EFFECTS OF A NEW POLYSACCHARIDE-BASED AMENDMENT ON FURROW IRRIGATION INFILTRATION AND EROSION

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ABSTRACT. *Controlling soil erosion on furrow-irrigated fields is essential to maintain productivity and reduce off-site impacts. Identifying effective alternatives to polyacrylamide (PAM) is desired for continued, affordable irrigation erosion control. We compared the effectiveness of a new polysaccharide/PAM amendment with water-soluble, high molecular weight, anionic PAM in two furrow-irrigated field tests in southern Idaho. Test 1 evaluated three rates of the polysaccharide/PAM amendment (6, 12, and 18 mg L^{-1} of polysaccharide/PAM), two rates of PAM (2 and 10 mg L^{-1} of PAM), 10 mg L^{-1} polysaccharide, and a control during two irrigations in a fallow field. Treatments were applied as a solution with furrow inflow water during irrigation advance. Test 1 results indicated that polysaccharide/PAM amendment could improve infiltration and reduce sediment loss compared to untreated furrows, but its effectiveness seemed to diminish when amendment application stopped. Polysaccharide alone did not significantly effect infiltration, runoff, or sediment loss compared to the control for either irrigation, whereas the polysaccharide/PAM amendment significantly increased infiltration and reduced sediment loss for one irrigation. Test 2 compared polysaccharide/PAM amendment and PAM, both applied at either 2 mg L^{-1} (active ingredient) continually during irrigation (dissolved treatments) or as a 20 g per furrow of dry material near the furrow inflow point (patch treatments), during four irrigations on a dry bean field. Both amendments significantly increased cumulative infiltration and decreased cumulative runoff and sediment loss compared to untreated furrows. Dissolved polysaccharide/PAM increased cumulative infiltration 19% compared to the control, while dissolved PAM, patch polysaccharide/PAM, and patch PAM treatments increased cumulative infiltration 13%, 11%, and 7%, respectively, compared to the control. Dissolved and patch PAM and dissolved and patch polysaccharide/PAM treatments significantly reduced cumulative sediment loss 98%, 90%, 65%, and 49%, respectively, compared to the untreated furrows. These test results indicate that the polysaccharide/PAM amendment can be used as an alternative, albeit less effective, to PAM for reducing sediment loss from furrow-irrigated fields.*

Keywords. *Infiltration, PAM, Polyacrylamide, Soil erosion.*

Soil erosion on furrow-irrigated fields reduces crop productivity and impairs off-site water quality. Eroding the topsoil from the inflow ends of furrow-irrigated fields can reduce crop yield 25% compared to the lower end of fields where sediment is deposited (Carter et al., 1985). Studies have documented soil loss of 0.5 to 141 Mg ha^{-1} (Berg and Carter, 1980) and 2 to 33 Mg ha^{-1} (Bjorneberg et al., 2007) from furrow-irrigated fields in southern Idaho. The USDA Soil Conservation Service estimated in 1985 that 21% of the irrigated cropland was affected by erosion (Koluvek et al., 1993). Soil and associated nutrients transported from furrow-irrigated fields can impair the quality of water bodies receiving return flow from irrigated tracts (Bjorneberg et al., 2002).

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Water-soluble, high molecular weight, anionic polyacrylamide (PAM) is an effective tool for controlling furrow irrigation erosion (Lentz et al., 1992; Sojka and Lentz, 1997; Sojka et al., 2007). Applying 10 ppm PAM in furrow irrigation inflow as water advances across the field reduced soil loss 94% and increased infiltration 15% compared to untreated furrows in one three-year study (Lentz and Sojka, 1994). The cost of PAM (currently \$7 to \$11 kg^{-1} retail) is primarily attributed to the cost of natural gas, the raw material used for PAM synthesis, which previously has been relatively abundant and inexpensive. Since 2000, demand and supply factors have raised natural gas prices, resulting in a 30% increase in the cost of PAM and related polymers, generating concern for future availability and affordability of PAM for irrigated agriculture. In addition to cost factors, the polymer industry is seeking biopolymer alternatives to PAM and related synthetic flocculants that are effective environmental polymers with more rapid and complete biodegradability. Some forms of polysaccharides can be effective flocculants (Helalia and Letey, 1988) and improve infiltration (Ben-Hur and Letey, 1989). Orts et al. (2000) identified several biopolymer surrogates for PAM, but these biopolymers generally needed to be applied at higher concentrations than PAM to have comparable effects on sediment transport. Acid-hydrolyzed cellulose microfibrils, for example, reduced sediment in lab-furrow tests by 88% when applied at 8 to 10 times greater concentrations than PAM (Orts et al., 2007).

