Polyacrylamide Effect on Erosion and Runoff at Selected Slopes

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Introduction

Anionic polyacrylamide monomer (PAM) is a material that acts as flocculating agent that binds soil particles (Agassi et al., 1981; Seybold, 1994; Sojka et al., 2007). Polyacrylamide stabilizes soil aggregates, thus maintaining water infiltration and decreasing soil erosion (Helalia and Letey, 1988; Ross et al., 2003; Sojka et al., 2007; Zhang and Miller, 1996).

The benefit of PAM for reducing erosion and runoff is not well-known when applied on steep slopes. Erosion is greatly increased as slope increases (VDCR, 2002; WDNR, 2001; WSDOT, 2008).

Rationale

Research by state and federal institutions including the US Department of Transportation (USDOT), the USDA-NRCS, and the USEPA have guidelines of use of PAM for erosion and runoff control (ASWCC, 2003; CASQA, 2003; USEPA, 1992; WDNR, 2001; WSDOT, 2008). However, these guidelines do not have specific recommendations for erosion and runoff control on different slopes.

Objectives

To evaluate the benefit of PAM (20- and 40-kg ha^{-1}) for controlling erosion and runoff on slopes of 10%, 20%, and 40% vs. unamended (0 kg ha^{-1} PAM) Mexico silt loam soil with the same slopes.

Materials & Methods

- A factorial experiment was used with: 1) three slopes (10%, 20%, and 40%), 2) two levels of PAM solution application (20- and 40-kg ha^{-1}), and unamended control, and 3) three replicates.
- Three dependent variables were measured: 1) time to initial runoff (TRO), 2) runoff (RO), and 3) sediment loss (SL).
- Aqueous PAM (600 ppm) was applied using the granular anionic PAM (MW of 15MDa).
- Air-dried, 10 mm sieved Mexico silt loam soil (fine, smectitic, mesic Aeric Vertic Epiaqualf; Table 1) was packed to a bulk density of 1.3 Mg m^{-3}.
- A 60 min simulated rainfall was applied at an intensity of 61 mm h^{-1} and a kinetic energy (KE) of 1.5 kJ m^{-2} h^{-1}, representing a 10-year, 1-hour return frequency across mid-Missouri (Hershfield, 1961).
- Sediment and runoff were collected for two min every five min and totaled.

Results & Discussions

Table 1. Physical and chemical properties of the Mexico silt loam soil from 0-300 mm.

Soil	Texture	Sand	Silt	Clay	Organic Matter	pH	Cation Exchange Capacity	Exchangeable Cations: Ca	Mg	Na	K
		---------- $g\ kg^{-1}$	----------				------------ $cmol_c\ kg^{-1}$	------------			
Mexico	Silt loam	55	723	222	28.9	7.4	23.1	16.6	2.4	1.0	0.3

Time to Initial Runoff (TRO; Fig. 1)

1) At 10% slope, TRO with 0P was slightly higher than 40P amended soil.
2) At 20% slope, TRO with 20P and 40P increased by an average of 12% vs. the 0P amended soil.
3) No difference in TRO was found between the 20P and 40P at slopes of 10% and 20%.
4) At 40% slope, TRO with 20P and 40P increased by 19% and 27% vs. the unamended soil.
5) PAM (20P, 40P) increased TRO at ≥20% slopes vs. 0P (p<0.05).

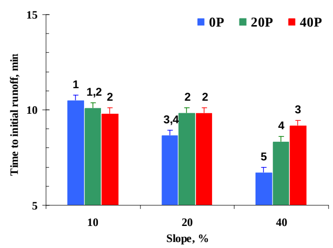

Fig. 1. Time to initial runoff on Mexico silt loam soil after a 60 min rainfall at an intensity of 61 mm h^{-1} (KE = 1.5 kJ m^{-2} h^{-1}). Error bars are the 95% confidence intervals of the mean; numbers above mean bars are not significantly different as determined by Tukey's HSD (p<0.05; n=3).

