

Impact of ENCAP's *Gypsum Plus ASTTM* Compared to Traditional Gypsum

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Introduction

Transport of soil particles, fertilizers and other nutrients throughout the landscape as a result of erosion and surface runoff poses significant economic costs and environmental concerns to society. Surface application of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) has been shown to increase infiltration rates, and decrease runoff and sediment loss (Keren et al., 1983; Smith et al., 1990; Zhang et al., 1998; Tang et al., 2006). Gypsum increases the electrolyte concentration in the soil solution and replaces exchangeable Na with Ca, decreasing the tendency of soil clay to disperse and form a surface seal (Keren et al., 1983). Thus, soil amendments containing gypsum are frequently used in agriculture to reduce chemical dispersion of clay particles and reduce soil surface sealing that leads to decreased infiltration rates, and increased runoff volumes and sediment loss.

Water soluble anionic polyacrylamides (WSPAM) are used to enhance aggregate stability, promote infiltration and reduce runoff and erosion. This practice has been widely accepted in irrigated agriculture where low application rates effectively increase infiltration and decrease sediment loss.

The combined application of WSPAM with gypsum to soil can be advantageous in that gypsum provides divalent cations in the form of Ca^{2+} , that enhance cation bridging and the sorption of WSPAM to soil particles (Laird, 1997; Green et al., 2000). ENCAP's Advanced Soil Technology (*ASTTM*) impregnates and/or coats soil conditioning and/or fertilizer products such as traditional gypsum with the intent of making them more effective by keeping them in place, overcoming soil and nutrient losses due to runoff, infiltration/leaching, and erosion. ENCAP LLC's (Green Bay, WI) patented carrier and delivery technology is utilized in one of their products called *Gypsum Plus ASTTM*.

The objective of this study was to evaluate the impact of ENCAP LLC's (Green Bay, WI) *Gypsum Plus ASTTM* product on sediment and nutrient transport with respect to the performance of traditional gypsum.

Methods and Materials

Rainfall Simulations

Infiltration, runoff, erosion and nutrient transport were studied using a laboratory rainfall simulator based on the design used in previous WSPAM tests by Petersen et al., 2007. The drip-type simulator consisted of an enclosed PVC chamber with approximately 700 hypodermic needles protruding from the base of the chamber in a 25 mm by 25 mm grid spacing. Water was pumped from a holding tank through a 19 mm (0.75 in) hose using a 1.5 HP submersible pump. A pressure regulator maintained a constant water pressure in the enclosed chamber and a ball valve allows flow to the simulator to be turned on or off. The enclosed chamber was positioned 1.5 m (5 feet) above a sloped platform (10%) on four support legs. Small oscillating fans positioned on the support columns of the simulator induced spatially random drop distributions on the test area below the simulator. Average droplet diameter was 3.5 mm, determined volumetrically by collecting 50 drops from twenty randomly selected needles. The 1.5 m (5 feet) drop height produced drops with a fall velocity of $4.94 \text{ m}\cdot\text{s}^{-1}$ according to Epema and Riezebos (1983).

Plano silt loam soil obtained from agricultural fields at Arlington Agricultural Research Station (Arlington, WI) was used in all experiments. Soil was taken from the upper 10 cm (4 inches) of the soil surface, air-dried, crushed and passed through a 4.0 mm sieve to maintain soil uniformity throughout the tests. The soil was spread evenly in two lifts over a pea gravel base layer in soil boxes measuring 0.457 m long by 0.203 m wide by 0.089 m deep. Dionized (DI) water was applied to each soil lift using a hand sprayer to achieve an overall moisture content of 20% by volume. The soil was compacted to a bulk density of 1.2 g cm^{-3} by pressing the soil with a flat piece of PVC to a known depth. Treatments were then spread on the soil surface, covered, and allowed to rest for 24 hours before rainfall simulations were performed.

