

2007 Summary Report for Field Experiments Evaluating Crushed Drywall Application to Agricultural Fields in Western Montana

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Report Summary

Field experiments testing recycled gypsum application to saline-sodic Montana soils were established at three sites in 2007. Post-treatment soil samples were taken two months after gypsum application and a number of variables relating to soil quality were assessed (EC, pH, PMN, Ca^{2+} , Mg^{2+} , K^+ , Na^+ , %WSA, ESP). Gypsum application significantly increased exchangeable Ca^{2+} levels from Control and Low treatments to Medium and High treatments at all three sites. Significant increases in electrical conductivity (EC) were observed at two sites, confirming dissolution of gypsum treatments in those soils. Biomass and % water stable aggregates (%WSA) were non-significant at all sites; however, gradients present in the field may have obscured treatment effects at one site. Results from 2007 field experiments indicate that gypsum applications can increase exchangeable Ca^{2+} levels in one growing season; however, more time is likely necessary for the increased Ca^{2+} to positively impact %WSA, biomass and exchangeable sodium percentage (ESP). Gypsum application to Montana saline-sodic soils may increase soil productivity in the long term; however, more research will be necessary to determine frequency of applications necessary to attain a desired level of soil quality improvement.

Introduction

Results from 2006 field experiments testing gypsum application to crop soils under alfalfa, potatoes and barley showed no significant effects of gypsum application on the variables tested (EC, pH, PMN, Ca^{2+} , Mg^{2+} , K^+ , Na^+ , %WSA, and biomass). While some of this lack of response may be due to difficulties coordinating with producers (i.e. farmer harvesting prior to biomass sampling, or the high level of cultivation activity associated with potato farming) obscuring treatment differences, it is likely that the relatively unweathered soils of Western Montana contain sufficient calcium and sulfur such that gypsum application results in no increase in plant biomass or favorable soil properties (%WSA, PMN, NH_4^+). Due to this lack of response, for the 2007 field season, we chose to focus on gypsum application to saline and saline/sodic suspected soils since gypsum application is an accepted method of ameliorating saline seeps. Salt-affected soils are common in central Montana due to the nature of the geologic formations in which the soils have developed and also due to the cultural practice of crop fallowing increasing groundwater discharge to lowlands (saline seeps) (ARS, Report No. 30).

Field Methods

During spring 2007, we selected three sites which were either confirmed or suspected saline/sodic soils. Three rates of gypsum application were tested at each site: 2000 kg ha^{-1} , 5000 kg ha^{-1} and 8000 kg ha^{-1} ($0.891 \text{ tons acre}^{-1}$, $2.23 \text{ tons acre}^{-1}$ and $3.56 \text{ tons acre}^{-1}$). These application rates are higher than rates used at last year's saline seep site, but are within the range of rates found in the literature for gypsum applied in the field to remediate saline seeps. The three sites consisted of a dryland range site under sparse wild rye, an irrigated hayfield under alfalfa and pasture grasses potentially slightly contaminated by the collapse of tailing holding ponds near Opportunity, and a sodic soil which had recently been put under irrigation. All

experimental plots were 5m² and separated from neighboring plots by 2m. Plots were established in May and June 2006 and initial sampling was undertaken to identify any pre-existing gradients in % organic matter, pH and electrical conductivity.

The dryland range site was established in mid-May on an EQIP participating ranch near Hot Springs, MT. The site was disked to remove existing vegetation and a blocked experimental design consisting of a no-gypsum control, Low (2000 kg ha⁻¹), Medium (5000 kg ha⁻¹) and High (8000 kg ha⁻¹) treatments was established. This site included 5 replicates per treatment. Gypsum amendment was hand applied and raked into the soil. After gypsum application, the site was seeded with a native grass, thick spike wheatgrass. Post-treatment soil samples were taken two months after gypsum application; due to the dryland nature of this site and the drier than average late spring, vegetation did not reestablish at this site and no biomass measurements were taken.