Runoff (RO; Fig. 2)

1) Slope was not a significant factor determining RO.
2) RO, when averaged across slopes, increased with increasing PAM vs. unamended soil (all p<0.05).
3) A higher level of PAM (40P) increased RO for all slopes vs. lower level of PAM (20P).

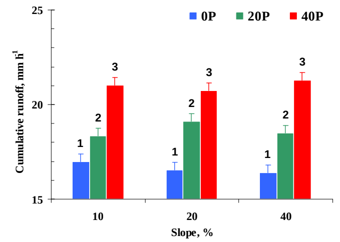

Fig. 2. Runoff on Mexico silt loam soil after a 60 min rainfall with an intensity of 61 mm h^{-1} (KE = 1.5 kJ m^{-2} h^{-1}). Error bars designate 95% confidence intervals of the mean; numbers above mean bars are not significantly different as determined by Tukey's HSD (p<0.05; n=3).

Sediment Loss (SL; Fig. 3)

1) Sediment loss increased with slope (p<0.05).
2) At 10% slope, average SL with PAM was 71% less than with unamended soil, and no difference in SL was found between 20P and 40P.
3) At 20% slope, SL with 20P and 40P was 40% and 53% less than 0P.
4) At 40% slope, SL with 20P and 40P was 20% and 54% less than 0P.
5) The effectiveness of 40P for reducing SL was the greatest for slopes ≥20%.
6) PAM reduced SL by up to 72% across all slopes vs. unamended soil.

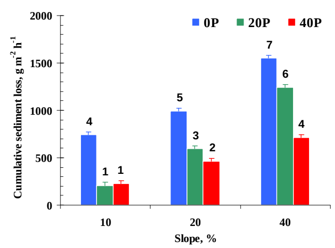

Fig. 3. Sediment loss on Mexico silt loam soil after a 60 min rainfall with an intensity of 61 mm h^{-1} (KE = 1.5 kJ m^{-2} h^{-1}). Error bars designate 95% confidence intervals of the mean; numbers above mean bars are not significantly different as determined by Tukey's HSD (p<0.05; n=3).

Slope Effects on Sediment Loss (SL; Fig. 4)

1) Sediment loss with 0P, 20P, and 40P had a nearly linear increase for all slopes.
2) Sediment loss decreased with increasing amount of PAM.
3) No difference was found between the 20P vs. 40P at a 10% slope.

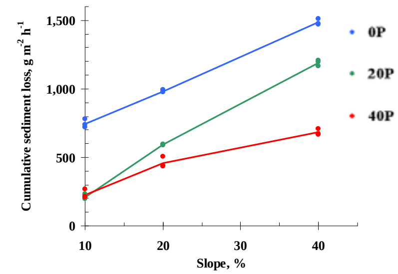

Fig. 4. Sediment loss after a 60 min rainfall with an intensity of 61 mm h^{-1} (KE = 1.5 kJ m^{-2} h^{-1}) as increasing slope. Dots indicate observations (n=3)

Summary and Conclusions

This study evaluated the sediment and runoff loss from 0-(0P), 20-(20P), and 40-kg ha^{-1} PAM (40P) amended Mexico silt loam soil at slopes of 10%, 20%, and 40%. Time to initial runoff (TRO), runoff (RO), and sediment loss (SL) were measured after a 60 min of simulated rainfall at 61 mm h^{-1} intensity (KE of 1.5 kJ m^{-2} h^{-1}).

- Applications of either 20P or 40P reduced SL for all slopes.
- No difference in reduction of SL was found between the 20P and 40P at 10% slope.
- Application of 40P was more effective for reducing SL than 20P at slopes of ≥20%.
- Slope is a critical factor in choosing the level PAM for erosion control.
- Work relating PAM applications for differing slopes, rainfall intensities, and plot sizes should improve guidelines for PAM use.

This study was supported by the USDOT Grant, the Missouri Agricultural. Station, and Graduate School Service Fellowship of the University of Missouri, Columbia.