Project Title: An integrated vegetated treatment system for mitigating imidacloprid and permethrin in agricultural irrigation runoff

Principal Investigator: Michael Cahn, Irrigation and Water Resources Advisor
University of California Cooperative Extension
1432 Abbott St.
Salinas CA 93901
mdcahn@ucanr.edu
O (831) 759-7377
C (831) 214-3690

Cooperating Personnel: Bryn Phillips, Toxicology Specialist
University of California Davis, Granite Bay Laboratory
34500 Highway
One Monterey, CA 93940
bmphillips@ucdavis.edu
O (831) 624-0947
C (831) 402-2395

Abstract

Growers rely on applications of pyrethroid and neonicotinoid pesticides for the control of an array of insect pests in leafy greens. Concerns about the off-site movement of these chemicals in irrigation runoff and impacts to water quality may lead to stricter governmental regulations or the eventual loss of registration of these pesticides for leafy green production. Effective on-farm management practices are needed to eliminate aquatic toxicity of pyrethroid and neonicotinoid pesticides in irrigation runoff. This project evaluated the integrated use of polyacrylamide (PAM) and a vegetated treatment system (VTS) for minimizing the toxicity of imidacloprid and permethrin pesticides in runoff from as sprinkler irrigated lettuce field. The VTS included a sediment trap, geotextile sleeves (socks) filled with compost or biochar. Pesticide applications were made by drenching seed at planting and a foliar spray application later in the season. Runoff was sampled at four locations along the VTS and analyzed for imidacloprid and permethrin concentration and aquatic toxicity using *Chironomus* and *Hyalella* as test organisms. The VTS was able to reduce the concentration of imidacloprid and permethrin in runoff by an average of 76% and 93%, respectively. The PAM application minimized the suspended sediment concentration of the runoff, however the suspended sediment concentration of the runoff was further reduced by an average of 81% by the VTS treatment. Aquatic toxicity of the runoff was greatly eliminated during the runoff events that followed the seed drenching application of pesticide. The concentration of imidacloprid was still too great to eliminate toxicity to *Chironomus* after the foliar spray application. However, *Hyalella* had greater than 50% survival after treating the runoff from the foliar spray application with the VTS. The VTS was also effective in infiltrating 94% of the runoff which would presumably greatly reduce the load of pesticides impacting downstream water bodies.

Objectives

The main objective of this project is to utilize an integrated vegetated treatment system (VTS) (sedimentation, vegetation, and GAC) to reduce imidacloprid and permethrin loading in agricultural runoff. The first objective was accomplished as part of the Year 1 tasks (2018).

Objective 1. *Evaluate the efficacy of the vegetated treatment system using simulated runoff*.

Objective 2. *Evaluate the efficacy of the treatment system with runoff from a lettuce crop*.

Objective 3. *Extend results to the vegetable industry.*

Procedures

The field trial was conducted at the USDA-ARS Spence Rd. research farm. A 2-acre field was planted with romaine lettuce (cv. True heart) in two rows spaced 12 inches apart on 40-inch wide beds on September 17, 2019. The seed was drenched with Admire-Pro (imidacloprid) and Perm-up (permethrin) at rates of 10.5 and 8 oz/acre, respectively, during planting. Anticrustant and kerb herbicide were sprayed in bands over the seed lines on Sept. 18th. The crop was germinated using overhead sprinklers spaced in a 30 ft x 33.3 ft pattern.

A flowmeter (4-inch diameter Seametrics Ag3000) was used to monitor applied water to the field. The irrigation water applied to the trial area was treated with polyacrylamide (PAM) by diverting approximately 1/3 of the flow through a "dry PAM applicator" that conditioned the water with a low concentration of PAM (<1 ppm).

Runoff from the field was channeled into a vegetated treatment system (VTS), which first consisted of a shallow basin that allowed large sized suspended sediment to settle out followed by 513 feet of a drainage ditch vegetated with red fescue *(Festuca rubra).* Compost filled geotextile sleeves were placed in the ditch perpendicular to the direction of flow and spaced at 50-ft intervals. Three geotextile sleeves filled with biochar, spaced 20 ft apart, were placed across the bottom starting at 40 feet from the lower end of the ditch (Fig. 1).

Runoff entering and exiting the VTS was monitored and sampled for chemical and toxicity analysis during irrigation events on 9/24/19, 10/8/19, and 11/12/19. The first 2 events followed the drenching application of Admire-Pro and Perm-up at planting. The third event was 6 days after the foliar spray of Admire-Pro and Perm-up applied at rates of 10.5 and 8 oz/acre, respectively

The volume of water entering and exiting the VTS was monitored with V-notch weirs equipped with a stilling well and float mechanism calibrated to estimate the height of the water in the stilling well. A datalogger recorded the height of the float mechanism in the stilling well at 5-minute intervals. The height values were transformed to an estimate of flow rate of the runoff exiting the weir using a calibration curve.