The irrigated hayfield site was established in early June on an EQIP participating ranch near Deer Lodge, MT. This site is directly adjacent to the Clark Fork River and the associated soil map unit is designated as “rarely flooded” in reference to contamination from the collapse of the Opportunity holding ponds. Biomass production at this site is low, and may be affected by salts in the soil whether from geologic origin or from metal salts in sediments deposited during flood events. This site was rototilled prior to application of gypsum. A blocked experimental design of no-gypsum Control, Low, Medium and High gypsum application was established. Gypsum amendment was hand applied and raked into the soil. After gypsum application, the site was seeded with a mix of pasture grasses, alfalfa and clover. Post treatment soil samples were taken two months after gypsum application; biomass samples were taken at the same time and plots were dismantled to allow the producer to do the first cutting of the hayfield. Irrigation frequency at this site was every 5-7 days.

The irrigated sodic soil site was established in mid-June on an EQIP participating farm near Logan, MT. Soils at this site are classic sodic soils with alkaline pH levels increasing with depth (0-10 cm, pH 8; 10-40 cm, pH 9). Two prior crops of barley (salt-tolerant crop) were grown at this site after pivot irrigation was installed. Soil at this site was disked prior to plot setup and hand application and raking in of the gypsum treatment. . A blocked experimental design of no-gypsum Control, Low, Medium and High gypsum application was established. The producer hopes to seed the entire field to alfalfa in spring 2008, so plots were seeded with Ladak alfalfa, a dryland variety of alfalfa which should withstand fairly well the additional osmotic stress posed by a sodic soil. Post treatment soil samples were taken two months after gypsum application. Biomass samples were taken 3 months post-seeding to ensure the alfalfa had time to mature. Irrigation frequency at this site was approximately every 2-3 days.

Laboratory Methods

Pretreatment samples were evaluated for pH, EC and % organic matter. Significant gradients in pH and EC may affect plant growth due to differential availability of plant nutrients (pH) or salt stress (EC). Percent organic matter may influence aggregate stability and possibly obscure increases in %WSA (Water Stable Aggregates) due to gypsum application.

Post-treatment soils were evaluated for ammonium (NH_4^+), potentially mineralizable nitrogen (PMN), exchangeable cations (Ca^{2+} , Mg^{2+} , K^+ and Na^+), electrical conductivity (EC), pH, % water stable aggregates (WSA), and exchangeable sodium percentage (ESP). Soils were analyzed using the same methods as in the 2006 field season, except for % WSA which was determined using a hydrometer method. Percent ESP was calculated by dividing the concentration of Na^+ by the sum of the four cations measured. ESP values greater than 15% are

associated with poor soil structure due to excessive Na^+ and alkaline pH which may limit solubility of certain plant nutrients such as phosphorous.

Results and Interpretation

Hot Springs, MT site

At the Hot Springs site, we detected significant effects of gypsum application in exchangeable Ca^{2+} and in EC as the level of gypsum application increased (Table 1). Certainly, gypsum application should increase exchangeable Ca^{2+} levels, so this result was anticipated. Increases in EC reflect the addition of Ca^{2+} and SO_4^{2-} and this is also to be anticipated at this non-irrigated site. Irrigation would serve to flush away excess salts from the soil and maintain a lower EC; unfortunately, irrigation at this site is impossible due to the producer having relatively little in the way of water rights. However, despite non-significant results for the remaining response variables, ESP and pH appear to decline from Control to High treatments indicating gypsum application may slowly improve exchangeable cation ratios and lessen the elevating influence of NaCO_3 on pH in the soil over time. Due to the dryland nature of this site, and the excessively dry spring this year, thick spike wheatgrass sown at this site did not establish and therefore no biomass samples were taken. Gypsum application to dryland sites is likely a long-term investment as gypsum is relatively slow to dissolve under normal Montana climate conditions of 12-15" precipitation per year. Long term assessments of gypsum application to dryland sites would be necessary prior to any recommendations of gypsum application to these types of sites.