Three soil boxes were positioned side-by-side on the sloped platform to allow simultaneous testing of three treatments. Rainfall was simulated at approximately 65 mm/hr for 60 minutes. Each soil box had a fixed gutter along the downslope edge with a PVC pipe outlet from which runoff was collected, and an infiltration outlet positioned at the underside of each soil box from which leachate was collected. Runoff was collected in 20 minute intervals throughout the 60 minute rainfall simulation. Leachate was collected for the entire 60 minute simulation. After samples were collected they were weighed and approximately 60 mL runoff samples were filtered (.45 micron) and analyzed by the Soil and Plant Analysis Lab (SPAL) at the University of Wisconsin-Madison for dissolved reactive phosphorus (DRP), soluble ammonium ($\text{NH}_4\text{-N}$), soluble nitrate ($\text{NO}_3\text{-N}$), soluble calcium (Ca), and soluble sulfur (S). The remaining runoff sample was oven dried. Dried runoff sediment was weighed, collected, and sent to SPAL for analysis of total phosphorus (TP) and $\text{NH}_4\text{-N}$.

Two treatments were tested in addition to a bare soil control: 1) soil conditioner, where Traditional Gypsum was applied to the soil surface at an application rate of 280 kg/ha (250 lb/acre); and 2) *Gypsum Plus AST*TM, where WSPAM coated gypsum, provided by ENCAP LLC. (Green Bay, WI), was applied at 280 kg/ha (250 lb/acre) [WSPAM application rate of 5.6 kg/ha (5.0 lb/acre)]. All treatments were replicated four times.

Data Analysis

Sediment loads, nutrient loads, mineral loads, runoff volumes, and leachate volumes were accumulated over the duration of the rainfall simulation for each replicate, averaged and the percent reduction in each variable was determined as

$$\% \text{ Reduction} = \frac{A_c - A_t}{A_c} \times 100 \quad (1)$$

where A_c is the average accumulated sediment load, nutrient load, mineral load, runoff volume or leachate volume from the control and A_t is the average sediment load, nutrient load, mineral load, runoff volume or leachate volume from the treatment.

Data obtained from the rainfall simulations were analyzed with SYSTAT using a multi-variable analysis of variance (ANOVA) and utilized a Bonferroni method Post hoc test to obtain critical levels of significance ($P < 0.05$).

Results and Discussion

Sediment and sediment bound P and NH_4

Traditional Gypsum and *Gypsum Plus AST*TM treatments decreased cumulative sediment loads throughout 60 minutes of simulated rainfall (Fig. 1A). *Gypsum Plus AST*TM was more effective than Traditional Gypsum alone. When compared directly to Bare Soil, the percent reduction of sediment load after 20 minutes of simulated rainfall (21 mm of applied rainfall) was 54, and 91% for gypsum and *Gypsum Plus AST*TM, respectively (Fig. 1B). After 40 minutes (43 mm of applied rainfall) the percent sediment load reductions had fallen to 19 and 73% and after 60 minutes (65 mm of applied rainfall) they were 18 and 69%. The results after 60 minutes are shown in Table 1. The consistent order of cumulative load among treatments is Bare Soil > Traditional Gypsum > *Gypsum Plus AST*TM. The apparent separation of slopes in Fig. 1 into two groups ((1) bare soil and gypsum and (2) *Gypsum Plus AST*TM) likely reflects the significant differences in how *Gypsum Plus AST*TM and traditional gypsum alone contribute to soil consolidation and stability. Table 1 also shows a 63 percent cumulative sediment load reduction when comparing the *Gypsum Plus AST*TM to gypsum treated soil.

The results for sediment bound P and NH_4 show similar trends to those of sediment load (Tables 1-2 and Fig. 2A-D). The one exception is that mean cumulative NH_4 loads were not significantly different for Traditional Gypsum compared to Bare Soil or *Gypsum Plus AST*TM (Table 2).

