Efficacy of Settlement Ponds for Reducing Pesticide Runoff in Almond Orchards

Project No.: **10-WATER4-MARKLE**

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Interpretive Summary:

The use of sediment basins have long been recognized as an effective Best Management Practice (BMP) for reducing sediment loads carried by irrigation drain water. The intention of this study was to examine the effectiveness of sediment basins when used in combination with other potential BMPs for reducing pyrethroid residue loads in tailwater in a large-scale commercial orchard in the Central Valley planted with Nonpariel almonds. The first trial was conducted under typical flow conditions using the sediment basin alone. The second trial was conducted using the sediment basin in combination with the use of a novel new enzyme technology designed to selectively degrade pyrethroid insecticides at a low (1X) rate. The third trial was a repeat of the second trial with a higher dose (10X) of the enzyme. The final trial was conducted with the sediment basin in combination with a 5 % v/v liquid formulation of PAM-calcium dosed just prior to the inlet of the basin. All four trials demonstrated a significant reduction of sediment as measured by the total suspended sediment (TSS) remaining in the irrigation water at the basin exit. The sediment loading was reduced by 90, 92, 89 and 95% respectively. Unfortunately, the pyrethroid levels did not decline as expected and instead were relatively constant across all samples taken and demonstrated no discernable pattern trend in the data. A number of possible theories for what may have happened are discussed.

Objectives:

This study was designed to investigate the effectiveness of sediment basins when used in combination with other Best Management Practices (BMP) to reduce sediment and pyrethroid loading in irrigation drainage water leaving almond orchards in the Central Valley of California.

The study was designed to test four Best Management Practices (BMP) scenarios:

- Sediment ponds alone
- Sediment ponds with Landguard^{TM} SP enzyme (low dose rate)
- Sediment ponds with Landguard^{TM} SP enzyme (high dose rate)
- Sediment ponds with a liquid formulation of PAM (polyacrylamide)

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

Materials and Methods:

Introduction

Off-site movement of pesticides and sediment from flood-irrigated agriculture has been a significant concern in the Central Valley of California. It is estimated that about 1.2 million tons per year of sediment are carried into the San Joaquin River by irrigation runoff from just West Stanislaus County farmland alone (1). These sediments may potentially carry pesticides, nutrients, metals and salts trapped in the soil matrix and degrade surface water quality. In California's Central Valley there are 11 water body segments listed as "impaired" under the draft 2008 Clean Water Act Section 303(d) list, due to sediment toxicity of agricultural origin (2). Pyrethroid insecticides, which are widely used in California (3), are commonly found in sediments in creeks and agricultural drains at concentrations toxic to sensitive aquatic species (4,5,6). These compounds are highly hydrophobic and readily bind to the sediment.

Two best management practices (BMPs) recommended by the Natural Resource Conservation Service (NRCS) to retain soil on croplands and mitigate the transport of sediments are the use of sediment basins (Conservation Standard Practice No. 350) and polyacrylamide or PAM (Conservation Standard Practice No. 450).

If sediment basins are designed correctly, they may trap up to 70-80% of the sediment that flows into them *(7)*. The sediment basins reduce flow rates and briefly retain water allowing deposition of the heavier suspended particles. 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 (*8,9)*, to date few data exist on the effectiveness of sediment basins for the removal of pyrethroid residues from agricultural runoff.

Polyacrylamide (PAM) is a water soluble, high molecular weight, synthetic organic polymer. Since 1995, its first year of commercial use for irrigation-induced erosion control, it has been used on about one million hectares worldwide *(10)*. It has also been used as a flocculent in municipal water treatment, paper manufacturing and food processing *(11)*. PAM interacts with soil particles to stabilize both soil surface structure and pore continuity *(12,13)*. 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 downstream of the field *(14)*. By increasing soil flocculation, PAM has been shown to be effective in reducing sediment erosion through runoff and increasing water infiltration *(15)*. A recent study has found that PAM applications to furrow irrigated crops reduced sediment erosion by over 90 percent *(16)*. As reductions in sediment transport are achieved, reductions in pesticides such as dicofol that are highly absorbed to soil particles also occur *(17)*. Broadcast applications of PAM were also found to be significantly effective in increasing water infiltration and reducing sediment transport *(18)*.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, has developed a new tool to help mitigate pesticide residues. Landguard™ is an enzyme-based technology technology that rapidly catalyzes the hydrolysis of a number of pesticides into less toxic and significantly more biodegradable by-products. The technology is based on research conducted by CSIRO Entomology (Canberra) which discovered genes from insects and soil bacteria responsible for the production of enzymes capable of breaking down a range of insecticides. By isolating specific bacteria and expressing these genes, commercial quantities of these enzymes have been produced. The first commercial product, Landguard OP-A was launched in 2004. A new enzyme, Landguard™ SP, selectively hydrolyzes synthetic pyrethroids and will be used in this study.