Table 1. Results for Hot Springs, MT dryland site.

	Control	Low	Medium	High	F	p-value
Ammonium $\mu\text{g g}^{-1}$	0.585 (0.085)	0.563 (0.082)	1.128 (0.35)	0.949 (0.164)	1.899	0.17
PMN $\mu\text{g g}^{-1}$ 14 days ⁻¹	54.7 (10.8)	45.9 (5.06)	48.2 (6.57)	34.1 (9.95)	1.045	0.4
Ca ²⁺ $\mu\text{g g}^{-1}$	288.8 (38.4)	712.9 (162.6)	1432.7 (320)	1394.5 (315)	5.366	0.009
K ⁺ $\mu\text{g g}^{-1}$	1042.4 (115.1)	1045.4 (119.3)	817.6 (135.2)	1262.1 (262)	1.152	0.359
Mg ²⁺ $\mu\text{g g}^{-1}$	34.4 (6.9)	26.7 (3.3)	37.5 (7.4)	48.0 (9.6)	1.519	0.248
Na ⁺ $\mu\text{g g}^{-1}$	4087.7 (163.1)	4595.9 (452.8)	4290.7 (313)	4476.3 (474.2)	0.356	0.785
EC mS	3.56 (0.46)	4.41 (0.64)	5.52 (0.12)	7.2 (0.60)	9.988	0.001
pH	9.68 (0.17)	9.56 (0.1)	9.22 (0.276)	8.98 (0.21)	2.595	0.089
% WSA	45.3 (3.2)	52.9 (3.0)	43.9 (5.5)	48.1 (4.4)	0.905	0.461
% organic matter	5.44 (0.57)	4.67 (0.09)	4.84 (0.45)	7.2 (1.12)	3.007	0.061
% ESP	75.0 (1.91)	72.1 (1.91)	65.9 (5.81)	62.7 (7.13)	1.368	0.288

^a p-values less than 0.05 indicate a significant difference between groups

^b PMN refers to potentially mineralizable nitrogen

^c WSA refers to water stable aggregates

^d ESP refers to exchangeable sodium percentage

Deer Lodge, MT site

At the Deer Lodge site, we detected significant effects of gypsum treatments on PMN and on exchangeable Ca²⁺. PMN decreased with increasing levels of gypsum application; this is possibly due to high paper content of the crushed gypsum increasing the C: N ratio in the soil and lowering nitrogen mineralization rates. Exchangeable calcium was significantly increased in the Medium and High gypsum treatments over the Control and Low treatments. This site was irrigated every 5-7 days and ~4000 $\mu\text{g g}^{-1}$ exchangeable Ca²⁺ may represent the maximum level of gypsum dissolution at this irrigation frequency. While this site was suspected by the producer to be salt affected, it is definitely not saline or sodic as evidenced by low Na⁺ and slightly acidic pH. Relatively high EC levels may indicate that it is high in metal salts deposited by flooding from the Clark Fork River. Further investigation of this site's extent of metal contamination might be useful to determine if gypsum application would be beneficial; for example, if the site

is relatively high in arsenic compounds, arsenic could be depressing plant growth due to its uptake by plants instead of phosphorous. Gypsum applications along with phosphorous fertilizer applications could help to rebalance the soil's exchangeable cations and dilute some of the ill effects of heavy metals on productivity. A significant row effect was detected for biomass and % organic matter measured in initial sampling; post hoc tests revealed significant differences for biomass between rows 1 & 3, 2 & 3, and 2 & 4 which could be masking treatment differences for these two variables. It is suspected that row 3 & 4 may have higher organic matter than rows 1 & 2, or perhaps these two rows may be less contaminated with heavy metals than rows 1 & 2. An increase in organic matter may be helpful at this site because humus compounds may be able to complex heavy metals and reduce their mobility in the soil, therefore increasing plant productivity.

