California Environmental Protection Agency
Department of Pesticide Regulation
P.O. Box 4015
Sacramento, CA 95812-4015

Protocol to Demonstrate the Effectiveness of Chemigation of Pre-emergence Herbicides through Low-Volume Irrigation Systems

Study 221

December 17,2003

I. Introduction

Chemigation is the application of agricultural chemicals through irrigation systems. It is increasing in popularity because of an increase in the adoption of pressurized irrigation systems. Some advantages and disadvantages of chemigation are:

- Advantages of chemigation:
    - Application of chemicals from a stationary source.
        - Increased flexibility in the timing of chemical applications.
        - Reduced soil compaction from vehicle traffic.
        - Potential reduction in fuel and labor costs.
        - Reduction in operation hazards.
    - Greater control over the deposition of pesticide residues to intended sites of activity.
        - Decreased chance for offsite movement of pesticide residues, especially when injected into low flow, pressurized systems.
        - Enhanced efficacy of pesticide applications. For example, with pre-emergent herbicides irrigation water both incorporates the herbicide and stimulates weed seeds to germinate precisely when the herbicide is present.
        - Potential for application of smaller amounts of chemicals but in more frequent applications.
- Potential disadvantages:
    - Chemical uniformity of application is limited by the irrigation system design and operational realities.
    - Over watering can result in deep percolation of residues.

The California Department of Pesticide Regulation is proposing mitigation measures to prevent further contamination of ground water. A summary of the changes is available at http://www.cdpr.ca.gov/docs/empm/gwp_prog/gwp_prog.htm. The proposed regulations will allow continued used of ground water contaminants but a permit for use will be required. The permit will specify management practices based on predominant soils of vulnerable areas (Troiano et al., 2000). Two pathways of pesticide movement to ground water have been determined. In coarse, permeable soils residues leach with water during normal percolation processes and in less permeable soils with a hardpan layer residues are moved offsite in runoff water to sensitive sites (Braun and Hawkins, 1991).

Vulnerable areas will be listed as ground water protection areas (GWPAs) and they will be classified as susceptible to either the leaching or runoff pathway to ground water contamination. Recommended management practices for each pathway have been developed based on studies conducted in small plots. For example, in areas of low rainfall and for coarse soils where pesticides leach to ground water, management of percolating water produced as a result of irrigation has been shown to be effective in maintaining residues in the upper surface layers (Troiano et al., 1993). In contrast, for soils with low permeability, use of mechanical incorporation instead of rainfall is an effective method to decrease offsite movement of pre-emergence residues (Troiano and Garretson, 1998).

Chemigation is a potential mitigation measure for both leaching and runoff GWPAs. However, pesticide labels must either contain directions for chemigation or they must contain the statement 'Do not apply through an irrigation system'. Most of the pre-emergence herbicide residues detected in ground water are not labeled in California for application through low-volume irrigation systems. The application of herbicides through low-volume systems is not a novel procedure as evidenced by a number of studies on the soil movement and efficacy of herbicides applied through low-volume irrigation systems (Del Amor et al., 1981; Gerstl and Albasel, 1984; Gerstl and Yaron, 1983; Ogg, 1986).

The objectives of this study are to develop data on the effectiveness of chemigation and to demonstrate the application of pre-emergence herbicides through low-volume irrigation systems. Irrigation systems of cooperating growers will be evaluated and renovated as required for chemigation. For example, backflow prevention devices will need to be installed if they are not present. DPR is inviting participation from registrants of ground water contaminants with respect to technical expertise on the products to be applied through the system. Since the pesticides of interest are not labeled for chemigation through low volume systems, their support is also requested in order to obtain a research authorization. It is anticipated that the data generated from the study will be useful in pursuing a label amendment to add chemigation, thereby, providing another mitigation measure for use of pesticides in ground water protection areas. DPR has contracted with the Center for Irrigation Technology at the California State University, Fresno to provide expertise in renovation, implementation, and management of the irrigation systems of the cooperating growers.

An important aspect of the study is to develop data demonstrating the effectiveness of chemigation. A proven method of change in the agricultural sector is to introduce the practice to a small segment of growers and test them for effectiveness on their property. Demonstrations are then conducted focusing on the grower's experience with the adoption of the practice. During the testing of the practice, environmental samples will be taken to demonstrate the effectiveness of the management practice. Observations on plant growth will be made to assure that the practice does not adversely affect plant health, and observations on economic costs will be made to determine potential benefits or costs of adopt the practice.

II. Study Objective

The objective of the study is to develop data on the adoption of chemigation as a management practice for mitigation of pesticide movement to ground water. Data will be collected on the effectiveness of the practice to mitigate contamination, on the effectiveness of the pesticide under the new management practice, and on potential economic impacts.

