Simazine Runoff Losses from A Cover Cropped Citrus Orchard

Final Report for Contract 01-0153C
Submitted to
The California Department of Pesticide Regulation

June 30, 2002

by

Neil O'Connell, Farm Advisor
Tulare County
Visalia, CA

Fuhan Liu, Postgraduate Researcher
Kearney Agricultural Center
University of California
Parlier, CA

California Environmental Protection Agency
Department of Pesticide Regulation
Environmental Monitoring Branch
Environmental Hazards Assessment Program
1001 I Street, Sacramento, California 95812-4015

EH 02-11

INTRODUCTION

Preemergent herbicide losses via runoff in California are a potential source for groundwater contamination (Braden and Uchtmann, 1985; Leonard, 1990). One mechanism of preemergent herbicide movement to ground water is through leaching from soil profile to a groundwater aquifer (Wehtje et al. 1984; Freeze and Cherry, 1979). Recharge may result from both natural rainfall and irrigation (Bouwer, 1987). Another mechanism involved in pesticide movement to groundwater is surface runoff from soils characterized by the presence of hardpan soils (Braun and Hawkins, 1991; Traoiano et al., 1997). In many of the hard pan soil areas, herbicide-containing runoff enters dry wells or other drainage structures, subsequently moving directly to deeper, more permeable subsurface regions below shallow hard pan layers. Surface water resources which receive drainage from intensively farmed agricultural production areas are likely to contain higher levels of pesticides, particularly at times related to recent use of pesticide (Barker and Mickelson, 1994; Goolsby et al., 1993). Larger amount of winter rain (November to March) occur in the Southern San Joaquin Valley of California, which is believed to be associated with pesticide contamination of receiving waters (Lee, 1983; Pickett et al., 1990). Concentrations of simazine, diuron, and bromacil ranging up to 1.1 mg L^{-1} have been detected in rain-runoff water entering dry wells in and around citrus orchards in Tulare County of California (Braun and Hawkins, 1991).

Preemergent herbicides are usually surface-applied in commercial citrus in California. Citrus orchards account for approximately 75 percent of the use of preemergent herbicides in the hardpan soil areas of Fresno and Tulare Counties (Spurlock et al., 1997). Citrus growers favor bare soil conditions in winter to enhance frost protection. Bare citrus orchard middles are often highly compacted with low infiltration rates. As a result, heavy rainfall events following herbicide applications can produce preemergent residue offsite movement via surface runoff. One method of reducing herbicide runoff losses at the soil surface is to incorporate herbicides into soil matrix by tillage, irrigation, or rainfall. Surface-applied preemergent herbicides should be incorporated into soil matrix within days after application to be effective (Ashton et al., 1989). The maximum incorporation time was determined by several factors such as temperature, weather condition, and persistence of the herbicides. A survey showed that 91% of citrus growers rely on rainfall to incorporate preemergent herbicides into the soil in the San Joaquin Valley of California (unpublished data). However, a previous study indicated that rainfall was a poor incorporation method for preemergence herbicides in pan or compacted soils with low infiltration, regardless of the choice of herbicides (Spurlock et al. 1997). In experimental plots, mechanical incorporation, down to 76 mm via a rototiller, was effective in mitigating herbicide (simazine) runoff losses from middles of citrus orchards. Total simazine mass removed in runoff from two simulated runoff events was estimated at 6.0% of the amount applied to row middles in undisturbed plots compared to only 0.8% in mechanically disturbed middles (Troiano and Garretson, 1998). However, many citrus growers are reluctant to disturb soil in orchard middles therefore additional alternatives for mitigating herbicide movement off-site from citrus orchard middles would be desireable. Our objective in this study was to evaluate the effects of cover crop on simazine losses in runoff that resulted from winter rainfall in commercial citrus growing conditions. Simazine was the representative preemergence herbicide studied because it is one of the most widely detected herbicides in ground water of citrus producing areas in Tulare and Fresno counties. Selected simazine characteristics are summarized (Table 1).

