Annual Report to
Almond Board of California
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Project No.: 2000-FZ-o0 Insect and Mite Research

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Project Participants: UC Farm Advisors in 9 counties, Walt Bentley (UC Kearney Agricultural Center) and Paula Flaugher (M.S. Student, UC Davis) for Objective 1; Walt Bentley, Mario Viveros (UCCE Kern Co.) and Francisco Badenes-Perez (M.S. Student, UC Davis) for Objectives 2 and 3; Barry Wilson (UC Davis), Dave Hinton (UC Davis), Bill Krueger (UCCE Glenn Co.), Mike Oliver and Roger Duncan (both UCCE Stanislaus Co.) for Objective 3.

Objectives:

1. Purchase pheromone traps and lures, and other monitoring supplies for UC Cooperative Extension Farm Advisors as part of their ongoing monitoring efforts. Determine relative trap catches and longevity of commercial lures for peach twig borer.

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 and deposition of different volumes of dormant sprays for control of San Jose scale.

3. Best management practices and runoff - Determine effects of treatment timing relative to bloom, volumes of application, and aerial versus ground sprays on organophosphate runoff, deposition and efficacy against San Jose scale and peach twig borer.

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 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 has served on several occasions as a database

for research and validation. Table 1 provides a summary of lures purchased through this project for use by the advisors and my lab for monitoring and applied research. The actual cost for these lures was $7824.

Table 1. Trapping supplies purchased for monitoring insect pests in almonds, 2000.

Name	Location	Wing Traps	Trap Liners	NOW Traps	SJS Traps	PTB Lures	OFM Lures	SJS Lures	NOW Bait (lb)
R. Coviello	Fresno Co.	20	300	8	80	232		80	
L. Hendricks	Merced Co.	50	150		300	100		100	10
J. Edstrom	Colusa Co.	8	40	4	10	20		10	1
R. Buchner	Tehama Co.	24	72	4	12	48	32	12	1
W. Bentley	UC KAC					1975		450	
W. Krueger	Glenn Co.	8	32			40	20		
W. Reil	Yolo Co.		200	15		125			2
M. Freeman	Fresno Co.	12	36	12	50	50		50	2
F. Zalom	UC Davis	176	192		450	300		216	
Total	All Sites	298	1022	43	902	2890	52	918	16

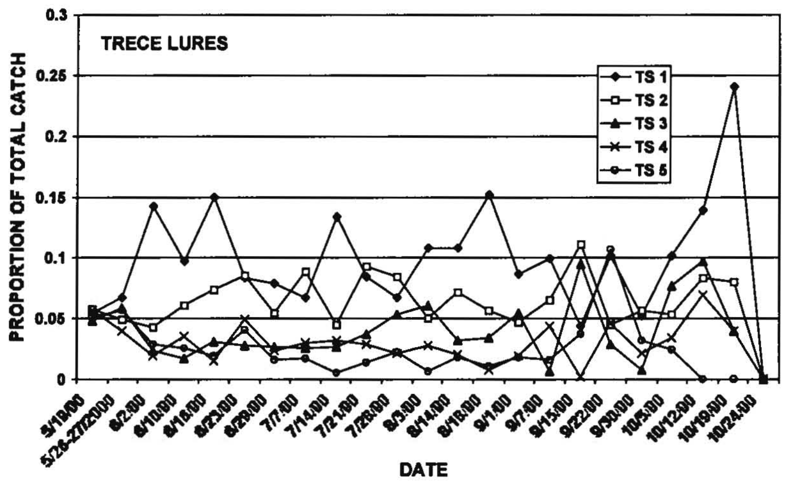
Since starting this effort in 1981, we have used lures purchased from Trece® Inc. for standard population monitoring in most of the orchards. We started using Trece (then Zoecon®) lures because this was the industry standard at that time. Since that time, several additional companies have begun manufacturing and selling lures, some utilizing the same red rubber septa dispensers and others utilizing other technologies for regulating pheromone release. Some of these lures (including one from Trece) are advertised as 'long life' lures because they are intended to last longer between lure changes. We continue to use the Trece red rubber septa lures in most of the orchards being monitored in order to maintain consistency and reduce the potential for variability due to lures between the years of this study. It is assumed that different types of lures, even those produced by Trece, will result in different patterns of trap capture due to differences in release rates and other factors. This is not a judgement about the 'quality' of different lures, but rather a recognition of the need to maintain consistency in any long-term study. Growers and PCAs should understand this as well if they are using pheromone traps to assess relative population densities or to compare flight patterns over years. Changing lures or trap types might well affect trap capture. Therefore it is a good idea to transition to using a new lure or trap type by running them together with the lure or trap type used historically in several orchards or for several years to gain an appreciation for differences that might exist.

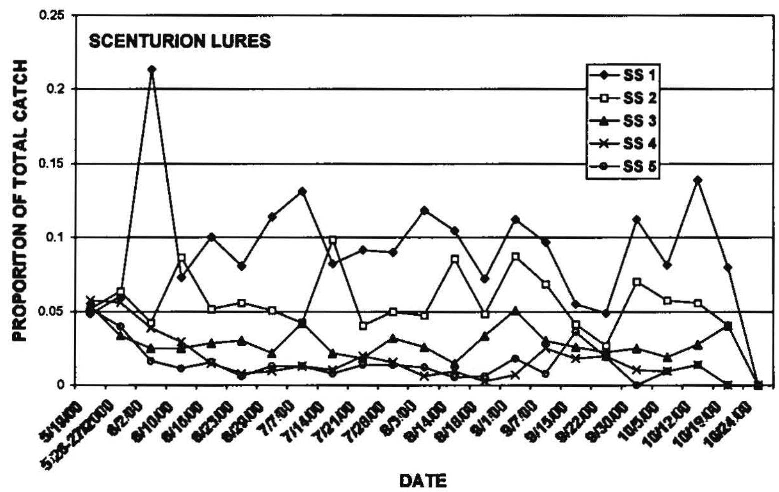
In 1999, we compared standard lures manufactured by Consep Membranes (Biolure), IPM Technologies, Scenturion, and Trece aged for different periods of time within four separate orchard blocks. Wing style traps baited with a lure of each experimental type were placed in a complete block design at a spacing of at least 4 trees or tree rows between traps, and replicated 4 times. "Aged" lures were compared to "new" (removed from the package the day before placing them in the orchard) lures of the same type, and to "new" Trece lures which served as a standard for reference. The "aged" lures were taken from their foil packets at weekly intervals before the start of the trial and placed into a trap out of doors for various periods of time before all being placed into the field on the same date. The traps with the different lure treatments were rotated through a grid in each block twice each week to reduce variability between lure treatments due to location in each orchard, and moth counts were taken at this interval. The results of this study indicated that peak moth capture per night with "new" lures were not significantly different for any of the lure types. Moth captures by "aged" lures did not consistently fall below that of a new lure for 3 weeks for the IPM Technologies and Scenturion lures, 3.5 weeks for the Trece lures, and 5 weeks for the Biolures.

