Efficacy of Settlement Ponds for Reducing Pyrethroid Runoff in Almond Orchards

Project No.: **08-WATER4-Klassen/Markle**

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Objectives:

This study is designed to investigate the effectiveness of sediment basins (with and without PAM) for reducing pyrethroid loading in irrigation drainage water leaving almond orchards in the Central Valley of California.

The study tests two Best Management Practices (BMP) scenarios:

- Sediment ponds alone (no PAM)
- Sediment ponds with PAM

Data from this study will be used to make recommendations on using these methods for controlling both sediment and pyrethroid residues in irrigated agriculture.

Interpretive Summary:

The use of polyacrylamide (PAM) and sediment basins have long been recognized as effective Best Management Practices (BMPs) for reducing sediment loads carried by irrigation drain water. By reducing sediment loads there is also the potential for reducing residues of highly hydrophobic chemicals such as the pyrethroid insecticides which adhere to the sediment particles in irrigation tailwater. This study examined the effectiveness of sediment basins for reducing pyrethroid residues in tailwater in two different trials conducted on a section of a large-scale commercial orchard in the Central Valley of California planted with Nonpareil almonds. The first trial was conducted under typical flow conditions with no PAM added to the irrigation water. The second trial was conducted under slightly higher flow conditions with PAM added to the irrigation water at

the beginning of the rows resulting in a five-fold reduction in total suspended solids (TSS) entering the sediment basin. In both trials, the total mass of the sediment leaving the sediment basin was reduced an additional 80%-84% at the discharge point of the basin. Although the use of PAM did not appear to significantly impact the total mass of pyrethroid coming off the field in this study, the sediment basin reduced the total pyrethroid load by 38%-61%. These findings support that the adoption of classical sediment control practices such as sediment basins will reduce the amount of pyrethroid residues in irrigation tailwater released to streams.

Materials and Methods:

Introduction

The Central Valley of California encompasses more than 6 million acres of irrigated cropland and is the most productive and diversified agricultural region in the world. Commonly referred to as the "fruit basket of the world," Central Valley agriculture is a major economic force for the region and is the primary U.S. source for numerous food products including almonds, pistachios, grapes, tomatoes and many other commodities (Izumi, 2007).

Advancements in production technologies have contributed significantly to the tremendous productivity gains of Central Valley farmers. These technologies, including the use of chemical pesticides and fertilizers and a highly efficient water distribution system, have offered solutions to the numerous production challenges facing farmers in the region and have helped turn the former desert and grassland plain into a productive region second to none in the world. These technologies can, however, create environmental concerns including the off-site transportation of pesticides, nutrients and sediment that must be addressed in order for the Central Valley to sustain and increase its current production levels.

Previous research indicates that sediment basins can play an effective role in the reduction of sediment and pesticide runoff from agricultural fields. If sediment basins are designed correctly, they may trap up to 70-80% of the sediment that flows into them (see California Stormwater BMP Handbook, 2003). Compounds that are highly hydrophobic such as the organochlorine pesticides, polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons, and pyrethroids bind readily to the sediment and are removed from the runoff water as the sediment settles. Although a number of papers have investigated the transport of highly hydrophobic compounds into agricultural streams with the sediment (Pereira et al., 1995; van Metre et al., 1997), to date no data exist on the effectiveness of sediment basins for the removal of pyrethroid residues from agricultural runoff.

Polyacrylamide (PAM) is a water soluble, synthetic organic polymer. It has been used in agriculture for soil erosion control on about one million hectares worldwide (Sojka et al., 1998). It has also been used as a flocculent in municipal water treatment, paper manufacturing and food processing (Sojka and Lentz, 1997). PAM interacts with soil particles to stabilize both soil surface structure and pore continuity (DeBoodt, 1990; Malik and Letey, 1991). Under experimental field-trial conditions, proper application of

PAM with the first irrigation has substantially reduced soil erosion in furrow systems with benefits that include reduced topsoil loss, enhanced water infiltration, improved uptake of nutrients and pesticides, reduced furrow-reshaping operations, and reduced sediment-control requirements below the field (Sojka and Lentz, 1996). By increasing soil flocculation, PAM has been shown to be effective in reducing sediment erosion through runoff and increasing water infiltration (Lentz et al., 1995). A recent study has found that PAM applications to furrow irrigated crops reduced sediment erosion by over 90 percent (Orts et al., 2007). As reductions in sediment runoff are achieved, reductions in pesticides such as dicofol that are highly absorbed to soil particles also occur (Singh et al., 1996). Broadcast applications of PAM were also found to be significantly effective in increasing water infiltration and reducing sediment runoff (Abu-Zreig, 2006).

