Evaluation of polyacrylamide (PAM) formulations for controlling suspended sediments and nutrients in sprinkler run-off

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Introduction

The renewal of the conditional waiver for agricultural discharge and proposed total maximum daily loads (TMDL) for nutrients and sediments may increase requirements for growers to implement best management practices that minimize impairments to surface and ground water quality on the Central Coast. Though many growers have made progress in implementing practices that reduce the impacts of agriculture on water quality, such as reducing fertilizer inputs, improving irrigation scheduling, and using drip irrigation, additional management tools could help achieve more dramatic improvements to water quality.

Overhead sprinklers, which are widely used on the Central Coast for vegetable production, often cause run-off. Although the volume of run-off is minimal or none on many fields, on some soil types the run-off can be as much as 20% of the applied water. Sediments concentrations and turbidity levels can be especially high in run-off from sprinklers because the force of the falling water droplets degrade soil aggregates and suspends sediments in the run-off. Significant amounts of phosphorus, nitrogen, and some classes of pesticides, such as pyrethroids, which adsorb to the suspended sediments, are also transported in the run-off.

Our previous field trials conducted in the Salinas Valley from 2003-2006 demonstrated that concentrations of suspended sediments and associated nutrients and pesticides in sprinkler run-off could be greatly reduced by adding small amounts of polymer to irrigation water. Specifically, anionic polyacrylamide (PAM) polymer was injected into the irrigation water to achieve a 5 ppm concentration. The small amount of polymer in the irrigation water flocculated out suspended sediments, reducing sediment concentrations by an average of more than 90% in the run-off. Linear polyacrylamides have been used successfully for erosion control in furrow irrigation in Idaho and eastern Washington since the early 1990s and are a recommended practice of the Natural Resource Conservation Service that can be cost-shared through the EQIP program.

Although PAM showed much promise as a tool for reducing sediment concentrations in preliminary trials, questions have remained on the best methods for injecting PAM into pressurized irrigation systems, and as to how often applications are needed to maximize the erosion control benefits. Also different formulations of liquid PAM polymers are available for commercial use but there are few comparisons of their water quality benefits. This report describes the results of trials conducted in commercial lettuce fields in the Salinas valley to evaluate the water quality benefits of 2 liquid PAM formulations (water-based and mineral oil based) and the effect of repeated applications on control of suspended sediments and nutrients.

Description of field trials

Four trials were conducted in commercial romaine lettuce fields (2 trials in 2007 and 2 trials in 2008) to evaluate PAM effects on sprinkler run-off. Soil characteristics at trial sites were summarized in Table 1. All fields were irrigated with solid-set impact sprinklers. Individual plots measured 3 to 6 acres in area.

The following treatments were compared: Soilfix PAM, Terawet PAM, and an untreated control (no polymer added). PAM was injected into the main sprinkler line to achieve a 5 ppm concentration in the irrigation water. The treatments were rotated among plots so that each plot received each PAM treatment during 3 consecutive irrigations. In addition to the 3 treatments described above, a 4th treatment consisting of an untreated control treatment, in which no polymer was applied during the 3 irrigations, was included in trials 2-4. By comparing the moving untreated control, which received PAM in previous irrigations, to the stationary untreated control, which never received PAM, we were able to assess the residual effects of PAM on water quality.

PAM Formulations

The trials compared 2 different water soluble liquid PAM products: Terawet PAM25, a 25% anionic polyacrylamide product which included water and humectant substances as inert ingredients, and Ciba Soilfix which was a 50% anionic polyacrylamide product with mineral oil as an inert ingredient.

PAM injection methods

PAM polymers were injected into the main lines of the sprinkler system by 2 different methods: 1. A batch solution of 0.25% polymer was premixed in a tank prior to the irrigation and injected using a high pressure centrifugal pump at a rate of 0.8-1.2 gal/min to achieve a 5 ppm PAM concentration in the irrigation water, 2. A Seepex dosing (progressive cavity) pump was also used to inject the liquid PAM products (without prior dilution) at rates of 0.5 to 1 ounce/min directly into the mainline to achieve a 5 ppm concentration.

