Determining the Effectiveness of Surface Water Best Management Practices (BMPs) For Grayland, WA Cranberry Bogs

A Final Report Submitted To The Cranberry Institute
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Introduction

Recent monitoring of surface water draining cranberry bogs in Grayland, WA by the WA Department of Ecology (DOE) (Davis, 1996) detected a number of cranberry pesticides at concentrations exceeding state water quality standards for the protection of aquatic organisms. In addition, chloropyrifos (Lorsban) was found in water samples from the Pacific Coast Drainage Ditch, a portion of the Grayland drainage flowing south to Willipa Harbor, at the highest concentrations ever recorded in WA state waters. Unless growers can significantly reduce pesticide residues levels in surface water draining cranberry bogs, enforcement action by regulatory agencies will probably occur.

This research project was undertaken to evaluate the effectiveness of several surface water quality best management practices (BMPs) to reduce pesticide concentrations in surface water discharged from cranberry bogs.

Chemigation BMPs evaluated in this study included: i) part-circle sprinkler heads; ii) part-circle sprinkler heads with several different types of sprinkler guards; iii) ditch covers; and iv) micro-irrigation technology. Performance of activated carbon filters was also evaluated as part of a comprehensive BMPs evaluation.

Material & Methods

BMPs were evaluated using RbCl and a cation dye rather than actual pesticides. Rubidium chloride (RbCl) was used as a substitute for pesticides for all BMP evaluations, except for activated carbon filters because: i) RbCl applications are safer for the applicator and sampler and no re-entry intervals are required; ii) RbCl is safe on the crop (same chemical family as potassium); iii) RbCl allows for more applications and at higher rates on the same cranberry bed, overcoming the inherent limitation of number of label-allowed applications; iv) RbCl is easier and cheaper to analyze; v) RbCl has no contribution from upstream growers; and vi) RbCl is easier to handle, store, and ship. RbCl in water samples was analyzed by atomic absorption spectrophotometry. The detection limit of RbCl in water samples was 0.1 ppm. Residue levels of <0.1 ppm are considered to be non-detected.

A unique cationic dye, formulated specifically for this project by Becker-Underwood Laboratories, Inc. was used to evaluate the effectiveness of grower constructed and implemented activated carbon filters. The dye was selected as a substitute for pesticides because: i) the dye is more environmentally friendly and poses no aquatic toxicity risk; ii) the application would not be violating any pesticides labels when placed in the ditch water; iii) visual observations about the performance of the filter could be made on site; iv) and the dye is easier and cheaper to analyze than pesticides.

In order to limit the amount of RbCl applied to the bog, several sprinkler heads were selected at each location for application of the RbCl, rather than using the growers entire chemigation system. Hyponex brand siphon mixers, installed on sprinkler risers just below sprinkler heads, were used to introduce the RbCl into the irrigation system. Siphon mixers were used to simultaneously inject one gallon of water which contained either 100 or 50 grams of RbCl into each sprinkler head in the test area. The amount of RbCl applied was related to the size of the ditch and volume of water it contained.

The circular area impacted by a sprinkler head (Rainbird 30 head with 5/32" nozzle operated at 50 psi) covers an area of 2827 sq. ft (Rainbird Corporation, 1996). The area of ditch impacted by the sprinkler was estimated to be 100 sq. ft. (50 ft. long x 2 ft wide) or 3.5% of the wetted area of a sprinkler head. Assuming a water depth of 0.5 ft, the water volume in the ditch impacted by the sprinkler would equal 1415 liters. The mass of RbCl reaching the ditch would therefore theoretically equal 3.5% of 100 or 50 grams or 3.5 or 1.75 grams, respectively. A mass of 3.5 or 1.75 grams of RbCl in 1415 L. of water would result in a RbCl concentration of approximately 2.5 ppm or 1.25 ppm, respectively, in the ditch water.

BMPs were evaluated at five grower locations in the Grayland area. BMPs modifications included: i) no modification to growers system, which served as a Control; ii) installation of a small, wire mesh guard attached to the sprinkler head; iii) installation of a plastic bucket guard attached to the sprinkler head; iv) installation of a conventional plastic mesh sprinkler guard; v) relocation of sprinkler head 3 to 4 ft away from ditch; vi) covering the ditch [both cribbed (wood lined) and non-cribbed ditches] with 10 mil plastic film; and vii) installation of a micro-irrigation/chemigation system. At selected sites, interior and/or perimeter ditches were evaluated with the chemigation BMPs.