In 2000, Standard lures from Consep Membranes (Biolure), IPM Technologies, Scenturion, and Trece were directly compared after being in the field for 1 to 5 weeks, the '1 week' lures being those the had been removed from their foil packets before being placed in the field for one week before counting moths captured. The lures were monitored in wing style traps in four separate orchard blocks. Treatments were placed in a complete block design at a spacing of at least 4 trees or tree rows between traps, and replicated 4 times. "Aged" lures were compared to the "1 week" (removed from the package the day before placing them in the orchard) lures of the same type, with the "1 week" lures replacing the 5 week old lures every week throughout the season. The traps were rotated through a grid in each block twice each week to reduce variability between lure treatments due to location in each orchard. Results (shown on Figure 1) indicate that significantly more moths of all lure types were captured during the first 2 weeks after being removed from their foil packets and placed in the pheromone traps than in weeks 3-5. Figure 2 shows comparisons between these same lure types including both 1 week and 5 week old long life Biolures.

Two other experiments were also established to address other questions concerning lure types. The first of the new experiments tested a series of load rates in "long-life lures" against the standard Trece red septa lures changed every 2 weeks, and is intended to determine the relative seasonal capture patterns of the long life lures and the standard rate lures. This comparision was run both in Winters (Yolo Co.) and at Parlier (Fresno Co.). Treatments were Trece long life lures loaded with the standard commercial concentration, 75%, 125%, and 150% of the long life standard, and a Scenturion long life lure. Traps were checked twice per week for 16 weeks and were rotated between trees after every sampling date. An additional group of all five Trece lure types was aged concurrently with the field trial, and returned to the Trece lab for gas chromatograph analysis to determine rate of pheromone release over time for each lure type. The second of the experiments compared trap captures for Trece lures that were believed to have been stored in their foil wrappers in a refrigerator freezer since they were purchased, and was intended to determine if "old lures" could still remain useable. Peach twig borer lures that had been packaged for 1990, 1991, 1995, 1997, 1999, and 2000, and oriental fruit moth lures that

Figure 1. Peach twig borer captures in wing style pheromone traps baited with either Trece, IPM Technologies or Scenturion lures. 'Weeks' indicates the time each lure was in the field on the corresponding sample date.





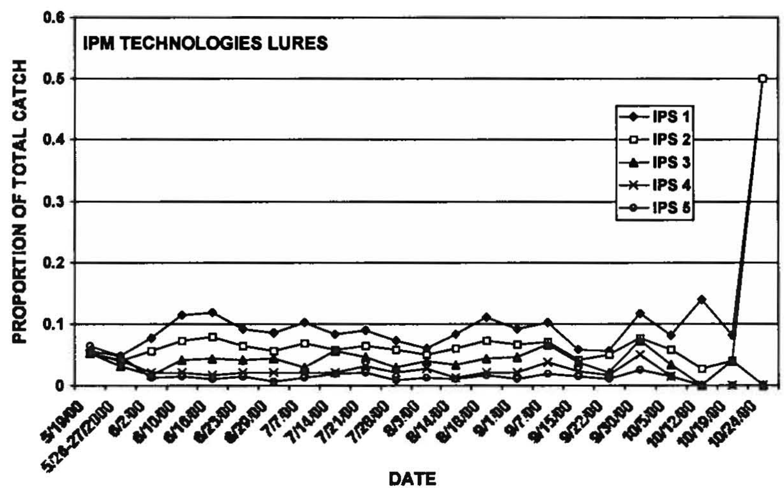
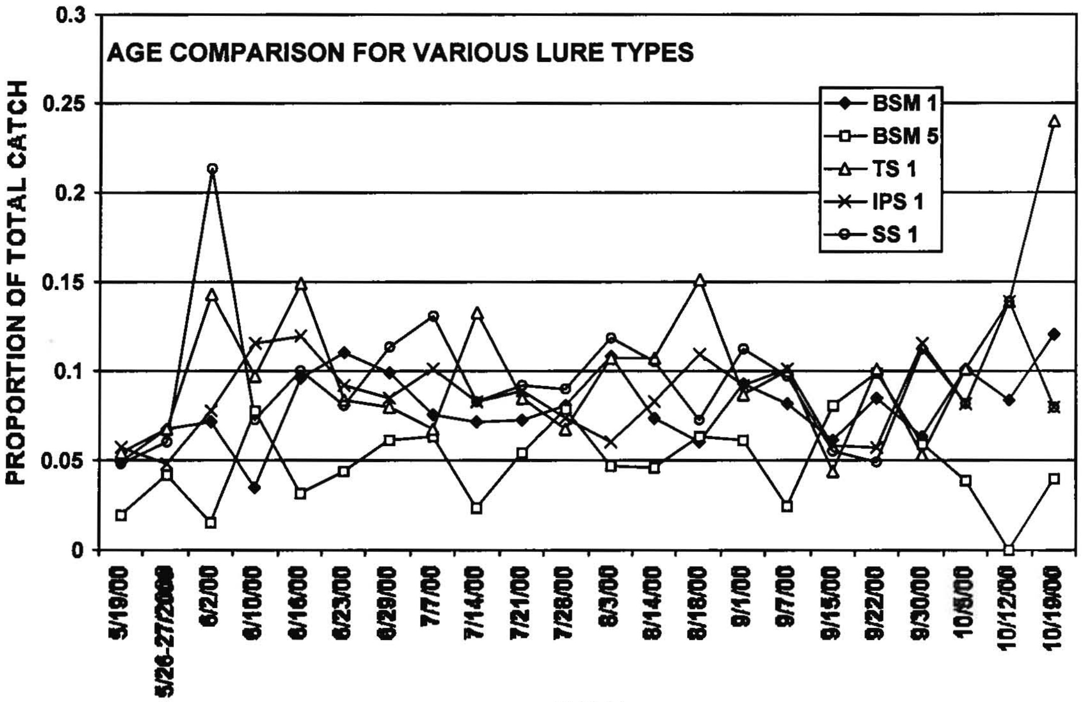


Figure 2. Peach twig borer captures in wing style pheromone traps baited with 'new' (1 week) Trece, IPM Technologies or Scenturion lures in comparison to 'new' and 5 week old 'long life' Biolures.



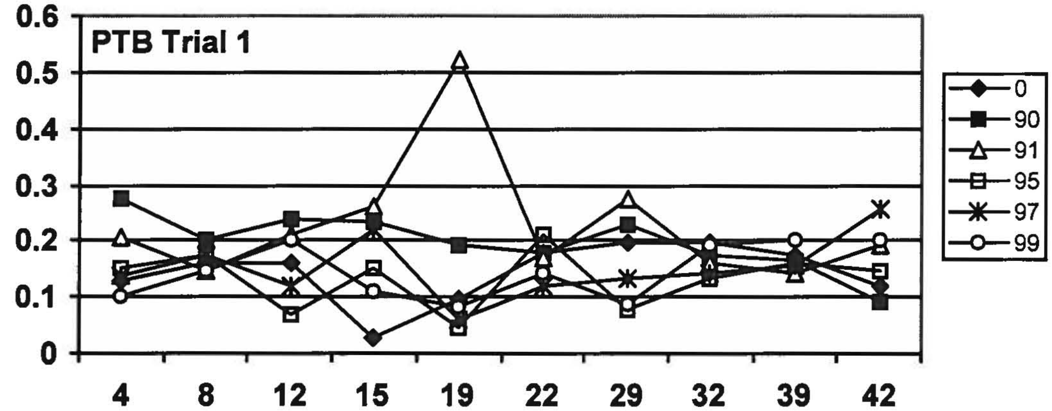
had been packaged for 1989, 1990, 1995, 1997, 1999 and 2000 were placed separately in the orchards in wing style traps, checked twice a week for three weeks, and systematically rotated between trees after each check. Relevant dates for this experiment are provided on Table 2. The last trap in a row was rotated to the first trap position in the same row so that the lures and traps remained in their complete block. It took 6 weeks for a trap to complete one circuit through the row. The lures were taken from storage in the refrigerator just prior to being opened for placement in the field. Several lures of each type and for each year were sent to a lab for gas chromatograph analysis to determine how much pheromone remained in the lures.

