*Yolo Co.*		*100*	*15*		*150*			*2*
P. Verdegaal	*San Joaquin*	*50*	*100*	*12*	*48*	*96*	*72*	*48*	*1*
M. Freeman	*Fresno Co.*					*192*		*108*	*1*
F. Zalom	*UC Davis*	*106*	*106*	*43*	*150*	*170*	*32/54*	*150*	*2*
Total	All Sites	268	860	90	510	956	244/129	610	11

Objective 2, San Jose scale. During the 2001 growing season San Jose scale was monitored in five Kern County almond orchards. The purpose of the study is to investigate the relationship between both male abundance and crawler abundance on spur infestation in almonds as a follow up to the study we concluded last year to determine the relationship between pheromone traps and crawler counts (Figure 1). That study indicated a significant positive relationship for both the first generation (r=0.727; F=25.712; P<0.0001; n=25)) and the entire season (r=0.777; F=63.239; P<0.0001; n=25) in 2000, but not for the other generations. The amount of spur wood death will be evaluated in spring, 2002 in each orchard. Our goal is to establish both an easy to use sampling program and a treatment threshold for San Jose scale in almonds.

The five almond orchards being monitored were selected in 1999, and all had a measurable San Jose scale infestation. Data from monitoring in 1999 and 2000 are presented in previous annual reports. Male San Jose scale (SJS) were monitored using standard pheromone lures and scale traps manufactured by Trece® Inc. Traps were place in orchards on February 19, 2001, and monitored weekly through November. The SJS traps were changed weekly, and the pheromone lures monthly. Three of the orchards were monitored with four SJS traps, evenly distributed throughout the orchard. These three orchards were all at least 60 acres in size. The remaining two orchards were smaller, being less than 20 acres in size. Only three SJS traps were placed in these orchards to avoid possibility of interference between traps. All five orchards produced the

NonPareil variety as 2/3 of the planting, and were mature. One of the smaller orchards was not well maintained. The remaining orchards were all well maintained and under standard grower horticultural practice.

Figure 1. Regression analysis of San Jose scale males and crawlers for the first generation and all generations.



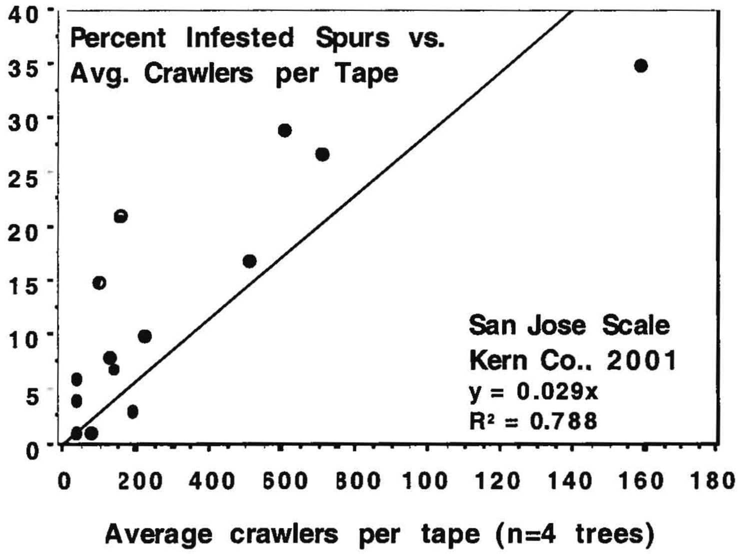
Crawlers were monitored on four trees around each of the pheromone trap locations. The tree located at each of the four compass points around the tree that held the pheromone trap was monitored for SJS crawlers. A single double sided sticky tape was placed on one of the scaffolds. The scaffold chosen ranged from 3 to 8 inches in circumference. Tapes were placed prior to crawler emergence in spring, 2001 (April 1), and were changed after each crawler generation (a total of five changes made at approximately 6 week intervals). Crawlers on the tapes were counted, and the number of crawlers per tape totaled for the year. Data presented are the number of crawlers per tape per trapping location for the entire season.

During December, 25 live spurs were collected from each of the trees where the sticky tapes were deployed. A total of 100 spurs were collected from the four trees surrounding the SJS pheromone traps, and the base to a distance of 3 inches along the spur examined for live scales. The number of SJS per spur were counted, and an estimate of dead wood was also made by gently scrapping the bark along the spur. Data obtained include the number of live scale per spur, and the number (and percent) of infested spurs. In Spring, 2002, a random collection of spurs will be made to estimate the number of dead spurs present to assist in establishing a damage threshold for SJS.