Pyrethroids are typically applied to the orchards as either a winter dormant spray or as in-season spray to control various pests including Navel Orange Worm. To reduce in-row erosion, a grower may apply insect polyacrylamide (PAM) using the “patch method” at each irrigation runoff event. The "patch method" involves applying PAM at the point in the furrow where the water first hits the soil; spreading it for a length of about 3-5 feet down the furrow to reduce the risk of the PAM becoming buried in the furrow or washing down the furrow where its effectiveness is reduced. The patch method creates a sort of gel-slab at the top of the furrow where the water slowly dissolves the PAM and carries it down the row furrow. Growers have indicated that without the use of PAM in erodible soils, a sediment pond quickly fills up with sediment and they would have to excavate the pond and dispose of the accumulated soil more frequently.

This study examines the use of sediment basins with and without the use of PAM to reduce pyrethroid residues in irrigation drainage water following a lambda-cyhalothrin (structure shown in **Figure 1**) application to almonds at the rate of 0.04 lb ai/A. Data from this study will be used to evaluate the effectiveness of using these technologies as Best Management Practices (BMPs) in reducing the off-site movement of pyrethroids in irrigation drain waters. The purpose of the study was not to repeat the body of research that has already confirmed the efficacy of PAM and sediment basins in reducing total suspended solids (TSS), but to learn more about how the pyrethroids behave with respect to the sediment in these systems.

<u>Study Site and Irrigation</u>

The study site was a 140 acre almond orchard near Chowchilla in the San Joaquin Valley. The field was divided into numerous blocks, 80 acres of which are planted to Nonpareil almonds. The site was relatively flat with a 1-2 percent slope. The Natural Resource Conservation Service (NRCS) has classified the soil type as a mixture of Chino fine sandy loam and Traver loam. A field diagram is provided in **Figure 2**.

The field was surface irrigated using district canal water. The border check system was 22 feet between borders and 1200 feet in length. Each check was provided with irrigation water from a single valve (**Figure 7**). At the bottom corner of each field block was an interception ditch (**Figure 4**) installed to capture irrigation drainage water which was subsequently directed to a sediment pond (**Figure 5**). The pond was basically rectangular in shape and measured 19 feet by 160 feet and averaged 7 feet deep (21,280 cubic feet). It had an estimated holding capacity of 159,175 gallons (603,271 liters). Opposite the inlet to the pond was a recirculation pump (**Figure 6**) that returns the water for reuse in other parts of the orchard. Irrigation water was applied to the field using an orchard irrigation head (see **Figure 7**).

<u>Climate</u>
Climate in the vicinity of the project was typical for the central San Joaquin Valley. Two seasons dominate: winters with cool temperatures and periods of rainfall (November through April) and summers with high temperatures and minimal to no rainfall. Data retrieved from the closest California Irrigation Management Information System (CIMIS) Weather Station (#145) in Madera, CA indicated no precipitation during the time from the application of the pyrethroid through the end of the study (July 27 - August 1, see **Table 1**) with a maximum temperature of 100.8 ^{o}F and a minimum temperature of 59.7 ^{o}F (see **Table 2**).

<u>Application of Lambda-cyhalothrin</u>
Lambda-cyhalothrin is typically applied to almonds in this region at the hull split nut growth stage to control navel orange worm (NOW) and chewing insects. In this study, lambda-cyhalothrin was applied by ground using an air blast sprayer as Warrior® with Zeon Technology™ at the rate of 0.04 lb ai/A on the morning of July 27, 2009. One entire block of 40 acres was treated for a total target mass of 1.6 lbs ai applied per acre.

<u>Study Design</u>
This study consisted of two trials:

- Sediment basins alone without the use of PAM
- Sediment basins in combination with PAM applications

In the first trial, rows 1-16 (number 1 is the southernmost row of the block) were irrigated but no PAM was applied. Irrigation water was added at the top of the field through a series of orchard irrigation valves into each row. The tailwater from each row was collected in a drainage ditch at the base of the field. The tailwater then passed through a six inch PVC pipe (**Figure 8**) and discharged into the northern end of the sediment basin. Water from the sediment basin was pumped out of the basin on the southern edge of the pond through a 4-inch diameter steel pipe and recirculated back to the top of the field. Duplicate 250 ml samples (one for pyrethroid analysis and one for TSS) of drainage water were taken every hour at the entrance of the sediment basin. Once water began to flow out of the sediment basin, samples were collected hourly at the exit of the sediment basin (**Table 3**).

In the second trial, rows 32 - 40 were irrigated and approximately one cup (180 g) of PAM was applied to each check (22 ft width) at the top of the block (southern end) where the irrigation water entered the field (see **Figure 10**). The product used was Soil Fix IR (CIBA Specialties) which contained 90% PAM. The effective rate on a product per treated acre was 300 g/acre. Duplicate 250 ml samples of drainage water were taken every hour at the entrance and exit (upon initiation of flow) of the sediment basin (see **Table 4**).

Flow Measurements

Flow measurements were taken both at the inlet and outlet of the sediment basin. In each case, a portable Doppler flow meter (Greyline PDFM 3.0, see **Figure 8**) was attached to a pipe (6 inch Schedule 40 c/100 PVC pipe at inlet and 4 inch steel at outlet) with a strap on sensor. Knowing the pipe inside diameter allowed the calculation of water flow. Flow readings were taken a minimum of every 30 minutes throughout the duration of the study.