Table 2. Relevant dates for the stored peach twig borer and oriental fruit moth lure experiment.

Insect and Trial Number	Date Traps Placed in Field	Date Traps were First Checked	Last Date Traps were Checked
PTB 1	6/29/00	7/3/00	8/4/00
PTB 2	9/22/00	9/25/00	10/12/00
OFM 1	6/29/00	7/3/00	8/4/00
OFM 2	4/21/01		

There were no significant differences in moth captures between years for the stored PTB lures (Figures 3a and 3b). However the lures packaged for 2000 and 1999 did show the least variance in proportion of moths caught during each trial. There were no significant differences between years for the stored OFM lures for the first trial (Figure 4), and the second trial is in progress. OF moth captures for each date were very low in 2000, so we do not have a lot of confidence in these results.

Figures 3a and 3b. Proportion of total peach twig borer moths caught on each sampling date in stored lures from the 2 field trials in 2000.



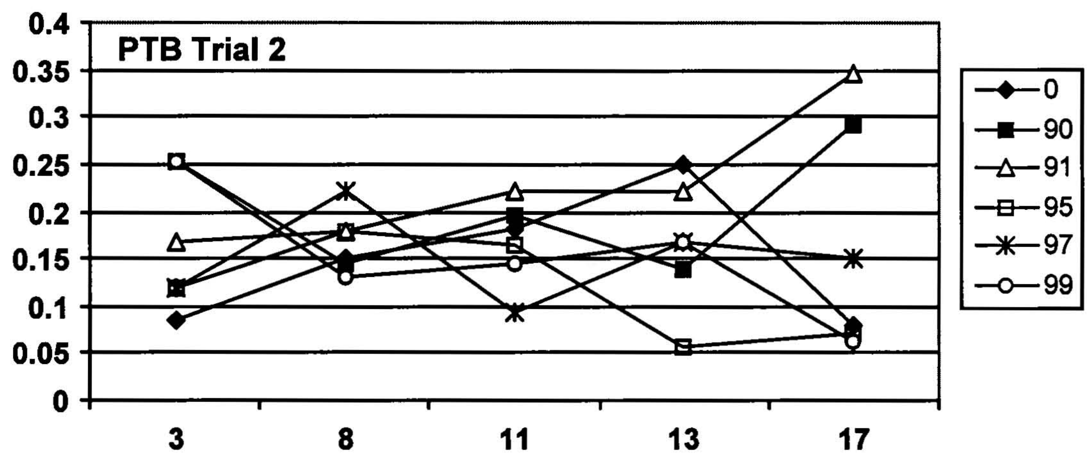
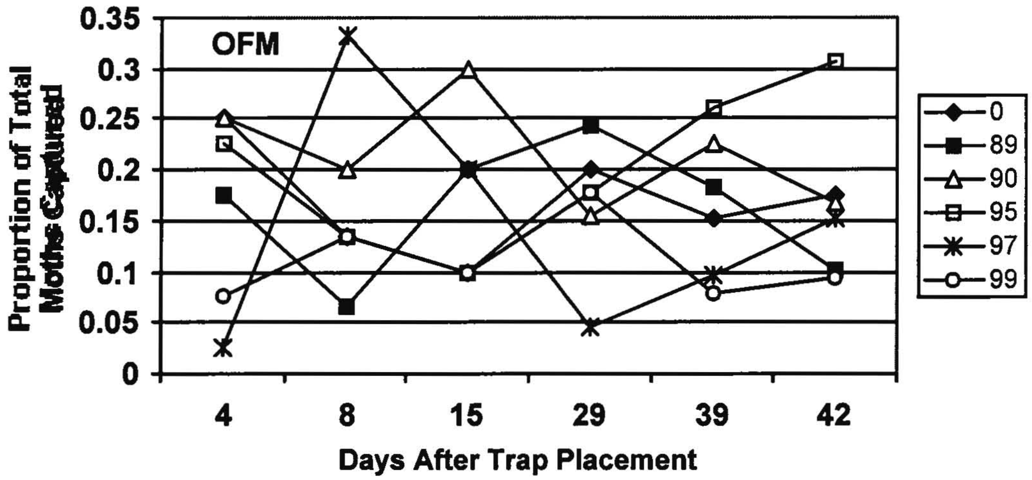


Figure 4. Proportion of total oriental fruit moths caught on each sampling date in stored lures from the 2 field trials in 2000.



The gas chromatograph analysis indicated that there was less than 10% loss of pheromone for the lures of the most recent three years tested (Table 3). The lures for both OFM and PTB from 1995 showed a greater than 20% loss, indicating that there might have been some difference in the manner in which these lures were stored, or possibly some difference in the original load rate for that year (although this did not appear to be the case in discussions with Trece). For 1990 and 1989, the OFM lures lost nearly 15% of their initial pheromone load rate, while the 1990 and 1991 PTB lures lost less than 3% of their initial pheromone load.

Table 3. Gas chromatograph analysis of stored PTB and OFM lures.

Year lure was packaged for	Years in storage	% OFM pheromone remaining	% PTB pheromone remaining	Last 2 numbers on lure package
1989	11	84.5	x	89
1990	10	86.4	98.6	90
1991	9	x	99	91
1995	5	78.6	76.8	95
1997	3	91.3	95.3	97
1999	1	95.1	96.2	99
2000	<1	100	91	0

Objective 2, San Jose scale. In 2000, 7 orchards were monitored in Kern Co. to determine the possible influence of different practices ranging from Bt and oil dormant sprays to organophosphate and oil dormant spray on San Jose scale and parasite population dynamics. In each orchard, pheromone traps were used to monitor male scale flights and adult parasitoid activity, sticky tapes to monitor scale crawler activity, and dormant wood to determine infestation levels and overwintering parasitism. Data included male scale counts from two pheromone traps placed at a 2 m height in trees at opposite sides of the plot. Minimum plot size was 3 acres. On the same tree where the pheromone trap was located, four branches were banded with double-sided sticky tape. The pheromone traps were replaced weekly, and the sticky-tape traps every other week, and all traps were returned to the lab for counting. In addition to San Jose scales, the parasitoids *Encarsia perniciosi* and *Aphytis* spp. were also counted on the pheromone traps. Figure 5 presents the weekly pheromone trap captures of San Jose scale males in each of the orchards. The number of male scales captured varied considerably across orchards. Figure 6 presents the number of crawlers on two sided sticky tape captured biweekly in the same 7 orchards.