MATERIALS AND METHODS

Site Description

This study was conducted in a citrus grove, on a 5.5 m x 6.1 m tree spacing, located in a runoff prone soil in Tulare County of California according to the statistical clustering/profiling method of Troiano et al. (1994, 1997). Soil at the study site was mapped as a San Joaquin loam (Fine, mixed, thermic, Abruptic Dulixeralfs) (USDA-SCS, 1971). Slope at the site was about 1 - 3 %. The infiltration rate of the row middles was measured on site using cylinder infiltrometer as described by Bouwer (1986) (Fig. 1). Average bulk density of the surface 5 cm of soil from the row middles (n = 10) was 1.76 Mg m^{-1} and from the adjacent furrows was 1.34 Mg m^{-1} (Table 2) (Blake and Hartge, 1986). High bulk density and low infiltration rate of the row middles supported field observations of compaction, a common condition in orchards where soil is kept barren due to herbicide use and is subjected to vehicular traffic (Meek et al., 1992).

Plot Preparation and Treatment Applications

A cover crop was planted in the row middles on November 15, 2001. Treatments included cover crop over 100% of the area in every row middle (**T1**), cover crop over 20% of the middle alternating with 100% of the area in middles (**T2-20%**) and cover crop over 100% of the middles alternating with 20% of the middles (**T2 -100%**), and a control with no cover crop (**T3**). Plot size was 1 middle wide and 10 trees long with 5.5 m x 6.1 m tree spacing. None of the plots (T1, T2, T3) received a preemergence herbicide application. Experimental design was a randomized complete block with 4 replications. Simazine was applied on November 16, 2002 at the rate of 2.2 kg ai ha^{-1}.

Soil berms were built across the up-slope end and sides of each plot to contain runoff. Runoff was collected at the down-slope of each plot through a PVC pipe placed into containers situated in pits excavated into the furrow. The collection container is 25-liter equipped with a battery powered submersible pump (3875 Liter per hour). When runoff water in the collection container fills to the level of the float switch, the pump is activated and water flows out through the flow meter. Flow is then divided into discharge (94% of total volume) and composite sample (6% of total volume) collected in a secondary container. The flow is divided by using a T connector with two different diameter sizes of hose (Fig. 2). Wire mesh was placed over the collection end of the pipe to screen out large objects such as leaves. Measured runoff volumes were listed in Table 3. The amount of rainfall related to each runoff event was obtained from a rain gauge installed at the study site (Table 3).

Soil and Runoff Water Sampling

Six background soil samples before simazine application were collected: each sample was a composite of 10 subsamples -5 taken from the row middle and 5 taken from the furrows within the plot. Each subsample was taken to 5 cm depth. Soil samples were stored frozen for a period of no longer than 16 weeks based on a simazine storage stability study. Average simazine content was 77 ug kg^{-1} from the 6 background soil samples.

One runoff sample was collected in a 1-L amber glass bottle per plot per runoff for simazine determination from the secondary container during agitation (Fig. 2). Water samples were immediately refrigerated at 4^0 C until analyzed.

Chemical Analysis / Quality Control

Samples were analyzed for simazine by California Food and Agriculture Analytical Chemistry Laboratory (CDFA) in Sacramento using the ELISA immuno-assay method; the detection limit in soil is 15 ug kg^{-1} , while that for water is 0.5 ug L^{-1}. Results obtained from ELISA have been demonstrated to be equivalent to results obtained using gas chromatography

(Goh et al., 1991; Goh et al., 1993). The soil ELISA QA/QC procedures consisted of a matrix blank plus two matrix spikes to be included with each extraction set.

Air Temperature Measurement in Citrus Orchard

One temperature HOBO with two sensors was installed in each plot for treatment T1 (cover crop in the tree middles) and treatment T3 (no cover crop in the tree middles) from November 2001 to March 2002. One sensor was set up at 0.5 feet from the ground and one sensor was set up 6 feet from the ground. Temperature was recorded every 30 minutes. Temperature data were downloaded into computer once a month.

RESULTS AND DISCUSSION

Effects of Cover Crop on Runoff Volumes

For the three runoff events, plots with cover crop growing in the row middles reduced runoff volume, since cover crop increased the amount of water infiltrated into the soil and acted as barrier for runoff. Average runoff volumes measured from plots with cover crop growing in the row middles ranged from 35% to 48% of the total amount of rainfall for treatment T1, ranged from 36% to 40% of the total rainfall for treatment T2-100% and ranged from 40% to 53% of the total rainfall for treatment T2-20% compared to from 63% to 65% of the total amount of rainfall measured from plots without cover crop in the row middles (treatment T3) (Table 3). Low infiltration rates in undisturbed and bare row middles resulted in significant runoff. These data indicated that the cover crop growing in the row middles was effective in reducing field runoff volume.