Summary of Results

<u>PAM effects on suspended sediments and turbidity</u> Both PAM products significantly reduced sediment, turbidity and total phosphorus concentrations in the sprinkler run-off (Tables 3 and 4) relative to the moving control treatment. Treatments effects were significantly different at sites 2-4 but not at site 1 (data not presented). Average reduction in suspended sediments in the irrigation run-off was 91% for Soilfix and 74% for PAM25 in comparison to the moving untreated control (Table 4). Average reduction in turbidity in the irrigation run-off was 95% for Soilfix and 91% for PAM25 compared to the moving untreated control treatment (Table 4). The average reduction in total suspended sediments relative to the fixed located control treatment for trials 2-4 was 96% for Soilfix PAM and 84% for PAM25 (Table 5). The average reduction in total turbidity relative to the fixed located control treatment for trials 2-4 was 92% for Soilfix PAM and 90% for PAM25. The reduction in suspended sediments and turbidity in the run-off was not statistically different between the Soilfix and PAM25 products.

<u>PAM effects on nutrients levels in run-off</u> Average reduction in total P in the irrigation run-off was 67% for Soilfix and 43% for PAM25 compared to the moving control treatment (Table 4).

The average reduction in total P relative to the fixed located control treatment for trials 2-4 was 77% for Soilfix PAM and 60% for PAM25 (Table 5). Soilfix PAM also significantly reduced soluble P in run-off compared to the moving and fixed control treatments (Tables 5 and 6). Soilfix significantly reduced total P, soluble P, and total N more than PAM25. The PAM treatments significantly reduced phosphorus loads relative to the moving untreated control treatment (Table 5).

The PAM treatments caused small or no reduction in the concentration of Nitrate-N, Total N, and K at most sites. Unlike results of past trials, high level of nitrate in the run-off limited the ability of PAM to reduce total N levels. The high levels of nitrogen at site 2 was caused by the grower injecting N fertilizer into the irrigation water during the 2^{nd} and 3^{rd} irrigation events and because the irrigation water had a high level of nitrate (Table 2). The irrigation water at site 4 also had a high concentration of nitrate (Table 2).

<u>PAM effects on run-off amounts</u> The PAM treatments had a modest effect on the volume of irrigation run-off relative to the moving control treatment (Table 3). PAM25 appeared to have the most effect on run-off volume. Reductions in run-off volume were also measured relative to the fixed control treatment for trials 2-4 (Table 5), which suggests that these products can modestly increase the infiltration rates of the soil types tested (Table 5). Irrigation run-off varied significantly between field sites (4.6% of applied water at site 1 and 51% of applied water at site 4), and may be attributed to the stage of the crop when the trials were conducted and soil type. The trial at site 1 was conducted during the germination of the crop, when the soil was not saturated. The trial at site 2 was conducted after the crop had received multiple irrigations, and therefore the soil would likely have been more saturated than at site 1.

<u>Residual effect of PAM on suspended sediments and nutrients</u> Comparison of the moving control treatment with the fixed-located control treatment at trials 2-4 demonstrated that prior applications of PAM continued to reduced suspended sediment, turbidity, and total P concentrations in the run-off when PAM was not applied (Table 5). The residual effect of PAM on total suspended sediments in the run-off increased with the number of previous applications of PAM (Figure 1).

Summary

The results of large scale trials conducted in commercial lettuce fields confirmed previous data showing that the addition of polyacrylamide polymer to irrigation water significantly reduced sediment and turbidity levels in sprinkler run-off. PAM was also found to reduce total and soluble phosphorus concentrations in run-off. We found less effect of PAM on total nitrogen concentration than we have previously reported, most likely because the effect of PAM on total N was masked by the high background level of nitrate in the irrigation water. Although no statistically significant differences were found between the two PAM formulations, suspended sediment concentrations were usually lower for the Soilfix PAM compared to the Terawet PAM25 and the Terawet appeared to increase infiltration more than the Soilfix product. These trials also showed that PAM had a residual effect on the quality of the run-off. Significant reductions in sediment and nutrients in sprinkler induced run-off may be achieved by alternating applications of PAM between irrigations.

The results of this and previous studies conducted on the central coast have demonstrated that polyacrylamide can be an important tool for growers to reduce sediment and nutrient losses in sprinkler run-off. PAM can also minimize aquatic toxicity of pyrethroid pesticides, which strongly bind to suspended sediments carried in irrigation run-off.