Pheromone trap and crawler data obtained from 3 of the orchards sampled in 1999, and from the 7 orchards (plus the orchard at Paramount Farms where our efficacy trial described later) were subjected to regression analysis to determine if male scales captured in the pheromone traps are predictive of scale crawler abundance. The crawler samples are presumed to provide a more accurate assessment of scale density because they provides a relative measure of abundance of scales on individual trees as opposed to male scale captures in pheromone traps which may

Table 4. Correlation between SJS males captured in pheromone traps and SJS crawlers collected on two-sided sticky-tape traps.

Year	No. of orchards	Generation	$r^2 =$	F =	p =	n
1999[1]	3	1	0.226	2.922	0.1182	12
1999[1]	3	2	0.022	0.223	0.6467	12
1999[1]	3	3	0.001	0.007	0.9365	12
1999[1]	3	4	0.011	0.106	0.7511	12
2000[2]	7	1	0.467	20.140	0.0002*	25
2000[2]	7	2	0.067	1.663	0.2100	25
2000[2]	7	3	0.040	0.962	0.3369	25
2000[2]	7	4	0.105	3.810	0.0632	25
2000[3]	1	1	0.428	25.389	<0.0001*	36
2000[3]	1	2	0.272	12.731	0.0011*	36
2000[3]	1	3	0.001	0.042	0.8393	36
2000[3]	1	4	0.015	1.524	0.2255	36

1: Includes orchards Buttonwillow, Peterson, and Randall.
2: Includes orchards Billings, Buttonwillow, Peterson, Randall, Rosales, Shafter Riverside, and Stockdale.
3: Includes Paramount Farms orchard (6 treatments and 3 replicates).

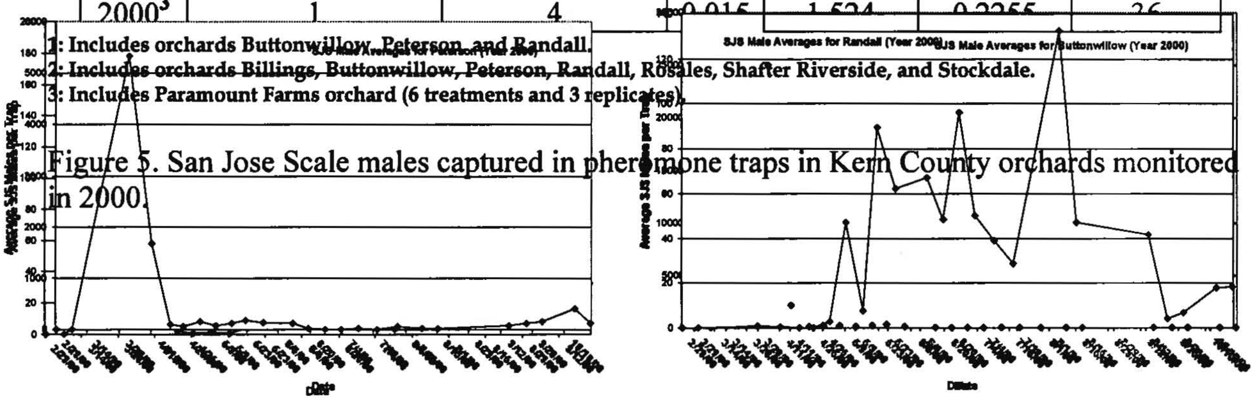


Figure 5. San Jose Scale males captured in pheromone traps in Kern County orchards monitored in 2000.

Figure 6. San Jose Scale crawlers captured on two-sided sticky tapes in Kern County orchards monitored in 2000.