The objective of this study was to evaluate the effects of a modified polysaccharide/anionic polyacrylamide amendment on furrow irrigation infiltration and erosion in the field. Two separate tests were conducted. The first test was to determine the relative effectiveness of the polysaccharide/PAM amendment compared to PAM during two controlled irrigations on a fallow field. The second test was designed to measure the impacts of the polysaccharide/PAM amendment on infiltration and erosion in a furrow-irrigated dry bean field during an irrigation season.

Methods and Materials

The two polymers used for this study were anionic, water-soluble, high molecular weight polyacrylamide (AN923 from SNF, Inc., Riceboro, Ga.) and a modified polysaccharide/PAM product under development by Innovium, LLC (St. Louis, Mo.). The effectiveness of the polysaccharide/PAM to enhance infiltration and control furrow irrigation erosion was compared against PAM in two field tests. The manufacturers continued to improve the formulation of the polysaccharide/PAM amendment during this study, so results from test 1 and test 2 cannot be directly compared. The prototype amendment used during test 1 was produced with an aqueous, heat-activation step. The amendment used during test 2 was blended as a dry formula. The blended dry formula is the same product that is commercially available as SoilSentry, a patent-pending amendment from Innovium, LLC (S. Sykes, personal communication, 24 May 2007). All polysaccharide/PAM amendments used were 5 parts polysaccharide and 1 part PAM.

Test 1

The first test involved two irrigations, about six weeks apart in July and August 2005, on the same fallow field. The soil was Portneuf silt loam (coarse-silty, mixed, superactive, mesic, Durinodic Xeric Haplocalcids). Field slope was 1.2% and length was 143 m. Residue from the previous dry bean crop was incorporated by disking in fall 2004. The field was tilled with a roller harrow, and furrows were formed less than one week before each irrigation. Furrow spacing was 0.76 m, and alternate furrows were wheel-compacted. Gated pipe with spigot valves was used to distribute water to the furrows. The irrigation water source was the Snake River (typical chemical analysis: pH = 8.2, electrical conductivity = 0.5 dS m^{-1}, sodium adsorption ratio = 0.7).

Seven treatments were applied to furrow irrigation inflow during the advance phase of the irrigation. To account for advance time differences, amendment application continued until water advanced in all furrows of one treatment to at least 90% of the furrow length. The polysaccharide/PAM was applied at 6, 12, and 18 mg L^{-1} (SS6, SS12, and SS18) active ingredient (a.i.) as water advanced across the field to identify an optimum application rate. Polysaccharide/PAM treatments were compared against a control (no treatment) and 10 mg L^{-1} a.i. PAM application (PAM10), which is considered the optimum PAM application rate (Lentz and Sojka, 1994). The remaining two treatments were the individual components of the 12 mg L^{-1} polysaccharide/PAM rate: 10 mg L^{-1} a.i. polysaccharide (starch) and 2 mg L^{-1} a.i. PAM (PAM2). Treatments were replicated four times during each irrigation in a randomized complete block design. The field was tilled and treatments re-randomized between the two irrigations.