The wire mesh sprinkler guard was fabricated by attaching a layer of 1/8 inch mesh hardware cloth and window screening bent into a arc and attached to 18 inch long x 3/16 inch diameter steel rods. The rods were attached to the sprinkler riser with hose clamps so that the screen was located approximately 4 inches behind the part-circle sprinkler head. The bucket guard was fabricated by removing approximately 1/3 of the side of a 5-gallon plastic bucket. The lid of the bucket was kept in place and a 1/2 inch diameter hole was drilled in the bottom of the bucket. The bucket was inserted down over the riser and the sprinkler head was attached to the riser inside the bucket. Two, 1/4"-diameter x 36" long steel rods were used to secure the bucket in place. RbCl-enriched water, which collected in the bottom of the bucket, was directed back to the bog surface through a 5 ft length of Tygon tubing attached to the bottom of the bucket. The plastic mesh guard was fabricated from 1/4 inch plastic hardware mesh cut to 24 inch by 24 inch dimensions and secured to 1/4 inch diameter x 36 inch long steel rods . The mesh was attached to 1/4 inch diameter steel rods and placed approximately 6 inches behind the part-circle sprinkler head. Three foot wide rolls of 10-mil plastic sheeting was used to fabricate ditch covers. The plastic sheeting was allowed to extend approximately 2 inches beyond the cribbing and it was attached to the top of the cribbing with wire and staples.

The micro-irrigation system consisted of a 3/4-inch diameter main line that supplied water to 3/16-inch diameter laterals fitted with low volume sprinkler heads (output 1.5 gallons water/hour). To minimize clogging, the ditch water was filtered through a 10 millimeter pre-filter. Irrigation technology is moving toward micro-irrigation systems because of the improved uniformity of application, water conservation benefits and low cost. We evaluated this technology to determine if, after moving conventional sprinkler heads away from ditches, it could be adapted to apply pesticides to the bed area between the conventional irrigation system heads and the ditch.

Six, one liter water samples (two samples from three locations along the ditch) were collected immediately after RbCl injection was complete. The samples were frozen and shipped to the Ocean Spray laboratory for analysis.

Filters constructed by growers were evaluated because it was felt that these filters would more truly represent the performance of filters that growers in the area would be using when actual pesticides would be applied. A variable quantity of cationic dye was added to the ditch on the upgradient side of the carbon filter to obtain a visible color change in the ditch water. One liter samples of untreated water and activated carbon treated water were subsequently collected.

Spectrophotometry was used to measure transmission of visible light by the untreated and treated water samples. Change in % light transmission in the treated sample as compared to the untreated sample was used to calculate percent reduction of dye as a result of activated carbon filtration. Water flow rates through filters were estimated by measuring ditch width, water depth and travel time of a float placed in the water. Flow rates were characterized as low, moderate, or high, respectively, for water flows of <1 cubic ft (8 gal.) per second, 1 to 3 cubic ft (8-24 gal.) per second, and > 3 cubic ft (24 gal.) per second.

Results

Chemigation BMPs

Evaluation of the micro-irrigation/chemigation system could not be performed because the high suspended solids load of the local water clogged the orifice of the micro-sprinkler nozzles. Installation of a pre-filter to remove suspended sediment greater than 20 millimeters in size also proved in-effective as the pre-filter clogged after 3 to 4 minutes of operation. It was concluded that the micro-irrigation system would be inappropriate for use in Grayland, WA due to the poor quality of most surface water.

Results of chemigation BMPs evaluations will be described for each site. Reduction in RbCl in surface water for the different chemigation BMPs is expressed as the concentration of RbCl found in surface water at the BMP implemented location as compared to the RbCl concentration in surface water at the adjacent control site.

Site 1 - Interior Ditch

A full-circle sprinkler head was located approximately 20 ft from an interior cribbed ditch at this site. Cribbing is a local term used by growers to describe the lining of the vertical walls of cranberry ditches with pressure treated lumber. Cribbing is installed to minimize slumping or erosion of bog edges into the ditches. Cribbing is a management practice somewhat unique to the Grayland area. RbCl was detected in the interior ditch control location at a concentration of 2.1 ppm (Table 1). This concentration is in agreement with the theoretical concentration of 2.5 ppm calculated to result when 100 grams of RbCl was injected into the sprinkler head. This data would suggest that approximately 3 to 4 % of the pesticide applied through a full-circle sprinkler head located within 20 ft of an interior ditch could find it's way into surface water. Covering the cribbed ditch with 10-mil plastic film resulted in a RbCl concentration of < 0.1 ppm or non-detected.