Linear regression analysis (Stat View 5.1) was performed to determine the relationship of number of crawlers per tape per year as the independent variable and the number of infested spurs per 100 (same as percent of spurs infested) as the dependent variable. Regression analysis was also performed to determine the relationship between the number of male SJS per pheromone trap as the independent variable and the number of infested spurs. Regressions were performed for each orchard independently and by pooling the five orchards.

Results of our analysis for male scales, crawlers and spur infestation showed no significant relationship (*P*>0.05) between either male scale and spur infestation or crawlers per tape and scale infestation for individual orchards. Although each of the orchards had remarkably uniform populations between the collection sites, the populations of male scale, crawlers per tape, and infested spurs was quite different between orchards. When the number of crawlers per tape per season at each trapping location in each orchard was pooled and regressed against the percent of

Figure 2. Relationship between mean number of San Jose scale crawlers per tape per season (n=4 trees per site) and percent spur infestation (n= 100 spurs per site) for all locations combined in the 5 orchards (n=18 locations) in December, 2001.



infested spurs (n=100 per tree), a highly significant ($P<0.0001$) relationship was indicated. The R^2 value was 0.788 (StatView 5.1, no intercept model). The regression equation was Y=0.029X (n=18) (Figure 2). When averaging the number of crawlers per tape per orchard for the season and regressing these data against the total number of infested spurs collected from each orchard (n=5 orchards), a highly significant ($P<0.001$) regression was indicated. The R^2 value was 0.982 (StatView 5.1, no intercept model). The regression equation was Y=–3.317+0.131X. Similarly, when the number of male scales per trap per season for each orchard was regressed against the number of SJS infested spurs, a significant ($P<0.0212$) regression was indicated (StatView 5.1, no intercept model). The R^2 vale was 0.772. The regression equation was Y=2.973X. A random sample of 100 spurs will be collected and evaluated for dead wood in April after trees have fully leafed out.

These results indicate that the use of sticky tapes provides a valid estimate of San Jose scale spur infestation. The use of male scales captured in SJS pheromone traps is less accurate as a predictor of scale infestation than is the abundance of SJS crawlers on double sided sticky tapes although it is an easier method of sampling and does provide a significant relationship for the first generation and when counts from all generations are combined. The information we have obtained together with the estimate of damage that we are trying to obtain will be used in establishing a needed guideline for San Jose Scale treatment.

Two studies to determine the effect of treatment timing on efficacy were conducted in an orchard east of Waterford in Stanislaus Co., and an orchard near Cortez in Merced Co. Treatment timing may be important to reducing organophosphate runoff as it is presumed that applications made before the soil is saturated will be absorbed into the soil where microorganisms can destroy the chemical naturally. The Stanislaus Co. orchard was divided into plots of ~500 trees. Five treatments, each replicated three times, were assigned to the plots in a randomized complete block design. The treatments were 6 pts/ac diazinon with 6 g/ac of horticultural mineral oil and 50 g/ac of water applied on either December 18, 2000, January 6, 2001, or January 30, 2001 and untreated. The Merced Co. orchard was divided into 9 plots. Three treatments, each replicated three times, were established in a randomized complete block design. The treatments were 6 pts/ac diazinon with 6 g/ac of horticultural mineral oil and 100 g/ac of water applied on December 18, 2000 or January 6, 2001 and untreated.

SJS adult males and their parasitoids were monitored using SJS pheromone traps (Trece Inc., Salinas, CA, USA). Both the trap and the lure were changed every four weeks. Two of the traps were placed in trees in the center row of each treatment replicate at a height of about 2 m on March 15, 2001 (Stanislaus Co.) and March 6, 2001 (Merced Co.). The pheromone traps were collected every 4 weeks and replaced with new traps and lures. The number of SJS males on the pheromone traps were determined in the laboratory using a dissecting microscope. No SJS parasitoids were found on the traps in this orchard. The number of SJS males per pheromone trap were summed for the first generation. SJS were also monitored by removing 50 first year spurs per treatment replicate on August 22, 2001, following the third SJS male flight, and returning them to the laboratory where the basal 3 inches were examined for scales under a dissecting microscope. Analysis of the spur counts has not been completed at this time.