This study examines the efficiency of sediment basins in combination with a number of other potential practices at reducing a synthetic pyrethroid, bifenthrin in irrigation drainage water following a bifenthrin application to almonds at the rate of 0.224 kg ai/ha. Pyrethroids, including bifenthrin, are typically applied to the orchards as either a winter dormant spray or as in-season spray to control various pests. It is a companion study to a previous study conducted in almonds (19) which was conducted with the pyrethroid, lambda-cyhalothrin. Data from these studies will be used to evaluate the effectiveness of using these technologies as Best Management Practices (BMPs) in reducing the off-site transport of pyrethroids in irrigation drain waters. The purpose of these studies was not to repeat the body of research that has already confirmed the efficacy of sediment basins in reducing total suspended solids (TSS), but to learn more about how these practices might mitigate pyrethroid transport in these systems.

Study Site and Irrigation

The study site is a 57 hectare almond orchard near Chowchilla in the San Joaquin Valley. The field is divided into numerous blocks, 16 hectares of which are planted to Nonpareil almonds. The site is relatively flat with a 1-2 percent slope. The National Resource Conservation Service (NRCS) has classified the soil type as a mixture of Chino fine sandy loam and Travers loam.

The field is surface irrigated using district canal water (see **Figure 2**). Each row in the field is provided with irrigation water from a single orchard irrigation head located at the top of the row and the rows are bermed on each side. The row is 6.7 m between berms and 366 m in length. At the bottom side of the field block is an interception ditch installed to capture irrigation drainage water which is subsequently directed to a sediment basin. The basin is basically rectangular in shape and measures 5.8 m by 49 m and averages 2.1 m deep. It has an estimated holding capacity of approximately 600,000 liters. Opposite the inlet side of the pond is a recirculation pump that returns the water for reuse to other parts of the orchard.

Climate

Climate in the vicinity of the project is 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 only a trace of precipitation (0.03 in, 0.76 mm) during the last day of the study (May 23-May 28, see **Table 1**) with a maximum temperature of 78.5 ^{o}F (25.8 ^{o}C) and a minimum temperature of 44.7 ^{o}F (7.06 ^{o}C. see **Table 2**).

Application of Bifenthrin

Bifenthrin (**Figure 1**) is typically applied to almonds in this region at either the May spray or the hull split nut growth stage to control navel orangeworm (*Amyelois transitella*) and other chewing insects. In this study, bifenthrin was applied by ground as Fanfare® 2EC using an air blast sprayer at the rate of 0.224 kg ai/ha on the morning of May 25, 2011. One entire block of 16 ha was treated for a total target mass of 3.58 kg ai.

Study Design

This study consisted of four trials:

- Sediment basin alone
- Sediment basin in combination with a Landguard™ SP enzyme (low dose) application made at basin inlet
- Sediment basin in combination with a Landguard™ SP enzyme (high dose) application made at basin inlet
- Sediment basin in combination with a liquid formulation of PAM applied at basin inlet

In the first trial, rows 41-47, the study examined the effect of the sediment basin only in removing sediment and pyrethroid. Irrigation was added at the top of the field through a series of orchard irrigation valves into each row. The tailwater then passes through a six inch PVC pipe and is discharged into the inlet of the sediment basin. Water from the sediment basin is pumped out of the basin at the exit of the pond through a 4-inch diameter steel pipe and is 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 30 minutes at the entrance of the sediment basin. Once water began to flow out of the sediment basin, samples were collected every 30 minutes at the exit of the sediment basin (**Table 3**).

In the second trial, rows 35-41, the study examined the effect of the sediment basin plus Landguard™ SP enzyme (low dose) added at the inlet to the sediment basin. Although no impact on the sediment was expected, the enzyme selectively breaks down bifenthrin and may potentially reduce pyrethroid residues at the discharge point of the basin.

In the third trial, rows 28-34, the study examined the effect of the sediment basin plus a higher concentration of the Landguard™ enzyme. The potential impact on sediment and bifenthrin residues at the basin exit was observed.

In the last trial, rows 21-27, a 5 % v/v liquid formulation of PAM-Calcium was metered into the irrigation runoff just prior to entering the sediment basin. It is expected that PAM-Calcium will further increase the flocculation of sediment particles resulting in further sedimentation in the basin. The hypothesis is that this should reduce both sediment and pyrethroid residues in the outflow.

Preparation and Dosing of Landguard™ SP

Landguard SP is a freeze-dried, flaky yellow powder which comes in a vacuum-sealed pouch. Prior to use, the Landguard was stored at refrigerated temperatures (<40 ^{o}F). When ready to use, the appropriate amount of Landguard was weighed out and transferred to a 30 gallon plastic carboy and filled with water. The Landguard is mixed to dissolve the material and the container placed at the field-edge next to the irrigation ditch. Additional water was added to the drum to bring the final volume to 20 gallons. The system was pre-calibrated to deliver the appropriate dose of Landguard over a 3 hour period. The Landguard dosing rates were based on an assumed runoff of 224-448 gallons/minute (data from a previous study). Trial 2 was dosed with a total of 70 g of enzyme and Trial 3 was dosed with a total of 700g of enzyme. In each trial, approximately 10% of the total dose was added to the sediment basin the night before to “activate” the enzyme and to potentially remove any pyrethroid remaining in the basin from the previous trial.

