REDUCING IMPACT OF DORMANT SPRAYS

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SUMMARY

A study was conducted in a Glenn County orchard to measure toxicity of stormwater runoff and the effectiveness of several best management practices (BMPs), such as alternative types of insecticides and different ground cover crops. Asana (esfenvalerate) is a pyrethroid pesticide that binds to soil more than the relatively water soluble organophosphate (OP) pesticide diazinon. Although off-site movement is minimal for Asana it has been shown to be highly toxic to fish at extremely low concentrations (parts per trillion to parts per billion), potentially posing a much higher risk to these organisms than OP pesticides.

Storm runoff was collected during a February 2000 rain event, 4 days after diazinon and Asana were applied to different orchard sections. Bare soil and 3 different cover crops were tested for their effect on runoff and its toxicity to aquatic organisms. Water samples were analyzed chemically for residues.

The presence of cover crops reduced the amount of runoff. The runoff water samples were toxic to larval fathead minnows and water fleas, but not to larval Sacramento splittail. Samples from the esfenvalerate plots were extremely toxic to the minnows, even though esfenvalerate concentrations were below the level detected by chemical analysis.

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

OBJECTIVE

The goal is to develop BMPs to minimize the movement of pesticides from orchards using animals to demonstrate that levels of pesticides can be achieved which are not toxic to non-target species, but still control pest populations. The long-term plan is to compare the efficacy, runoff and toxic impact of two chemicals from two risk groups of the FQPA categories. The OP diazinon (Group 1) and the pyrethroid esfenvalerate (Group 2) were chosen as representative chemicals. Both are neurotoxins, but with differing toxicities and major mechanisms of action.

PROCEDURE

Almond Board of California sponsored research was incorporated into a large CALFED sponsored field study conducted in Glenn County on 42 rows of a French prune orchard to measure toxicity of stormwater runoff as well as the effectiveness of some best management practices (BMPs). Rows 1-8, 21-25, and 38-42 were unsprayed; rows 9-20 were sprayed with diazinon; and rows 26-37 were sprayed with Asana. Each spray treatment was made on 4 cover crop types: bare ground, perennial sod mix, non-tillage clover, and resident vegetation. Each cover crop was placed in adjacent single rows to form a 4 row block. These 4 row blocks were replicated three times within each spray treatment. A break of untreated rows was provided half way across the orchard to avoid cross contamination between the diazinon and Asana treated sections. The orchard was sprayed with a volume of 100 gallons per acre. Diazinon 4EC was applied at a concentration of 3 pints per 100 gallons and Asana XL was applied at 9.8 oz. per 100 gallons.

The hydrologic behavior of the cover crops in the orchard (soil is Tehema silt-loam) and their impact on off-site transport of pesticide in surface water runoff was studied using a plot retention-tank technique in conjunction with a large (15m long) rainfall simulator. This was carried out in the diazinon treated plot. The rainfall simulator consisted of two parallel PVC pipe booms of 15 m length, an inlet valve and a pressure gauge at the inlet. Nine continuous spray brass nozzles arranged in a diamond pattern dispensed water at a mean rate of 3.20 cm/hr. The performance of the simulation was monitored with an array of 30 catch cans along both sides of the plot. The total volume of runoff was obtained from measurements in stainless steel retention-tanks installed at the downstream-end of the plots and is used in a kinematic wave computer model to simulate surface water runoff. The approach hinged upon the site specific infiltration function, as influenced by BMPs, and utilized the total volume of runoff as a key to modeling the process.

Water runoff samples from natural rain events were collected via 2 distinct sets of sampling apparatus: in-ground jars and automated samplers. All of the water samples generated were analyzed chemically and several composite samples have been analyzed by toxicity tests.

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.

Toxicity tests of aquatic species were conducted on composited field jars from 3 replicate rows of each treatment. Acute toxicity was tested by exposing larval fathead minnows (*Pimephales promelas*), larval Sacramento splittail (*Pogonichthys macrolepidotus*), and water flea (*Ceriodaphnia dubia*) to the field water samples using standard U.S. EPA methods. Mortality was recorded after 96 hours for fathead minnows and Sacramento splittail, and after 48 hours for water flea.

Hydrology experiments were carried out by Till Angerman, Dr. Wallender's graduate student. Field collections were made by Tom Kimball, Mike Oliver, and Bill Krueger. Chemical analysis was done by Georgino Oliveira and Jack Henderson in Dr. Wilson's group. Aquatic toxicology was done by Linda Deanovic and Inge Werner in Dr. Hinton's lab group.