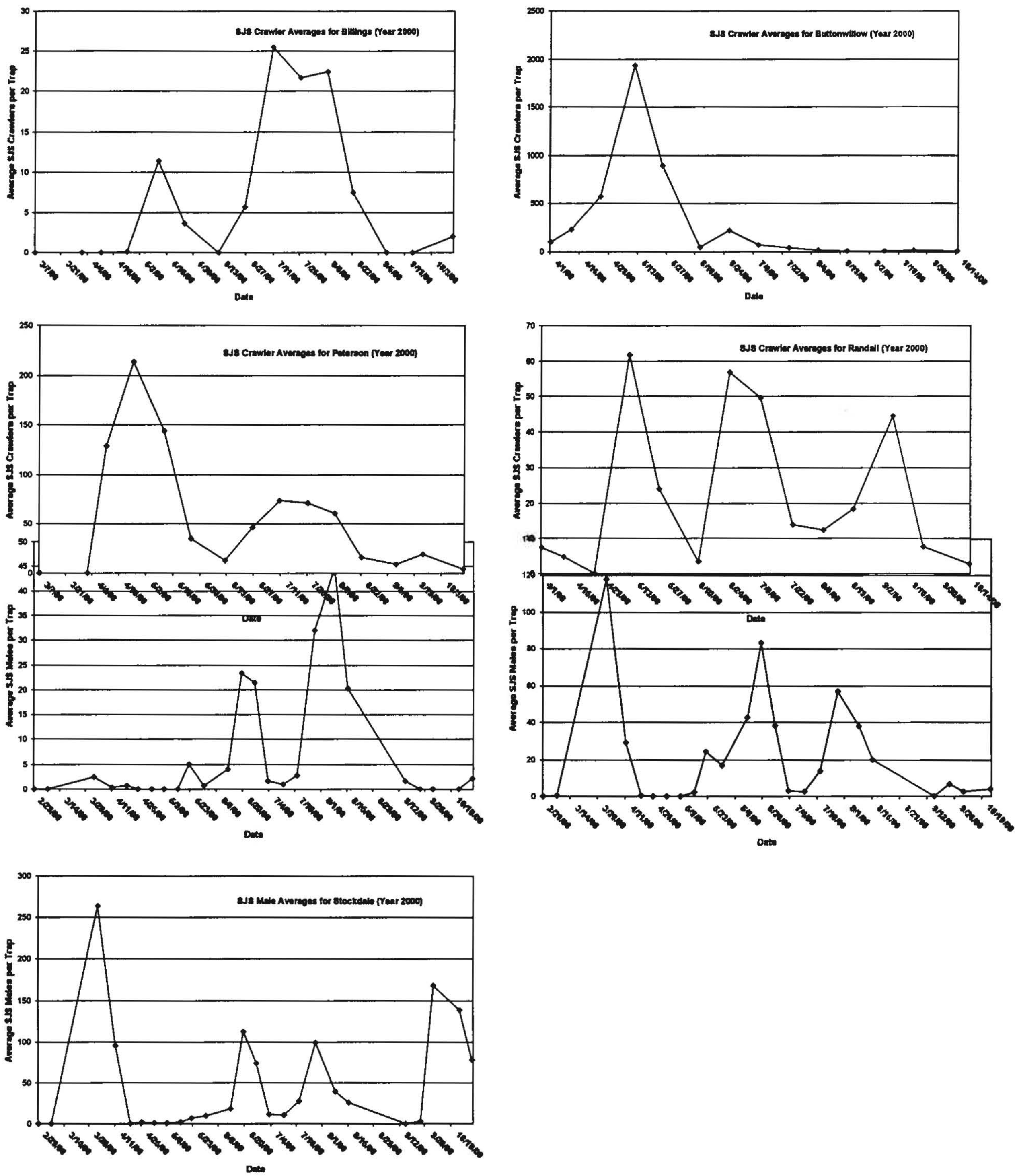
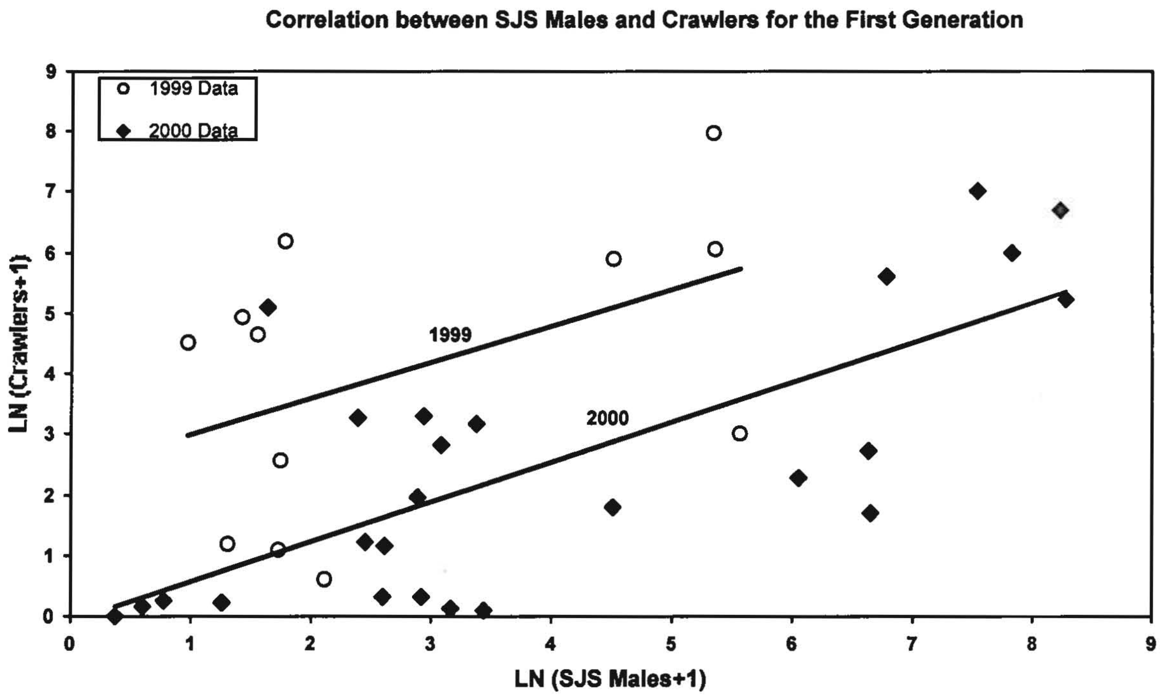
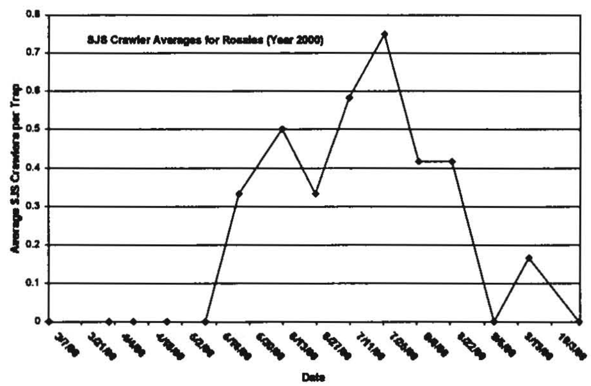
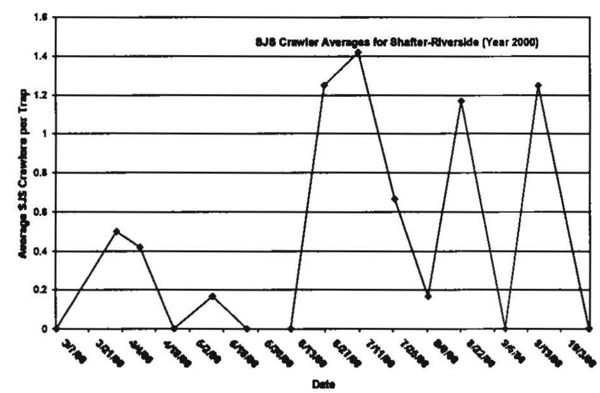


Figure 7. Regression analysis of San Jose scale males and crawlers for the first generation.







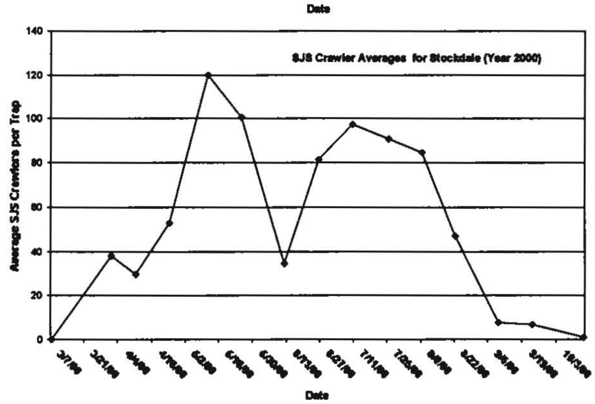
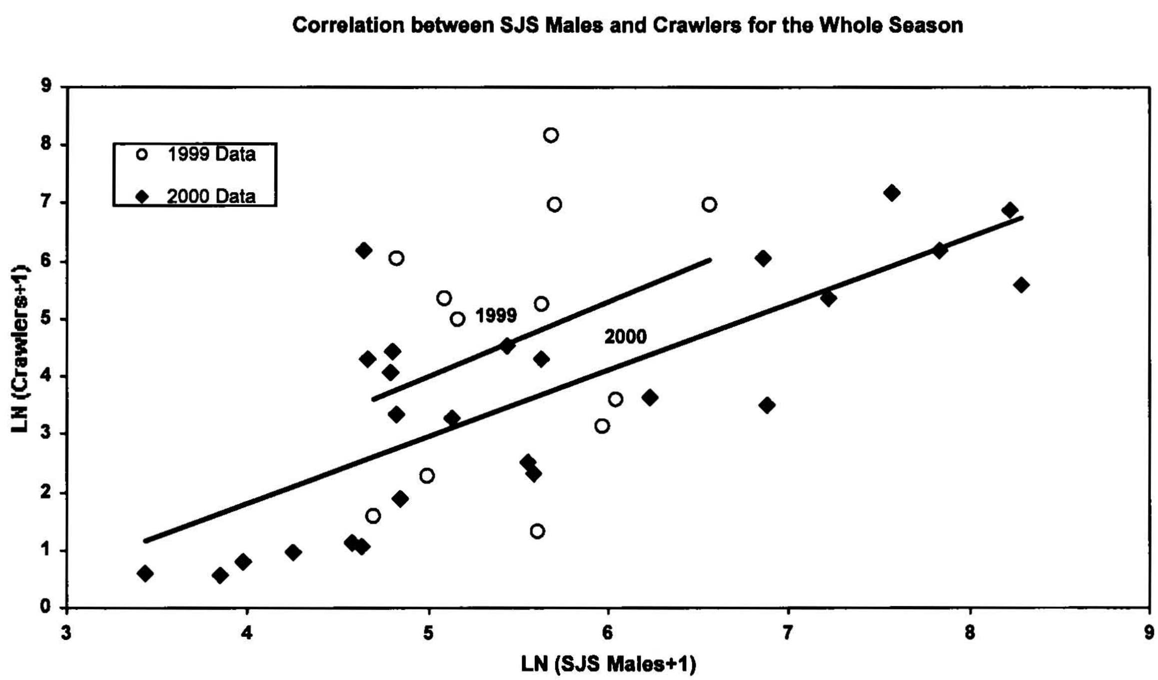


Figure 8. Regression analysis of San Jose scale males and crawlers for all generations.



attract the motile males from some distance away from the trap location. Table 4 summarizes the regression analyses for each generation of scales from the orchards monitored in each year.