Sample Collection

Tailwater samples were sampled either by hand or with a pole sampler (Wildco 12-foot swing sampler, 165-C10, (see **Figure 9**) every hour from the exit side of a 4-inch pipe located between the interception ditch at the base of the field and the entrance to the sediment basin (see **Figures 8 and 9**) and from the field drain at the end of the sediment basin (see **Figure 11**). Note that samples at the exits of the sediment basin were not available during the initial sample intervals, as the basin had not filled up to a sufficient height and therefore was not discharging. At each sampling interval and location, a sample of approximately 250 ml was collected for pyrethroid analysis in a 500 ml amber boston round glass (Fisher Scientific, P/N 02-911-738) and another sample of approximately 250 ml was collected for measuring total suspended solids in a 500 ml Nalgene polypropylene bottle (Fisher Scientific, A71841086). Within five minutes of collection, the samples were placed in a cooler filled with ice and kept on ice until delivery to the analytical laboratory. Samples were kept in ice chests for a maximum period of 6 days prior to delivery to the analytical laboratory where they were immediately placed in refrigerators for storage until extraction.

Sample Analysis-Pyrethroids

All samples were delivered to Morse Laboratories, Inc., in Sacramento, California for analysis. Samples were extracted within 21 days and analyzed within 24 days of receipt.

To extract samples prior to lambda-cyhalothrin analysis, 100 ml of MeOH and 25 ml of hexane were added to each sample bottle. The samples were shaken on a mechanical shaker for approximately 10 minutes and the solvent layers were allowed to separate. A 5.0 ml aliquot of the upper hexane layer was transferred to a test tube (13 x 100 mm) and concentrated to ~0.2 ml using an N-evap evaporator set to ≤40^{o}C. The samples were manually evaporated to dryness with nitrogen. To each sample, 2.0 ml hexane was added, mixed well and sonicated. The sample was transferred to a 500 mg Varian Silica Bond Elut solid phase extraction cartridge with a 1.0 ml rinse of hexane. The cartridge was eluted under gravity or low volumetric pressure and the eluate discarded. A 10 ml collection tube was placed under each cartridge and the cartridge was eluted with 6 ml of a hexane/diethyl ether [9:1, v/v] solution. The eluate was concentrated to dryness under a stream of dry, clean air in a heating block set to 40^{o}C. The sample was redissolved in acetone +0.1% peanut oil solution with ultrasonication. The sample was transferred to an autosampler vial for final determination by GC-MSD/NICI.

Note: The 0.1% peanut oil in acetone solution is used to minimize the effect of matrix related to GC-MSD response enhancement and to minimize possible peak tailing due to adsorption.

Final Determination by GC-MSD

The following instrument and conditions have been found to be suitable for analysis. Other instruments can also be used, however optimization may be required to achieve the desired separation and sensitivity.

Instrument Conditions

GC system	:	Agilent 6890 with split/splitless injector
MSD system	:	Agilent 5973 with negative ion chemical ionization
Injection temperature	:	275°C
Injection liner	:	4 mm i.d. double gooseneck splitless liner (unpacked)
Column	:	Varian CPSil 8 30 m × 0.25 mm, 0.25 μm film thickness (5% diphenyl, 95% dimethylpolysiloxane)
Column flow rate	:	0.9 ml min^{-1} constant flow
Injection mode	:	Pulsed splitless, 30 psi for 1 min, purge flow to split vent 50 psi @2 min
Injection volume	:	2 μL
Column temperature program	:	80°C for 1 min then program at 40°C/min to 180°C, hold for 0 min then program at 5 °C/min to 305°C, hold for 0 min.

Under these conditions, lambda-cyhalothrin has retention times of 19.6 and 19.9 minutes for the two resolved isomers.

Sample Analysis-Total Suspended Solids

The analysis of tailwater samples for Total Suspended Solids (TSS) was based on Method 2540 D "Total Suspended Solids Dried at 103-105^{o}C" as described in Standard Methods for Examination of Water and Wastewater (18th Edition, 1992).

The glass fiber filter and planchet were weighed prior to filtration. The filter disk was inserted into the filtration apparatus. The sample of tailwater water was added to the filter and rinsed with three successive 10 ml portions of reagent grade water. Continuous suction for about 3 minutes after filtration is complete was applied. The filter and planchet were removed from the filtration unit and dried in an oven at 103 to 105^{o}C for one hour. The sample was cooled in a desiccator to balance temperature and weighed. This cycle of drying, desiccation and weighing was repeated until a constant weight was obtained. The total mg of suspended solids in each sample was calculated using the following formula.

mg total suspended solids/sample = (weight of filter + dried residue) – (weight of filter)

Calculation of Water, Sediment and Pyrethroid Discharges
Amounts of water, suspended solids, and pyrethroids entering and leaving the sediment basin were calculated for each sampling interval (see **Tables 6 and 7**). Using the Doppler flow meter for measuring the water velocity in the pipes and knowing the cross-sectional area of the inlet and outlet pipes, the flow volumes between each interval can be calculated. This volume is then multiplied by the residue concentration in ug/l for the pyrethroid mass load (mg) and the mg/l concentration to determine the mass load (g) of total suspended solids. We assumed that the flow velocity is relatively constant between each sampling interval.