Sample Quenching

To quench the enzymatic activity of Landguard prior to sample analysis, several alternatives were discussed. Acidification (<pH 2.0) with acetic acid was ruled out as data suggests that there was significant degradation of bifenthrin at low levels. The method suggested by CSIRO involved the use of an organoposhate, dibrom®. For each sample of runoff collected, 125 µm of dibrom (1ml of a 46.7 mg/L solution) was added and shaken for 1 minute. This has proved to be effective in the laboratory and did not appear to affect sample analysis.

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) 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 allows the calculation of water flow. Flow readings were taken a minimum of every 15 minutes throughout the duration of each trial.

Sample Collection

Tailwater samples were sampled either by hand or with a pole sampler (Wildco 12-foot swing sampler, 165-C10) every 30 minutes 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 and from the field drain at the end of the sediment basin. 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 bifenthrin 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 $\leq 40^{o}C$. The samples were manually evaporated to dryness with nitrogen. To each sample, 2.0 mL hexane were 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 25°C/min to 300°C, hold for 13 min.

Under these conditions, bifenthrin has a retention time of 10.4 minutes.

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 (*20*).

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. Allow continuous suction for about 3 minutes after filtration is complete. 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 is 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 8-11**). 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, a calculation of 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 assume 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.

During this study, we examined the daytime sets from four consecutive irrigation trials over two days. On the first day of the study, Trial #1 (rows 41-47) tested the efficacy of the sediment pond alone in reducing sediment loads and pyrethroid residues. On the second day of the study, Trial #2 (rows 34-40) tested the efficacy of using Landguard SP at a low dose when used in conjunction with the sediment ponds. This was followed by Trial #3 (Rows 27-33) which was identical to Trial #2 except a 10X higher rate of the Landguard SP enzyme was used and then Trial #4 (Rows 20-26) in which a 5 % v/v rate of a liquid formulation of PAM-Calcium was metered into the irrigation water prior to the Sediment basin. In each case, samples were collected at the sediment basin entrance and at the sediment basin exit to examine changes in sediment and pyrethroid loading. Total flow for these four trials was over 670,000 liters.

Flow rates at the inlet to the pond varied from a maximum of 0 to 369.5 gallons/minute (23.3 liters/sec).At the outlet, the flow was regulated by a discharge pump that was kept at a constant 175 gallons/minute (11.0 liters/sec). 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 nine 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 every 30 minutes from the start of runoff (7:19 pm) through 11 pm. Flow velocity in Trial #1 ranged from a low of 1 gallons/minute (0.06 liters/sec) to a maximum of 215 gallons/minute (13.6 liters/sec) at the inlet. Total flow observed at the inlet was 130,293 liters during the 5 hours of monitoring. (**Table 8**)

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 (6:30 am). Landguard SP was applied to the sample inlet (see Figure x) at the start of runoff. As above, samples were collected every 30 minutes until 12:45 pm. Flow in the second trial was higher than the first. The flow velocity ranged from 54 gallons/minute (3.41 liters/sec) to a maximum of 350 gallons/minute (22.1 liters/sec). Total flow observed was 230,887 liters. (**Table 9**)

In the third trial, runoff began at 2:10 pm. The high dose (700 g) of the Landguard enzyme was dosed into the basin inlet and samples were collected from the inlet and outlet every 30 minutes until 6:10 pm. The flow velocity ranges from 63.4 gallons/minutes (3.99 liters/sec) to 369.5 gallons/minute (23.3 liters/sec). The total observed flow was 195,070 liters. (**Table 10**)

In the final trial; runoff began at 7:45 pm. A liquid formulation of PAM-calcium (5% v/v) was metered into the runoff water just prior to the sediment basin entrance. Samples were collected every 30 minutes from both the sediment basin entrance and exit until 10:22 pm. Flow velocities entering the basin ranged from 122.4 gallons/minute (7.72 liters/sec) to 287.9 gallons/minute (18.2 liters/sec). Total observed flow was 108,143 liters/minute. (**Table 11**)

Bifenthrin Residues and Total Suspended Solids (TSS)

The concentration of bifenthrin (expressed in ug/L) and TSS levels (expressed in mg/L) for each runoff sample can be found in **Tables 3 to 6**.

With each set of analyses for bifenthrin, two untreated water samples were fortified at two different rates to validate the analytical set. The average recovery of lambda-cyhalothrin was 108 ± 8.07% over the course of the study (see **Table 7**). The Limit of Determination (LOD) for the analytical method was 0.01 ug/L.

TSS levels in the runoff samples from Trial #1 (See **Table 3**) ranged from 1915 to 3030 mg/L in the samples taken from the sediment basin entrance and dropped significantly from 225 mg/L to 420 mg/L at the sediment basin exit. At the same time, there was very little difference in the bifenthrin residues taken at both the inlet and outlet. The samples ranged from 0.382 ug/L to 0.648 ug/L in the inlet and from 0.430 to 0.626 at the outlet.

