Evaluation of practices to minimize chlorpyrifos in tail water from sprinkler irrigated vegetable fields

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Introduction

Chlorpyrifos is commonly used for control of soil insect pests in cole crops grown on the central coast of California. Either a granular or a liquid formulation of the pesticide is applied at planting, before the crop is irrigated with overhead sprinklers. Monitoring data from tributaries near commercial cole crop fields has confirmed that concentrations of chlorpyrifos in surface water are often sufficiently high to cause toxicity to aquatic test organisms. The central coast regional water quality control board has proposed 25 parts per trillion (25 nano-grams per liter) the total maximum daily load target concentration for chlorpyrifos in the Salinas River. Although, chlorpyrifos is readily soluble in water, it also binds to soil and organic matter. Because a high concentration of suspended sediments (>500 mg of sediment per liter) usually is present in sprinkler induced run-off during germination and stand establishment of cole crops, a significant portion of chlorpyrifos may be associated with the suspended sediments. In addition, granular applications of chlorpyrifos may result in some product dispersed on the surface of the soil where it could be more susceptible to loss during irrigation events than liquid formulations sprayed on the seedline.

Objective We conducted a large scale field trial in a commercial broccoli field to evaluate if the addition of polyacrylamide (PAM) polymer to the irrigation water can reduce suspended sediments and chlorpyrifos concentration in run-off. We also evaluated if liquid and granular formulations affected the residual concentration and cumulative load of chlorpyrifos in the irrigation run-off.

Procedures The field trial was conducted on an 18-acre, commercial vegetable field located in Monterey County, near Chualar. The soil at the site was 75% Arroyo Seco gravelly loam and 25% Danville sandy clay loam. The field had a 2 % slope. The trial was seeded with broccoli on 40-inch wide beds on 8/12/10 and irrigated with solid set overhead sprinklers. Plots received the following treatments: 1. untreated irrigation water + liquid formulation of Lorsban (Lorsban 4E) , 2. untreated irrigation water + granular formulation of Lorsban (Lorsban 15G) irrigation, 3. Irrigation water treated with 5 ppm of emulsified liquid polyacrylamide (PAM, Ciba Soilfix 50% ai) + liquid formulation of Lorsban, 4. Irrigation water treated with 5 ppm PAM + granular formulation of Lorsban. Lorsban applications were 1 lb ai/acre for both the liquid an granular formulations. The standard granular application of chlorpyrifos was made in the seed lines at planting and the liquid application of chlorpryrifos was sprayed in bands on the seedlines immediately after planting. Treatments were replicated 3 times. Applied water was measured using flow meters installed on the main line of the sprinkler system. Volume of run-off was measured at the lower end of the plots using flumes. Composite samples of bulk run-off were collected from the plots during 5 successive irrigation events. The bulk water samples were analyzed for chlorpyrifos concentration and suspended sediments. Sediment was extracted from a subset of run-off samples to determine the portion of chlorpyrifos in the water and sediment fractions.

Results

A total of 7.5 inches of water was applied during 5 irrigation events. Less than 0.5% of the applied water was lost as run-off during the trial. The cooperating grower applied more water than normally required for germination to create sufficient run-off for comparing treatments. Irrigations lasted longer than normal and only 3 irrigations were needed to germinate the crop.

Run-off did not occur until the 2nd irrigation event (Figure 1), and only in plots receiving untreated water (no addition of PAM). Run-off occurred in plots receiving both water treatments by the 3rd irrigation event, though the average volume of run-off was highest in plots receiving untreated water (Figure 1). Several of the PAM treated plots had no run-off until the 4th and 5th irrigations when the soil was saturated. By the end of the 4th irrigation, the average cumulative volume of run-off in plots receiving untreated water was approximately 3 times greater than the volume of run-off from PAM treated plots (Figure 1).

The concentration of total suspended sediments in the sprinkler run-off ranged from greater than 400 ppm to 23 ppm. The concentration of suspended solids in run-off from both water treatments decreased with successive irrigations, presumably because fine particles were lost from the soil surface with each irrigation. (Figure 2). The PAM treatment had significantly lower suspended solids concentration in the tail water compared to plots receiving untreated water (Figure 2), reducing sediment concentration in run-off during the 3rd, 4th, and 5th irrigations by 74%, 82%, and 84% , respectively.

Although the application of PAM significantly reduced sediment concentration in the run-off, the polymer did not reduce the concentration of chlorpyrifos. In fact, the highest concentration of chlorpyrifos was measured in plots treated with liquid Lorsban and irrigated with water treated with PAM (Figure 3). Since the least run-off was measured in the PAM treated plots, the concentration of chlorpyrifos might be expected to be highest in these plots. .