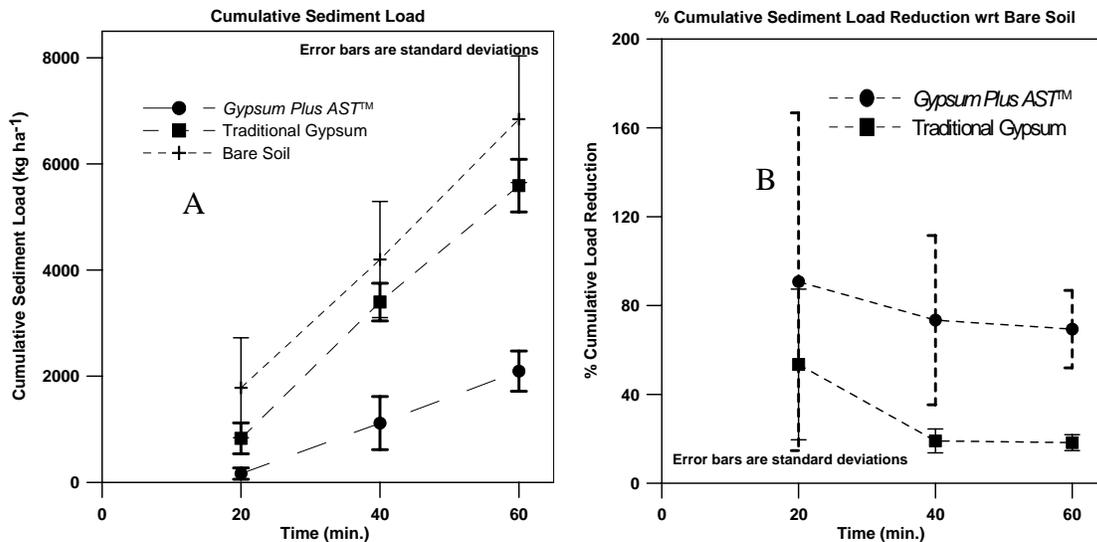


Figure 1. (A) Cumulative sediment load during 60 minutes of simulated rainfall (total precip ~ 65 mm) for Bare Soil, Traditional Gypsum treated soil and Gypsum Plus ASTTM treated soil. (B) Percent reduction in cumulative sediment load wrt Bare Soil for soils treated with Traditional Gypsum and Gypsum Plus ASTTM

Table 1. Percent reduction in 60 minute cumulative sediment load and sediment bound and dissolved runoff constituent loads. Comparisons are made between both experimental treatments and Bare Soil as well as between Traditional Gypsum and Gypsum Plus ASTTM (ns= means were not significantly different based on ANOVA).

	Runoff Sediment			Runoff Solution				
	Sediment	P	NH ₄	Percent Reduction compared to bare soil				
				DRP	NH ₄	NO ₃	Ca	S
Traditional Gypsum	ns	ns	ns	59	ns	ns	-903	-9600
Gypsum Plus AST TM	69	69	57	68	ns	ns	ns	-4634
	Percent Reduction compared to Traditional Gypsum							
	Sediment	P	NH ₄	DRP	NH ₄	NO ₃	Ca	S
Gypsum Plus AST TM	63	63	ns	ns	ns	ns	55	51

Table 2. Runoff sediment and sediment bound P and NH₄ (kg ha⁻¹) and standard deviations for 0-60 minutes of simulated rainfall.

	Runoff Sediment (all units are kg ha ⁻¹)				
	Sediment	P		NH ₄	
Bare Soil	6.8E+03 ±	1.2E+03 a	4.7E+00 ±	7.8E-01 a	2.8E-01 ± 8.7E-02 a
Traditional Gypsum	5.6E+03 ±	5.0E+02 a	4.0E+00 ±	3.2E-01 a	2.0E-01 ± 5.0E-02 ab
Gypsum Plus AST TM	2.1E+03 ±	6.3E+02 b	1.5E+00 ±	2.9E-01 b	1.2E-01 ± 7.3E-02 b

Means followed by the same letter are not significantly different by ANOVA (P < 0.05)