Figure 4 plots the total suspended solids load in Trial #1 over each sampling interval. As expected, there is a significant reduction of sediment load after passing through the sediment basin (90%). The examination of TSS in Trials 2, 3 and 4, show a similar reduction in sediment loads---92, 89 and 95% reduction, respectively, after passing through the sediment basin.

Given the fact that pyrethroids as a class are highly hydrophobic and readily bind to the organic fraction in soils (bifenthrin K_{OC}=1.31-3.02 x 10^5), it is reasonable to expect that pyrethroids would be similarly reduced as sediment levels decline. **Figure 5** plots the bifenthrin residues in Trial #1 on the same time scale as the TSS plot. The data apparently indicate that bifenthrin residues increase when passing through the basin. This was unexpected as data from a previous study (*19*) run at the same site and using a related pyrethroid, lambda-cyhalothrin, showed reductions of 38-61% with the sediment basin.

The consistently high bifenthrin residues found in the four trials was highly suspect. Bifenthrin residues in Trial #1 ranged from 0.382 to 0.648 in the inlet and from 0.430 to 0.626 in the outlet (**Table 3**). Residues in Trial #2 ranged from 0.424 to 1.02 ug/L in the inlet and from 0.466 to 0.637 ug/L in the outlet (**Table 4**). Residues in Trial #3 ranged from 0.405 to 0.820 ug/L in the inlet and from 0.495 to 0.706 ug/L in the outlet (**Table 5**). Residues in Trial #4 ranged from 0.416 to 1.86 ug/L in the inlet and 0.524 to 1.10 in the outlet (**Table 6**). In all cases, there were no discernable patterns of increase or decline.

Conclusions

As has been demonstrated previously, the use of sediment basins is an effective BMP for reducing sediment loads in irrigated agriculture. However, the lack of clear, consistent trends in the bifenthrin residue data prevented making any definitive conclusions on the effect of the BMPs tested in this study on bifenthrin loading. There could be a number of potential explanations for what transpired in this trial including:

- Previous use of bifenthrin at the study site
- A problem with the methodology in the analytical laboratory
- Overspray of the sediment basin during bifenthrin application
- A high percent of fine clay particles in the system

Prior to the start of the study, the grower indicated that he had not used bifenthrin in previous insecticide sprays on his orchard. This was validated by taking pretreatment samples from the site. In each case, no detectable residues of bifenthrin (<0.01 ug/) were found in any sample.

To check the methodology, the laboratory was asked to re-extract selected inlet and outlet samples. In each case, the residues found were similar to those seen previously and showed no difference between the inlet and outlet samples. The laboratory used has had extensive experience with pyrethroids residue methodology and is one of the primary laboratories used by the Pyrethroid Working Group (an industry work group of pyrethroid manufacturers). This doesn’t necessarily rule out that an error may have been made, but appears to be unlikely.

Overspray of the sediment basin may be a possibility. The weekend prior to the application had high winds in the San Joaquin Valley delaying the application. Although the winds were down below the legal limit, the possibility of some drift is a possibility and the application was not observed. However, one would have expected that the effect of the initial overspray would have subsided as the trial progressed. In addition, the increasing sedimentation in the pond should have still resulted in a decrease of bifenthrin at the outlet. This was not observed. In future trials, post-application samples from the sediment pond should be taken prior to study initiation to rule this out.

The final possibility would be a high percentage of very fine, light-weight clay particles in the system. In this scenario, the heavy clay particles would still settle out, but bifenthrin would get carried through the system on these light-weight particles. If the percentage was large enough, you could still see significant settling (as measured by TSS), but residues between inlet and outlet could be similar. To test this theory, future studies should measure the particle size of the inlet and outlet samples.

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Tables and Figures

Table 1. Timing of Major Study Events

5/24/2011	Application of pyrethroid
5/26/2011 6:50 am	Start of irrigation for Trial 1
5/26/2011 17:45 pm	Water begins flowing into interception canal
5/26/2011 18:19 pm	Collection of 0-hour sample (inflow)
5/26/2011 19:05 pm	Collection of 0-hour sample (outflow)
5/26/2011 19:20 pm	Irrigation for Trial 2 started
5/26/2011 22:23 pm	Completion of Trial 1 Last sample take from pond outlet. Enzyme added to pond.
5/27/2011 06:30 am	Trial 2-Water begins flowing into interception canal
5/27/2011 06:55 am	Irrigation for Trial 3 started
5/27/2011 07:42 am	Trial 2-Collection of 0-hour sample (inflow)
5/27/2011 07:45 am	Trial 2-Collection of 0-hour sample (outflow)
5/27/2011 12:15 pm	Completion of Trial 2 Last sample take from pond outlet. Enzyme added to pond.
5/27/2011 14:00 pm	Irrigation for Trial 4 started
5/27/2011 14:10 pm	Trial 3-Collection of 0-hour sample (inflow)
5/27/2011 14:48 pm	Trial 3-Collection of 0-hour sample (outflow)
5/27/2011 17:50 pm	Completion of Trial 3. Last sample take from pond outlet.
5/27/2011 19:52 pm	Trial 4-Collection of 0-hour sample (inflow)
5/27/2011 20:48 pm	Trial 4-Collection of 0-hour sample (outflow)
5/27/2011 22:25 pm	Completion of Trial 4. Last sample take from pond outlet.