RESULTS AND CONCLUSION

Empirical hydrographs from all four treatments are shown in Figure 1. First flushes were conducted on the orchard floor long after the last flood irrigation at a volumetric moisture content of 27-30%. At this time, the soil showed shrinkage cracks most noticeably on bare ground. Second flushes were conducted 24 hours after first flushes with moisture contents of approximately 33%.

Figure 1 shows in a quantitative manner the intuitively anticipated fact that a rain event on dryer ground needs more time before ponding and subsequent runoff occurs, and that peak discharge is lower than during a second rain event of equal intensity (perennial sod-mix, bare ground). Perennial sod mix retained much more water during the first flush than bare ground as indicated by the retarded onset of discharge and its lower peak flow. However, during the second flush it performed very similar to bare ground, which may be due to the development of smooth channels between the disked-in sod (4-inch spacing). Resident vegetation showed a peak flow higher during the first flush than during the second flush due to a higher water application rate during the first flush. Pressure fluctuations in the water supply lines were responsible for variations in application rates. The outcome of the experiments was particularly sensitive to these application variations in the vicinity of peak flow. Measures have been taken to correct this situation by installing an auxiliary supply line in later experiments. Equipment failure resulted in premature termination of the non-tillage clover experiment. Consequently, this experiment could not be modeled, but the second flush gave information about the onset of discharge, which is significantly later than for all other treatments.

The results of these hydrological experiments, along with ongoing experiments done at UC Davis, are being used to construct a computer model of orchard runoff. Verification of this model will allow measurements from simpler experiments in other orchards to be used to predict the extent of surface runoff.

The results of the aquatic toxicology tests are summarized in Table 1.

Fathead minnow toxicity: Control treatments did not cause mortality of fathead minnow larvae. Orchard runoff samples were highly toxic when collected in orchard sections treated with Asana, causing 93-100% mortality of test organisms within 96 hours of exposure. Significant mortality (25-26.8%) also occurred in water samples from diazinon treated rows with resident vegetation, and in samples from unsprayed rows with resident vegetation. Of interest was the presence of diazinon in the untreated sections of the orchard; presumably from spray drift.

Mortality of water flea (*C. dubia*): All water samples tested caused 100% mortality of the test organisms within 24 hours of the 48-hour tests. Subsequently, water samples were tested in dilutions of 50%, 25%, 12.5% etc. to determine the lowest observed effect concentrations (LOEC) using significant mortality as test endpoint. The smaller the LOEC number, the more toxic the sample. Runoff from rows treated with diazinon was 10-40 times more toxic to the test organisms than runoff from the Asana treated orchard sections. Rows without groundcover vegetation were most toxic.

Mortality of Sacramento Splittail: No significant mortality occurred in the 96 hour toxicity tests using Sacramento splittail.

Table 2 shows results of our laboratory tests to determine LC_{50} concentrations for test organisms when exposed to diazinon and Asana. Fathead minnows were more sensitive to esfenvalerate than splittail, which could explain the difference in response seen in our toxicity tests. Additionally, LC_{50} values were very close to our detection limit of 0.2 µg/L Asana. This may explain why the samples from Asana treatments caused mortality, though the chemical wasn't detected. Asana is known to be toxic at concentrations below the detection limit of our instruments. The results show that surface runoff from an Asana treated orchard may have less pesticide than that from a diazinon treated orchard, but still constitute an environmental risk due to its high toxicity to fish.

Table 1. Aquatic Toxicity Results

Field Treatment	Fathead Minnow (% Mortality)	Waterflea (LOEC)	Sacramento Splittail (% Mortality)	Diazinon concentration (µg/L)	Esfenvalerate concentration (µg/L)
Laboratory Control	0		2.5		
Unsprayed Res Veg	25.0	2.5	3.3	15.6	nd
Diazinon Bare	2.5	0.125	2.5	210.4	nd
Diazinon Sod	7.5	0.25	5.0	135.9	nd
Diazinon Res Veg	26.8	0.25	2.5	155.2	nd
Diazinon Clover	5.0	0.25	2.5	118.2	nd
Esfenvalerate Bare	100.0	5	0.0	3.6	nd
Esfenvalerate Sod	100.0	5	10.0	6.3	nd
Esfenvalerate Res Veg	97.8	2.5		3.9	nd
Esfenvalerate Clover	93.0	10	2.5	2.9	nd