Results of the regressions indicate that male captures in pheromone traps are most predictive of crawler densities in the first generation (Figure 7), although a relationship is apparent for all generations combined (Figure 8). This regression was significant for both the first and second generations in 2000, but was not significant in 1999.

A field trials was established at Paramount Farms in Kern Co. to test the efficacy and deposition of different volumes of dormant sprays for control of San Jose scale. The 6 treatments compared were 6 pts./ac of diazinon + 8 gal/ac of Orchex (horticultural mineral oil) applied in water volumes of 400 gal/ac, 200 gal/ac, and 100 gal/ac, 8 gal/ac of Orchex alone applied at a volume of 400 gal/ac, 10 oz/ac of Asana + 8 gal/ac of Orchex applied at a volume of 400 gal/ac, and an untreated control. Applications were made on January 21, 2000, with a commercial smart sprayer. The 24 plots were about 3 acres in size. Results of the trial indicated that all of the insecticide treatments significantly reduced the first generation San Jose scale crawlers relative to the untreated control (Figures 9 and 10, and Tables 5 and 6).

Table 5. ANOVA results for San Jose scale males captured in pheromone traps.

	Generation	df	F =	P =
Treatment	1	5	2.655	0.0228*
	2	5	1.440	0.2123
	3	5	0.872	0.5014
	4	5	8.859	< 0.0001*
Replicate	1	1	1.118	0.2912
	2	1	1.518	0.2197
	3	1	6.730	0.0106*
	4	1	0.002	0.9607
Treatment x Replicate	1	5	0.381	0.8615
	2	5	1.206	0.3087
	3	5	1.570	0.1732
	4	5	9.981	< 0.0001*
Residual	1	312		
	2	312		
	3	312		
	4	312		

The treatment effect was significant for the first and fourth generations as indicated by Fisher's PLSD (5% significance level) following log n+1 transformation, with the untreated control having more SJS males than the other treatments. However, in the fourth generation, male scale density in the untreated control treatment differed only from the Orchex treatment.

Table 6. ANOVA results for San Jose scale crawlers captured on sticky tapes.

	Generation	df	F =	p =
Treatment	1	5	5.052	0.0003*
	2	5	2.011	0.0899

	3	5	3.325	0.1020
	4	5	3.514	0.0058*
Replicate	1	1	3.881	0.0509
	2	1	0.058	0.8113
	3	1	1.417	0.2387
	4	1	3.796	0.0543
Treatment x Replicate	1	5	1.890	0.1003
	2	5	2.939	0.0194*
	3	5	5.324	0.0004*
	4	5	6.406	<0.001*
Residual	1	132		
	2	60		
	3	60		
	4	96		

Similarly, the treatment effect was significant for the first and fourth generation when assessing number of scale crawlers in each treatment, with the untreated control having more crawlers than the other treatments. In the fourth generation, the untreated control differed only from the treatment of Asana and the treatments with medium and high volume applications of diazinon.

All dormant treatments appeared to affect parasitism by *Encarsia perniciosi* (Figure 11) and *Aphytis aonidiae* (Figure 12), in the first generation. Both treatment and replicate effects were significant for *E. perniciosi* (Table 7). Mean separation by Fisher's Protected LSD showed that significantly more *E. perniciosi* were captured in the untreated control plots than in all other treatments in the first generation (Figure 13). This could be either the result of mortality of the parasites resulting from the dormant treatment, or from the presence of more scales in the untreated control plots.

Table 7. ANOVA statistics for *Encarsia perniciosi* captured in pheromone traps in the first generation following dormant treatment.

	df	F =	p =
Treatment	5	3.056	0.0121*
Replicate	1	4.026	0.0468*
Treatment x Replicate	5	1.743	0.1292
Residual	132		

Figure 9. Mean $\pm$ SE San Jose scale crawlers in plots treated with diazinon in 3 volumes of water, Asana, mineral oil alone and in untreated control plots.

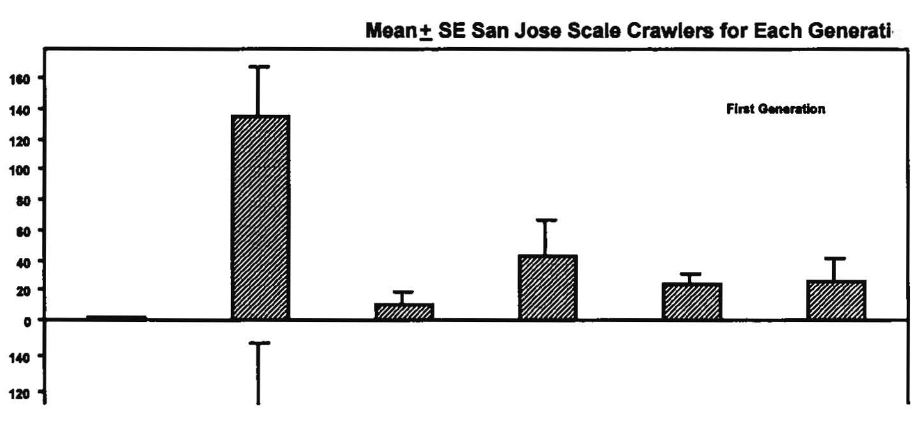
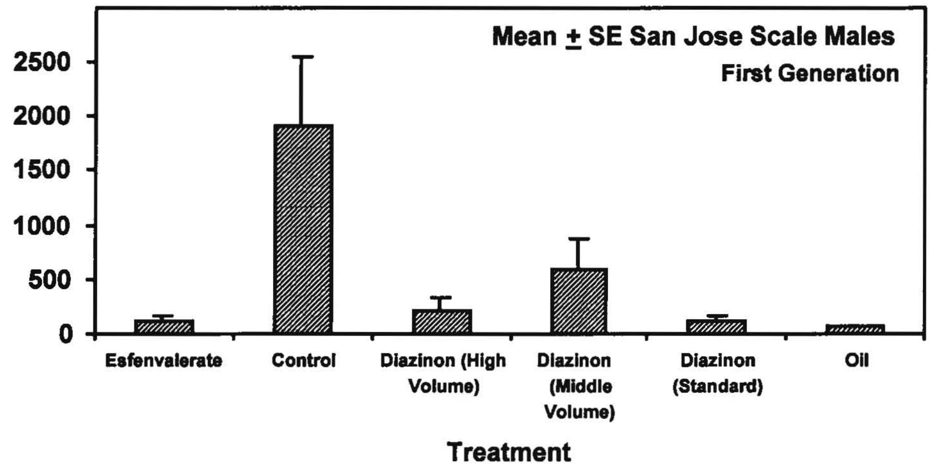


Figure 10. Mean ± SE first generation San Jose scale males captured in pheromone traps in plots treated with diazinon in 3 volumes of water, Asana, mineral oil alone and untreated control plots.



