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DATE: December 18, 2006

SUBJECT: RESULTS FOR STUDY 235: CONSTRUCTED VEGETATED DITCHES AS A MANAGEMENT PRACTICE IN IRRIGATED ALFALFA

## I. INTRODUCTION

This study was part of a larger Pesticide Research and Investigation of Source and Mitigation Grant Program (PRISM) project designed to demonstrate the use of several best management practices that may reduce chlorpyrifos loading in return water from irrigated crops in the Orestimba Creek region of the San Joaquin River watershed. Attached are Tables 1–12 and Figures 1–8.

Typically, irrigation occurs in this region throughout the summer, coinciding with periods of pesticide application. Irrigation water moving across a recently sprayed field can mobilize chlorpyrifos, which is relatively water soluble, and move it to conveyance ditches at the edge of the field where it is then drained to tailwater ponds or discharged into local surface waters.

Agricultural irrigation return ditches in California are commonly dredged to remove as much vegetation as possible in order to maintain flow-carrying capacity. However, by allowing vegetation to remain within the ditch, thus slowing the flow rate and providing more time and potential for degradation, pesticide concentrations in runoff may be reduced. Previous research shows that ditch vegetation can play an important role in the reduction of pesticides associated with runoff from agricultural fields (Cooper *et al.*, 2004).

This study demonstrates a constructed, vegetated conveyance ditch as a potential management practice for reducing off-site movement of chlorpyrifos to surface water in irrigated alfalfa.

## II. STUDY OBJECTIVE

This was a demonstration study designed to evaluate the effects of two management practices on chlorpyrifos concentrations in irrigation runoff. The management practices consisted of: (1) a standard irrigation return ditch that was dredged to remove vegetation just prior to irrigation event and (2) a specially constructed ditch that was planted with grasses and kept well vegetated for the irrigation event.

The evaluation was based on whole-water irrigation runoff samples collected at the inflow and outflow points of both the standard and vegetated ditches. The effect of the management practices was determined as the difference between chlorpyrifos concentrations in runoff entering and exiting the ditches.

## III. STUDY DESIGN

### Study Site

The study site is a 75-acre commercial alfalfa field near the cities of Crow's Landing and Patterson in the San Joaquin Valley of California (Figure 1). Chlorpyrifos is commonly applied to alfalfa in this region several times during the irrigation season (April-October) to control several species of aphids including the green peach aphid (*Myzus persicae)* and worms such as the beet armyworm (*Spodoptera exigua*), western yellowstriped armyworm (*Spodoptera praefica*) and the alfalfa caterpillar (*Colias eurytheme*).

The study field is flood irrigated using two sets of gated pipe, one set at the top of the field and one set midway through the field (Figures 2 and 3). The field, which is divided into 10 irrigation sets that are rotated every 12 hours, takes 5 days to irrigate. Each irrigation set waters approximately seven acres and results in a discrete runoff episode that lasts four to six hours. It takes approximately eight hours for water to travel down the field and reach the drainage ditches at the low end of the field (Figure 3). Tailwater leaving the site drains into Crow Creek, which flows through a pipe to Orestimba Creek and eventually to the San Joaquin River. Water is applied at rate of four to six inches approximately seven times per irrigation season.

### Sampling Frequency and Location

Irrigation at the site began 48 hours after an aerial application of chlorpyrifos. Each sampling event represented the first flush of water leaving the field from each of five irrigation sets. Runoff samples were collected at 30 minute to 1-hour intervals at three sampling sites (described below) during each set. Whenever possible six samples at each sample site were collected for every irrigation set (Table 1). However, the first irrigation set did not generate enough runoff for six samples at the outflow of either the vegetated or standard ditch. Sampling began as soon as

there was enough water present at the sampling site to submerge the sample bottle and continued for three to four hours.

**Sample Site 1**

Represented the inflow location for both the conventional and vegetated ditches (Figure 2). Samples were collected just upstream of the weirs that split the water into the two test ditches.

**Sample Site 2**

Represented the outflow location of the vegetated ditch (Figure 2). Samples were collected from the vegetated ditch just upstream of the stand pipe that carries return water off-site to Crow Creek.