Cover Crop on Simazine Runoff Losses

The first runoff occurred 35 days after the simazine application following 14.2 mm of rainfall (Table 3). In plots without cover crop, the first runoff event following simazine application produced high concentrations at 31.8 μg L^{-1}; then concentrations decreased rapidly with subsequent rainfall events (Table 4). In plots with cover crop, simazine concentrations in runoff ranged from 11.0 to 14.0 μg L^{-1} from the first runoff event; simazine concentrations from the second and the third runoff events ranged from 7.7 to 11.8 μg L^{-1} (Table 4). The cover crop reduced simazine concentration in runoff for the first runoff event by a factor of 3.

Average simazine recoveries in runoff from plots without cover crop were 1.30, 0.58 and 0.71 g ha^{-1} respectively for the three runoff events; simazine mass recoveries from plots with cover crop were estimated at 0.34, 0.28, and 0.31 g ha^{-1} respectively for the three runoff events (Table 4). Simazine mass losses in runoff from plots without cover crop were much higher than those from plots with cover crop.

Cover Crop Effects on Air Temperature

Air temperature data showed that no significant difference was found between plots with cover crop growing in the tree middles and plots without cover crop (data not showed). It indicated that cover crop growing in the tree middles has no significant effects on temperature during the winter time.

REFERENCES

Baker J.L., and S.K. Mickelson. 1994. Application technology and best management practices for minimizing herbicide runoff. Weed Technology, 8:862-869.

Blake, G.R., and K.H. Hartge. 1986. Bulk Density. P. 367-375. *In* A. Klute (ed) Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods-Agronomy Monograph no. 9 (2^{nd} Edition), American Agronomy Society-Soil Science Society of America, Madison, WI.

Bouwer, H. 1986. Intake rate: Cylinder infiltrometer. In A. Klute, ed. Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods-Agronomy Monograph no. 9 (2nd Edition), American Agronomy Society-Soil Science Society of America, Madison, WI.

Bouwer, H. 1987. Effect of irrigated agriculture on groundwater. J. of Irri. and Drain. Eng. 113:4–15.

Braden, J. B., and D. L. Uchtmann. 1985. Agricultural nonpoint pollution control: An Assessment. J. Soil Water Conserv. 40:23-26.

Braun, A.L. and L.S. Hawkins. 1991. Presence of Bromacil, Diuron, and Simazine in Surface Water Runoff From Agricultural Fields and Non-Crop Sites in Tulare County, California. report PM91-1. Environmental Monitoring and Pest Management Branch, California Department of Pesticide Regulation.

Freeze, R.A., and J.A. Cherry. 1979. Groundwater. Prentice–Hall, Inc. Englewood Cliffs, N.J.

Goh, K.S., J. Hernandez, S.J. Powell, C. Garretson, J. Troiano. M. Rany, and D.D. Greene. 1991. Enzyme immunoassay for the determination of atrazine residues in soil. Bull. Environ. Cont. Toxicol. 46:30-36.

Goh, K.S., D.J.Weaver, J. Hsu, S.J. Richman, D. Tran, and T.A. Barry. 1993. ELISA regulatory application: compliance monitoring of simazine and atrazine in California soils. Bull. Environ. Cont. Toxicol. 51:333-340.

Goolsby, D.A., W.A. Battaglin, and E.M. Thurman. 1993. Occurrence and transport of agricultural chemicals in the Mississippi River basin, July through August 1993. U.S.G.S. Circular 1120-c. 22p.

Lee, M. 1983. Aldicarb contamination of groundwater in Del Norte County. Internal Memo Sep. 21, 1983. PMAP program, California Department of Food and agriculture, Sacramento, CA.

Leonard, R. A. 1990. Movement of pesticides into surface waters. *In* H.H. Chen(ed.) Pesticides in the soil environment: Processes, impacts, and modeling. P. 303-349. Soil Sci. Soc. Amer. Book Series No 2. Soil Sci. Amer. Madison, WI.

Meek, B.D., E.R. Rechel, L.M. Carter, and W.R. DeTar. 1992. Bulk density of a sandy loam: traffic, tillage, and irrigation-method effects. Soil Sci. Soc.Am.J. 56:562-565.

Pickett, C.H., L.S. Hawkins, J.E. Pehrson, and N.V. O'Connell. 1990. Herbicide use in citrus production and groundwater contamination in Tulare county. California Department of Food and Agriculture, Sacramento, CA 95814.