Dataloggers were used to activate four peristaltic pumps (RF-100, Greylor Co., Cape Coral, FL. USA) that sampled the runoff throughout each runoff event. The pumping stations were controlled by a datalogger using an electronic relay and CAT5 telephone cable wire. The pumps were located at the inlet of the sediment trap (location A), at the inlet to the vegetated treatment system (location B), after the compost geotextile sleeves, (location C, 134 m [440 ft] from the inlet), and after the biochar geotextile sleeves (location D, [502 ft] from the inlet) near the outlet (Figure 1). The pumps were activated at 5-minute intervals and sampled approximately a 600 ml volume for a duration of 2 minutes.

The runoff was drawn through a stainless-steel tube suspended in the center of the ditch and through silicone tubing into a 20 L stainless-steel container. Ten liters of composite sample from each sampling location were transferred into amber glass bottles at the end of a runoff simulation and brought back to laboratory for toxicity testing, chemical analysis, and measurement of turbidity and suspended solids concentration. *Chironomus dilutus* was used as the test organism for imidacloprid toxicity *Hyalella azteca* was used as the test organism for permethrin toxicity.

Results and Discussion

The average reduction in concentration of imidacloprid and permethrin in runoff during the three monitored irrigation events was 76% and 93%, respectively (Table 1). The first two events, which followed the seed drenching application had the most reduction in pesticide concentration between the inlet and outlet of the VTS, as well as the lowest concentration of pesticides exiting the field.

After the foliar spray, the concentration of imidacloprid in the runoff increased to 22.8 ppm billion, about 20 times higher than the concentration in runoff after the seed drenching application. The permethrin concentration also increased to twice the concentration measured for the first two irrigation events.

The sediment trap (sample locations A and B) was effective in decreasing the concentration of permethrin in runoff, reducing the concentration by an average of 50% (Table 1), but had little effect on imidacloprid which is a much more water soluble pesticide.

The VTS was able to completely remove permethrin from the runoff during the first two irrigation events and reduce the concentration of imidacloprid to a level less than 0.05 toxicity units for *Chironomus* (Table 2). Survival of *Chironomus* and *Hyalella* at the outlet of the VTS was greater than 75% for the first irrigation event and greater than 90% for the second irrigation event (Table 3). The VTS was not able to reduce toxicity sufficiently to improve survival of *Chironomus* during the third irrigation event but was able to decrease toxicity enough for *Hyalella* survival to increase from 0 to 56% between the inlet and outlet of the VTS (Table 3).

The VTS was able to reduce the concentration of suspended sediments and turbidity in the runoff by an average of 81% and 87%, respectively. The effect of the polyacrylamide treatment of the irrigation water was not measured in this trial, but presumably minimized the suspended sediment concentration of the runoff leaving the field. Past trials have shown that sprinkler runoff at the Spence farm is typically greater than 1000 mg/L. The sediment concentration of the runoff for these three sprinkler events averaged 318 mg/L at the entrance to the sediment trap (location A) and 181 mg/L at the outlet of the trap (location B) (Table 4). The concentration of suspended sediment continued to decrease as the runoff flowed through the vegetated ditch averaging 60 mg/L at the outlet of the ditch. Note that the average turbidity of the runoff at the outlet, 31 NTU, is close to the water quality objective of the proposed Ag Order 4.0.

An error that occurred when retrieving data from the dataloggers resulted in a loss of flow data from the inlet and outlet weirs for the first two irrigations. However, we observed similar flow characteristics in the VTS among all runoff events. As shown in Figure 2, greater than 90% of the runoff infiltrated in the grass-lined ditch during the third irrigation event, which reduced the load of sediment loss by 99% (Table 4). Similarly, the load (mass) of permethrin and imidacloprid would be reduced by 99% due to the infiltration of most of the runoff within the VTS.

Conclusions

The combination of conditioning irrigation water with polyacrylamide (PAM) and treating runoff using a sediment trap, vegetated treatment system (VTS), and carbon containing socks, can greatly reduce aquatic toxicity caused by imidacloprid and permethrin pesticides. The sediment trap likely increased the effectiveness of the PAM treatment by providing time for the suspended sediment to settle out of the runoff. This combination of practices provides a strategy to eliminate pesticides bound to suspended sediments and bind water soluble pesticides to carbon materials such as grass, and compost and biochar. The highest concentration of pesticides in the runoff were measured after the foliar spray; however, the toxicity impact downstream would likely be small because 94% of the runoff infiltrated before exiting the VTS.