**Sample Site 3**

Represented the outflow location for the conventional ditch (Figure 2). Samples were collected from the conventional ditch just upstream of the stand pipe that carries return water off-site to Crow Creek.

Ditches

**Vegetated Ditch**

The vegetated ditch was a shallow conveyance ditch constructed at the low end of the field in December 2005, six months prior to the study date, and planted with several species of native and introduced perennial grasses (Figure 3). Half of the ditch was planted with *Dactylis glomerata* 'Potomac' (orchard grass) and *Agropyron trichophorum* 'Luna' (pubescent wheatgrass). The other half of the ditch was planted with a mix of *Leymus triticoides* 'Yolo' (Yolo creeping wildrye) *Elymus glaucus* (blue wildrye), and *Hordeum brachyantherum* (California meadow barley).

The vegetated ditch was two meters wide and ran the entire bottom width of the field (400 meters). The vegetation was well established in the ditch and was mowed to just above the estimated high water mark prior to the irrigation season.

**Conventional Ditch**

The conventional ditch used for the study was a standard V-shaped groove (Figure 3). The design and dimensions (50cm wide by 35cm deep) represents what the grower traditionally uses to intercept runoff water from the site.

## IV. MATERIALS AND METHODS

### Application

The field was treated by air at daybreak on July 11, 2006 with Chlorpyrifos (Lorsban® 4E, Dow AgroSciences LLC) and a binder/spreader adjuvant (Latron® CS-7, Rohm and Haas Co.). The chlorpyrifos was applied at a rate of 1 pint per acre, which is the low end of label rates for worm control, and allows a 14-day pre-harvest interval (Dow AgroSciences, 2004). The label also requires a minimum 24-hour delay between application and start of flood irrigation.

A 100-ft un-sprayed buffer was left between the field and study ditches to prevent direct over-spray into the ditches. Over-spray into the ditches could have potentially resulted in higher and inconsistent chlorpyrifos depositions, which may have obscured the treatment effect. Twenty-nine mass deposition (MDS) sheets were placed in the ditches prior to application to determine if any accidental over-spray occurred. They were set out at equal intervals along the length of the study ditches, approximately every six meters. Samples were collected following DPR SOP #FSOT005.00, Mass Deposition Sampling Using Mass Deposition Sheets (Walters, 2003).

### Runoff Samples

Whole water runoff samples were collected by hand directly into 1-L amber glass bottles and sealed with Teflon-lined lids. Samples were stored on wet ice then refrigerated at 4ºC until extraction for chemical analysis. Samples were collected following DPR SOP #FSWA008.00 Sampling for Surface Water Runoff in Agricultural Fields (Spurlock, 1999).

### Suspended Sediment

Suspended sediment measurements were performed on companion samples collected at the same sampling locations and times as the runoff samples. Measurement was conducted by vacuum filtration of the samples and subsequent oven drying of the filtrate collected on tared, rinsed, and oven-dried filters following EPA Method 160.2 Non-Filterable Residue (Gravimetric, Dried at 103-105°C)(EPA, 1971).

### Chemical Analysis and Quality Control

Collection and transport of samples followed DPR SOP #QAQC004.01, Transporting, packaging, and shipping samples from the field to the warehouse or laboratory (Jones, 1999). A chain-of-custody record was completed and accompanied each sample.

The California Department of Fish and Game, Fish and Wildlife Water Pollution Control Laboratory (WPCL) conducted chemical analysis of all water and MDS sheet samples. Quality control (QC) was conducted in accordance with DPR SOP # QAQC001.00, Chemistry Laboratory Quality Control (Segawa, 1995) and included general continuing QC.

MDS field samples were extracted at the lab the day after they were collected. Water samples were extracted an average of six days after they were collected in the field.