USDA-Soil Conservation Service. 1971. Soil survey: Eastern Fresno Area, California. United States Department of Agriculture in Cooperation California Agricultural Experiment Station, Superintendent of Documents, Washington, D.C. : US Government Printing Office.

Spurlock, F., C. Garretson, and J. Troiano. 1997. Runoff from Citrus Orchard Middles: Comparison of Three Herbicides and Effect of Organosilicon Surfactant. Report EH 97-02, EHAP, Calif. Dept. of Pesticide Regulation.

Troiano, J., B. Johnson, S. Powell, and S. Schoenig. 1994. Use of cluster and principal component analyses to profile areas in California where ground water has been contaminated by pesticides in California. Environ. Monitor. Assess. 32:269-288.

Troiano, J., C. Nordmark, T. Barry, and B. Johnson. 1997. Profiling areas of Ground Water Contamination by Pesticides in California: Phase 11 - Evaluation and Modification of a Statistical Model. Environ. Monitor. Assess. 45:301-318.

Troiano, J. and C. Garretson. 1998. Movement of Simazine in Runoff Water from Citrus Orchard Row Middles as Affected by Mechanical Incorporation. J. Environ. Qual. 28: 488-494.

Wehtje, G., L.N. Mielke, J.R.C. Leavitt, and J.S. Schepers. 1984. Leaching of atrazine in the root zone of an alluvial soil in Nebraska. J. Environ. Qual. 13:507–513.

Table 1. Selected simazine characteristics †.

Molecular formula:	$C_7H_{12}ClN_5$
$T_{1/2}$:	21 days on a sandy loam at 25^0 C under natural light; 91 days for aerobic microbial metabolism in a sandy loam at 25^0 C; 70 -77 days for anaerobic microbial metabolism in a sandy loam at 25^0 C.
Vapor pressure:	9.2 x 10^{-10} mm Hg at 10^0 C, 6.1 x 10^{-9} mm Hg at 20^0 C, 2.2 x 10^{-2} mm Hg at 25^0 C.
Stability:	Decomposed by UV light; Slowly hydrolyzed at natural pH and 70^{0}C, but hydrolysis rate increases at higher or lower pH.
Solubility:	3.5 mg L^{-1} at 20^0 C, 6.2 mg L^{-1} at 22^0 C.
PK_a:	1.62
K_{oc}:	130 mL g^{-1}.

† Weed Science Society of American, 1994. William Ahrens (Ed) , 7th edition. Herbicide handbook. Champaign, Illinois 61821

Table 2. Bulk density of the surface 5 cm of soil from the row middles and furrows.

	Study Site	
Replication	Middle	Furrow
1	1.82	1.40
2	1.72	1.30
3	1.83	1.32
4	1.76	1.37
5	1.71	1.29
6	1.73	1.34
7	1.77	1.31
8	1.71	1.38
9	1.80	1.36
10	1.74	1.28
Mean ± SD	1.76 ± 0.04	1.34 ± 0.04

Table 3. The amount of rainfall and measured runoff volumes.

Events	Treatment			
	T1	T2-100%	T2-20%	T3
First Runoff Event (35 days after simazine application, 36 days after cover crop plating)				
Rainfall (mm)	14.2	14.2	14.2	14.2
Runoff (mm)	6.8	7.0	7.5	9.0
Second Runoff Event ((45 days after simazine application, 46 days after cover crop plating)				
Rainfall (mm)	17.3	17.3	17.3	17.3
Runoff (mm)	6.5	6.9	7.5	11.3
Third Runoff Event (48 days after simazine application, 49 days after cover crop planting)				
Rainfall (mm)	16.7	16.7	16.7	16.7
Runoff (mm)	5.8	6.0	6.7	10.8

Table 4. Simazine concentration and mass losses in runoff during winter rain with and without cover crops.

Events	Treatment			
	T1	T2-100%	T2-20%	T3
First Runoff Event (35 days after application)				
Simazine Concentration in Runoff (µg L^{-1})	11.0	10.1	14.0	31.8
Simazine Mass Losses in Runoff (g ha^{-1})	0.34	0.32	0.48	1.30
Second Runoff Event (45 days after application)				
Simazine Concentration in runoff (µg L^{-1})	7.8	9.0	8.5	11.2
Simazine Mass Losses in runoff (g ha^{-1})	0.28	0.27	0.29	0.58
Third Runoff Event (48 days after application)				
Simazine Concentration in Runoff ((µg L^{-1})	11.8	8.9	7.7	14.4
Simazine Mass Losses in Runoff (g ha^{-1})	0.31	0.24	0.24	0.71