Treatment effects were significant for *Aphytis aonidiae* (Table 8). Mean separation by Fisher's Protected LSD showed that significantly more *Aphytis aonidiae* were captured in the untreated control plots than in all other treatments for the year (Figure 14). As was the case for Encarsia perniciosi, this could be either the result of mortality of the parasites resulting from the dormant treatment, or from the presence of more scales in the untreated control plots.

Table 8. ANOVA statistics for Aphytis aonidiae captured in pheromone traps for the year.

	df	F =	p =
Treatment	5	3.285	0.0212*
Replicate	1	1.584	0.2203
Treatment x Replicate	5	1.392	0.2624
Residual	24		

Figure 11. Average Encarsia perniciosi per trap in different experimental treatments.

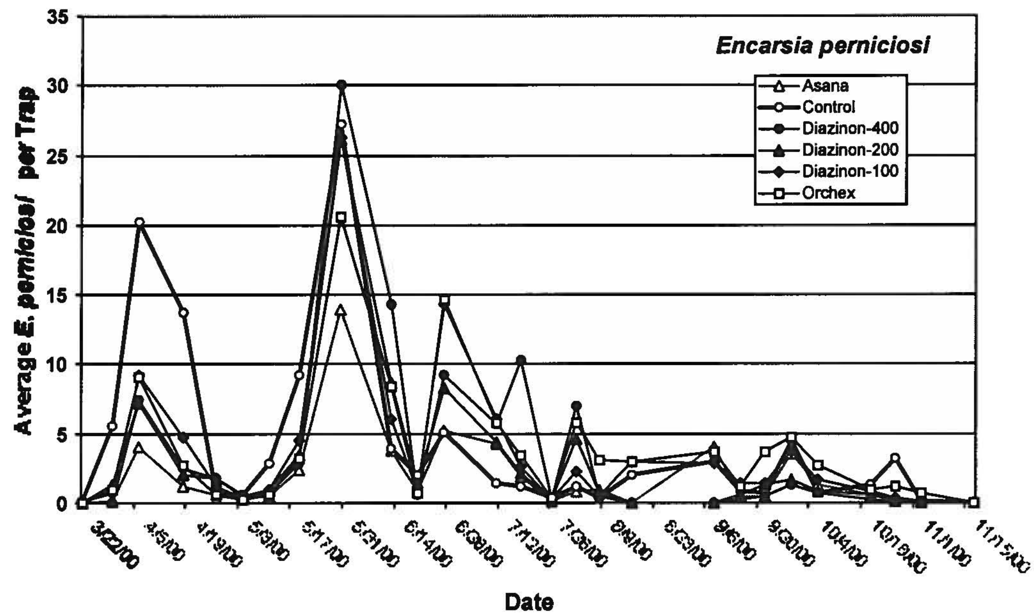


Figure 12. Average Aphytis aonidiae per trap in different experimental treatments.

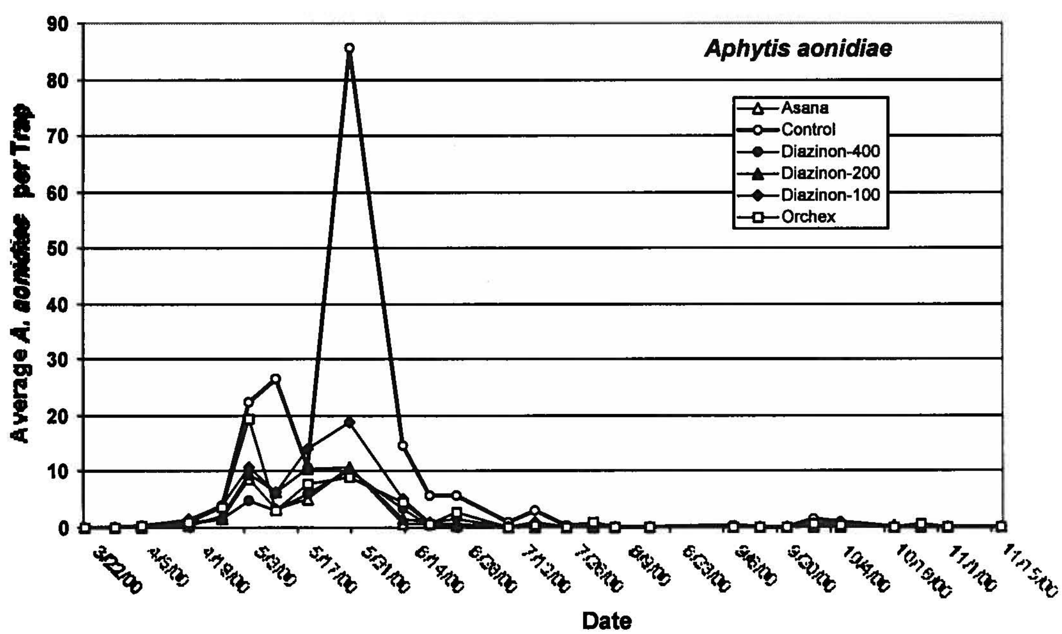


Figure 13. Mean + SE Encarsia perniciosi per trap in different experimental treatments for the first generation and for the year.