Concentrated solutions (1000 mg L^{-1}) of PAM, polysaccharide/PAM, and polysaccharide were prepared the day before each irrigation using tap water. Concentrated polysaccharide solution was metered into furrow flow with a peristaltic pump for each starch-treated furrow. To reduce the number of pumps needed for each irrigation, SS treatments were applied to furrows with one peristaltic pump connected to a manifold. The manifold was 19 mm diameter polyethylene pipe with 600 mm long, 1.3 mm diameter tubing outlets. One outlet tube was used for the 6 mg L^{-1} treatment (SS6), two for the 12 mg L^{-1} treatment (SS12), and three for the 18 mg L^{-1} treatment (SS18). These small-diameter tubes produced uniform flow rates at each outlet along the length of the manifold. PAM was applied with a similar manifold with one 300 mm long, 0.9 mm diameter outlet tube for the 2 mg L^{-1} treatment (PAM2) and two 600 mm long, 1.3 mm diameter outlet tubes and one 300 mm long, 0.9 mm diameter outlet tubes for the 10 mg L^{-1} treatment (PAM10). Application rates for each treatment were measured by recording the volume collected in a graduated cylinder in 15 s. Treatment application rates were checked approximately hourly during the 11 h irrigations, and more frequently at the start of the irrigation. The peristaltic pump speed was adjusted as necessary to maintain the appropriate amendment application rates.

Furrow inflow was measured by the time required to fill a known volume (3.8 L). Inflow rate for all furrows was set at 19 L min^{-1} for the first irrigation and 27 L min^{-1} for the second, comparable inflow rates to those used on commercial fields in the area. A higher inflow rate was used for the second irrigation because infiltration rate was so high during the first irrigation that some furrows advanced too slowly across the field (>5 h). Furrow inflow rates were checked approximately hourly during each irrigation.

Only wheel-compacted furrows (i.e., alternate furrows) were irrigated during each irrigation, so irrigated-furrow spacing was 1.5 m. In addition to monitoring furrow flow at the field end (143 m), furrows were monitored 36 m from the gated pipe to determine if treatments differed on the inflow end of the field where detachment is the primary erosion mechanism. Small trapezoidal flumes (Clemmens and Bjorneberg, 2005) were installed in furrows for measuring flow rate and allowing water sample collection. Sediment concentration was measured by the volume of sediment settled in 1 L Imhoff cones after 30 min, which is highly correlated with sediment mass (Sojka et al., 1992). Flow rate was measured and sediment samples were collected 15 min after water advanced past a flume. The next measurements were made approximately 30 min later and then at 1 to 3 h intervals, for a total of 6 to 8 measurements during the 11 h irrigations, depending on furrow flow advance rate.

The volume of furrow flow was calculated for each sampling interval and then multiplied by the sediment concentration to determine sediment loss. Imhoff cone samples were not filtered in a timely fashion before the starch compounds began to decompose, and therefore samples were not filtered to correlate settled volume with sediment mass. Thus, sediment concentrations and losses are reported on a volume basis, not mass basis. Total flow and total sediment loss for each furrow are the sums of the flow volumes and sediment losses for each sampling interval. Total furrow flow, at the quarter or field end locations, was subtracted from total inflow to determine total infiltration. Flow and infiltration volumes were converted to depth by dividing by furrow spacing (1.5 m) and field length (36 or 143 m). Analysis of variance was used to compare infiltration, advance time, flow volume, and sediment loss among treatments. Treatment means were separated with Duncan's multiple range test ($P < 0.05$).

Test 2

The second test was conducted in 2006 on a 150 m long field with 1% slope, Rad silt loam soil (coarse-silty, mixed, mesic Durinodic Xeric Haplocambid), and planted to dry bean ('Viva Pink' *Phaseolus vulgaris* L.). Row spacing was 0.56 m, furrow spacing was 1.12 m, and every other furrow was wheel-compacted during planting and cultivation. The field was planted to barley in 2005, moldboard plowed in the fall, and roller harrowed in spring 2006 before planting. No crop growth or crop yield measurements were made during this test.

