REDUCING IMPACT OF DORMANT SPRAYS

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SUMMARY

A multidisciplinary team of scientists is studying the movement of the water soluble insecticide diazinon and the more hydrophobic insecticide esfenvalerate from the orchards to which they are applied during orchard dormancy. Research currently focuses on potential site management practices, sometimes referred to as BMPs to mitigate or reduce runoff, suitability of alternative pest management approaches, and impacts of these practices on EPA indicator and endemic non-target aquatic organisms. Hydrological field models are being developed to predict insecticide runoff, and are based on water flow and concentration as affected by physical, chemical and environmental variables. Potential site management practices and alternative pest management approaches were identified through a literature review, and selected practices are being evaluated for pest control efficacy and non-target impacts. Toxicity of field runoff samples was determined through exposure of the EPA test organisms, fathead minnow, *Pimephales promela*, and the water flea, *Ceriodaphnia dubia*.

This progress report is adapted from one prepared for the CALFED project of Frank Zalom, Michael Oliver, Inge Werner, Wes Wallender and Barry Wilson.

OBJECTIVE

The research focuses on assessing efficacy and impacts of alternatives to dormant season uses of chlorpyrifos and diazinon and practices that can mitigate runoff. This is accomplished through bioassays of target and non-target organisms. The biological objective has required that methodologies be refined to quantify infiltration and runoff, and to collect experimentally controlled runoff water samples.

PROCEDURE

Study sites consist of a primary site where two BMPs, orchard floor cover crops and a pyrethroid insecticide, are being evaluated for reducing the toxicity of stormwater runoff, and several secondary sites where more detailed studies are conducted to develop and refine methodologies and test new alternative practices. Cover crops are believed to enhance water infiltration (Hargrove, 1991), presumably reducing runoff and increasing the movement of OPs into the soil where they are available for degradation by resident microorganisms. Pyrethroid pesticides are more hydrophobic (solubility in water: 0.4 µg/l) than are OP pesticides such as diazinon (solubility in water: 40,000 µg/l). Therefore, runoff of pyrethroids is believed to be minimal. However, esfenvalerate has been shown to be toxic to fish at extremely low concentrations (e.g. Haya, 1989).

The primary study site, monitored since the winter of 1998-99, is a commercial French prune orchard, planted on berms, located near Artois, Glenn Co., CA. Soil type is Tehama silt-loam. Within the orchard, rows 1-8, 21-25, and 38-42 remain unsprayed; rows 9-20 are sprayed with diazinon; and rows 26-37 are sprayed with esfenvalerate. Each spray treatment is overlaid on 4 cover crop treatments; no cover, planted grass cover, planted legume cover and native vegetation. All 4 of these one-row treatments are adjacent to one another forming a complete 'block' of treatments. The complete blocks of 4 rows are replicated 3 times for both pesticides across the orchard. The untreated rows are intended to avoid cross contamination between the diazinon and esfenvalerate treated sections. Pesticides applications are made with an air blast orchard sprayer at a volume of 933 l/ha. Diazinon 4EC (Wilbur-Ellis Co.) is applied at a formulated rate of 3.5 l/ha, and Asana XL® at a rate of 0.71 l/ha. Water runoff samples are collected within these treatments via 2 types of sampling apparatus; in-ground jars, and automated samplers.

Water samples from the simulated rainfall hydrologic experiments were analyzed for diazinon. Samples from natural rain events were analyzed for diazinon and Asana. The water samples were stored frozen, then thawed and pushed through a 0.45 um filter to remove particulates. Pesticides were extracted by liquid-liquid extraction with ethyl acetate, and analyzed by gas chromatography. The detection limits in the water samples were 0.5 ug/L for diazinon and 0.2 ug/L for esfenvalerate.

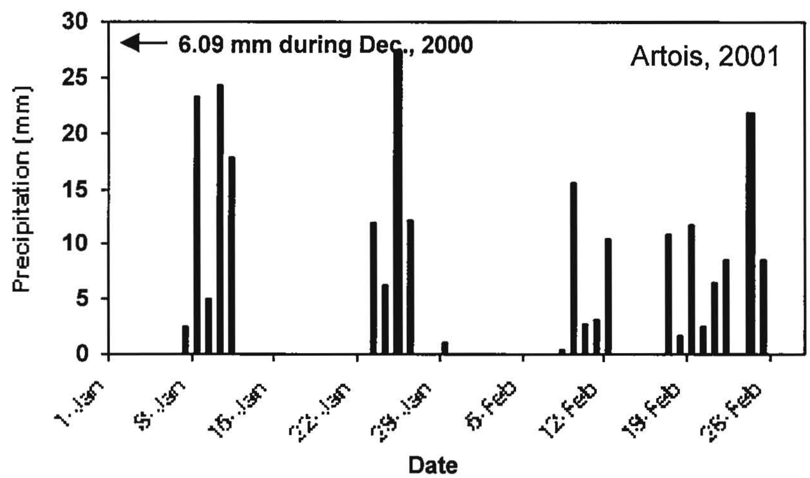
Acute toxicity is tested by exposing larval fathead minnows, larval Sacramento splittails (*Pogonichths macrolepidotus*) and water fleas to the field water samples using the EPA standard static renewal method (EPA-600-4-91-002 7/1994). Water samples are composited from the 3 replicate rows prior to conducting each bioassay. Mortality is recorded after 96 hr for fathead minnow and Sacramento splittail (an endemic species), and after 48 hr for the water flea. Methods follow the quality assurance (QA) plan designed by Connor *et al.* (1993). Duplicate quality assurance samples were included in each series of bioassays. For fathead minnow and Sacramento splittail, the laboratory control water consists of deionized water amended to EPA moderately hard standards. For the water flea, Sierra Springs® water is amended to EPA moderately hard standards. Field collections have been made of other endemic organisms that may serve as alternative bioassay species more reflective of toxicity in California waters.

