

2006 Summary Report for Field Experiments Evaluating Crushed Drywall Application to Agricultural Fields

Introduction

Crop Soils

Gypsum (CaSO_4), the primary component of drywall, contains two plant essential macro-nutrients, calcium and sulfur. Demand for these two nutrients by most plant species is secondary to nitrogen, phosphorous, and potassium; however, some crop species, such as potatoes and alfalfa have high calcium requirements, and thus often demonstrate improved growth with the addition of gypsum. Gypsum is an ideal amendment to support growth of plants with high calcium requirements because it has little effect on soil pH, compared to other calcium salts, which greatly increase soil alkalinity.

In addition to its role as a plant nutrient, calcium has several indirect effects on soil fertility. The double charge on the calcium ion, and its small hydrated radius, results in flocculation of clay particles, and thus increases soil aggregation and aggregate stability. Improved soil aggregation and aggregate stability usually corresponds with greater infiltration rates and gas exchange. This improved soil physical structure also can result in reduced wind and water erosion, and higher rates of nutrient mineralization.

Saline Seep Soils

In addition to its use as a calcium and sulfur fertilizer, gypsum has been successfully used to restore saline soils. Soil salinization is a widespread problem in arid and semi-arid regions where parent materials provide a large source of sodium salts, and crop fallow systems increase the rate of groundwater discharge. Salinization has taken approximately 300,000 acres of cropland out of production in Montana. Salinization occurs when sodium is transported via groundwater discharge from upland areas to low lying areas (usually less than two miles from the crop-fallow lands). Sodium accumulates in low lying soils as water resurfaces and evaporates. This process has been greatly accelerated in the last 50 years in association with crop-fallow agriculture, which increases groundwater discharge during fallow periods.

The accumulation of sodium has a negative effect on the fertility of soil because sodium ions have a single charge, and a very large hydrated radius. These two properties cause clay particles to disperse, resulting in the break down of soil aggregates. A loss of soil aggregation greatly diminishes gas exchange and water infiltration rates, and thus greatly diminishes soil fertility and plant productivity.

Gypsum can be an ideal amendment for the restoration of saline seep areas. The calcium in gypsum can displace sodium from clay particles, and allow clays to flocculate, generating soil aggregation and aggregate stability. Arid land soils are often alkaline, which can lead to low phosphorous availability. Thus an ideal amendment for saline soils would both displace sodium from clay particles and cause no increase in soil pH. Gypsum is potentially an ideal material to reclaim saline soils because it is a significant source of calcium, yet does not significantly increase soil alkalinity, as do many other calcium salts such as CaCO_3 , CaO , $\text{Ca}(\text{OH})_2$ and even CaHPO_4 .

The following data was gathered in the year 2006, from three separate experiments, where we evaluated the affect of three concentrations of gypsum addition on alfalfa, potato, and a saline seep degraded soil.

Field Methods

During the growing season of 2006, we initiated studies at three sites in western Montana to test the effect of three concentrations (low, medium, high) of gypsum application on a variety of soil properties. The three sites consisted of an alfalfa field near Missoula, a potato field near Ronan, and a saline seep site on a small grain field near Choteau. All three sites were set up as a stratified block design (because of the relatively small number of replicates) to assure good dispersal of each treatment. All experimental plots were 5 m², and separated by neighboring plots by 1 m. Plots were established in April/May, 2006, and initial soil sampling was done to establish that there were no pre-existing conditions between treatments in several basic soil parameters (texture, pH, electrical conductivity).

The first site was established in late April in Missoula County on an EQIP farm site on the west side of the Missoula valley. We established a stratified block design consisting of Low (0.625 tons acre⁻¹), Medium (1.25 tons acre⁻¹), and High (2.5 tons acre⁻¹) gypsum concentration, with a no-gypsum control. These concentrations were chosen to reflect a reasonable range of annual calcium uptake by alfalfa. This site included 8 replicates per treatment. Following gypsum amendment, the site was planted with Alfalfa. Post-treatment soil samples were collected at the end of July, and biomass of alfalfa was collected in the center 1 m² of each plot in September.