Four treatments and a control were compared in a randomized complete block design with five replications. Treatments were not re-randomized between irrigations, so the same furrows received the same treatments for four irrigations. The treatments involved dissolved application, where a concentrated solution of the amendment was added to irrigation water at the inflow point of each furrow during the entire irrigation, and patch application, where the dry amendment was applied directly to the first 1 to 1.5 m of furrow soil prior to irrigation. The treatments were control (no treatment), 2 mg L^{-1} a.i. PAM (PAM2) or 2 mg L^{-1} a.i. polysaccharide/PAM (SS2) dissolved in inflow water, and dry PAM (PAMpatch) or polysaccharide/PAM (SSpatch) applied directly to the furrow soil surface. Test 1 results indicated that the polysaccharide/PAM amendment provided better erosion control during amendment application, and control decreased when application stopped. Thus, amendments were applied continuously during the entire irrigation rather than only applying the treatment until water advanced to the end of the field. Lentz and Sojka (2000) found that continuous PAM application at 2 mg L^{-1} reduced sediment loss similar to the standard 10 mg L^{-1} PAM application during irrigation advance. The patch treatment can be a simple yet effective method for PAM application where the hydrated PAM on the furrow soil slowly dissolves during irrigation. The SoilSentry product label does not list direct application of dry material to the furrow soil; this treatment was only included for comparison purposes.

For the patch treatments, 20 g a.i. of PAM or polysaccharide/PAM were applied to the first 1 to 1.5 m of the furrow immediately before the irrigation. This was approximately the same mass of material that would be applied with the dissolved treatments. Dissolved treatments were applied using similar manifolds as test 1, with one 300 mm long, 1.3 mm diameter outlet tube per treated furrow. Concentrated PAM and polysaccharide/PAM solutions (2000 mg L^{-1}) were prepared with tap water one or two days before each irrigation. These concentrated solutions were diluted to 200 mg L^{-1} before pouring into the 110 L supply tank for each manifold. Separate manifolds were used for PAM and polysaccharide/PAM.

Runoff and soil loss were measured during four of the six irrigations with similar methods as test 1. The first and last irrigations on this dry bean field were not monitored due to personnel constraints. Monitored irrigations will be referred to as irrigations 1 to 4 in this article. The field was cultivated about two weeks before the first monitored irrigation. This was the only monitored irrigation where furrows were freshly tilled before irrigation. Treatments were applied only during irrigations 1 and 2 to allow some comparison of the residual effects of treatments during irrigations 3 and 4. All monitored furrows were non-wheel-compacted furrows to potentially enhance infiltration differences among treatments.

Irrigation water was distributed to furrows by gated pipe with spigot valves. Furrow inflow rate was the same for every furrow during an irrigation. Inflow rates were approximately 20 L min^{-1} for all four irrigations. Runoff flow rate was measured and sediment samples collected 15 min after water advanced past a flume at the end of the furrow. The next two measurements were collected approximately 30 and 60 min later, and then two to four additional measurements were made every 1 to 2 h during the rest of irrigation, which lasted 8 to 12 h. One Imhoff cone sample was collected from each furrow during irrigations 2 and 4 to convert sediment concentration from a volume basis to a mass basis. The 1 L samples were filtered in the laboratory one day after collection, and the dried filter papers were weighed to measure the mass of sediment in each sample to correlate sediment volume with sediment mass. Sediment samples from polysaccharide/PAM treated furrows had a slightly different relationship than PAM and control samples for irrigation 2 when treatments were applied. The sediment that settled to the bottom of the Imhoff cones was less dense when furrows were treated with polysaccharide/PAM. The multiplier to convert sediment concentration from volume basis (mL L^{-1}) to mass basis (g L^{-1}) was 0.78 g mL^{-1} for polysaccharide/PAM ($r^2 = 0.96$) and 0.93 g mL^{-1} for PAM and control ($r^2 = 1.00$). These multipliers were used for both irrigations 1 and 2 when treatments were applied. The relationship between sediment volume and mass was the same for all treatments for irrigation 4 (1.03 g mL^{-1}, $r^2 = 0.95$). A multiplier of 0.9 g mL^{-1} was used for all treatments for irrigation 3.