Site 1 - Perimeter Ditch

Except for drift, theoretically little or no RbCl should be entering a perimeter ditch when the sprinkler is a properly adjusted part-circle sprinkler head. At site 1, we found 1.7 ppm in the perimeter cribbed ditch or 80% of the concentration found in the interior ditch (Table 1). RbCl was sprayed directly into the ditch as a result of back splash from the concave side of the impact rotation arm of the sprinkler head and not from drift. The sprinkler head was located 1 ft from the edge of the ditch, which is typical for heads adjacent to the perimeter of bogs in the Grayland area.

Installation of a wire mesh guard on a sprinkler head reduced the RbCl concentration in ditch water to 0.8 ppm, a 53% reduction compared to the RbCl concentration at the adjacent control location. Installation of a plastic bucket guard to a sprinkler head reduced the concentration of RbCl in ditch water to 0.5 ppm, a 71 % reduction compared to the RbCl concentration at the adjacent control location. Replacing a part-circle impact sprinkler head with a Toro lawn-type gear driven sprinkler head resulted in a 0.2 ppm concentration of RbCl in the ditch water, a 88% reduction compared to the RbCl concentration at the control location. Covering the cribbed perimeter ditch with plastic film, for a distance of 30 ft on either side of the part-circle sprinkler head, resulted in a RbCl concentration of < 0.1 ppm or non-detected in ditch water.

Moving the part-circle sprinkler head 4 ft from the ditch reduced the RbCl concentration in ditch water to 0.9 ppm, a 47 % reduction compared to the RbCl concentration at the adjacent control location. Adding a wire mesh guard to a part-circle sprinkler head that was moved 4 ft from the ditch further reduced the concentration in ditch water to 0.5 ppm, a 71% reduction compared to the RbCl concentration in the control location. Moving a part-circle sprinkler head 4 ft from the ditch and installing a plastic mesh ground guard between the head and the ditch reduced the concentration to 0.7 ppm, a 59% reduction compared to RbCl concentration in ditch water at the control location. These results indicate that wire mesh sprinkler guards are better than plastic mesh guards in keeping residues out of ditch water.

Site 2 - Perimeter Ditch

This site also utilized part-circle sprinkler heads around the perimeter of the bog and they were located 1 ft from the cribbed ditch. Fifty grams of RbCl was injected simultaneously into three sprinkler heads at this location. RbCl concentration in surface water sampled in the cribbed perimeter ditch was 0.7 ppm (Table 2). Installation of a plastic bucket guard to a part-circle sprinkler head reduced the concentration detected in surface water to 0.2 ppm, a 71% reduction compared to RbCl concentration in ditch water at the control location . Moving a part-circle sprinkler head 3 ft from the cribbed ditch and installing a plastic mesh ground sprinkler guard reduced the concentration of RbCl in surface water to 0.4 ppm, a 43% reduction compared to the RbCl concentration in the control area.

Site 3 - Perimeter Ditch

The ditches at this site were not cribbed. This is atypical for Grayland but is typical of how ditches are constructed in other cranberry growing regions. Fifty grams of RbCl was injected simultaneously into three sprinkler heads at this location. A concentration of 1 ppm of RbCl was detected in ditch water sampled from the non-cribbed, non-BMP implemented perimeter ditch - the control location. Covering the non-cribbed ditch with 10-mil plastic film, secured with wire and steel pins, resulted in a concentration of 0.6 ppm RbCl in the ditch water, a 40 % reduction in RbCl concentration compared to the control location. Reduction in RbCl concentration with installation of the plastic ditch cover at this non-cribbed location was considerably lower than at Site 1. Site one had ditch covers installed on cribbed ditches, Without cribbing it was difficult to create a watertight seal with the plastic film and RbCl containing irrigation water was able to enter the ditch through gaps in the plastic film.

Furthermore, maintaining ditch covers throughout an entire pesticide application season on non-cribbed ditches would be very difficult due to windy conditions that occur in the area.

Site 4 Perimeter Ditch

At this site, two sprinkler head types were evaluated: a full circle head, located 20 ft from the cribbed perimeter ditch, and a part-circle head located 1 ft from the same cribbed ditch. Fifty grams of RbCl was injected simultaneously into four sprinkler heads at this location. RbCl was detected at concentrations of 1.2 and 1.0 ppm, respectively, in ditch water sampled adjacent to the full circle head and the part-circle head (control location). Installation of a wire mesh spray guard to a part-circle sprinkler head resulted in a RbCl concentration in ditch water of 0.6 ppm, a 40% reduction in RbCl compared to the control location. Covering the cribbed ditch with 10-mil plastic film for a distance of 20 ft on either side of the ditch resulted in a RbCl concentration of < 0.1 ppm in ditch water (non-detected).