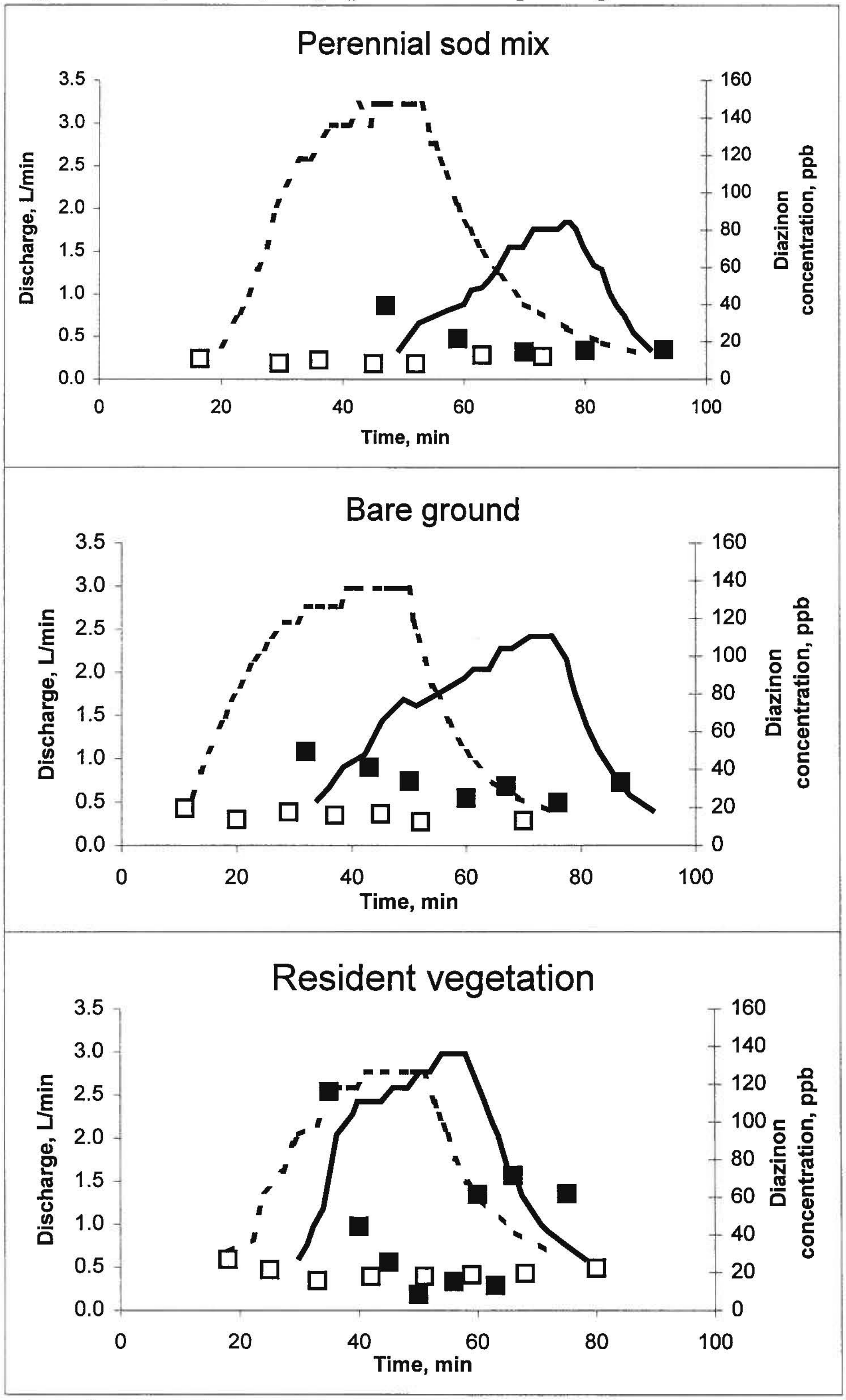
LOEC = lowest observed effect concentration
nd = not detected

Table 2. LC_{50} Values of Diazinon and Esfenvalerate in Aquatic Test Species

Species	Toxicity (96h-LC_{50}) Diazinon	Esfenvalerate
Waterflea	0.4 µg/L	0.28 µg/L
Fathead Minnow	6000 µg/L	0.25 µg/L*
Splittail	7500 µg/L	0.50 µg/L*

* These LC_{50} values are for adult fish (7 days or older).
Larval fish are less sensitive to esfenvalerate.

Figure 1. Empirical Hydrographs and Corresponding Diazinon Concentrations



First Flush: Discharge = Solid Line; Diazinon = Solid Square
Second Flush: Discharge = Dashed Line; Diazinon = Open Squares