The volume of runoff from each furrow was calculated for each sampling interval and multiplied by sediment concentration to determine sediment loss. Total runoff and total sediment loss for each furrow were the sums of the runoff and sediment loss for each sampling interval. Total runoff was subtracted from total inflow to determine total infiltration for each furrow. Runoff and infiltration volumes were converted to depth by dividing volume by furrow spacing (1.12 m) and field length (150 m). Similarly, sediment loss per unit area was calculated by dividing total sediment mass by furrow spacing and field length. Flow-weighted sediment concentration was calculated by dividing total sediment loss (mg) by total runoff volume (L) for each furrow for an irrigation and for all four irrigations. Analysis of variance was used to compare total inflow, infiltration, runoff, and sediment loss among treatments. Cumulative totals for the four monitored irrigations were also analyzed. Treatment means were separated with Duncan's multiple range test ($P < 0.05$).

Results and Discussion

Test 1

Furrow inflow volume was not significantly different among treatments ($P > 0.33$, data not shown) for either irrigation because inflow rates were set the same in every furrow. The coefficient of variation for inflow volume was 5% for irrigation 1 and 6% for irrigation 2. About 45% more water was applied during the second irrigation (86 mm) compared to the first (59 mm) because of the higher inflow rate (27 L min^{-1} versus 19 L min^{-1}).

Table 1. Average advance time, infiltration, and sediment loss at the end of the field for Test 1.[a]

Treatment	Advance Time Irrig. 1 (min)	Advance Time Irrig. 2 (min)	Infiltration Irrig. 1 (mm)	Infiltration Irrig. 2 (mm)	Runoff Irrig. 1 (mm)	Runoff Irrig. 2 (mm)	Sediment Loss Irrig. 1 (L)	Sediment Loss Irrig. 2 (L)
PAM2	184	79	41 ab	60 a	19 ab	28 c	42 ab	28 bc
PAM10	165	50	45 a	55 ab	14 b	31 bc	21 b	3 c
SS6	232	62	43 a	40 c	18 ab	46 a	72 a	83 a
SS12	247	52	46 a	40 c	14 b	45 a	28 b	70 ab
SS18	203	60	43 a	51 abc	15 b	35 abc	23 b	38 abc
Starch	101	57	31 c	41 c	27 a	46 a	78 a	86 a
Control	116	52	33 bc	43 bc	25 a	43 ab	77 a	84 a
Probability	(0.06)	(0.23)	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(<0.01)

[a] Values in a column within an irrigation followed by the same letter are not significantly different at P > 0.05. Letters are not shown when differences among treatments were not significant.

Advance time, infiltration depth, and runoff depth were not significantly different among treatments on the upper quarter of the field during either irrigation (data not shown). Only sediment transport during irrigation 2 was significantly different among treatments at the quarter point (P = 0.03). The PAM10 treatment reduced sediment transport past the quarter point by at least 90% compared to the control, SS6, SS12, and starch treatments (data not shown).

Advance time for furrow flow to reach the end of the field was not significantly different among treatments for either irrigation (table 1). Advance time was quite variable among the furrows during irrigation 1, ranging from 45 to 360 min (CV = 64%) for individual furrows (data not shown). Seven furrows required >5 h of the 11 h irrigation for water to reach the end of the field; six of these seven furrows were SS treatments. The greater inflow rate used during irrigation 2 reduced average advance time, especially for SS treatments, and the variation ranged from 40 to 100 min (CV = 28%). Shorter advance times for SS treatments resulted in shorter treatment application times and 33% to 43% less polysaccharide/PAM amendment being applied during irrigation 2 compared to irrigation 1 (table 2), even though injection rates increased proportionally with flow rate to maintain the same treatment concentration.