Table 2. Weather Data from CIMIS 145 (Madera) for the Period 5/23/2011 to 5/28/2011

Daily Report

California Irrigation Management Information System
Department of Water Resources
Office of Water Use Efficiency
Rendered in ENGLISH units
May 23, 2011 - May 28, 2011
Printed on October 5, 2011

San Joaquin Valley - Madera - 145

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)
05/23/11	0.24	0.00	680	9.4	73.0	46.7	60.2	81	33	53	42.8	7.1	172.2	68.3
05/24/11	0.24	0.00	553	9.3	77.1	55.0	67.0	86	20	41	42.6	4.3	103.5	71.2
05/25/11	0.24	0.00	687	10.7	78.5	44.7	60.8	92	31	59	46.3	6.7	161.0	69.1
05/26/11	0.27	0.00	775	9.0	72.9	45.6	60.0	90	29	51	41.8	8.0	192.1	68.4
05/27/11	0.27	0.00	768	10.5	77.4	47.2	62.6	88	32	54	45.7	7.4	179.4	69.2
05/28/11	0.23	0.03	662	9.2	74.4	47.3	59.7	91	25	53	42.4	8.1	196.5	69.4
Tot/Avgs	1.49	0.03	688	9.7	75.6	47.8	61.7	88	28	52	43.6	6.9	167.5	69.3

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 alone)

Sample Number	Location	Interval	Volume	TSS (mg/L)	Residue (ug/L)
100	Inlet	0	250 ml	3030	0.506
101	Inlet	1	250 ml	2720	0.648
102	Inlet	2	250 ml	1450	0.535
103	Inlet	3	250 ml	1860	0.516
104	Inlet	4	250 ml	2155	0.447
105	Inlet	5	250 ml	1915	0.382
106	Inlet	6	250 ml	2390	0.383
107	Inlet	7	250 ml	1930	0.406
120	Outlet	0	250 ml	290	0.626
121	Outlet	1	250 ml	420	0.449
122	Outlet	2	250 ml	340	0.430
123	Outlet	3	250 ml	270	0.476
124	Outlet	4	250 ml	225	0.518

Table 4. Analytical Data from Trial 2 (Enzyme plus Sediment Basin-Low Dose)

Sample Number	Location	Interval	Volume	TSS (mg/L)	Residue (ug/L)
300	Inlet	0	250 ml	285	0.499
301	Inlet	1	250 ml	140	0.467
302	Inlet	2	250 ml	110	0.508
303	Inlet	3	250 ml	230	0.473
304	Inlet	4	250 ml	2930	1.02
305	Inlet	5	250 ml	1200	0.502
306	Inlet	6	250 ml	NA	0.433
307	Inlet	7	250 ml	1080	0.433
308	Inlet	8	250 ml	1165	0.424
309	Inlet	9	250 ml	740	0.434
310	Inlet	10	250 ml	420	0.491
320	Outlet	0	250 ml	100	0.637
321	Outlet	1	250 ml	90	0.599
322	Outlet	2	250 ml	115	0.519
323	Outlet	3	250 ml	60	0.563
324	Outlet	4	250 ml	50	0.500
325	Outlet	5	250 ml	50	0.466
326	Outlet	6	250 ml	45	0.505
327	Outlet	7	250 ml	75	0.560
328	Outlet	8	250 ml	70	0.518

Table 5. Analytical Data from Trial 3 (Enzyme plus Sediment Basin-High Dose)

Sample Number	Location	Interval	Volume	TSS (mg/L)	Residue (ug/L)
500	Inlet	0	250 ml	1935	0.715
501	Inlet	1	250 ml	390	0.766
502	Inlet	2	250 ml	220	0.675
503	Inlet	3	250 ml	2485	0.820
504	Inlet	4	250 ml	1540	0.405
505	Inlet	5	250 ml	2270	0.431
506	Inlet	6	250 ml	1650	0.528
507	Inlet	7	250 ml	595	0.516
508	Inlet	8	250 ml	515	0.541
520	Outlet	0	250 ml	350	0.576
521	Outlet	1	250 ml	265	0.706
522	Outlet	2	250 ml	190	0.630
523	Outlet	3	250 ml	235	0.593
524	Outlet	4	250 ml	190	0.495
525	Outlet	5	250 ml	150	0.535
526	Outlet	6	250 ml	110	0.526

Table 6. Analytical Data from Trial 4 (Liquid PAM Sediment Basin)

Sample Number	Location	Interval	Volume	TSS (mg/L)	Residue (ug/L)
700	Inlet	0	250 ml	6255	0.416
701	Inlet	1	250 ml	4510	0.848
702	Inlet	2	250 ml	3920	1.05
703	Inlet	3	250 ml	1815	1.86
704	Inlet	4	250 ml	2390	1.71
705	Inlet	5	250 ml	1040	1.46
720	Outlet	0	250 ml	345	0.524
721	Outlet	1	250 ml	215	0.695
722	Outlet	2	250 ml	175	0.969
723	Outlet	3	250 ml	175	1.10
724	Outlet	4	250 ml	145	1.08
725	Outlet	5	250 ml	220	1.06