Laboratory Quality Control

Laboratory control spikes and blanks were conducted to assess lab accuracy. Lab control water was spiked at 0.2 ppb by the chemist, and then extracted and analyzed. All lab blanks had no detectable residues. Recoveries of lab spikes ranged from 61.2% to 80.4% (Table 8). The lab control spikes were run in two sets between the batches of field samples. The mean recovery of the lab control spikes was 70.5% with a standard deviation of 7.8%. The detector was changed between validating the method and running the field samples, so validation data could not be used to evaluate the recoveries. The lab spikes were spiked in duplicate, however since all were run in two batches, each batch consisted of eight and four replicates. Just over 5% of the water samples run by WPCL were lab control spikes.

The surrogate triphenyl phosphate was added to every sample and every lab QC sample. The mean recovery of the surrogate in the lab QC water was 77.8% and a standard deviation (SD) of 4.79, whereas the field sample surrogate result mean was 93.0% and a SD of 16.7% (Table 9). The percent difference of 17.8% between the two means was low considering the matrix effects of the dirty field water versus the lab water. The higher triphenyl phosphate recoveries in the field water may indicate some enhancement of the triphenyl phosphate by matrix effects.

A WPCL chemist in another section of the lab fortified the matrix blind spikes. The matrix water was pesticide free North Fork American River water. The blind spikes were given to the Department of Pesticide Regulation (DPR) staff, relabeled, and then intermingled and delivered with field samples. Initial results showed approximately 50% recovery (Table 10). The chemist that fortified the blind spikes was notified about the problem by DPR, and double-checked fortification calculations. They were correct. The regular chemist was notified and the two analyzed the calibration and blind spike standards on separate instruments. They each found that the blind spike standard was less than 50% of its stated chlorpyrifos purity. This result was confirmed by the California Department of Food and Agriculture, Center for Analytical Chemistry Laboratory. The spike amount was adjusted and the average percent recovery in the blind spikes was 98.8%.

MDS sheets were spiked and analyzed in the same batch as the field sample MDSs. The mean recovery of the chlorpyrifos spiked onto the MDSs was 91.3%, with a SD of 9.55 (Table 11).

The triphenyl phosphate surrogate was also spiked onto the QC samples and field samples. The recovery of the surrogate on the QC samples was 88.9% with very low variation, and the surrogate recovered on the field samples was 84.0% with an SD of 9.89. The percent difference between the mean recovery of the surrogate on lab MDSs and field MDSs was low as expected since the matrix is essentially the same. All MDSs lab control blanks had no detectable chlorpyrifos.

Field Quality Control

All field control blanks (one MDS and two water) had no detectable chlorpyrifos. Five field replicate samples were analyzed. Relative percent difference for replicates ranged from 7% to 36.9 % (Table 12). Relative percent difference for split replicates should be less than 25%. The replicate pairs were collected at the same time but were not true splits, this may explain the higher than expected relative difference.

## V. RESULTS AND DISCUSSION

Runoff Samples

Chlorpyrifos concentrations in the irrigation runoff were variable and ranged from 0.22 µg/L to a maximum of 1.67 µg/L (Table 2 and Figure 4). In general, concentrations were lower in the vegetated ditch (Site 2) than at the inflow (Site 1) or in the conventional ditch (Site 3). On average the median concentration reduction at the end of the vegetated ditch was about 38% as compared to approximately 1% in the conventional ditch.

Paired t-tests were used to compare changes in chlorpyrifos concentrations between the inflow site and outflow point of each ditch. There was no significant difference in concentrations between paired samples at the inflow (Site 1) and the end of the conventional ditch (Site 3) (two tailed, $\alpha$=0.05, t=1.19, P=0.247). This indicates that the conventional ditch did not significantly reduce concentrations in runoff (Figure 5).

There was a significant difference (Figure 6) in concentrations between paired samples at the inflow (Site 1) and the vegetated ditch (Site 2) (two tailed, $\alpha$=0.05, t= 6.20, P=0.000). Concentrations were lower at the end of the vegetated ditch (Figure 4), indicating that the ditch was effective in reducing off-site movement of chlorpyrifos. A probability plot of the range of expected concentration decreases for the vegetated ditch (Figure 7) shows the median reduction was approximately 38% with the 25th and 75th percentiles falling at 28% and 49% respectively.