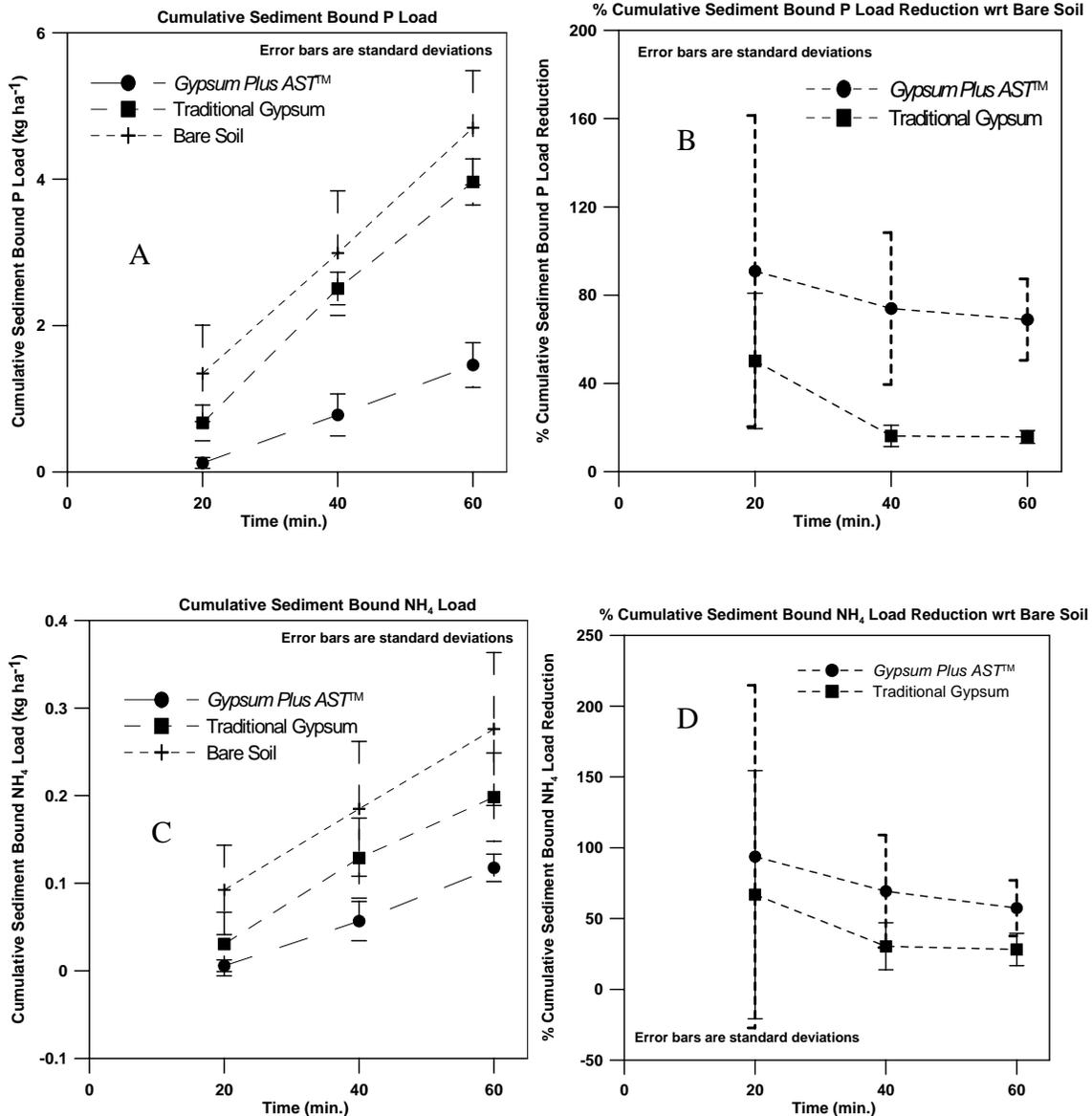


Figure 2. (A) Cumulative sediment bound P load during 60 minutes of simulated rainfall (total precip ~ 65 mm) for Bare Soil, Traditional Gypsum and *Gypsum Plus ASTTM* treated soils. (B) Percent reduction in cumulative sediment bound P load wrt bare soil for soils treated with the two different conditioners. (C) Cumulative sediment bound NH₄ load during 60 minutes of simulated rainfall (total precip ~ 65 mm) for Bare Soil, Traditional Gypsum treated and *Gypsum Plus ASTTM* treated soils. (D) Percent reduction in cumulative sediment bound NH₄ load wrt bare soil for soils treated with the two different conditioners.

Dissolved Runoff Constituents

Table 3 lists the cumulative loads of dissolved runoff constituents dissolved reactive phosphorus (DRP), NH_4 , NO_3 , Ca and S. Only Ca, S, and DRP have significant differences between treatment means. It is expected that Ca and S in runoff would increase because they are added in significant quantities with the gypsum. For Ca, the treatment results fall into two statistical groups: 1) Bare Soil and *Gypsum Plus AST*TM, and 2) Traditional Gypsum (Table 3). For S, the cumulative loads follow the statistical order of Traditional Gypsum > *Gypsum Plus AST*TM > Bare Soil. Because DRP can also be correlated to sediment yield, it is difficult to assess the reason for DRP load reduction.

Table 3. Runoff solution constituent loads (kg ha⁻¹) for 0-60 minutes of simulated rainfall. The NO_3 value for Bare Soil (highlighted in grey) is influenced by an outlier.