Table 7. Bifenthrin Analytical Recovery from Fortified Basin Water Samples

Sample ID	Fort.Level (ug/L)	Recovered (ug/L)	% Recovery
87638 Fort. Control 1	0.10	0.110	110
87638 Fort. Control 2	1.0	0.966	97
87638 Fort. Control 3	0.01	0.0117	117
87638 Fort. Control 4	1.0	1.017	102
87638 Fort. Control 5	0.01	0.0113	113
87638 Fort. Control 6	1.0	0.961	96
87638 Fort. Control 7	0.01	0.0120	120
87638 Fort. Control 8	0.10	0.102	102
87638 Fort. Control 9	0.01	0.0113	113
87638 Fort. Control 10	1.00	1.04	104
87638 Fort. Control 11	0.01	0.0117	117
87638 Fort. Control 12	2.0	2.12	106
		Average±Std. Dev.	**108±8.07**

Table 8. Summary of Flow Data for Trial 1 (Sediment Basin Only)

Time Period (hours)	Flow (L)		Sediment (g)		Pyrethroids (mg)	
	Into Basin	***Out of Basin***	**Into Basin**	**Out of Basin**	**Into Basin**	**Out of Basin**
0.0-0.5	397	---	1204	---	---	---
0.5-1.0	13,664	---	37,165	---	8.9	---
1.0-1.5	14,731	9,936	21,360	2,881	7.9	6.2
1.5-2.0	11,866	9,936	22,070	NA	6.1	NA
2.0-2.5	21,415	19,871	46,150	8,346	9.6	17.8
2.5-3.0	22,168	19,871	42,451	6,756	8.5	25.6
3.0-3.5	17,747	19,871	42,417	5,365	6.8	37.8
3.5-4.0	14,977	9,936	28,907	NA	6.1	NA
4.0-4.5	13,328	9,939	12,128	2,236	5.8	51.5
Totals	**130,293**	**99,360**	**253,852**	**25,584**	**59.7**	**138.9**

Table 9. Summary of Flow Data for Trial 2 (Enzyme plus Sediment Basin-Low Dose)

Time Period (hours)	Flow (L)		Sediment (g)		Pyrethroids (mg)	
	Into Basin	***Out of Basin***	**Into Basin**	**Out of Basin**	**Into Basin**	**Out of Basin**
0.0-0.5	19894	9936	5670	---	9.92	---
0.5-1.0	42159	19871	5902	1987	19.7	19.0
1.0-1.5	36211	19871	3983	1788	18.4	29.8
1.5-2.0	37009	19871	8512	2285	17.5	36.1
2.0-2.5	24294	19871	71181	1192	24.8	50.3
2.5-3.0	17977	19871	21573	993	9.01	54.6
3.0-3.5	17959	19871	19395	993	7.78	60.2
3.5-4.0	15726	19871	18321	894	6.68	75.3
4.0-4.5	11082	19871	8201	1490	4.81	94.6
4.5-5.0	8576	19871	3602	1390	4.21	97.8
Totals	**230,887**	**188,775**	**166340**	**13012**	**122.81**	**517.7**

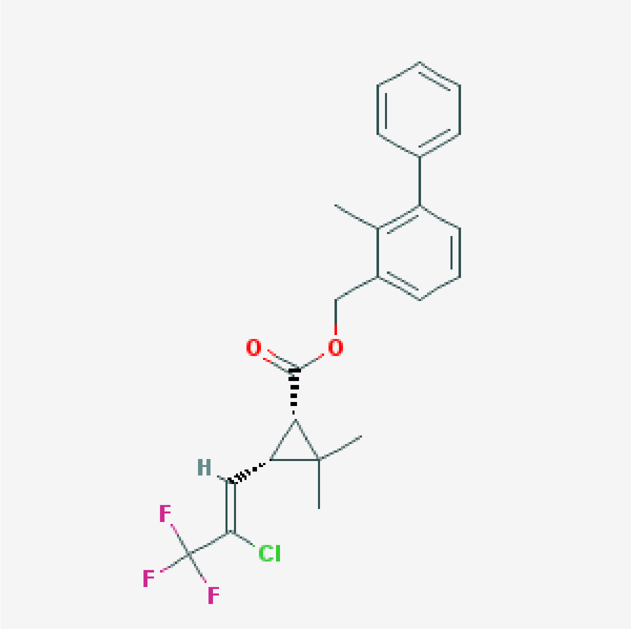
Table 10. Summary of Flow Data for Trial 3 (Enzyme plus Sediment Basin-High Dose)