Results and Discussion:

Flow Rates
During the study, considerable variability in drainage flows occurred between trials and among irrigation rows within a trial which must be considered in the interpretation of the study results. In addition, the grower consciously conserves his water by turning rows off as they reach the end of the row and adds subsequent new rows to the irrigation cycle for maximum efficiency. As a result, the flows do not exhibit a typical bell-shaped curve with flow building up at the inlet as rows enter the interception ditch and gradually decline once irrigation is stopped. Instead, we observed a more constant flow throughout the day of the trial with a series of pulses to the flow as new rows were started and came on line.

During this study, we examined the daytime sets from two consecutive irrigation days. On the first day of the study, Trial #1 (rows 1-16) tested the efficacy of the sediment pond alone (no PAM) in reducing sediment loads and pyrethroid residues. On the second day of the study, Trial #2 (rows 32-40) tested the efficacy of using PAM when used in conjunction with the sediment ponds. Two other irrigations sets (rows 17-31 and rows 41-56) were run at night and no samples were collected. Flows were measured throughout the course of the irrigation cycle (day and night). Total flow off the field as measured at the inlet to the sediment pond was 588,562 gallons (2,227,707 liters) is shown in **Figure 3**. This volume equates to approximately 0.5 acre-inches of runoff from the estimated 6 inch irrigation that the grower planned or 15% of the nominally applied amount. This closely equates with the estimated runoff from other irrigations in the field.

40 acres x 27,154 gallons/acre-inch x 6 inches= 4,116,960 gallons applied

Flow rates at the inlet to the pond varied from a maximum of 0 to 341 gallons/ minute during the course of the study. At the outlet, the flow was regulated by a discharge pump that was kept at a constant 175 gallons/minute. The pump was started when the levels in the pond reached approximately 2 feet above the bottom of the pond and were turned off when the pond went below this level.

At the start of the first trial, there was some water in the interception ditch from an irrigation that had been completed in another part of the orchard earlier the same week.

It is recognized that this may dilute the absolute concentration in the tailwater samples (TSS or pyrethroid). However, it should not affect the mass balance differential between the inlet and outlet of the sediment basin on which we draw conclusions about the ponds effectiveness. It took approximately five hours from the start of irrigation until the runoff water reached the interception ditch (about a quarter of a mile from discharge to row end)). Samples for TSS and pyrethroid analyses were collected each hour from the start of runoff (12:45 am) through 11 pm. The night time irrigation set (rows 17-31) was started at 10:45 pm.

Flow velocity in Trial #1 ranged from a low of 1 gallons/minute to a maximum of 297 gallons/minute at the inlet. Total flow observed at the inlet was 101,584 gallons (384,000 Liters) during the 10 hours of monitoring.

In the second trail, water from the previous night's irrigation was still draining into the sediment basin although this dramatically tapered off by the time the irrigation for Trail #2 was started (9:50 am). PAM was applied to each irrigation row (see **Figure 10**). By 3:00 pm (five hours after the start of irrigation), water from the top of the field began to drain into the interception ditch. As above, samples were collected each hour until 12:00 pm. Irrigation was switched to the night time set (rows 41-56) at 11 pm.

Flow in the second trial was generally higher than the first perhaps due to the fewer number of rows irrigated. The flow velocity ranged from 69 gallons/minute to a maximum of 369 gallons/minute. Total flow observed was 155,878 gallons (590,000 Liters) during the 10 hours of monitoring.

<u>Lambda-Cyhalothrin Residues and Total Suspended Solids (TSS)</u>
The concentration of lambda-cyhalothrin (expressed in ug/l) and TSS levels (expressed in mg/l) for each runoff sample can be found in **Tables 3 and 4**.

With each set of analyses for lambda-cyhalothrin, two untreated water samples were fortified at two different rates to validate the analytical set. The average recovery of lambda-cyhalothrin was 103 ± 12.7% over the course of the study (see **Table 5**). The Limit of Determination (LOD) for the analytical method was 0.01 ug/l.

Lambda-cyhalothrin residue levels in the runoff samples from the study conducted without adding PAM to the irrigation runoff (**Table 3**) ranged from 0.555 down to <0.01 ug/l at the field exit (prior to entering the sediment basin) and 0.185 down to 0.012 at the exit of the sediment basin. At the same time, the levels of total suspended solids ranged from 1280 mg/l down to 50 mg/l prior to entering the sediment basin and 300 mg/l down to 50 mg/l at the exit of the sediment basin. The results show a decline in both TSS and pyrethroid concentration during the time the sediment basin was discharging.