Table 2. Results for Deer Lodge, MT irrigated hayfield.

	Control	Low	Medium	High	F	p-value	Gradient
Ammonium	1.59 (.64)	1.83 (.53)	2.81 (.55)	3.62 (.70)	2.355	0.11	
PMN $\mu\text{g g}^{-1}$ 14 days ⁻¹	30.89 (9.1)	21.59 (5.26)	7.24 (3.48)	12.29 (2.85)	3.362	0.045	
Ca ²⁺ $\mu\text{g g}^{-1}$	3207.2 (302.7)	3602.4 (305.0)	4052.4 (223.7)	4072.3 (129.6)	2.708	0.08	
K ⁺ $\mu\text{g g}^{-1}$	239.5 (27.9)	253.5 (22.6)	300.4 (30.3)	272.6 (25.9)	0.965	0.433	
Mg ²⁺ $\mu\text{g g}^{-1}$	351.9 (55.2)	320.2 (54.3)	480.6 (92.2)	404.2 (81.2)	0.932	0.448	
Na ⁺ $\mu\text{g g}^{-1}$	130.1 (42.7)	127.9 (40.5)	213.9 (63.1)	221.4 (84.4)	0.723	0.553	
EC mS	3.5 (0.91)	4.11 (0.69)	3.36 (0.55)	4.06 (0.50)	0.321	0.81	
pH	6.6 (0.08)	6.36 (0.08)	6.6 (0.03)	6.43 (0.17)	1.354	0.292	
% WSA	28.8 (1.82)	32.3 (2.36)	30.7 (1.74)	31.5 (1.44)	0.659	0.589	
Biomass kg ha ⁻¹	2303.5 (592)	2280.9 (341)	2618.6 (664)	2739.6 (266)	0.215	0.885	*
% organic matter	5.08 (.97)	5.07 (1.13)	5.23 (.94)	4.84 (.65)	0.029	0.993	*
% ESP	3.11 (.91)	2.73 (.73)	4.09 (1.14)	4.23 (1.40)	0.465	0.711	

^a p-values less than 0.05 indicate a significant difference between groups

^b PMN refers to potentially mineralizable nitrogen

^c WSA refers to water stable aggregates

^d ESP refers to exchangeable sodium percentage

^e Row effects were detected by running a second ANOVA that included "row" as a random factor to reduce spatial variation. The star denotes the significant presence of this variation for a given variable.

Logan, MT site

At the Logan site, we detected significant treatment effects on ammonium, exchangeable Ca^{2+} , EC, and pH. Exchangeable Ca^{2+} and EC again increased substantially from the Control and Low treatments to the Medium and High treatments due to dissolution of gypsum. Changes in pH were relatively slight, from a mean of 7.86 in the Control decreasing to 7.49 and 7.51 in the Medium and High treatments which could indicate that the irrigation was successful at flushing out some Na^+ which may have been displaced from clay particles by Ca^{2+} . While this site is much less sodic than the dryland site at Hot Springs, all treatments still have ESP in excess of 15% and qualify as sodic soils with the attendant issues of osmotic stress for plants and soil structure dispersal under wet conditions. While there were no significant differences in % organic matter, the Control and Low gypsum treatment have relatively higher % organic matter with higher variation which may mask any treatment effects on plant biomass. Also, a number of plots at this site were very weedy and may have crowded out the alfalfa fairly early in the growing season; we also observed evidence of wildlife grazing in a number of plots which may have also influenced biomass measurements. Though also non-significant, % WSA appears to increase from Control to the High gypsum treatment and may represent a slow displacement of Na^+ and replacement with Ca^{2+} .

Table 3. Results for Logan, MT irrigated alfalfa site.