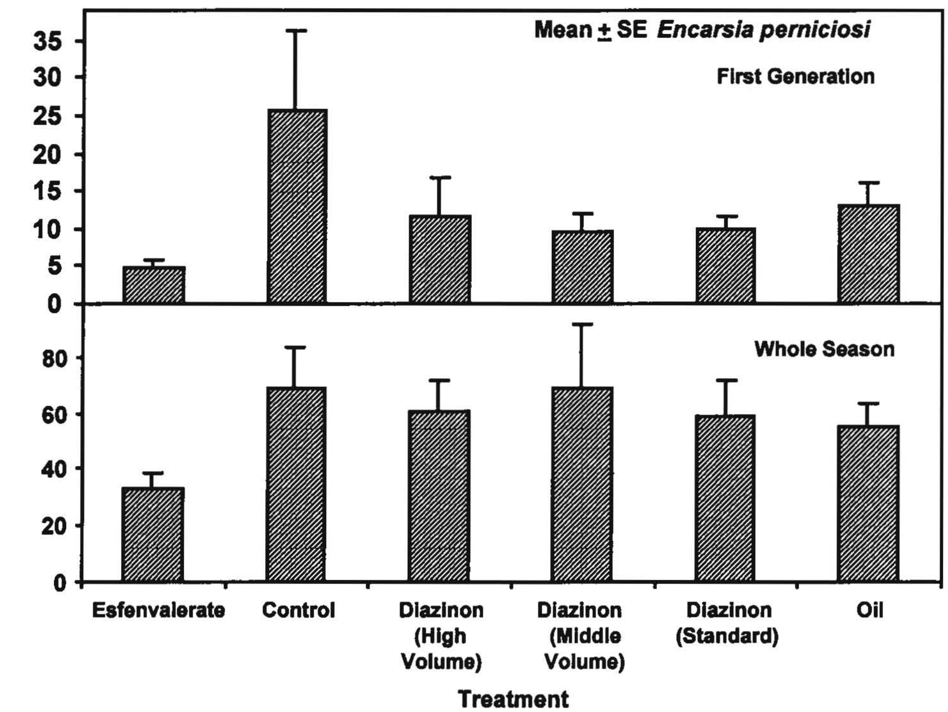
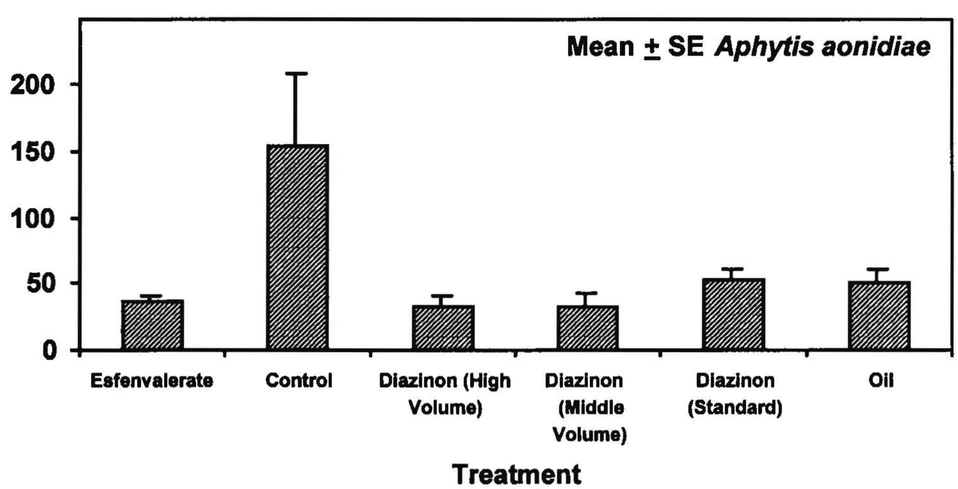


Figure 14. Mean + SE Aphytis aonidiae per trap in different experimental treatments for the year.



Objective 3, Best management practices and runoff. Results for this objective are being conducted as part of a larger study which is funded by CALFED for insecticide residue and water quality analysis. Study sites included the aforementioned site in Kern Co., the Sunflower Ranch in Stanislaus Co., and the Versegian prune orchard in Glenn Co.

The Kern Co. results efficacy results for San Jose scale were presented in Objective 2. Efficacy results against peach twig borer showed no significant differences between treatments ($F = 1.141$, $p = 0.2232$, $df = 5$). Data for peach twig borer are presented in Table 9, and show that the densities were low which probably resulted in the lack of significance.

Table 9. Peach twig borer shoot strikes in plots treated with diazinon in 3 volumes of water, Asana, mineral oil alone and untreated control plots.

Treatment	Mean strikes per tree	SD
Untreated	6.67	5.69
Diazinon, 100 gal.	3.00	1.73
Diazinon, 200 gal.	1.67	1.53
Diazinon, 400 gal.	2.33	1.53
Orchex @ 2%, 400 gal.	2.67	0.58
Asana, 400 gal.	1.33	0.58

Table 10. Percent coverage on Kromecoat cards placed near the top of almond tree canopies, 2/3 of tree height and under the dripline at different volumes of dormant spray (n=5 per treatment).

Volume (gal./acre) and location	Mean %	SD
400, ground	99.90	0.224
400, top	92.96	4.477
400, middle	96.96	3.953
200, ground	99.40	0.652
200, top	83.90	5.185
200, middle	91.58	6.230
100, ground	67.54	22.627
100, top	53.64	10.243
100, middle	67.36	16.307
Untreated, ground	0	0
Untreated, top	0	0
Untreated, middle	0	0

Deposition at the 3 spray volumes (400 gal/ac, 200 gal/ ac and 100 gal/ac and untreated) was measured using Kromecoat cards placed near the top of the tree canopy (~20 feet), at 2/3 of the tree height, and under the dripline of the tree. Each card location was repeated 5 times in different trees. 1-way ANOVA statistics indicated a significant difference between treatments

(F=99.849, df=11, p<0.0001). Percent deposition on the cards at each location are shown on Table 10.

Clearly, better deposition at the top of the tree canopy, where San Jose scales and peach twig borers are typically more concentrated, can be achieved with higher volume sprays. There is a trade-off, however between dose and volume when the same amount of a.i. is applied as the higher volumes result in lower effective dose being applied. This is particularly important for reduced risk pesticides. For example, if horticultural mineral oil is applied alone for San Jose scale control, the same concentration should be applied no matter what the volume. There is also more deposition on the ground under the dripline at the highest volumes, but the significance of this in terms of pesticide runoff has yet to be determined.

At the Sunflower Ranch, different treatment timings of diazinon (4 lbs. /acre Diazinon 50WP) were applied to determine efficacy against peach twig borer and San Jose scale. The presumption is that an earlier dormant spray might result in less runoff since the most intensive winter rainfall events usually occur in January and February, soil microorganisms would have more time to degrade the organophosphates before they might be displaced into waterways. Three spray timings (Dec. 13, 1999, Jan. 3, 2000, and Jan. 18, 2000) and an untreated control were applied with an airblast sprayer at 80 gal/acre and replicated 3 times in 8 acre plots assigned in a randomized complete block design. Peach twig borer and San Jose scale flights were monitored with pheromone traps and lures placed 2 to a plot within each plot, and checked weekly. Table 11 presents the data for mean peach twig borer moths and San Jose scale males captured during the season. There was no significant difference between means trap captures for these treatment dates, but there was a difference in peak captures during the first flight. That there might be a difference only during the first flight is not unexpected since movement between treatments during the season is expected to occur.

Table 11. Mean peach twig borers and San Jose scales captured from plots treated on different dates at the Sunflower Ranch (n=4 with 2 trap for each insect per replicate).

Spray date	PTB mean	PTB SD	SJS mean	SJS SD
No spray	115.00	72.96	1.32	2.14
12/3/99	124.48	73.58	2.13	3.7
1.53	109.04	56.95	1.53	2.00
1/18/00	100.67	66.80	1.12	1.68

A study was conducted on 42 rows of a French prune orchard in Glenn Co. to measure toxicity of stormwater runoff as well as the effectiveness of various types of orchard floor vegetation as a best management practice. Rows 1-8, 21-25, and 38-42 were unsprayed; rows 9-20 were sprayed with diazinon; and rows 26-37 were sprayed with Asana. Each spray treatment was overlaid on 4 cover crop treatments; no cover, grass cover, legume cover, and native vegetation. All 4 of these one-row treatments were located next to one another to form a complete 'block' of treatments. These complete 'blocks' of 4 rows were replicated three times across the orchard. There was a break of untreated rows half way across the orchard to avoid cross contamination between diazinon and Asana treated sections. Water samples were collected within these treatments via 2 distinct sets of sampling apparatus; in-ground jars, and automated samplers. All of the water samples generated have been analyzed chemically and several composite samples have been analyzed via standardized bioassay techniques by our interdisciplinary CALFED team. These results are presented in an exhaustive annual report to the CALFED Bay-Delta Program, and a copy of this report is available on request.