Table 1. Soil physical and chemical characteristics at trial sites 1, 2, and 4.

depth	pH	EC	SAR	TKN	Olsen P	Cation Exchange Capacity	Organic Matter	Sand	Silt	Clay
		dS/m		%	ppm	meq/100 g	-------------------	%	-------------------	
						site 1[x]				
0 - 1 ft	7.1	1.46	2	0.072	75	14.5	0.93	56	28	16
1- 2 ft	7.2	1.46	2	0.053	61	14.9	0.73	57	26	17
1 -3 ft	7.2	1.22	2	0.043	27	19.1	0.46	51	26	23
						site 2				
0 - 1 ft	7.4	0.74	1	0.054	144	10.0	0.84	66	21	13
1- 2 ft	7.4	1.04	2	0.042	97	9.1	0.67	68	20	12
1 -3 ft	7.3	1.70	2	0.029	60	7.7	0.38	69	19	12
						site 4				
0 - 1 ft	7.2	1.16	1	0.041	72	26.8	0.78	81	11	8
1- 2 ft	7.2	1.11	2	0.031	50	10.5	0.71	80	13	7
1 -3 ft	7.1	1.29	2	0.026	27	5.4	0.61	82	11	7

[x] sites 1 and 3 had similar soil types

Table 2. Chemistry and nutrient content of irrigation water from trial sites.

Site	pH	EC	TDS	SAR	Total Kjeldahl N	Ammonium-N	Nitrate-N	P (Total)	P (Soluble)	Total Suspended Solids	Turbidity
		dS/m	ppm		-------------------	-------------------	-------------------	ppm	-------------------	-------------------	NTU
1	7.5	0.7	430	2.1	0.2	<0.05	6.9	<0.1	0.06	<4	1
2	8.0	1.0	580	2.3	0.2	<0.05	14.8	<0.1	0.07	9	2
3	8.4	0.6	350	2.7	0.4	<0.05	5.3	<0.1	0.07	50	26
4	8.2	1.0	702	1.4	0.8	0.78	51.1	<0.1	<0.05	26	13

Table 3. Effect of PAM treatments on suspended sediments, turbidity, volume, and nutrient loads of sprinkler induced run-off (average of 4 sites).

Treatment Description	Total Suspended Solids	Turbidity	Run-off		Sediment load	Total P load	Total N load
	mg/L	NTU	gal/acre/irrigation	% of applied water	--------	lb/acre/irrigation	--------
Untreated Moving Control[x]	555	382	4964	21.5	28.2	0.076	1.069
PAM25	137	34	3961	18.1	5.0	0.031	0.467
Soilfix	42	20	4613	21.4	1.8	0.022	0.782
$LSD_{0.05}$	263	206	919	3.7	3.8	0.029	0.525
statistical significance[z]	***	***	*	NS[y]	**	**	*

[x] PAM was applied during previous irrigations

[y] not statistically significant

[z] symbols *,**,*** signify that treatment means are statistically different at the 90%, 95%, 99% confidence levels, respectively

Table 4. Effect of PAM treatments on chemistry and nutrient content of sprinkler run-off (average of 4 sites).

Treatment Description	pH	EC	Total Dissolved Solids	Total P	Soluble P	Total Kjeldahl N	Nitrate-N	Ammonium-N	Soluble K
		dS/m	----------	----------	----------	ppm	----------	----------	----------
Untreated Moving Control[x]	8.1	1.08	720	1.51	0.38	15.7	29.0	7.94	3.9
PAM25	8.2	0.96	618	0.86	0.37	10.2	22.3	3.88	4.3
Soilfix	8.3	0.98	604	0.50	0.28	11.1	33.8	9.82	4.0
$LSD_{0.05}$	0.3	0.21	208	0.26	0.06	6.9	12.6	4.46	0.8
statistical significance[z]	NS[y]	NS	NS	***	***	NS	NS	**	NS

[x] PAM was applied during previous irrigations

[y] not statistically significant

[z] symbols *,**,*** signify that treatment means are statistically different at the 90%, 95%, 99% confidence levels, respectively

Table 5. Effect of PAM treatments on chemistry and nutrient content of sprinkler run-off relative to fixed control treatment (average of 3 sites).