	Control	Low	Medium	High	F	p-value	Gradient
Ammonium $\mu\text{g g}^{-1}$	0.42 (0.22)	1.56 (0.21)	2.16 (0.20)	2.03 (0.40)	8.598	0.001	
PMN $\mu\text{g g}^{-1}$ 14 days ⁻¹	21.4 (3.99)	28.2 (9.35)	18.5 (4.88)	10.8 (1.52)	1.594	0.23	*
Ca^{2+} $\mu\text{g g}^{-1}$	1891.2 (200.3)	2511.2 (411.2)	3245.0 (357.0)	3224.6 (240.2)	4.263	0.022	
K^+ $\mu\text{g g}^{-1}$	955.1 (81.0)	989.3 (117.1)	1027.3 (34.4)	1089.7 (82.6)	0.471	0.707	
Mg^{2+} $\mu\text{g g}^{-1}$	743.5 (80.2)	752.9 (121.3)	714.1 (74.9)	788.0 (129.1)	0.086	0.967	
Na^+ $\mu\text{g g}^{-1}$	1238.0 (330)	898.7 (350.7)	1266.8 (331.3)	1289.8 (255.2)	0.334	0.801	
EC mS	1.23 (0.18)	1.38 (0.16)	3.55 (0.42)	3.03 (0.34)	15.622	0	
pH	7.86 (0.09)	7.60 (0.08)	7.49 (0.059)	7.51 (0.04)	5.602	0.008	
% WSA	36.1 (3.1)	37.1 (2.8)	38.6 (2.4)	41.5 (1.8)	0.834	0.494	

Biomass kg ha ⁻¹	1587.6 (214.5)	1857.3 (352.6)	1756.3 (270.2)	2018 (403.0)	0.321	0.81	
% organic matter	6.70 (1.28)	6.82 (1.95)	5.51 (0.631)	5.63 (0.635)	0.305	0.822	
% ESP	24.9 (5.82)	18.1 (6.62)	20.5 (5.23)	19.7 (3.57)	0.29	0.832	

^a p-values less than 0.05 indicate a significant difference between groups

^b PMN refers to potentially mineralizable nitrogen

^c WSA refers to water stable aggregates

^d ESP refers to exchangeable sodium percentage

^e Row effects were detected by running a second ANOVA that included “row” as a random factor to reduce spatial variation. The star denotes the significant presence of this variation for a given variable.

Conclusion

Gypsum application to saline and sodic soils in Montana may have positive effects on soil structure and productivity. However, it is likely that even under irrigation, gypsum treatments may take more than one season to show positive effects on soil attributes such as %WSA and biomass. It is also possible that highly saline or sodic soils may need several years of gypsum applications prior to significant improvement of these soil properties. Unfortunately, such studies are outside the scope of this project. Gypsum applications may take more time to dissolve and become well incorporated into soil aggregates than is observable in one growing season. It is recommended elsewhere in the literature that gypsum treatments be applied in sequence or conjunction with additions of organic material as these two types of material both promote soil aggregation (Hanay et al 2004; Agostini et al 2003); however, many studies are conducted in the laboratory where optimal temperature and moisture can be maintained and results are unlikely to be replicable in the field. However, applications of organic material along with gypsum may be something to consider. Significant variation occurs at relatively small spatial scales on working farms due to variations in fertilization rates (whether chemical or manure applications) and irrigation rates and these variations can further lead to variations in pH, EC and % organic matter. Our recommendation for further investigation of gypsum application in MT saline/sodic soils is to establish large scale demonstration plots of the three levels of

gypsum application used this year. Spatial variation within the plots can be assessed by grid sampling, and larger scale biomass measurements can be made which should help determine if gypsum application can improve plant productivity.

Additional reasons for large scale demonstration plots are the opportunity to test mechanized methods of application to the soil, to assess economies of scale, and to determine the limits of time and fuel expenditure producers are willing to undergo for an increase in productivity of their land. Recycled gypsum application to irrigated saline-sodic soils in Montana may improve soil structure and plant biomass over time, however longer term study will be necessary to determine frequency of application needed to achieve the desired level of improvement in soil quality.

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