A second research site was established in early May, 2006 in Lake County Montana on an EQIP participating potato farm approximately 1 mile north of Ronan, MT. At this site we established Control, Low (0.5 tons acre⁻¹), Medium (1.0 tons acre⁻¹), and High (2.0 tons acre⁻¹) plots, consisting of 5 replicates per treatment. The gypsum amended plots were planted with potatoes using the normal operational procedures at this farm in mid May. Post-treatment soil samples were collected at the end of July. Potato biomass was collected from a 1 m long row in the center of each plot, in Mid September 2006.

A third research site was established in Teton County Montana, near the town of Choteau, on an EQIP eligible farm. This research site was established to test the effect of gypsum addition on saline seep soils. A stratified block experimental design was established consisting of Control, Low (4 tons acre⁻¹), Medium (8 tons acre⁻¹), and High (12 tons acre⁻¹) gypsum concentrations. Following gypsum addition, the site was seeded with Barley, the standard crop at this site. Pre-treatment soil samples were collected in May, and mid season soil samples were collected in mid July. Aboveground biomass was not collected at this site because the farmer mistakenly plowed the field before we were able to make this measurement.

Laboratory Methods

Post-treatment soils were evaluated for a variety of properties. We measured soil pH, using a 2:1 slurry of soil and 0.01 M CaCl. This basic soil parameter is important because it can reveal the availability of several essential nutrients, such as phosphorous. Electrical conductivity was measured using an EC meter, on a paste consisting of a 1:1

ratio of soil and deionized water. This basic parameter is highly responsive to soluble salt concentrations in the soil, which can negatively influence soil fertility when excessive concentrations occur. We measured potentially mineralizable nitrogen, by incubating 5 g of soil in an anaerobic chamber for 14 days, and quantifying the amount of NH_4^+ generated during this period. This parameter can reveal the potential of soil to release a usable form of nitrogen from a larger pool of nitrogen that is not readily available to plants. Gypsum addition may indirectly influence this process by altering soil aggregation, and soil gas exchange, which may ultimately influence this essential process. We also measured extractable Ca^{++} , Mg^{++} , K^+ , and Na^+ , by extracting 25 grams of soil in 50 ml of 1 M NH_4Cl extracts. These extracts were analyzed using Inductively Coupled Plasma (ICP) spectrometer. Lastly we measured % stable aggregates by separating particles in the 1-2 mm size class. We measured the percentage of these particles that were aggregates vs. primary particles through a wet sieving procedure. This variable may be greatly influenced by gypsum addition, because Ca may stimulate clay flocculation, and thus promote soil aggregation. This may in turn affect other important soil processes, such as nutrient turnover, gas exchange.

Results and Interpretation

Potato Research Site

At the potato research site, we were unable to detect any significant effects of gypsum addition on any variable we measured, either positive or negative. There are several possible reasons for this: 1) We may not have had a large enough sample size (i.e. statistical power) to pick up subtle effects. We should consider setting up plots in 2007 with a larger sample size. 2) A surprisingly large amount of background spatial variation occurred at the experimental site due to a gradual slope, and proximity of plots to irrigation equipment. This variation might be better handled experimentally by doing greenhouse experiments vs. field experiments in the future. 3) The potato site did not allow for the placement of permanent markers, due to the normal field operation of planting potatoes, thus we relied on GPS and surveying (distance and direction measurements) to relocate plots. There may have been some error associated with this, which may have effected the accuracy of mid and late season data. 4) Lack of a significant difference between treatments for all of these variables might indicate that the soil is not calcium deficient.

	Control	Low	Medium	High	f-value	p-value
EC μS	175.4 (14.8)	286.0 (98.9)	194.4 (49.8)	277.0 (88.5)	0.695	0.569
pH	3.74 (0.05)	3.71 (0.08)	3.68 (0.04)	3.67 (0.04)	0.319	0.812
PMN $\mu\text{g g}^{-1}$ 14 days ⁻¹	43.0 (1.8)	40.8 (1.2)	45.7 (1.1)	43.2 (2.6)	1.313	0.305
Ca^{++} $\mu\text{g g}^{-1}$	675.4 (57.9)	672.4 (96.4)	665.4 (178.5)	614.6 (36.7)	0.252	0.858
Mg^{++} $\mu\text{g g}^{-1}$	33.9 (2.2)	32.9 (2.0)	33.9 (2.2)	32.4 (2.6)	0.109	0.954
K^+ $\mu\text{g g}^{-1}$	205.5 (13.1)	206.6 (2.2)	219.1 (26.0)	269.3 (44.2)	1.288	0.312
Na^+ $\mu\text{g g}^{-1}$	14.2 (7.2)	13.0 (7.8)	21.3 (9.3)	10.0 (4.4)	0.420	0.741
% WSA	49.7 (2.8)	50.2 (3.6)	47.7 (3.1)	56.5 (4.4)	1.139	0.363