Site 5 Perimeter Ditch

A part-circle sprinkler head located adjacent to a cribbed ditch was evaluated at this site. Fifty grams of RbCl was injected simultaneously into three sprinkler heads at this location. A concentration of 0.8 ppm RbCl was detected in ditch water at the control location. Installation of a plastic mesh ground guard between the sprinkler head and the cribbed ditch resulted in a concentration of 0.8 ppm RbCl being detected in the ditch water, or no reduction in concentration as a result of installing the conventional plastic mesh guard. Installation of a plastic bucket guard to the sprinkler guard reduced the RbCl concentration in ditch water to 0.4 ppm, a 50% reduction in RbCl concentration compared to the control location.

Site 6 Experimental site

An additional site was set up to evaluate how far a sprinkler head would have to be set back to prevent back splash from a brass arm-type sprinkler head from reaching a perimeter ditch. This evaluation differed from other chemigation BMP evaluation in that it used the cationic dye rather than RbCl. After several trials using the cation dye, we determined that a part-circle head without a sprinkler guard would have to be set back at least 15 ft from the ditch in order prevent or minimize direct input of sprinkler back splash water from entering the ditch. Installation of a wire mesh or bucket guard to the head reduced the distance that the head needed to be from the ditch to approximately 10 ft. Additionally, water ejected from the concave side of the brass impact arm of the sprinkler extended at least 12 ft down the length of the ditch. We further concluded that a plastic ditch cover would have to extend approximately 30 ft (15 ft on either side of the head) adjacent to a part-circle sprinkler head in order to be highly effective.

Activated Carbon Filter Evaluation

Activated carbon filters, fabricated and installed by growers, were evaluated at five locations. One evaluation was undertaken at each location except at site 5 where three evaluations were conducted. Sites 1 through 3 utilized a multiple component filter design and sites 4 and 5 used a single filter screen design (Table 6).

The greatest reduction in dye concentration, 79%, occurred with an activated carbon filter installed in a ditch with low water flow and with minimum leakage of untreated water around the filter. Leakage of water around the filter, primarily where the filter meets the flume guides, was a problem atmost sites. Reduction in dye concentration in filters with moderate water flow rates and moderate leakage of untreated water ranged from 52 to 62%. The poorest performing filter, with only a 15% reduction in dye concentration, was a thin single filter containing coarse-sized carbon in a ditch with high water flow and moderate leakage of untreated water. At this location, dye was observed to flow through the center of the filter immediately after being introduced into the ditch water on the upgradient side of the filter.

Based on the relatively high concentration of pesticide residues that could be sprayed directly into interior and perimeter ditches, it does not appear that activated carbon filters would be effective in lowering pesticide residues below levels that the Washington DOE would consider to not adversely affect aquatic organisms. Additionally, growers with activated carbon filters reported that the high suspended solids load of ditch water tended to clog filters prematurely, making their use problematic.

The original intent of activated carbon filters was to reduce high concentrations of residues in ditch water that could be acutely toxic to fish. To that end activated carbon filters can be effective, but to rely on activated carbon treatment to reduce pesticide residue levels below aquatic toxicity levels is erroneous.

Conclusions

Sprinkler heads located adjacent to both interior and perimeter ditches can be a significant source of non-target application of pesticides. Unprotected interior ditches received as much as 3 to 4% of the applied RbCl supplied by adjacent sprinkler heads. Part-circle sprinkler heads, located 1 ft from ditches, contributed as much as 2.5% of the applied RbCl to ditches. Plastic mesh sprinkler guards, typically used by growers to reduce non-target application of pesticides, were least effective in reducing RbCl input into adjacent ditches (0 - 40% reduction in RbCl concentration compared to control). Moving part-circle heads 3 or 4 ft from ditches reduced RbCl levels by 40%. Installation of wire mesh spray guards to sprinkler heads reduced RbCl inputs to surface water by 40 to 50%, compared to controls with no modifications. Moving heads to 4 ft from the ditch and adding a wire mesh guard reduced levels by more than 70%. Installation of plastic bucket guards to sprinkler heads reduced RbCl inputs to adjacent ditch water by 50 to 70%. Replacing a conventional brass arm impact sprinkler head with a gear driven sprinkler head at one location reduced RbCl inputs to ditch water by 88%. Covering interior and perimeter cribbed ditches with plastic covers reduced RbCl to non-detectable levels. Covering non-cribbed ditches with a plastic cover was less effective, with only a 50% reduction in RbCl compared to the control.