PAM10 and all SS treatments increased infiltration by about 40% compared to the control and starch treatments during irrigation 1 (table 1). Conversely, only PAM2 increased infiltration compared to the starch and control treatments during irrigation 2 (table 1). There is not a direct correlation between PAM application rate and infiltration (Lentz et al., 2002; Lentz, 2003), so it is reasonable that PAM2 was significantly different and PAM10 was not compared to the starch and control treatments. PAM2 and PAM10 also had 50% and 37%, respectively, greater infiltration than SS6 and SS12 during irrigation 2. Runoff followed similar statistical trends as infiltration for both irrigations. SS12, SS18, and PAM10 had less runoff than the starch or control treatments during irrigation 1, while PAM2 had less runoff than the starch and control treatments for irrigation 2 (table 1). The higher inflow rate used during irrigation 2 reduced the advance time, especially for SS treatments, which decreased the time that treatments were applied during irrigation 2 and reduced the amount of polysaccharide/PAM amendment applied (table 2). With lower amendment application rates, infiltration and runoff were not different between SS treatments and control, even though amendment concentrations in furrow flow were the same during both irrigations. The polysaccharide/PAM amendment may need to be applied at higher rates than PAM to be as effective, similar to what Orts et al. (2007) showed for other biopolymers in the laboratory. It is also possible that the polysaccharide/PAM amendment does not have the same soil stabilizing effect as PAM and is therefore less effective after application ends.

Table 2. Average treatment amounts applied for irrigations 1 and 2 during Test 1.

Treatment	Application Rate Irrig. 1 (kg ha^{-1})	Application Rate Irrig. 2 (kg ha^{-1})
PAM2	0.6	0.7
PAM10	2.8	3.0
SS6	3.2	1.9
SS12	6.1	3.5
SS18	9.3	6.2
Starch	3.4	3.1

SS12, SS18, and PAM10 had significantly less sediment loss than SS6, starch, and control treatments during irrigation 1 (table 1). During irrigation 2, only PAM2 and PAM10 had significantly less soil loss than the SS6, starch, and control treatments. Field observations indicated that sediment concentration tended to increase in SS-treated furrows after application stopped. Figure 1 shows an example of sediment concentration in furrow flow at the quarter point for one block of furrows (not including SS6 and SS18). The total amount of sediment transported in these five furrows was 6 L for PAM10, 44 L for PAM2, 51 L for SS12, 55 L for starch, and 46 L for control. Sediment concentration increased from 1.5 to 8 mL L^{-1} in the SS12 furrow approximately 2 h after application stopped. A similar increase was noted in the PAM2 furrow after application stopped, but not in the PAM10 furrow. The polysaccharide/PAM amendment seems to be more effective if applied continually during irrigation rather than only during the advance. Previous studies documented that continuous application of PAM can effectively control erosion as long as the PAM concentration is great enough to protect the furrow soil early in the irrigation (Lentz and Sojka, 1994 and 2000).

PAM is an important component of the polysaccharide/PAM amendment. The starch treatment was not significantly different from the control for any parameter during either irrigation (table 1). However, SS12 had greater infiltration and less runoff and sediment loss than starch during irrigation 1. PAM2 and SS12 were not statistically different except for greater infiltration and less runoff for PAM2 during irrigation 2. This seems to indicate that much of the effectiveness of the polysaccharide/PAM amendment is due to the PAM, possibly because the polysaccharide primarily flocculates suspended material rather than stabilizing the soil surface as PAM does (Orts et al., 2007).

Test 2

Inflow rates were set equal for all monitored furrows, so the volume of water applied was not significantly different among treatments for any irrigation (P > 0.36, data not shown). Inflow rate was approximately 20 L min^{-1} for all four monitored irrigations, which caused furrow flow to advance down the field in approximately 2 to 5 h. Advance times were significantly different among treatments only during irrigations 1 and 3 (table 3). Both PAM and SS treatments had slower advance times than the control for irrigations 1 and 3, indicating greater infiltration for the treated furrows. SS2 also had slower advance time than both PAM treatments during irrigation 1, while PAM2 had slower advance time than both SS treatments for irrigation 3.