A general linear model was used to determine if the fraction of chlorpyrifos reduced by the vegetated ditch was constant throughout the study or if it changed between irrigation events, the thought being that the efficacy of the ditch may decrease over time (Figure 8). The model

indicates that while the fraction of chlorpyrifos reduced may have been slightly lower for the last irrigation event, there was no significant difference between the events (F=2.46, P=0.088). Therefore, the fraction of chlorpyrifos reduced by the vegetated ditch was relatively constant.

Statistical analysis was performed using MINITAB® Statistical Software (MINITAB, 2003).

Deposition Samples

Although a 100-ft un-sprayed buffer was left between the field and the tailwater ditches and no direct over-spray occurred, some chlorpyrifos did drift into the study area. The concentrations on the mass deposition sheets ranged from 10.4 $\mu g/ft^2$ to 64.8 $\mu g/ft^2$ which represents 0.2% to 1.24% of the application rate respectively. The mean concentration was 42.3 $\mu g/ft^2$ or 0.8% of application rate (Table 4). Application rate was 1 pt /acre which is equivalent to 5206 $\mu g/ft^2$.

The low concentrations detected indicate that the minimal amount of spray drift was not enough to affect the study results and did not obscure treatment effects. Additionally, the flight path of the airplane (perpendicular to the ditches) resulted in equal deposition of drift into both ditches.

Suspended Sediment

Suspended sediment concentrations were variable and ranged from 0.011 g/L to 0. 330 g/L with a mean of 0.046 g/L (Table 5).

Paired t-tests were used to compare changes in suspended sediment concentrations between the inflow site and outflow point of each ditch. Means and standard errors are shown in Table 6. Suspended sediment in the vegetated ditch was not significantly different (two tailed, $\alpha$=0.05, T=1.81 P=0.085) than in the conventional ditch indicating that there was no treatment effect on the amount of suspended sediment present in runoff from the test ditches. This result is not unexpected given that the sediment concentrations at the inflow site were low to begin with and that in general, runoff from alfalfa fields contains relatively low levels of suspended sediment.

Statistical analysis was performed using MINITAB® Statistical Software (MINITAB, 2003).

Irrigation Timing

The current California specimen label (Dow AgroSciences, 2004) for Lorsban® 4E requires a minimum 24 hour delay between application and the start of flood irrigation in alfalfa. The question has been raised that requiring a longer lag time to start of irrigation may help to reduce pesticide concentrations in runoff. Although it was not an objective of this study, data gathered may help address this issue.

As described above and shown in Figure 2, the field was irrigated in sets that were changed every 12 hours. Runoff data collected represented first flush runoff from sets that were irrigated 48, 60, 72, 84, and 96 hours after the chlorpyrifos application. Additional runoff samples from the conventional ditch (Sample Site 3) were collected from two irrigation sets that began 120 and 144 hours after the study application.

In this study there were many factors that could potentially affect the runoff concentrations between irrigation sets. These include unequal deposition from the aerial application, variations in plant cover, and amount of irrigation water applied to each set. Although chlorpyrifos concentrations in the runoff water in this study may have slightly decreased as irrigation lag time increased, any potential decrease was small compared to the natural variability at the study site (Table 7 and Figure 9). This indicates that there was essentially no decrease in chlorpyrifos concentrations for irrigation lag times up to 144 hours. Consequently these data show that delaying irrigation for periods of up to five days is an ineffective management practice for reducing chlorpyrifos concentrations in runoff under the soil, climate, and irrigation conditions of this study.

## V. ACKNOWLEDGEMENT

This was a cooperative study between several entities, including DPR, under the direction of the San Luis and Delta-Mendota Water Authority. Funds for this project were provided by the California State Proposition 13 (2000 Water Bond) PRISM Grant Program. The vegetated ditch system was designed and constructed by staff from Ducks Unlimited. DPR's Environmental Monitoring Branch staff–under the general direction of Dr. Kean S. Goh, Agricultural Program Supervisor IV, was responsible for collecting and transporting samples for chemical analysis.

The California Department of Fish and Game, Fish and Wildlife Water Pollution Control Laboratory conducted chemical analysis of all water and MDS.

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