In order to significantly reduce pesticide inputs directly into ditch water, growers will have to adopt and implement a number of BMPs. The only logical solution to minimize direct chemical inputs to interior cribbed ditches is to cover them with an impermeable barrier (eg. plastic film, non-corrosive metal sheeting , etc). Growers should also consider installation of perforated drainage pipe and filling ditches with stone in non-cribbed interior ditches.

If growers do not want to move existing sprinkler heads away from ditch edges, then a ditch cover may be the best choice for cribbed perimeter ditches as well. Covered perimeter ditches will allow growers to apply pesticides very close to the edge of the bog with minimal impact to surface water. Alternatively, growers should consider replacing brass arm impact sprinklers with gear driven heads, or should move perimeter sprinkler heads at least 10 ft from ditches and install wire mesh or bucket guards to the sprinklers. Installation of sprinkler guards to sprinkler heads located 1 ft from the ditch can lower but not eliminate direct input of pesticides to surface water. However, reducing pesticide residue concentrations by 50 to 70% may not be sufficient to meet DOE water quality criteria.

Despite reasonably effective performance of activated carbon filters, dependence on filters to treat pesticide impacted ditch water should be discouraged in favor of pro-active efforts to keep pesticides out of ditch water. Activated carbon filters should not be a substitute for implementation of chemigation BMPs.

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Future Efforts

Chemigation BMPs evaluated in this study should be implemented on a number of micro-watersheds in the Grayland area to demonstrate to growers their effectiveness in minimizing direct input of chemicals to surface water.

Citations

Davis, Dale, 1997. Draft - Assessment of cranberry bog drainage pesticide contamination, Results from chemical analyses of surface water, tissue, and sediment samples collected in 1997. Washington State Department of Ecology, Olympia, WA.

Rainbird Corporation. 1996. Agricultural irrigation Equipment. Generic performance data for 3/4 inch brass sprinklers, page 11. Glendora, CA.

Table 1. Results of RbCl evaluations at Site 1.

BMP	Mean RbCl (ppm)	Reduction Compared to Control (%)
Interior Ditch		
Control - No Modifications	2.1	---
Ditch Cover/Cribbed Ditch	N.D.	100
Perimeter Ditch - All Part-Circle Heads		
Control, Head 1 ft from Ditch	1.7	---
Wire Mesh Sprinkler Guard	0.8	53
Plastic Bucket Guard	0.5	71
Gear Driven Head	0.2	88
Relocated Head 4 ft	0.9	47
Relocated Head 4 ft & Wire Sprinkler Guard	0.5	71
Relocated 4 ft & Plastic Mesh Ground Guard	0.7	59
Ditch Cover/Cribbed Ditch	N.D.	100

Table 2. Results of RbCl evaluations at Site 2.

BMP	Mean RbCl (ppm)	Reduction Compared to Control (%)
Perimeter Ditch - All Part-Circle Heads		
Control - No Modifications	0.7	---
Plastic Bucket Guard	0.2	71
Relocate Head 3 ft & Plastic Mesh Guard	0.4	43

Table 3. Results of RbCl evaluations at Site 3.

BMP	Mean RbCl (ppm)	Reduction Compared to Control (%)
Perimeter Ditch - All Part Circle Heads		
Control - No Modifications/No Cribbing	1.0	---
Ditch Cover/No Cribbing	0.6	40

Table 4. Results of RbCl evaluations at Site 4.

BMP	Mean RbCl (ppm)	Reduction Compared to Control (%)
Perimeter Ditch		
Full Circle Head Located 20 ft From Ditch	1.2	---
Control - No Modifications, Part-Circle Head 1 ft From Ditch	1.0	---
Wire Mesh Guard	0.6	40
Ditch Cover/Cribbed Ditch	N.D.	100

Table 5. Results of RbCl evaluations at Site 5.

BMP	Mean RbCl (ppm)	Reduction Compared to Control (%)
Perimeter Ditch - Part-Circle Heads		
Control - No Modifications, Head 1 Ft From Ditch	0.8	---
Plastic Mesh Ground Guard	0.8	0
Plastic Bucket Guard	0.4	50

Table 6. Construction characteristics and performance of activated carbon filters.

Site Location	Relative Water Flow Rate	Filter Type	Leakage Around Filter*	Reduction in Dye Conc. (%)
1	Low	Multi-filter	minimal	79
2	Moderate	Multi-filter	moderate	62
3	Moderate	Multifilter	moderate	59
4	High	Single	moderate**	15
5	Moderate	Single	none	58
5	"	"	"	59
5	"	"	"	52

* Relative measure of how much water leaked around the frame of the filter and was not treated.
**At this site, dye was passed directly through the filter. This was probably due to the thinness of the filter and the high flow rate of the water.

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