The cumulative loss of chloropyrifos from each plot was estimated by multiplying the volume of run-off by the concentration of chlorpyrifos in the run-off. The least amount of chlorpyrifos was lost from plots treated with the granular Lorsban and PAM (Figure 4). The application of PAM limited the volume of run-off, and the granular formulation of Lorsban minimized the concentration of chlorpyrifos in the tail water. The greatest lost of chlorpyrifos was from plots irrigated with untreated water and treated with the liquid formulation of Lorsban.

Suspended sediments were extracted from run-off samples collected from plots receiving untreated water. The average concentration of chlorpyrifos on the sediments ranged from 86 to 821 nanograms per gram of dry soil. Samples from the Lorsban 4E plots had higher concentrations of chlorpyrifos in the bulk, supernatant, and sediment fractions than samples analyzed from Lorsban 15G plots. Adjusting for the suspended solids concentration of the run-off, on average only 4% of the chlorpyrifos was associated with the sediment fraction of the run-off. The remainder (96%) of the chlorpyrifos would therefore be in the water fraction of the run-off.

Discussion and conclusions

The results of this trial showed that polyacrylamide did not reduce the concentration of chlorpyrifos in sprinkler run-off, but the polymer did reduce the load of chlorpyrifos lost in run-off by improving infiltration during the first 3 irrigation events. Following normal practices, the grower would have irrigated less than occurred in this trial such that the PAM treatment may have had minimal loss of tail water. A number of studies conducted in the northwestern region of the United States have documented improved infiltration with the application of PAM under furrow irrigation. However, few studies have shown the same infiltration benefit from the application of PAM in California.

The concentration of suspended sediments was lower than measured in other soils on the east-side of the Salinas Valley. Typically fields in the same area have 1000 to 2000 ppm of suspended sediments in irrigation tail water. The untreated plots had less than 400 ppm in our trial, which means that flocculating sediments from tail water may have minimal effects on the overall concentration of chlorpyrifos in the run-off. Although PAM was effective in reducing sediment concentration in the run-off, the polymer was less effective than on other sites where it has been tested in the Salinas Valley. Other trials have shown that the addition of PAM reduced suspended sediment concentration by more than 90%. The average reduction in suspended sediment concentration was 80%. Our estimates are that less than 4% of the chlorpyrifos was associated with the suspended sediments in the run-off. Because chlorpyrifos may be attracted to organic matter more than soil colloids, the low organic matter content of this soil may have also lessened the amount of chemical associated with the suspended sediments.

The results of the trial also showed that a concentration of about 2000 ppt was measured in run-off from plots treated with granular Lorsban but initially greater than 6000 ppt in plots treated with the liquid formulation (Lorsban 4E). The high concentration of chlorpyrifos in the tail water suggests that the liquid formulation mobilizes more rapidly than the granular product during an irrigation event. The liquid product was sprayed on the soil surface while the granular product was buried about ¼ inch below the soil surface in the seed line. In this trial, granular product on the soil surface had a negligible effect on the final concentration of chlorpyrifos in the run-off.

Recommendations for minimizing chlorpryifos in run-off

The lowest concentration of chlorpyrifos measured in the run-off during this field trial was significantly higher than the water quality target of 25 ppt for surface water in the lower Salinas valley. Although it may not be possible to reach this water quality target in tail water, the combination of limiting run-off during germination and using a granular formulation of Lorsban may minimize the load of chlorpryifos impacting surface water in Salinas valley. Our main recommendations are to:

1. Minimize overall irrigation run-off by optimizing the duration of the irrigation sets.
2. Use PAM to improve infiltration and to reduce the load of suspended sediments in the run-off

3. Use the granular rather than the liquid formulation of chlorpyrifos. The results of this trial showed that the liquid formulation was more likely to be carried in the run-off than the granular formulation.
4. Avoid applying granular or liquid product directly on the soil surface where it may be easily carried in run-off during irrigation events.