In the second trial, lambda-cyhalothrin residue levels in the runoff samples from the study conducted with PAM added to the irrigation water (**Table 4**) were slightly lower and ranged from 0.33 down to 0.21 ug/l at the entrance to the sediment basin and were similar (although the peak concentration was higher) ranging from 0.50 down to 0.11

ug/l at the exit of the sediment basin. At the same time, the concentrations of TSS ranged from 280 to 10 mg/l at the entrance to the sediment basin and 35 to 0 mg/l at the exit of the sediment basin.

<u>Estimation of Efficiency for Removing Residues</u>

Using the flow measurements and the concentrations of sediment and pyrethroids, the amount of water, sediment, and pyrethroids entering and leaving the sediment basin were calculated as a function of time using the methods as described earlier. The results of these calculations are presented in **Tables 6 & 7** and summarized in **Table 8**.

In Trial #1 (no PAM), a significant amount of sediment (205 kg) entered the sediment basin. As has been reported previously, sediment basins are very effective in reducing this constituent from the runoff. In this study, only 43 kg (80% efficiency) remained in the runoff water at the basin exit.

Although only low levels pyrethroid leave the treated field (0.05% of applied), the levels found in runoff water are high enough to be of biological significance to some aquatic species. As a result, developing methods for reducing pyrethroid discharges continue to be of importance. In this trial, there was a 61% reduction of pyrethroids with the sediment basin, presumably because of the adherence to the sediment particles as they settle out. The fact that the reduction is not to the same degree as that observed for the sediment suggest that either some pyrethroid is left in solution (unlikely given the hydrophobic nature of lambda-cyhalothrin (water solubility-0.004 mg/l) or that loss may be occurring by adherence to fine, low weight sediment particles that have not settled out. In this study, no attempt was made to differentiate the size of the soil particles entering and exiting the sediment basin.

In Trial #2, although the flows were higher, the levels of sediment entering the sediment basin were significantly reduced by almost a 5X factor (38 kg) due to the application of PAM. In addition, the sediment basin removed an additional 84% of the sediment from the runoff as measured at the basin exit.

For lambda-cyhalothrin residues, the higher flow rates resulted in more chemical reaching the entrance to the sediment basin (0.12 % of applied). Again, presumably due to the higher flow rates, the reduction of pyrethroid residues was significant (38%), but not as great as those observed in the previous trial.

Conclusions:

Sediment basins can play an important role in mitigating the irrigation runoff potential for both soil and pyrethroid residues. In this trial, 80-84% of the total suspended sediment entering a sediment pond was removed from the runoff. Given the hydrophobic nature of the pyrethroids as a class of insecticides, they should rapidly attach to any organic matter in sediments and be removed from the runoff stream as the sediment settles out. Although removal of the pyrethroids was significant (38% to 61%), the levels observed were not as significant as the sediment response. This, possibly, may be due to either the low water solubility of lambda-cyhalothrin (0.004 mg/l) or to the absorption of lambda-cyhalothrin residues to lighter weight clay particles which did not have a chance to settle out in this trial. Efficiency may be improved with either lower flow rates or longer retention times in the ponds.

The use of polyacrylamide (PAM) at each irrigation event can significantly reduce the levels of sediment leaving the field. Under the conditions observed in this study, a fivefold increase in sediment retention and subsequently sediment runoff reduction from the field was observed. The sediment that did make it off the field was effectively removed with the sediment basin. Although application of PAM did not have as dramatic an effect on the total amount of pyrethroid residues leaving the field, any field management measures taken to reduce the total sediment loads leaving the orchard would be expected to have a positive effect on pyrethroid residue mitigation.

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Tables and Figures

Table 1. Timing of Major Study Events

7/27/2009	Application of pyrethroid
7/29/2009	Problems with water delivery from central water district. Will start tomorrow
7/30/2009 7:00 am	Start of irrigation for Trial 1(rows 1-8)
7/30/2009 12:37 pm	Water begins flowing into interception canal
7/30/2009 12:45 pm	Collection of 0-hour sample (inflow)
7/30/2009 1:45 pm	Irrigation stitched to rows 9-16
7/30/2009 1:50 pm	Collection of 0-hour sample (outflow)
7/30/2009 10:58 pm	Completion of Trial 1 Last sample take from pond outlet.
7/31/2009 9:50 am	Start of irrigation for Trial 2 (rows 32-38)
7/31/2009 3:02 pm	Collection of 0-hour sample (inflow)
7/31/2009 3:04 pm	Collection of 0-hour sample (outlet). Note: pond is full from previous night's irrigation.
7/31/2009 4:45 pm	Grower added rows 39 and 40
7/31/2009 12:00 pm	Completion of Trial 2. Last sample from pond outlet collected.