	Runoff Solution (all units are kg ha ⁻¹)									
	DRP		NH ₄		NO ₃		Ca		S	
Bare Soil	4.0E-02 ±	5.1E-03 a	6.9E-03 ±	4.9E-03 a	2.5E-01 ±	3.6E-01 a	5.3E-01 ±	1.2E-01 a	6.2E-02 ±	3.1E-02 a
Traditional Gypsum	1.6E-02 ±	1.5E-03 b	4.7E-03 ±	2.9E-03 a	6.0E-02 ±	5.8E-02 a	5.4E+00 ±	8.4E-01 b	6.0E+00 ±	8.8E-01 b
<i>Gypsum Plus AST</i> TM	1.3E-02 ±	2.6E-03 b	7.3E-03 ±	5.9E-03 a	5.0E-02 ±	1.6E-02 a	2.4E+00 ±	1.6E+00 a	2.9E+00 ±	1.9E+00 c

Means followed by the same letter are not significantly different by ANOVA (P < 0.05)

Comparisons between 0-40 and 0-60 min.

The decrease in percent load reduction over time (Fig. 1B) motivated ANOVA of results of the first 40 minutes of simulated rainfall. Table 4 contains percent load reduction for all runoff constituents for 0-40 minutes. The reduction, with respect to bare soil, in sediment load and sediment P and NH_4 for the Traditional Gypsum treated soil were not significant for 0-40 minutes or 0-60 minutes.

For sediment load and sediment bound P load reductions from *Gypsum Plus AST*TM, which were statistically significant for 0-60 minutes, there is an increase in percent reduction for 0-40 minutes. Table 5 lists the increase in percent reduction for 0-40 minutes when compared to 0-60 minutes. The increases (*i.e.*, 4 % for sediment load, 5% for P and 12 % for NH_4 when comparing *Gypsum Plus AST*TM to Bare Soil) likely reflect the decrease in effectiveness of PAM over time as cumulative rainfall increases.

The reduction in runoff DRP with respect to bare soil increases significantly between 40 and 60 minutes for both Traditional Lime (21%) and *Gypsum Plus AST*TM (78%) (Table 5). While this result is statistically significant it may not represent results when DRP values approach field conditions. DRP values for samples collected during this study were all much less than 1 mg L⁻¹.

Table 4. Percent reduction in 0-40 minute cumulative sediment, sediment bound and dissolved runoff constituent loads. Comparisons are made between the two experimental treatments and bare soil as well as between *Gypsum Plus AST*TM and Traditional Gypsum (ns= means were not significantly different based on ANOVA).

	Runoff Sediment			Runoff Solution				
	Percent Reduction compared to bare soil							
	Sediment	P	NH4	DRP	NH4	NO3	Ca	S
Traditional Gypsum	ns	ns	ns	39	ns	ns	-1128	-10801
<i>Gypsum Plus AST</i> TM	73	74	69	-11	ns	ns	ns	ns
	Percent Reduction compared to Traditional Gypsum							
	Sediment	P	NH4	DRP	NH4	NO3	Ca	S
<i>Gypsum Plus AST</i> TM	67	67	56	ns	96	ns	57	71

Table 5. Difference (%) between 0-40 (Table 4) and 0-60 (Table 1) minute percent reduction of RO constituent loads. “ns” indicates value from at least one time period was statistically insignificant.

	Runoff Sediment			Runoff Solution				
	Percent Reduction compared to bare soil							
	Sediment	P	NH4	DRP	NH4	NO3	Ca	S
Traditional Gypsum	ns	ns	ns	-21	ns	ns	-225	-1201
<i>Gypsum Plus AST</i> TM	4	5	12	-78	ns	ns	ns	ns
	Percent Reduction compared to Traditional Gypsum							
	Sediment	P	NH4	DRP	NH4	NO3	Ca	S
<i>Gypsum Plus AST</i> TM	5	4	ns	ns	ns	ns	3	20

Leachate

There were no significant differences in leachate volumes among treatments (Table 6). Ca and S loads in leachate were significantly greater for Traditional Lime compared to both Bare Soil and *Gypsum Plus AST*TM (Table 7). This may indicate that *Gypsum Plus AST*TM is binding the Ca and S that is supplied with the addition of gypsum.