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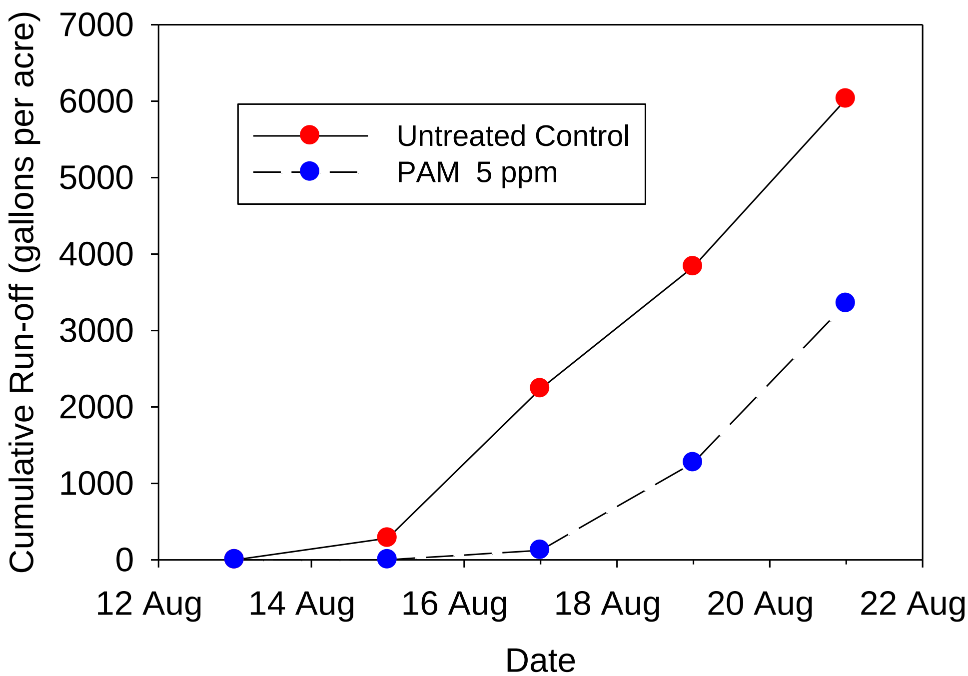

Figure 1. Effect of PAM on cumulative volume of run-off during 5 irrigations with overhead sprinklers.

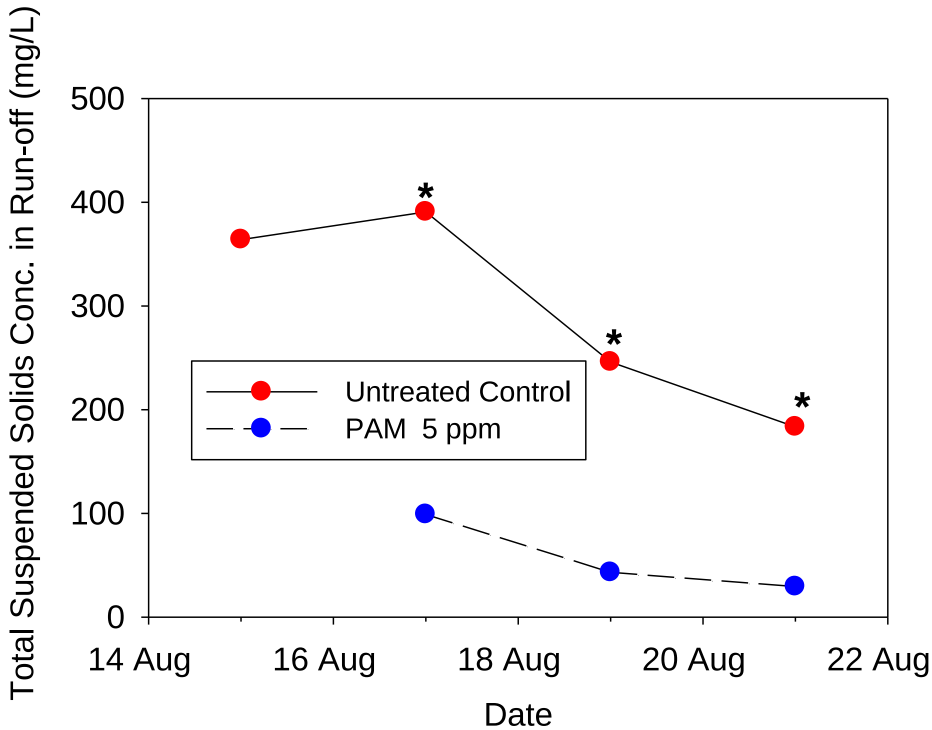

Figure 2. PAM treatment effects on average suspended solids concentration in sprinkler run-off from a commercial broccoli field. Treatment means on dates denoted with "*" are statistically different at the $p < 0.05$ confidence level.