Treatment Description	Total P	Soluble P	Total Kjeldahl N	Nitrate-N	Total Suspended Solids	Turbidity	Run-off
	----------	----------	----------	**% of fixed location control[x]**	----------	----------	----------
Untreated Moving Control[x]	64	101	86	83	57	77	85
PAM25	40	99	81	80	16	10	71
Soilfix	23	69	50	86	4	8	76
$LSD_{0.05}$	10	22	35	31	15	32	17
statistical significance[z]	***	**	*	NS[y]	***	***	NS

[x] PAM was applied during previous irrigations

[y] not statistically significant

[z] symbols *,**,*** signify that treatment means are statistically different at the 90%, 95%, 99% confidence levels, respectively

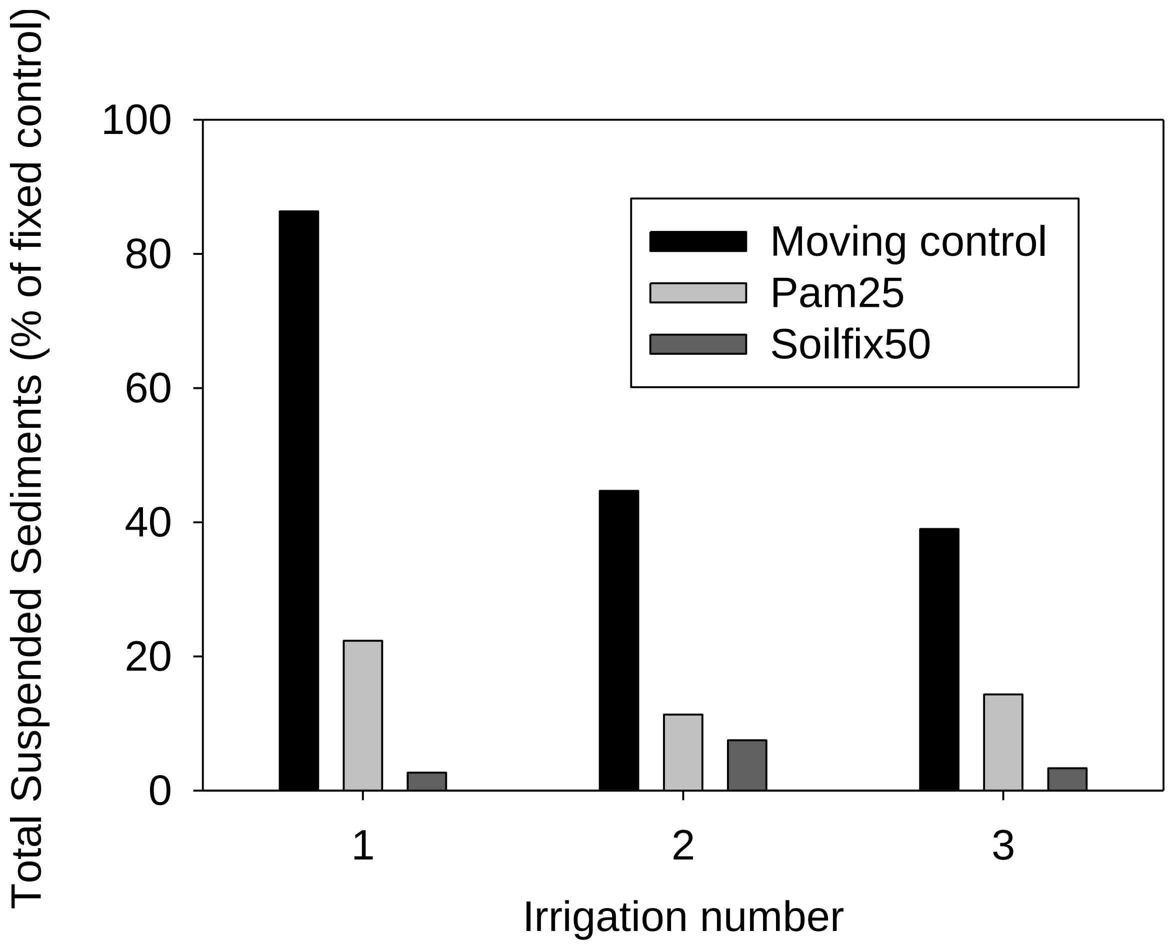

Figure 1. Effect of PAM and moving control treatment on total suspended sediments with increasing number of irrigations expressed as a percentage of the fixed location control treatment. PAM was previously applied before irrigations 2 and 3 in the moving control treatment.