Table 6. Averages and standard deviations of leachate volumes (L).

	Bare Soil	Traditional Gypsum	<i>Gypsum Plus AST</i> TM
Average:	0.04 a	0.20 a	0.34 a
Std. Dev:	0.05	0.08	0.36

Table 7. Leachate solution loads (kg ha⁻¹).

	NH4	NO3	DRP	Ca	S
Bare Soil	6.92E-04 a	4.32E-02 a	3.78E-04 a	8.69E-02 a	1.61E-02 a
Traditional Gypsum	7.60E-03 a	8.70E-01 a	2.94E-03 a	8.72E-01 b	1.53E+00 b
<i>Gypsum Plus AST</i> TM	1.50E-03 a	1.78E-02 a	3.11E-03 a	1.65E-01 a	2.34E-01 a

Means followed by the same letter are not significantly different by ANOVA (P < 0.05)

Significant Findings

- *Gypsum Plus ASTTM* reduced sediment in runoff by 63% over a 60 minute period compared to Traditional Gypsum.
- *Gypsum Plus ASTTM* reduced sediment-bound phosphorus in runoff by 63% over a 60 minute period compared to Traditional Gypsum.
- *Gypsum Plus ASTTM* reduced Ca in runoff by 55% over a 60 minute period compared to Traditional Gypsum.
- *Gypsum Plus ASTTM* reduced S in runoff by 51% over a 60 minute period compared to Traditional Gypsum.
- Although a significant amount of Ca was added to the soil with the gypsum, Ca in runoff from *Gypsum Plus ASTTM* was not significantly different from Bare Soil.
- *Gypsum Plus ASTTM* reduced Ca in leachate by 81% over a 60 minute period compared to Traditional Gypsum.
- *Gypsum Plus ASTTM* reduced S in leachate by 85% over a 60 minute period compared to Traditional Gypsum.

Summary

The significant reduction of sediment and sediment bound nutrient loss from *Gypsum Plus ASTTM* treated soils was likely due to reduced chemical and physical dispersal of soil particles. Similarly, Smith et al. (1990) found WSPAM treated soils were more effective in reducing soil erosion, irrespective of raindrop kinetic energy. The addition of *Gypsum Plus ASTTM* likely guarded against raindrop impact and helped preserve aggregate stability throughout the rainfall duration. The increased Ca content supplied by the gypsum (approximately 103% increase with the addition of gypsum) likely increased WSPAM sorption to soil particles through cation bridging while simultaneously reducing chemical dispersal of soil particles.

The lack of significant reduction in dissolved runoff constituents may partly be explained by WSPAM's primary function of binding soil particles together and maintaining aggregate stability. The ability of WSPAM in combination with gypsum to "entrap" soluble nutrient forms is less understood and may only be linked to reducing runoff volumes. Predictably the amount of Ca in runoff was increased with the addition of gypsum however Ca loads in runoff from the *Gypsum Plus ASTTM* treatment were similar to those from bare soil.

References

- Chan, K.Y. and D.P. Heenan. 1999. Lime-induced loss of soil organic carbon and effect on aggregate stability. *Soil Sci. Soc. Am. J.* 63:1841-1844.
- Epema, G.F. and H.T. Riezebos. 1983. Fall velocity of waterdrops at different heights as a factor influencing erosivity of simulated rain. *Catena*:1-17.

Green, V.S., D.E. Stott, L.D. Norton, and J.G. Graveel. 2000. Polyacrylamide molecular weight and charge effects on infiltration under simulated rainfall. *SSSA Journal*. 64:1786-1791.

Kelling, K.A. and E.E. Schulte. 2004. Understanding plant nutrients: Soil and applied calcium. University of Wisconsin Extension Publication A2523.

Laird, D.A. 1997. Bonding between polyacrylamide and clay mineral surfaces. *Soil Science* 162:826-832.

Petersen, A., A.M. Thompson, C. Baxter, J. Norman, and A. Roa-Espinosa. 2007. A new polyacrylamide (PAM) formulation for reducing erosion and phosphorus loss in rainfed agriculture. *Trans. ASABE*. 50(6). In Press.

Smith, H.J.C., G.J. Levy, and I. Shainberg. 1990. Water-Droplet Energy and Soil Amendments - Effect on Infiltration and Erosion. *Soil Science Society of America Journal* 54:1084-1087.