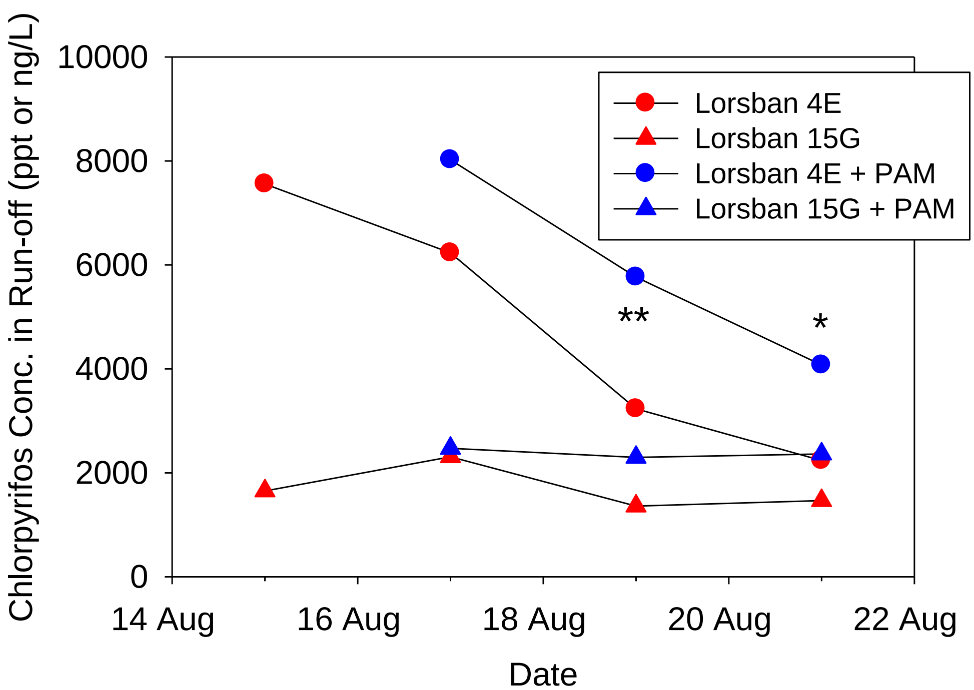

Figure 3. PAM and formulation treatment effects on chlorpyrifos concentration in composite samples of sprinkler run-off from a commercial broccoli field. Treatment means on dates denoted with "*" or "**" are statistically different at the $p < 0.05$ and 0.01 confidence levels, respectively.

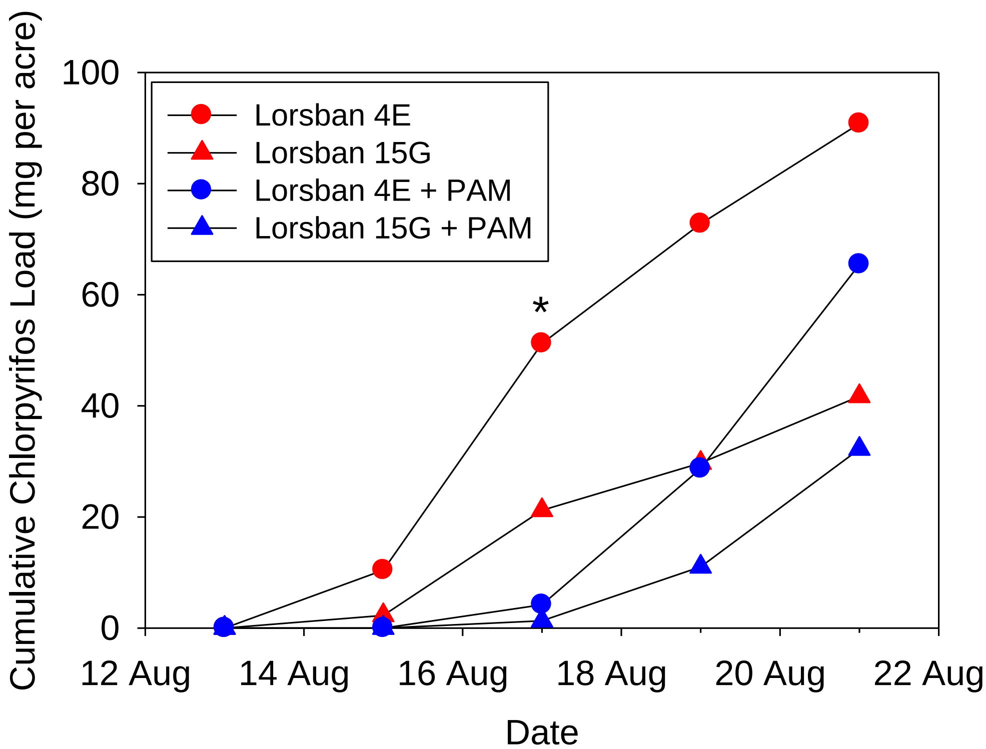

Figure 4. PAM and formulation treatment effects on cumulative load of chlorpyrifos transported in sprinkler run-off from a commercial broccoli field. Treatment means on dates denoted with "*" are statistically different at the $p < 0.10$ confidence level.