Table 2. Weather Data from CIMIS 145 (Madera) for the Period 7/27/2009 to 8/1/2009

Daily Report

California Irrigation Management Information System
Department of Water Resources
Office of Water Use Efficiency
Rendered in ENGLISH units
July 27, 2009 - August 1, 2009
Printed on August 14, 2009

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Date	CIMIS ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Pt (°F)	Avg wSpd (MPH)	Wnd Run (miles)	Avg Soil Temp (°F)
07/27/09	0.30	0.00	692	15.6	100.8	59.7	81.9	86	18	42	56.4	4.7	113.3	81.3
07/28/09	0.29	0.00	674	17.0	98.8	62.9	81.1	82	23	47	58.8	5.1	122.1	81.9
07/29/09	0.28	0.00	674	17.2	93.5	64.3	77.9	79	30	53	59.2	6.3	150.9	82.0
07/30/09	0.27	0.00	674	18.2	93.2	62.3	77.1	85	33	57	60.7	6.3	151.5	81.9
07/31/09	0.28	0.00	666	16.5	93.3	61.6	77.5	86	29	51	58.1	5.9	142.2	81.9
Tot/Avgs	1.42	0.00	676	16.9	95.9	62.2	79.1	84	27	50	58.6	5.7	136.0	81.8

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Date	CIMIS ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Pt (°F)	Avg wSpd (MPH)	Wnd Run (miles)	Avg Soil Temp (°F)
08/01/09	0.29	0.00	667	14.6	93.1	59.9	77.5	77	25	45	54.7	5.8	140.8	83.2
Tot/Avgs	0.29	0.00	667	14.6	93.1	59.9	77.5	77	25	45	54.7	5.8	140.8	83.2

Flag Legend

A - Historical Average	I - Ignore	R - Far out of Normal Range
C or N - Not Collected	M - Missing Data	S - Not in Service
H - Hourly Missing or Flagged	Q - Related Sensor Missing	Y - Moderately Out of Range

Conversion Table

W/sq.m = Ly/day / 2.065	inches * 25.4 = mm
C = 5/9 * (F - 32)	m/s = mph * 0.447
kPa = mBars * 0.1	

Table 3. Analytical Data from Trial 1 (Sediment Basin without the use of Polyacrylamide (PAM))

Sample Number	Location	Interval	Volume	TSS (mg/l)	Residue (ug/l)
LCYH-09-01	Inlet	0	250 ml	185	<0.01
LCYH-09-02	Inlet	1	250 ml	535	0.311
LCYH-09-03	Inlet	2	250 ml	120	0.35
LCYH-09-04	Inlet	3	250 ml	915	0.462
LCYH-09-05	Inlet	4	250 ml	460	0.342
LCYH-09-06	Inlet	5	250 ml	50	0.553
LCYH-09-07	Inlet	6	250 ml	385	0.037
LCYH-09-08	Inlet	7	250 ml	1280	0.281
LCYH-09-09	Inlet	8	250 ml	570	0.251
LCYH-09-10	Inlet	9	250 ml	270	0.233
LCYH-09-11	Inlet	10	250 ml	150	0.177
LCYH-09-13	Outlet	0	250 ml	125	0.012
LCYH-09-14	Outlet	1	250 ml	115	0.025
LCYH-09-15	Outlet	2	250 ml	110	0.081
LCYH-09-16	Outlet	3	250 ml	70	0.143
LCYH-09-17	Outlet	4	250 ml	50	0.185
LCYH-09-18	Outlet	5	250 ml	300	0.11
LCYH-09-19	Outlet	6	250 ml	80	0.073
LCYH-09-20	Outlet	7	250 ml	90	0.113
LCYH-09-21	Outlet	8	250 ml	65	0.143
LCYH-09-22	Outlet	9	250 ml	65	0.178

Table 4. Analytical Data from Trial 2 (Sediment Basin and Polyacrylamide (PAM))

Sample Number	Location	Interval	Volume	TSS (mg/l)	Residue (ug/l)
LCYH-09-23	Inlet	0	250	280	0.213
LCYH-09-24	Inlet	1	250	150	0.233
LCYH-O9-25	Inlet	2	250	145	0.265
LCYH-09-26	Inlet	3	250	30	0.228
LCYH-09-27	Inlet	4	250	20	0.214
LCYH-09-28	Inlet	5	250	20	NA
LCYH-09-29	Inlet	6	250	35	0.211
LCYH-09-30	Inlet	7	250	25	0.210
LCYH-09-31	Inlet	8	250	35	0.225
LCYH-09-32	Inlet	9	250	10	0.334
LCYH-09-35	Outlet	0	250	10	0.120
LCYH-09-36	Outlet	1	250	15	0.137
LCYH-09-37	Outlet	2	250	30	0.111
LCYH-09-38	Outlet	3	250	25	0.170
LCYH-09-39	Outlet	4	250	15	0.207
LCYH-09-40	Outlet	5	250	0	0.240
LCYH-09-41	Outlet	6	250	10	0.249
LCYH-09-42	Outlet	7	250	5	0.501
LCYH-09-43	Outlet	8	250	35	0.251
LCYH-09-44	Outlet	9	250	10	0.272