A significant difference (*F*=4.391, *P*=0.0419, df=3,8) in SJS males captured in pheromone traps was observed between treatments in the Stanislaus Co. orchard (Table 2). There was little difference in abundance between any of the diazinon treatment timings. No significant difference (*F*=1.139, *P*=0.3809, df=2,6) in SJS males captured in pheromone traps was observed between treatments in the Merced Co. orchard (Table 3). However, the average number of male scales trapped in the early diazinon treatment was only about 60% that of that in the late diazinon untreated plots.

Table 2. Total San Jose scale males per trap during the first flight, 2001, Stanislaus Co.

Treatment	Mean	± SD
Untreated	641.7	± 176.4 b
Diazinon mid-December	351.7	± 63.7 a
Diazinon early January	335.0	± 85.4 a
Diazinon late January	308.3	± 155.1 a

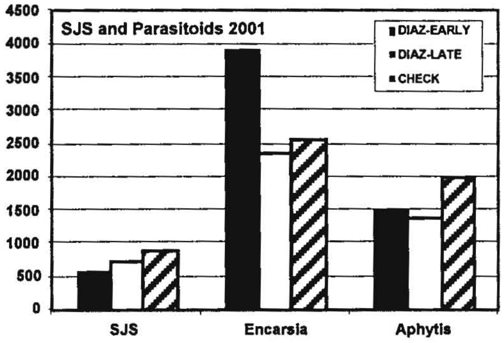
Means followed by the same letter do not differ significantly (*P*>0.05) by Fisher's Protected LSD.

Table 3. Total San Jose scale males per pheromone trap during the first flight, 2001, Merced Co.

Treatment	Mean	± SD
Diazinon mid-December	81.2	± 27.1
Diazinon late January	132.8	± 60.9
Untreated	131.8	± 49.6

San Jose scale parasitoids were not found on pheromone traps in the Stanislaus Co. orchard, but both *E. perniciosi* and *Aphytis* spp. were counted on the pheromone traps in the Merced Co. orchard. Figure 3 presents the total number of San Jose scale males, *E. perniciosi* and *Aphytis*

Figure 3. Total number of San Jose scale males, *Encarsia perniciosi* and *Aphytis* spp. per SJS pheromone trap captures for the first two flights of 2001 (n=3 replicates with 2 pheromone traps per replicate) in the Merced Co. orchard.



spp. per SJS pheromone trap captured for the first two flights of 2001. No significant difference (*P*>0.05) was found between treatment, but the total number of *E. perniciosi* was greater in the plots sprayed earlier with diazinon as opposed to those plots sprayed later or untreated, corresponding to the number of male SJS captured in the first flight.

Objective 3, Oblique-banded leafroller/ peach twig borer. Six treatments, each replicated three times, were established in a randomized complete block design in a Stanislaus Co. orchard. The treatments were 6 pts/ac diazinon with 6 g/ac of horticultural mineral oil and 50 g/ac of water applied on either December 18, 2000, January 6, 2001, or January 30, 2001; 1.5 pts/ac spinosad (Success, Dowagro Inc.) applied on either January 30, 2001 or February 23, 2001; and untreated.

We attempted to evaluate OBLR damage on May 3, 2001, by counting the number of OBLR webs per tree in each treatment replicate. OBLR webs were only found in one of the replicates, so no evaluation was possible. Peach twig borer shoot strikes were recorded from 15 watersprouts collected at random from trees near the center of each treatment replicate on May 5, 2001. The watersprouts were returned to the laboratory where flagged shoot tips were dissected to determine if the flagging was due to peach twig borer, the oriental fruit moth, or the fungal disease brown rot. Because the trees were relatively tall and not very vigorous, watersprouts were used for this assessment as there were insufficient numbers of new shoots on which to evaluate shoot strikes.

A significantly lower (*F*=11.147, *P*=0.0004, df=5,12) proportion of shoots with PTB shoot strikes were found in all treatments compared to untreated (Table 4). Although there was no significant difference between diazinon treatment timings, there tended to be more shoot strikes on the trees that were treated earlier during orchard dormancy. The number of PTB shoot strikes for spinosad at both treatment timings did not differ significantly (*P*>0.05) from the diazinon treatments.