Applying the polysaccharide/PAM amendment at 2 mg L^{-1} during the entire irrigation (SS2) increased infiltration 46% and 20% compared to the control for irrigations 1 and 2, respectively (table 3). SS2 also increased infiltration 15% compared to both PAM treatments during irrigation 1, and 22% and 28% compared to PAM2 and PAM10, respectively, during irrigation 2. Both PAM application methods and SSpatch increased infiltration about 25% compared to the control for irrigation 1, but were not different from the control during irrigation 2. In irrigation 3, the residual effects of all treatments applied during the two previous irrigations increased infiltration 6% to 18% compared to the control.

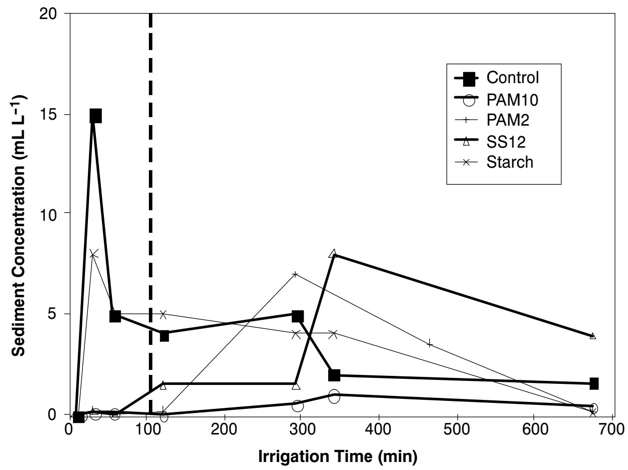

Figure 1. Sediment concentration measured in furrow flow 36 m from the inflow (quarter field length) for five furrows in one block during irrigation 2. The dashed vertical line indicates the time when treatment application ended.

Table 3. Average advance time, infiltration, runoff, sediment concentration, and sediment loss for Test 2.[a]

Irrigation Number and Date[b]	Treatment	Advance Time (min)	Infiltration Depth (mm)	Runoff Depth (mm)	Sediment Concentration (mg L^{-1})	Sediment Loss (kg ha^{-1})
1	Control	118 c	41 c	18 a	4470 a	828 a
(3 July 2006)	PAM2	187 b	51 b	6 b	395 c	24 d
	PAMpatch	186 b	51 b	7 b	637 c	43 cd
	SS2	243 a	59 a	5 b	1290 c	67 c
	SSpatch	202 ab	51 b	9 b	3340 b	297 b
	Probability	(<0.01)	(0.03)	(<0.01)	(<0.01)	(<0.01)
2	Control	136	60 b	34 ab	4340 a	1451 a
(14 July 2006)	PAM2	121	59 b	34 ab	44 c	15 d
	PAMpatch	119	56 b	37 a	308 c	95 c
	SS2	130	72 a	23 c	3130 b	758 b
	SSpatch	143	70 a	27 bc	3490 ab	945 ab
	Probability	(0.24)	(0.01)	(<0.01)	(<0.01)	(<0.01)
3	Control	216 c	62 d	18 a	1700 a	298 a
(25 July 2006)	PAM2	323 a	74 a	7 b	29 d	2 c
	PAMpatch	303 ab	70 b	10 b	602 c	60 b
	SS2	275 b	70 b	11 b	798 bc	102 b
	SSpatch	262 b	66 c	12 ab	1020 b	131 ab
	Probability	(<0.01)	(<0.01)	(0.01)	(<0.01)	(<0.01)
4	Control	139	73	17	1690 a	339 a
(1 Aug. 2006)	PAM2	158	82	9	47 c	4 d
	PAMpatch	183	76	14	502 bc	87 cd
	SS2	160	80	11	935 b	93 bc
	SSpatch	157	76	13	681 b	104 ab
	Probability	(0.57)	(0.16)	(0.26)	(0.01)	(0.02)
Total	Control		236 c	87 a	3360 a	2916 a
	PAM2		266 b	56 b	76 c	45 d
	PAMpatch		252 b	69 b	411 c	285 c
	SS2		281 a	50 b	1940 b	1019 b
	SSpatch		263 b	62 b	2520 b	1477 b
	Probability		(0.01)	(<0.01)	(<0.01)	(<0.01)

[a] Values in a column within an irrigation followed by the same letter are not significantly different at P > 0.05. Letters are not shown when differences among treatments were not significant.
[b] Treatments were applied during irrigations 1 and 2.