Table 5. Lambda-Cyhalothrin Analytical Recovery from Fortified Basin Water Samples

Sample ID	Fort. Level (ug/l)	Recovered (ug/l)	% Recovery
86331 Fort. Control 1	0.01	0.01075	103
86331 Fort. Control 2	0.50	0.46698	93
86331 Fort. Control 3	0.01	0.01130	113
86331 Fort. Control 4	0.50	0.47624	95
86331 Fort. Control 5	0.01	0.01292	119
86331 Fort. Control 6	0.50	0.56062	112
86331 Fort. Control 7	0.01	0.00979	98
86331 Fort. Control 8	0.50	0.39483	79
86331 Fort. Control 9	0.01	0.01290	119
86331 Fort. Control 10	2.00	2.07304	103
		Average±Std. Dev.	**103±12.7**

Table 6. Summary of Flow Data for Trial 1 (No PAM)

Time Period (hours)	Flow (l)		Sediment (g)		Pyrethroids (mg)	
	Into Basin	*Out of Basin*	Into Basin	Out of Basin	Into Basin	Out of Basin
0-1	31,476	39,742	16840	4968	9.8	0.5
1-2	72,229	46,366	8667	5332	25.3	1.2
2-3	60,370	33,781	55239	3716	27.9	2.7
3-4	18,353	44,379	8442	3107	6.3	6.3
4-5	639	39,742	32	1987	0.4	7.4
5-6	40,972	39,742	15774	11923	1.5	4.4
6-7	53,493	41,729	68471	3338	15.0	3.0
7-8	29,579	37,755	16860	3398	7.4	4.3
8-9	31,555	43,054	8519	2798	7.4	6.2
9-10	45,317	39,742	6798	2583	8.0	7.1
Totals	**383,988**	**406,035**	**205642**	**43150**	**109**	**43.0**

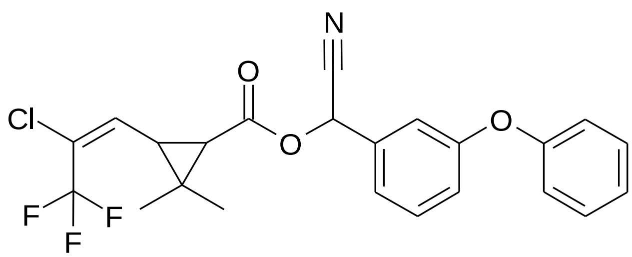
Table 7. Summary of Flow Data for Trial 2 (PAM)

Time Period (hours)	Flow (l)		Sediment (g)		Pyrethroids (mg)	
	Into Basin	*Out of Basin*	Into Basin	Out of Basin	Into Basin	Out of Basin
0-1	20,337	20,337	5694	203	4.3	2.4
1-2	63,596	45,042	9539	675	14.8	6.2
2-3	76,060	39,080	11029	1172	20.2	4.3
3-4	85,930	39,742	2578	994	19.6	6.8
4-5	73,440	41,067	1469	616	15.7	8.5
5-6	56,253	40,405	1125	0	12.0	9.7
6-7	68,421	44,379	2395	443	14.4	11.0
7-8	57,494	39,742	1437	199	12.0	19.9
8-9	56,722	39,742	1985	1391	12.8	10.0
9-10	51,748	37,092	517	371	17.3	10.1
Totals	**610,002**	**386,630**	**37768**	**6065**	**143**	**89**

Table 8. Overall Summary for Both Trials

	Trial 1 (no PAM)	Trial 2 (with PAM)
Treated Area	11.6 acres	6.4 acres
Pyrethroid Applied	0.464 lb ai	0.256 lb ai
	210 g ai	116 g ai
Pyrethroid in inlet stream (% of applied)	0.05	0.12
Sediment Reduction (%)	80%	84%
Pyrethroid Reduction (%)	61%	38%

Figure 1. Chemical Structure of Lambda-Cyhalothrin



Chemical Structure for Lambda-Cyhalothrin

(1α(*S**),3α(*Z*)]-(±)-cyano(3-phenoxyphenyl)methyl 3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate)