Measuring water movement in the experimental plots hinges upon the site specific infiltration function, as influenced by BMPs, and utilizes total volume of runoff resulting from one precipitation event as a key to modeling the process by establishing a hydrograph. Total runoff volume is obtained from measurements in stainless steel retention-tanks installed at the downstream end of 5 m^2 plots within the experimental treatment rows defined by parallel metal barriers with their bases driven into the soil. A kinematic wave model is used to simulate surface water runoff. The model incorporates an infiltration function that determines the split between infiltrating water and surface water runoff. A 15 m long rainfall simulator is used together with the retention tanks to gather *in situ* information on hydrologic behavior of additional experimental variables including soil type, and their impact on off-site transport of pesticide in runoff independent of natural rainfall events. The rainfall simulator consists of two parallel PVC pipe booms, an inlet valve and a pressure gauge at the inlet. Nine continuous spray brass nozzles arranged in a diamond pattern dispense water at a mean rate of 3.2 cm/hr. Simulation performance is monitored with an array of 30 catch cans along both sides of the plot.

RESULTS AND CONCLUSION

Runoff data presented are the result of rainfall events (Figure 1) occurring on 23-29 January and 17-25 February, 2001, which followed the insecticide application on 20 January, and are representative of data collected in the autosamplers.

Figure 1. Daily precipitation (in mm) at Artois, CA, during Winter, 2000-01.



It is clear that groundcover affected the amount of runoff. Significantly ($p<0.05$) greater runoff was measured from the bare ground treatment rows than from any of the rows with groundcovers (Table 1), but only for the February event. No significant differences ($p>0.05$) in runoff were observed for the January rainfall event that was monitored. The groundcover presumably increased water penetration for the latter event.

Table 1. Liters of water runoff from rows with different orchard floor ground covers (n=3) and runoff as a percent of bare ground treatment on each sampling date in 2001.

Type of ground cover	Water runoff (l) and % of bare ground treatment on each sampling date					
	Total	1/25	1/26	1/29	2/18	2/20	2/23
Non-tillage clover	46056 (61%)	6137 (81%)	5298 (68%)	359 (143%)	255 a (16%)	1380 a (44%)	1924 a (41%)
Perennial sod mix	52769 (70%)	6528 (87%)	5664 (72%)	202 (80%)	763 a (47%)	1791 a (57%)	2643 a (56%)
Resident vegetation	46668 (62%)	5758 (76%)	5714 (73%)	328 (130%)	389 a (24%)	1466 a (46%)	1908 a (40%)
Bare ground	75474 (100%)	7535 (100%)	7846 (100%)	252 (100%)	1635 b (100%)	3156 b (100%)	4734 b (100%)
LSD$_{0.05}$[1]	NS	NS	NS	NS	730	.1086	1540

[1] Means followed by the same letter are not significantly different by Fisher's Protected LSD at $p<0.05$.

Toxicity data and bioassay results are reported for 2000 by Werner *et al.* (2001). Those data indicated that diazinon concentrations were lower in the composite water samples from rows with any vegetative cover relative to rows with bare ground. Esfenvalerate could not be detected in any samples, while diazinon was detected in all samples even with a minimum of 5 untreated buffer rows between plots indicating that drift, in addition to runoff, is a potential source of insecticides affecting surface water.

Fathead minnow larvae were not killed by runoff from control treatment rows. Water from esfenvalerate treated rows resulted in 93-100% fathead minnow mortality. No significant mortality occurred in the 96 h toxicity tests using Sacramento splittail, an endemic species, indicating a potential for differential effects on alternative bioassay species. All water samples caused water flea mortality within 24 h. The no observed effect concentration (NOEC) and the lowest observed effect concentration (LOEC) of runoff water from diazinon treated rows was 10-40 times more toxic to the test organisms than runoff from esfenvalerate treated rows. Runoff from rows without ground cover were most toxic.

Aquatic toxicity of runoff from a rainstorm last season is summarized in Table 2. Water from the diazinon rows was very toxic to the water flea, but had little effect on the minnow. Conversely, water from the esfenvalerate rows killed almost all the minnows, but was not toxic to the water flea.

Table 2. Acute Toxicity of First Post-Application Rainstorm Runoff Water (1-25-01)

Cover Crop	Water Flea Relative Toxicity[1] (1/LOEC)	Minnow Mortality (%)
Unsprayed - Resident Vegetation	0.2	10.0
Diazinon - Bare Ground	5	20.0
Diazinon - Sod	10	5.0
Diazinon - Resident Vegetation	5	2.5
Diazinon - Clover	10	12.5
Esfenvalerate - Bare Ground	0.125	100.0
Esfenvalerate - Sod	0.125	100.0
Esfenvalerate - Resident Vegetation	0.125	97.5
Esfenvalerate - Clover	0.125	100.0

[1]Relative toxicity shown as the inverse of the Lowest Effective Concentration (LOEC). The LOEC is the lowest dilution of runoff water which produces mortality. The higher the inverse LOEC, the more toxic the sample.

These results present a worst case scenario where water collected in the orchard is directly evaluated for toxicity, and neither hydrological parameters predicting discharge into nearby lakes or rivers nor the effects of dilution from entering the larger water bodies are considered.

Part of the practical significance of this work is the testing and formulation of Best Management Practices for the state of California and meeting head on the concern expressed by US EPA

Counselor for Agricultural Policy Jean-Mari Peltier about the risks of runoff expressed at a keynote talk at the latest Almond Research Conference, December 6, 2001.

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