PAM2 had the greatest infiltration during irrigation 3, followed by PAMpatch and SS2 and then SSpatch (table 3). There were no residual effects of amendment treatments on infiltration during irrigation 4.

Runoff followed similar statistical trends as infiltration because inflow was the same for each treatment (table 3). SS2 had less runoff than the control for the first three irrigations, while PAM treatments had less runoff than the control only during irrigations 1 and 3.

PAM2, PAMpatch, and SS2 treatments had significantly lower sediment concentrations than the control for all four irrigations (table 3). Sediment concentrations were not significantly different between PAM2 and SS2 treatments during irrigation 1 when furrows were recently tilled before irrigation. PAM2 had significantly lower sediment concentrations than SS2 during irrigations 2, 3, and 4.

PAM2 had significantly less sediment loss than the control and both SS treatments for all four irrigations, and SS2 had less sediment loss than the control for all four irrigations (table 3). PAM had a greater ability than SS2 to stabilize furrow soil, as indicated by reduced sediment concentrations for irrigations 2 through 4 (table 3). Although SS2 had less runoff than both PAM treatments during irrigation 2, the much greater sediment concentration in SS2-treated furrows resulted in significantly more sediment loss for SS2 compared to the PAM treatments. Sediment loss reductions relative to the control for PAM2 and SS2 were: 97% and 92% for irrigation 1, 99% and 48% for irrigation 2, 99% and 66% for irrigation 3, and 99% and 73% for irrigation 4.

SS2 had the greatest cumulative infiltration for the four irrigations (table 3). SS2 had 19% greater infiltration than the control compared to 7% to 13% for the other three treatments. Conversely, PAM2 had the least cumulative sediment loss, followed by PAMpatch and then the two polysaccharide/PAM treatments (table 3). PAM2 reduced cumulative sediment loss by 98% compared to the control, and PAMpatch reduced cumulative sediment loss by 90%. Even though SS2 had about 20 times more sediment loss than PAM2, SS2 still reduced cumulative sediment loss by 65% compared to the control. PAM2 and PAMpatch had similar effects on cumulative infiltration and runoff, but PAM2 more effectively controlled sediment loss than PAMpatch. Conversely, SS2 and SSpatch had similar effects on sediment loss, but SS2 increased infiltration more than SSpatch.

Conclusion

The results of these two field tests indicate that the polysaccharide/PAM amendment can be used as an alternative to PAM for controlling erosion and increasing infiltration on furrow-irrigated fields. PAM is an important component of the polysaccharide/PAM amendment. The polysaccharide alone did not significantly affect infiltration, runoff, or sediment loss compared to the control during two irrigations on a fallow field, while 12 mg L^{-1} of the polysaccharide/PAM amendment increased infiltration and reduced runoff and sediment loss during one irrigation on the fallow field. Sediment concentration seemed to increase in furrows after the polysaccharide/PAM amendment application stopped, indicating that this amendment is more effective when applied continually during irrigation.

PAM more effectively controlled erosion than the polysaccharide/PAM amendment during four irrigations on a dry bean field, reducing sediment loss 90% to 98% compared to 49% to 65% reduction for the polysaccharide/PAM. Applying the polysaccharide/PAM amendment at 2 mg L^{-1} during the entire irrigation increased infiltration 19% compared to the control, while the dissolved and patch PAM treatments increased infiltration 13% and 7%, respectively. In situations where maintaining high infiltration rate is a greater concern than erosion control, the polysaccharide/PAM blend may be a better amendment, depending on cost and application considerations. Applying the polysaccharide/PAM blend at a higher rate may enhance erosion control and maintain a higher infiltration rate.

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