Figure 2. Plot Diagram for Study Site

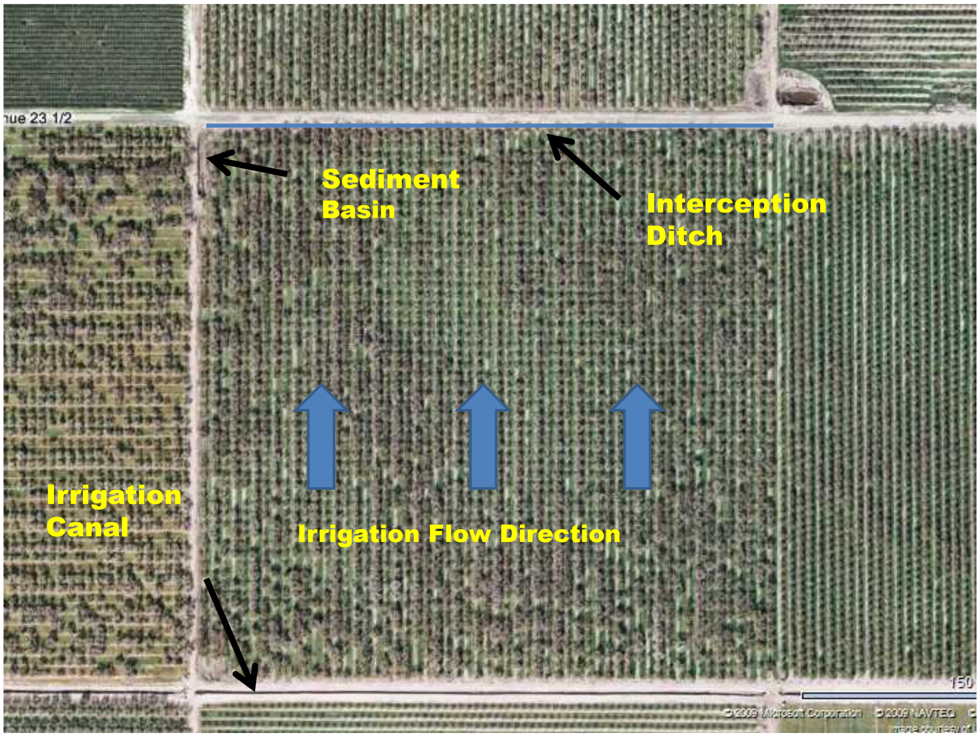


Figure 3. Graph of Flows at Entrance to Sediment Basin from Start of Trial to Study Termination

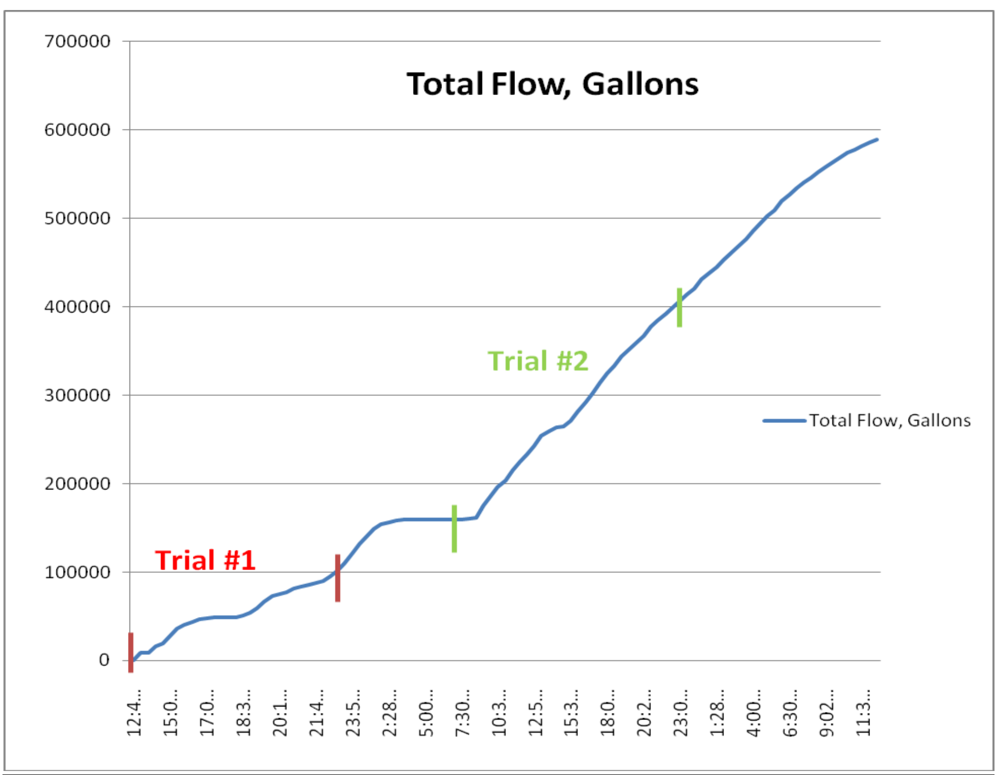


Figure 4. Interception Ditch along North End of Field

Figure 5. Sediment Basin in Northeast corner of Orchard

Figure 6. Recirculation Pump and Stand Pipe at South Side of Basin

Figure 7. Orchard Irrigation Valves Along South Side of Orchard

Figure 8. Doppler Flow Meter at Entrance to Sediment Basin

Figure 9. Sampling Residues with Swing Sampler at Entrance to Sediment Basin

Figure 10. Application of PAM to top of Field

Figure 11. Sampling Residues at Sediment Basin Exit