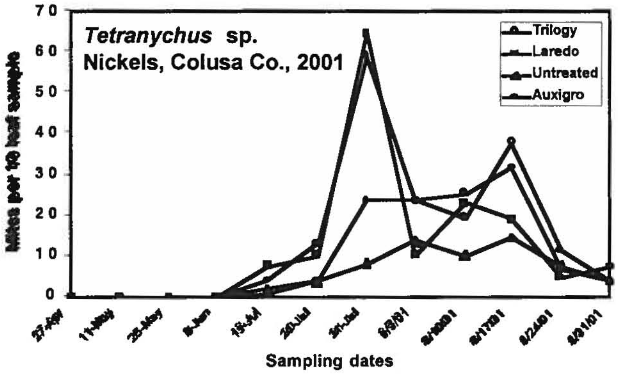
Table 4. Proportion of shoots with peach twig borer shoot strikes collected May 5, 2001, Stanislaus Co. Sample size is all shoots on 15 watersprouts per treatment replicate.

Treatment	Mean	± SD	
Untreated	0.217	± 0.047	b
Diazinon mid-December	0.073	± 0.042	a
Diazinon early January	0.067	± 0.021	a
Diazinon late January	0.037	± 0.006	a
Spinosad late January	0.060	± 0.044	a
Spinosad petalfall	0.057	± 0.025	a

Means followed by the same letter do not differ significantly (*P*>0.05) by Fisher's Protected LSD.

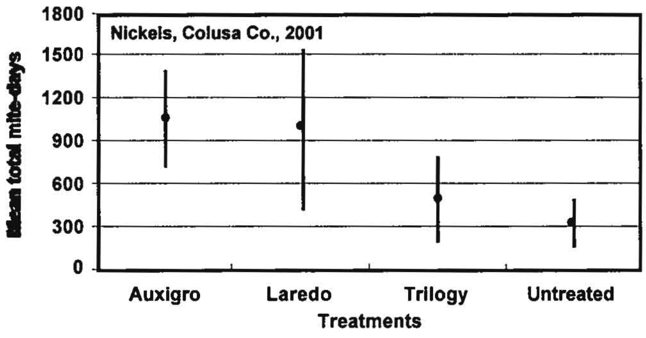
Objective 4, Spider mite/ predator mite bioassays. John Edstom has been working with Beth Teviotdale on fungicides for control of brown rot and leaf blight. Observations of their experimental plots in July and August, 2000 indicates the possibility that there might be some effects of the fungicides on webspinning spider mites. To determine possible effects of fungicides on webspinning spider mites, four treatment replicates from their 2001 fungicide trial at Nickels Estate (Colusa Co.) that were sprayed using a handgun sprayer to runoff with Trilogy (neem oil, 1% by volume), Laredo 2EC (12.8 oz/ac), and Auxigro WP (4 oz + Brkthru) plus the untreated controls were monitored for spider mites. Ten leaves were collected per treatment replicate beginning April 26, 2001, and returned to the laboratory where they were mite-brushed and counted. Sampling continued at 2 weeks intervals until the mites began to increase in mid-summer and then sampling occurred at weekly intervals. Figure 4 presents the sampling results.

Figure 4. Mean number of mites per 10 leaves in experimental plots at Nickels, Colusa Co.



Significant differences (*F*=3.875; df= 3,12; *P*=0.0378) were indicated for mean cumulative mite-days through August 16, 2001 (Figure 5).

Figure 5. Mean cumulative mite-days through August 16, 2001, at Nickels, Colusa, Co.



Laboratory bioassays of registered and candidate fungicides are being conducted on the western orchard predator mite, *Galendromus occidentalis*. Bioassays of registered and candidate miticides are being conducted on the common almond orchard mite predators the green lacewing (larvae), *Chrysoperla carnea*, the minute pirate bug (adults), *Orius* sp., and the western orchard predator mite (adult females), *G. occidentalis*. All of these laboratory bioassays are conducted using a Petri dish bioassay.

For the bioasssays, the predators mites are individually transferred to treated petri dish arenas that contain spider mite eggs as a food source. Each arena contained 4 predators, and each treatment was replicated 5 times for each trial. Untreated control Petri dishes were maintained to determine mortality due to factors other the pesticides applied. Survival was assessed after 48 and 72 hours, providing a residual bioassay of each pesticide. The Petri dish bioasssays were repeated 3 times for each predator species and all pesticides Fungicides tested included Abound, Auxigro, Captan, Flint, Rovral, Laredo, Trilogy (neem oil) and Ziram. Pyridaben (Pyramite), a miticide, serves as a treated control. Miticides tested included Agrimek, Apollo, Omite, Acramite, Pyramite, Valero, Mesa (milbemectin, not yet registered), and Secure (etoxizole, not yet registered).