Acknowledgments

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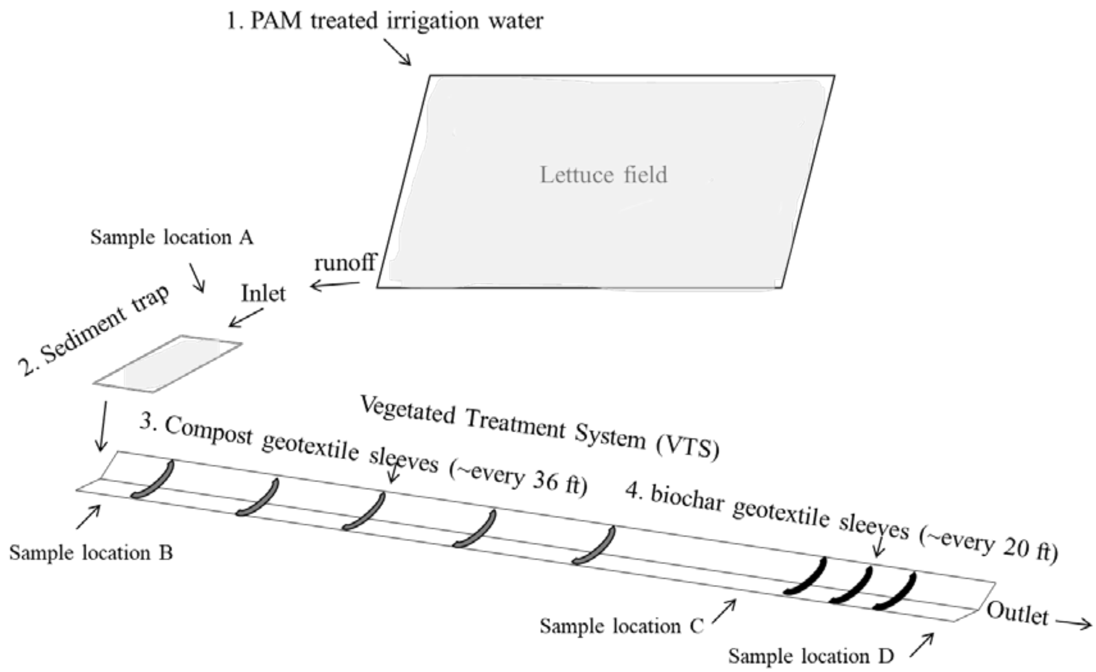

Figure 1. Diagram of vegetated treatment system showing runoff sampling locations A, B, C and D.

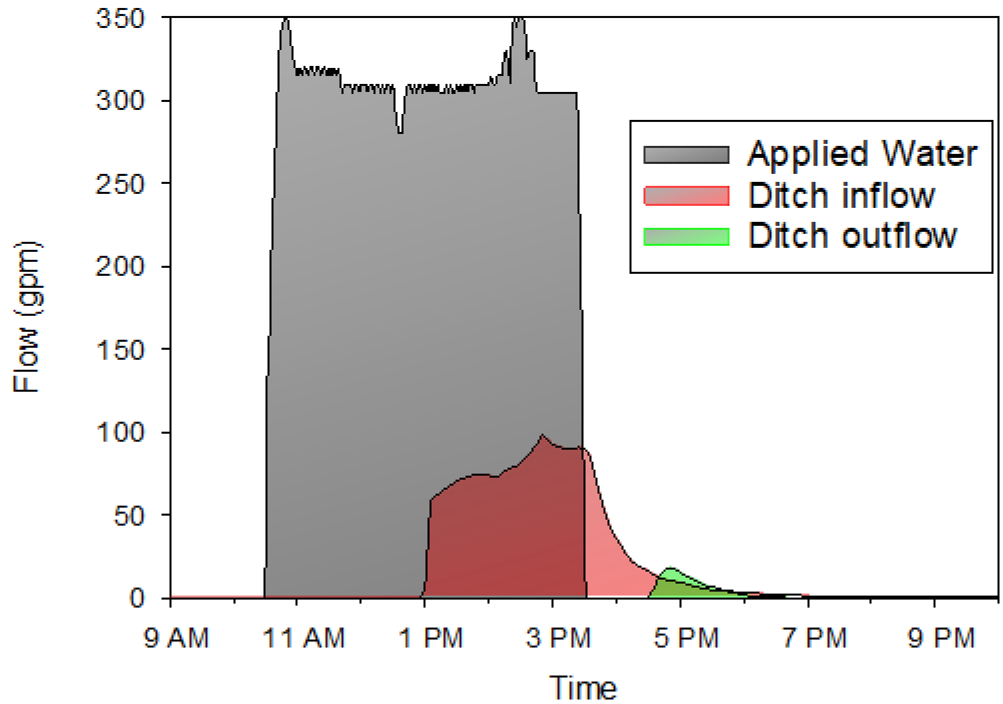

Figure 2. Flow rate of applied water from sprinklers and of runoff entering and exiting the vegetated treatment ditch.