III. Personnel

Study personnel from the Environmental Monitoring Branch of DPR include:

Project Leader:	John Troiano
Field Coordinator:	Alfredo DaSilva
Senior Scientist:	Bruce Johnson
Laboratory Laison:	Carissa Ganapathy for analyses conducted by CDFA laboratory
	Cindy Garretson for analyses conducted by Fresno Staff
Agency/Public Contact:	Mark Pepple

Questions concerning this monitoring program should be directed to Mark Pepple at (916) 324-4086, e-mail mpepple@cdpr.ca.gov, and FAX (916) 324-4088.

IV. Study Design

Monitoring Chemigation Applications: Chemigation is a mitigation that should be appropriate for coarse soils where leaching is the predominant method for offsite movement of residues and for harpan layered soils where runoff is the predominant method for offsite movement of residues. The studies will be situated in ground water protection areas so cooperating growers will enlisted from these areas. Observations will be taken on the specific soil at each site with chemigation parameters based on the infiltration and water holding capacity of the soil at each site. Pre-emergence herbicides will be metered into the irrigation system most likely through a slow electrical injection pump system. The target concentration in the irrigation water and runtime of the irrigation system will be based on the area covered by the irrigation emitters and the desired soil concentration. Water from the emitters will be sampled to determine actual concentration in the irrigation water as compared to the calculated concentration. The uniformity of the irrigation system will be determined and used to estimate the uniformity of the chemical application. Uniformity will be measured by spacing catch cans in a grid along the spray path of an emitter and measuring the amount of water captured in each catch can over a specified period of time. The uniformity will be measured for a number of emitters.

Herbicide Residues in Soil and Water Samples: Most pre-emergence applications occur in the fall and early winter to control winter weed growth so the study will be targeted for the fall of 2003 through spring of 2004. First, the irrigation system of the cooperating grower will be evaluated and renovated as required for chemigation. Soil will be sampled prior to chemigation applications to determine the background concentration of pre-emergence herbicides. The application of simazine and diuron is the predominant combination used in Fresno and Tulare Counties in California. It is anticipated that the application of a combination of appropriate products for these two

active ingredients will be investigated. For studies conducted on hardpan soils where runoff condition is prevalent, chemigation will be studied as a method to provide better incorporation of residues into soil and with a reduction in residues present in runoff water. For studies conducted on coarse soils, runoff water is not expected so the location of residues in the soil profile with respect to leaching will be studied.

Background concentrations of herbicides in soil from previous applications will be determined from soil samples obtained prior to chemigation applications. Samples will be obtained to the 60-inch depth where the first two soil segments will be taken at 3-inch intervals, the next 3 segments in 6-inch intervals, and the next 3 in 12-inch increments. Soil will also be sampled after chemigation application down to the 18-inch depth where the first two soil segments will be taken at 3-inch intervals and the remainder at 6-inch intervals. A shallow core will be taken after the chemigation application to ensure the placement of the residues in the first few inches of soil. Then in order to follow potential for subsequent leaching, soil will be sampled at 1 and 4 months after application. Soil sampling depths will be the same as for the background soil samples.

At each sampling interval, five cores will be sampled at each site. Each core will be a composite of three samples taken on a transect that crosses the treeline. Runoff water when generated from winter rainfall or irrigation events will also be sampled to determine the potential concentration of residues. Table 1 contains an approximate timeline for the sampling schedule, media sampled, and number of samples taken.

DPR has established SOPs for soil and water sampling and the following SOPs will be followed:

Soil:

SOP FSSO002.00 for soil sampling, including auger and surface soil procedures (Garretson 1999).
SOP FSSO001.00 for soil bulk density determination (Garretson 1999).
SOP METH001.00 for soil water content (Garretson 1999).

Water:

SOP FSWA008.00 for Sampling for Surface Water Runoff in Agricultural Fields (Spurlock 1999).

Table 1. Approximate sampling schedule, media sampled and number of samples.

Date	Type	Purpose	Samples per Replicate[a]	Replicates per Site	Number of Sites	Total
November 2003	Soil	Background Soil	8	3	3	72
November/December 2003	Water	During Application	2	5	3	30
November/December 2003	Soil	After Application	4	4	3	48
December 2003-April 2004	Runoff	Rain Event Runoff	5	5	3	75
January/February 2004	Soil	1 Month Sample	8	3	3	72
March/Arpil 2004	Soil	4 Month Sample	8	3	3	72

[a] For soil cores, the samples per replicate is the number of samples taken per soil core. For application, the samples will be taken from a sprinkler emitter.