Time Period (hours)	Flow (L)		Sediment (g)		Pyrethroids (mg)	
	Into Basin	*Out of Basin*	Into Basin	Out of Basin	Into Basin	Out of Basin
0.0-0.5	11923	---	23071	---	8.52	---
0.5-1.0	37358	9936	14570	3478	28.6	11.4
1.0-1.5	40756	19871	8966	5266	27.5	28.1
1.5-2.0	31709	19871	78796	3776	26.0	37.6
2.0-2.5	20033	19871	30850	4670	8.09	47.1
2.5-3.0	15593	19871	35397	3776	6.72	49.2
3.0-3.5	11105	19871	18323	2981	5.86	63.8
3.5-4.0	14344	9936	8535	1093	7.40	67.9
4.0-4.5	12249	---	6308	---	6.62	---
Totals	**195070**	**119227**	**224816**	**25040**	**125.31**	**305.1**

Table 11. Summary of Flow Data for Trial 4 (Liquid PAM plus Sediment Basin)

Time Period (hours)	Flow (L)		Sediment (g)		Pyrethroids (mg)	
	Into Basin	*Out of Basin*	Into Basin	Out of Basin	Into Basin	Out of Basin
0.0-0.5	10656	---	66653	---	4.43	---
0.5-1.0	21787	19871	98261	6856	18.5	20.8
1.0-1.5	24924	19871	97703	4272	46.4	41.4
1.5-2.0	15723	19871	28539	3477	26.9	77.0
2.0-2.5	19582	19871	46800	1738	20.6	98.4
2.5-3.0	15471	19871	16090	2881	22.6	107
Totals	**108143**	**99355**	**354046**	**19224**	**139.43**	**344.6**

Figure 1. Chemical Structure of Bifenthrin



(2-methyl-3-phenylphenyl)methyl-(1S,3S)-3-[(Z)-2-chloro-3,3,3-trifluoroprop-1-enyl]-2, 2-dimethylcyclopropane-1-carboxylate (IUPAC)

Figure 2. Plot Diagram of Study Site

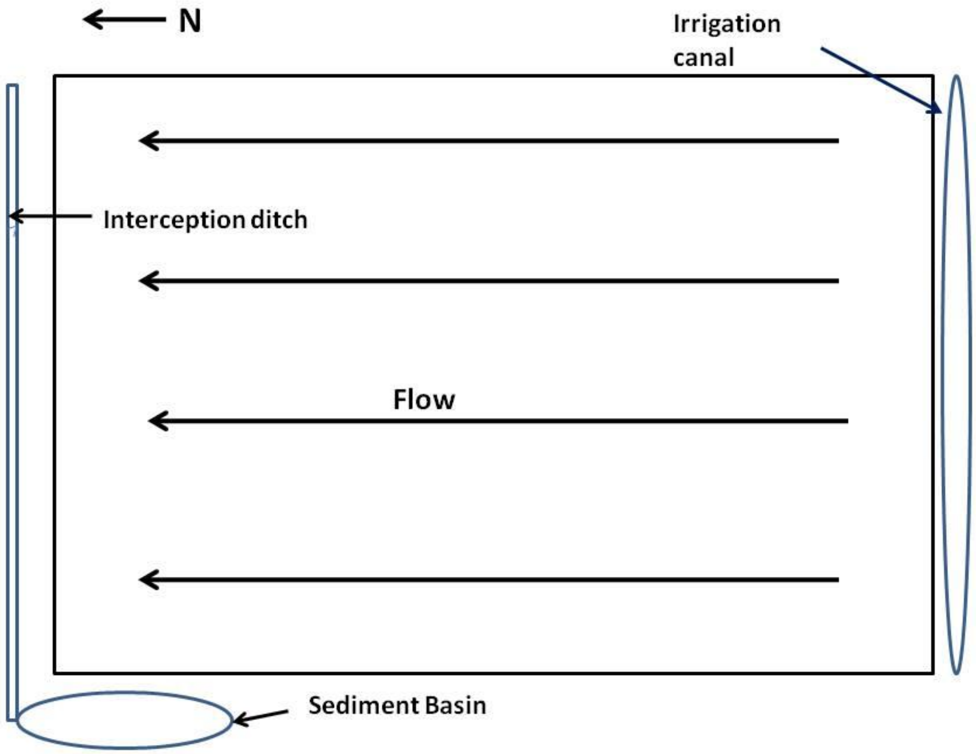


Figure 3. Graph of Flows at Entrance to Sediment Basin from Start of Trial to Study Termination