Table 1. Concentration of imidacloprid and permethrin in runoff from a lettuce field treated with a VTS.

		Imidacloprid concentration					Permethrin concentration				
		Sample location					Sample location				
Date	Pesticide treatment	A	B	C	D	Reduction	A	B	C	D	Reduction
		-------------- ng/L ----------				%	-------- ng/L ---------				%
9/26/2019	drench	912	1090	317	186	80	43	27	0	0	100
10/8/2019	drench	546	422	314	135	75	33	17	0	0	100
11/12/2019	foliar spray	22800	23600	7580	5860	74	73	30	11	16	78
Average		8086	8371	2737	2060	76	50	24	4	5	93

Table 2. Toxicity units of imidacloprid and permethrin in runoff from a lettuce field treated with a VTS.

			Imidacloprid toxicity units				Permethrin toxicity units			
			Sample location				Sample location			
Date	Pesticide treatment	Test Organism	A	B	C	D	A	B	C	D
9/26/2019	drench	*Hyalella*	0.01	0.02	0.00	0.00	2.02	1.26	0.00	0.00
		Chironomus	0.16	0.19	0.06	0.03	0.43	0.27	0.00	0.00
10/8/2019	drench	*Hyalella*	0.01	0.01	0.00	0.00	1.55	0.78	0.00	0.00
		Chironomus	0.09	0.07	0.05	0.02	0.33	0.17	0.00	0.00
11/12/2019	foliar spray	*Hyalella*	0.35	0.36	0.12	0.09	3.48	1.44	0.51	0.75
		Chironomus	3.97	4.10	1.32	1.02	0.74	0.31	0.11	0.16
Average		*Hyalella*	0.12	0.13	0.04	0.03	2.35	1.16	0.17	0.25
		Chironomus	1.41	1.46	0.48	0.36	0.50	0.25	0.04	0.05

Table 3. Toxicity of runoff from a lettuce field treated with a VTS to *Hyalella* and *Chironomous.*

			Toxicity Test			
	Pesticide		Sample location			
Date	treatment	Toxcity test	A	B	C	D
9/26/2019	drench	*Hyalella* Survival (%)	0	0	24	76
		Chironomus Survival (%)	0	0	0	75
		Chironomus Growth (mg)	NA	NA	NA	0.72
10/8/2019	drench	*Hyalella* Survival (%)	22	40	90	96
		Chironomus Survival (%)	21	90	96	92
		Chironomus Growth (mg)	0.10	1.89	2.18	5.03
11/12/2019	foliar spray	*Hyalella* Survival (%)	0	0	29	56
		Chironomus Survival (%)	0	0	0	0
		Chironomus Growth (mg)	NA	NA	NA	0.20
	Overall	*Hyalella* Survival (%)	7	13	48	76
		Chironomus Survival (%)	7	30	32	56

Table 4. Total suspended solids, turbidity, and sediment load of runoff from a sprinkler irrigated lettuce field treated with a VTS.

						Total Suspended Solids					Turbidity					Sediment load		
						Sample location					Sample location							
Date	Pesticide treatment	Applied Water	Inflow volume	Outflow volume	Infiltration of Runoff	A	B	C	D	Reduction in Concentration	A	B	C	D	Reduction in Turbidity	Inlet	Outlet	Reduction in sediment load
		------------ gallons --------			%	-------------- mg/L ------------				%	------------ NTU --------------				%	lbs	lbs	%
9/24/2019	drench	80930	M	M	M	424	265	101	77	82	356	92	31	39	89	M	M	M
10/8/2019	drench	85550	M	M	M	249	100	45	41	84	113	38	22	24	79	M	M	M
11/12/2019	spray	91900	15359	873	94	282	179	66	61	78	440	102	33	30	93	36.1	0.4	99
Average			15359	873	94	318	181	71	60	81	303	77	29	31	87	36.1	0.4	99

M missing

NTU Nephelometric Turbidity Unit