Efficacy: It is anticipated that the cooperators will be citrus, deciduous, or grape growers. The prevalent practice for these growers is to adhere to an annual application of pre-emergence herbicides that results in a clean orchard floor and low weed seed populations. Thus, efficacy concerns will focus on determining if the chemigation applications provide a continued clean orchard floor. Plots will be maintained where no herbicide is applied and they will act a control plot to determine the effect of no treatment on potential weed growth. In addition, there are instances where breakthrough may have occurred from the previous application. In this case, the weeds will be burned back with a contact herbicide such as roundup and potential for breakthough will be monitored for the chemigation treatments.

The level of weed control will be monitored in randomly chosen plots throughout the sites. Weed control will be determined through graphical estimation of the amount of weed growth in each plot. Digital pictures taken from each monitored plot will provide digital measures of the amount of plant growth and these values will be used to test for treatment differences.

V. Chemical Analysis and Quality Control

Water Samples: The CDFA laboratory has developed analytical methods for analysis of simazine and diruon in soil and water samples. For water samples, personnel at DPR's worksite in Fresno will use the established ELISA method to measure simazine concentrations in water samples. In addition, an ELISA kit is available for diuron and this method will be used to determine diuron concentration in water. The reporting limit for the methods are 0.15 ppb for simazine and 5 ppb for diuron.

Soil Samples: The CDFA laboratory will analyze soil samples for simazine and diuron using the established LC/MS analytical sceen method for these herbicides. The established reporting limit for simazine in soil is 5 ppb and for diuron is 8 ppb. Quality control procedures for both analytical methods will follow established SOP QAQC001.00 for Chemistry Laboratory Quality Control (Segawa 1995).

VI. References

Braun, A. and L. S. Hawkins. 1991. Presence of Bromacil, Diuron, and Simazine in Surface Water Runoff from Agricultural Fields and Non-crop Sites in Tulare, California. Environmental Monitoring Branch, California Department of Pesticide Regulation, Sacramento, CA 95812-4015. PM 91-01. Available at: http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps.htm.

Del Amor, F., A. Leon, A. Torreciallas, and A. Ortuno. 1981. Herbicide applications in citrus through drip irrigation systems. Proceeding of the International Society of Citriculture. 2:493-496; 1981.

Garretson, C. 1999. Soil Sampling, Including Auger and Surface Soil Procedures. SOP FSSO002.00. Environmental Monitoring Branch, California Department of Pesticide

Regulation, Sacramento, CA 95812-4015. Available at: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Garretson, C. 1999. Soil Bulk Density Determination. SOP FSSO001.00. Environmental Monitoring Branch, California Department of Pesticide Regulation, Sacramento, CA 95812-4015. Available at: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Garretson, C. 1999. Soil Water Content Determination. SOP METH001.00. Environmental Monitoring Branch, California Department of Pesticide Regulation, Sacramento, CA 95812-4015. Available at: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Gerstl, Z., N. and Albasel. 1984. Field distribution of pesticides applied via a drip irrigation system. Irrig Sci. 5:181-193; 1984.

Gerstl, Z., and B. Yaron. 1983. Behavior of bromacil and napropamide in soils: II. Distribution after application from a point source Soil Sci. Soc. Am. J. 47:478-483.

Ogg, A. G. JR., 1986. Applying herbicides in irrigation water-a review. Crop Prot. 5:53-65.

Segawa, R. 1995. Chemistry Laboratory Quality Control. SOP QAQC001.00. Environmental Monitoring Branch, California Department of Pesticide Regulation, Sacramento, CA 95812-4015. Available at: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Spurlock, F. 1999. Sampling for Surface Water Runoff in Agricultural Fields. SOP FSWA008.00 Environmental Monitoring Branch, California Department of Pesticide Regulation, Sacramento, CA 95812-4015. Available at: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Troiano, J., C. Garretson, C. Krauter, J. Brownell, and J. Hutson. 1993. Influence of Amount and Method of Irrigation Water Application on Leaching of Atrazine. J. Environ. Qual. 22: 290-298. (PDF, 680 kb). Available at: http://www.cdpr.ca.gov/docs/empm/pubs/ehapref.htm.

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. 27: 488-494. Available at: http://www.cdpr.ca.gov/docs/empm/pubs/ehapref.htm.

Troiano, J., F. Spurlock, and J. Marade. 2000. Update of the California vulnerability soil analysis for movement of pesticides to ground water: October 14, 1999. Environmental Monitoring Branch, California Department of Pesticide Regulation, Sacramento, CA 95812-4015. EH 00-05. Available at: http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps.htm.