All pesticides were applied to the Petri dishes at a series of doses beginning from below the label rate to exceeding the label rate until some predators were observed to survive. Once dose was found at which predator survival was beginning to be observed, this value was bracketed by other doses so that the predators would ultimately be exposed to a range of 5 or 6 doses. Predators which did not move during the 48 and 72 hour evaluations were touched with a probe and observed for movement. For fungicides, average survivorship after 72 hours is reported directly. In the case of the miticides, the resulting mortality data were subjected to Probit Analysis using the POLO Program so that LD50 values (the dose at which 50% of a population survives the application) were obtained.

The 72 hour residual bioassays of the almond fungicides showed very little impact against *G. occidentalis* indicating that the increase in spider mite abundance observed at Nickel's was probably not due to predator mortality, but rather to some unknown factor that might have affected the plant and therefore the spider mites directly. Results of the fungicide bioassays

Table 5. Average (n=4) proportion of *Galandromus occidentalis* surviving fungicide treatments 72 hours after exposure in a Petri dish bioassay.

	Proportion surviving exposure	
Trade name	@ 1X label rate	@ 10X label rate
Untreated	0.925	0.925
Pyramite[1]	0.037	0.017
Abound	0.967	0.833
Auxigro	0.885	0.813
Captan	0.936	0.800
Flint	0.808	0.936
Laredo	0.895	0.700
Rovral	0.846	0.876
Trilogy (neem oil)	0.000	0.000
Ziram	1.000	0.917

[1] Pyramite is a miticide that was applied as a treated control to confirm efficiency of the methodology.

expressed as proportion of *G. occidentalis* surviving an application at the top label rate of each chemical is shown on Table 5.

The 72 hour residual bioassays of registered and candidate miticides show that many of the chemicals tested caused relatively great mortality to the predators. Table 6 presents the LD50 and LD90 values for 5 registered miticides against *G. occidentalis*. These data indicate that 50% of a population will survive a standard Omite treatment. We have always considered Omite to be a 'selective' miticide because of relatively good predator survival even at the full label rate. Previous field trials have also shown that an even greater proportion of *G. occidentalis* will survive below label rates of Omite. Most of the newer miticides including Agrimek, Pyramite and Valero are less selective than Omite. Apollo is relatively nontoxic to the adult predators, but this probably reflects the ovicidal activity of this chemical. Our study does not examine the effects on *G. occidentalis* eggs or any reduction in fecundity that might result from exposure.

Table 6. Proportion of the high label rate of registered almond miticides at which 50% (LD50) and 90% (LD90) of *Galandromus occidentalis* survive 72 hours after exposure in a Petri dish bioassay.

		Proportion of field rate	
Trade name	Chemical name	LD50	LD90
Agrimek	avermectin	0.006	0.049
Apollo	clofentezine	253.075	2112.850
Omite	propargite	1.040	9.177
Pyramite	pyridaben	0.015	0.012
Valero	Cinnamic aldehyde	0.229	1.862

Table 7. Proportion of the high label rate of selected miticides at which 50% (LD50) of green lacewings (*Chrysoperla carnea*) and minute pirate bugs (*Orius* sp.) survive 72 hours after exposure in a Petri dish bioassay.

			Proportion of field rate for LD 50	
Trade name	Chemical	Rate applied (a.i./acre)	Green lacewing larvae	Minute pirate bug, *Orius* sp.
Agrimek	Abamectin	0.0188 lbs	3.93	0.12
Mesa	Milbemectin[1]	48 oz* /1	5.13	0.33
Acramite	Bifenazate	0.38 lb/1	>100.00	60.00
Secure	Etoxizole[1]	0.09 lb/1	>100.00	5.73
Pyramite	Pyridaben	0.3 lb/1	>100.00	0.06
Valero	Cinnamic aldehyde	0.2%	5.93	2.53

[1] Mesa and Secure are not registered for use on almonds at this time.

Clearly a new miticide which has less toxicity to *G. occidentalis* is needed for the almond production system.

Table 7 presents the LD50 values for 4 registered miticides and 2 that will likely be registered on almonds (Mesa and Secure) against green lacewing larvae and minute pirate bug adults. Omite is believed to be relatively nontoxic against these predatory insects and was not tested. These data indicate that all of the miticides tested are not very toxic to green lacewing larvae, but that some of the chemicals do have a significant negative impact on the smaller species (minute pirate bug). Dose rather than selectivity is a likely cause for this observation as the body weight of minute pirate bugs is much less than that of green lacewing larvae. Acramite is especially safe against adult minute pirate bugs relative to the other chemicals, and the unregistered miticide Secure is also quite safe against both predators. Both Mesa and Secure represent excellent candidates for registration on almonds in terms of their selectivity.