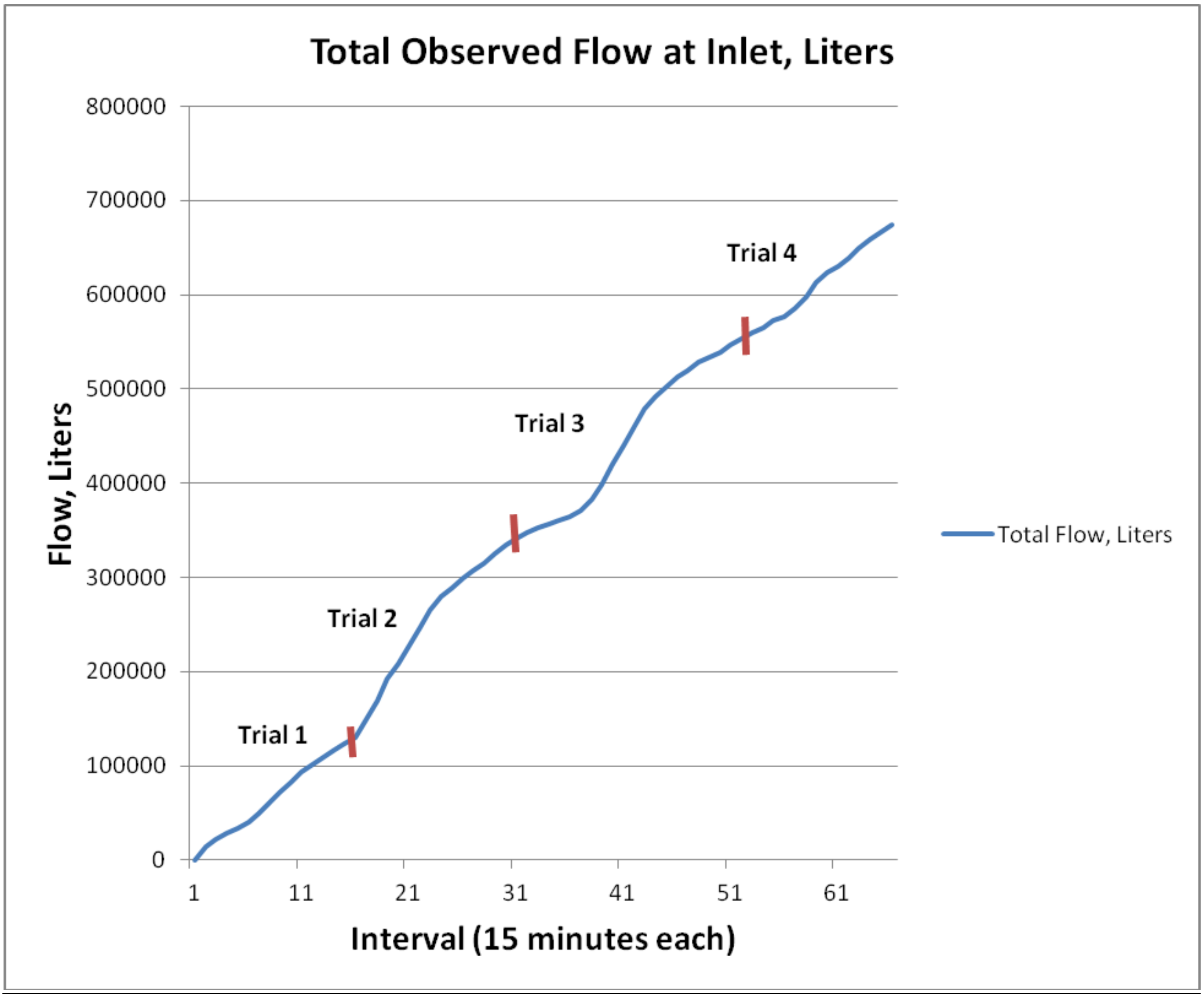


Figure 4. Total Suspended Solids (TSS) in the Inlet and Outlet of the Sediment Basin in Trial 1

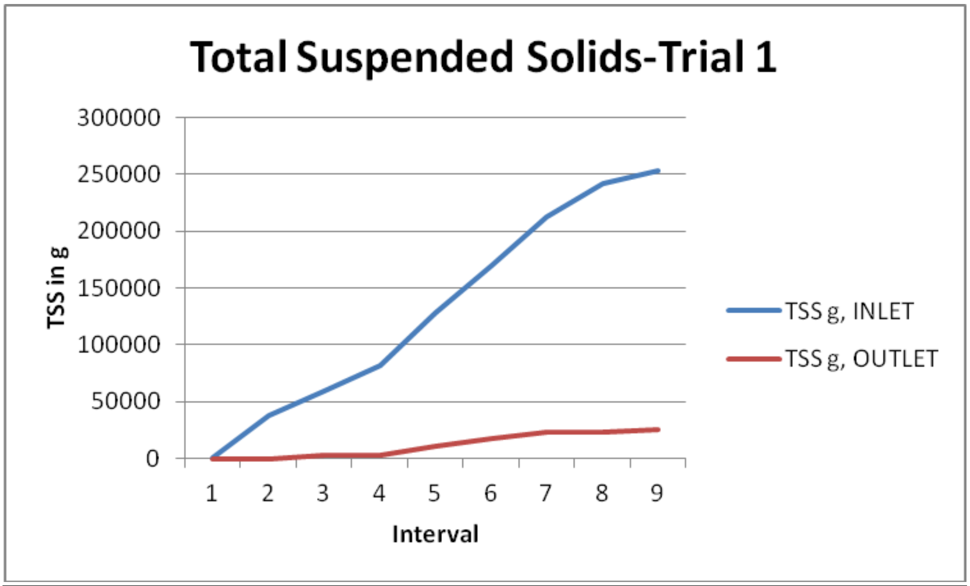


Figure 5. Total Bifenthrin Residues in the Inlet and Outlet of the Sediment Basin in Trial 1