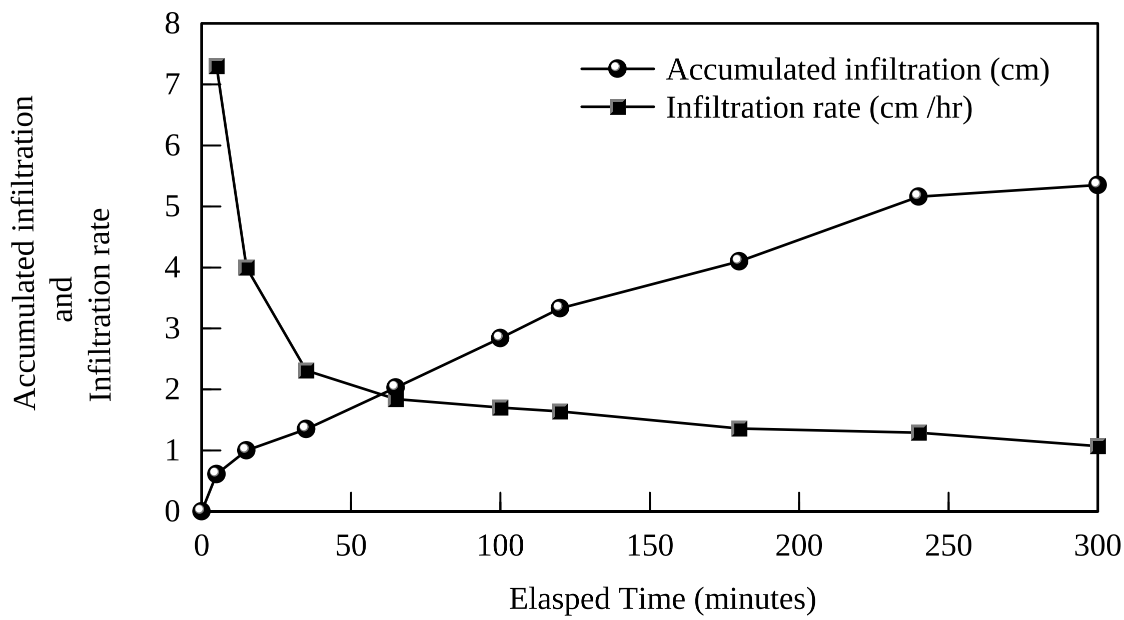

Fig. 1. Averaged soil infiltration rate (n = 6) measured on site using cylinder infiltrometer.

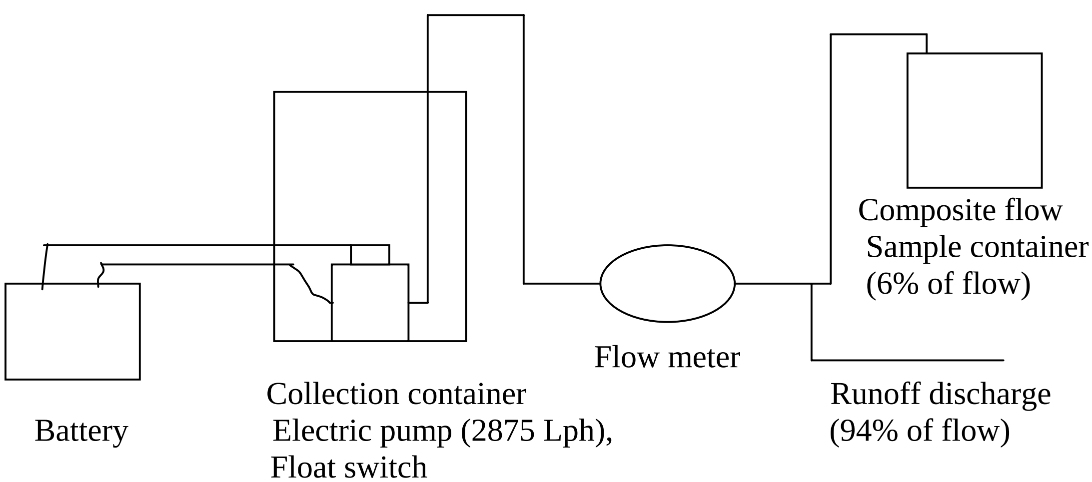

Fig. 2. The diagram of runoff collection and sampling.