Appendix 1. Results of Artois groundcover study to mitigated dormant season pesticide runoff.

Since 1999, we have been conducting a study on 42 rows of a French prune orchard in Glenn Co. to measure the impact of various types of orchard floor vegetation as a best management practice in mitigating stormwater runoff from orchards, and the resulting toxicity of the runoff. Rows 1-8, 21-25, and 38-42 are unsprayed; rows 9-20 are sprayed with diazinon; and rows 26-37 are sprayed with Asana (esfenvalerate). Each spray treatment is overlaid on 4 cover crop treatments; no cover, grass cover, legume cover, and native vegetation. All 4 of these one-row treatments are located next to one another to form a complete 'block' of treatments. These complete 'blocks' of 4 rows are replicated three times across the orchard. There is a break of untreated rows half way across the orchard to avoid cross contamination between the diazinon and Asana treated sections. Water samples are collected within these treatments using 2 types of sampling apparatus; in-ground jars, and automated samplers.

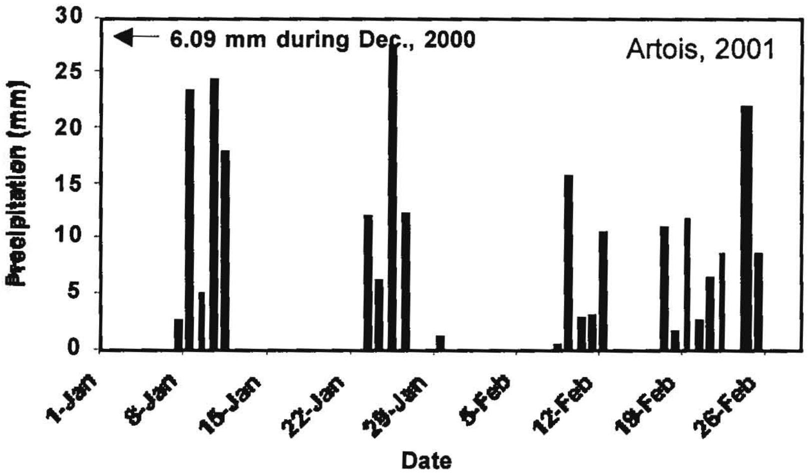
Table 8. Liters of water runoff from rows with different orchard floor ground covers (n=3) and runoff as a percent of bare ground treatment on each sampling date, 2001.

Type of ground cover	Water runoff (l) and % of bare ground treatment on each sampling date						
	Total	1/25	1/26	1/29	2/18	2/20	2/23
Non-tillage clover	46056 (61%)	6137 (81%)	5298 (68%)	359 (143%)	255 a (16%)	1380 a (44%)	1924 a (41%)
Perennial sod mix	52769 (70%)	6528 (87%)	5664 (72%)	202 (80%)	763 a (47%)	1791 a (57%)	2643 a (56%)
Resident vegetation	46668 (62%)	5758 (76%)	5714 (73%)	328 (130%)	389 a (24%)	1466 a (46%)	1908 a (40%)
Bare ground	75474 (100%)	7535 (100%)	7846 (100%)	252 (100%)	1635 b (100%)	3156 b (100%)	4734 b (100%)
LSD$_{0.05}$[1]	NS	NS	NS	NS	730	1086	1540

[1] Means followed by the same letter are not significantly different by Fisher's Protected LSD at $p<0.05$.

Figure 6 presents runoff data resulting from rainfall events occurring on January 23-29 and February 17-25, 2001, which followed the insecticide application on 20 January, and are representative of data collected in the autosamplers. It is clear that groundcover affected the amount of runoff. Significantly (*P*<0.05) greater runoff was measured from the bare ground treatment rows than from any of the rows with groundcovers (Table 8), but only for the February event. No significant differences (*P*>0.05) in runoff were observed for the January rainfall event that was monitored. The groundcover presumably increased water penetration for the latter event.

Figure 6. Daily precipitation (in mm) at Artois, CA, during Winter, 2000-01.



In the Winter of 2001-02, our CALFED water quality team began to work with the Almond Board of California's Prop 13 demonstration project, providing technical support in terms of measuring water movement from the plots and conducting water chemistry and bioassays on the samples.