^d Biomass kg m ⁻¹	5.96 (0.78)	5.08 (0.28)	4.92 (0.34)	5.72 (0.38)	1.050	0.398
---	-------------	-------------	-------------	-------------	-------	-------

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

^bPMN refers to Potentially mineralizable nitrogen

^cWSA refers to water stable aggregates

^dPotato biomass was measured on a 1 m long section of a row in the center of the 5 m² plot.

Alfalfa Research Site

At the alfalfa research site, we were only able to detect one significant treatment effect (pH), whereas all other variable showed no significant difference between treatments. The difference in pH we detected appears to be an erroneous result, because both no-gypsum and high gypsum treatments resulted in significantly higher pH than low and medium treatments. There are several possible reasons that may explain why significant differences between variables did not occur. 1) Very strong gradient effects were detected for several variables, including calcium. Because this research site is in close proximity to the processing area where drywall is crushed, it is highly possible that the plots were incidentally contaminated with gypsum before and after experimental plots were established. This research site also exhibited calcium concentrations an order of magnitude higher than the other two site research sites, further supporting this idea. These high background levels of Ca⁺⁺ may also be a function of the glacial lake Missoula sediments that are the parent materials at this site. It is our opinion that the power to detect differences between treatments at this site could be dramatically improved if: a) soil is collected further from the drywall processing facility, and, b) the experiment is done in a greenhouse setting to remove other unwanted variation. 2) As with the potato site, it should be considered that a lack of a significant difference between treatments at this sight might indicate that the soil is not calcium deficient, and thus is not likely to respond to further addition of calcium.

	Control	Low	Medium	High	f-value	p-value	^d Gradient effect
EC μS	210.1 (10.7)	223.0 (7.1)	212.5 (11.7)	230.0 (17.4)	0.57	0.64	
pH	6.39 (0.07)	6.35 (0.06)	6.31 (0.07)	6.28 (6.95)	6.48	0.01	*
PMN μg g ⁻¹ 14 days ⁻¹	48.2 (3.3)	53.5 (5.4)	44.3 (8.6)	46.0 (2.5)	1.14	0.35	
Ca ⁺⁺ mg g ⁻¹	1.7 (0.0)	1.8 (0.02)	1.8 (0.1)	1.7 (0.1)	0.202	0.894	*
Mg ⁺⁺ μg g ⁻¹	294.5 (17.6)	325.5 (34.6)	325.6 (31.3)	279.0 (27.1)	0.674	0.575	*
K ⁺ μg g ⁻¹	123.0 (10.8)	114.0 (10.0)	117.4 (11.9)	119.0 (15.4)	0.095	0.962	
Na ⁺ μg g ⁻¹	21.6 (6.4)	19.7 (2.8)	23.0 (4.9)	21.5 (6.0)	0.067	0.977	
% WSA	87.9 (1.5)	88.3 (2.0)	90.0 (2.1)	92.4 (2.2)	1.082	0.373	
Biomass g m ⁻²	482.0 (21.2)	474.2 (27.8)	440.7 (21.7)	478.1 (17.4)	0.723	0.547	

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

^bPMN refers to Potentially mineralizable nitrogen

^cWSA refers to water stable aggregates

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

Saline Seep

Two of the variables measured indicated significant treatment effects (pH and K^+); however, both of these results appear to be erroneous because the high gypsum treatment appeared to be more similar to the control treatment than either low or medium treatments. There are several possible reasons why we did not find significant treatment effects at this research site. 1) Shortly following gypsum application to research plots, an abnormal rain event lead to flooding of the research area, which may have redistributed some of the gypsum in the research area. This problem could be avoided in the future by conducting greenhouse experiments, where extraneous factors such as these can be removed. 2) It is possible that not enough time had passed for Ca^{++} to displace Na^+ from clay exchange sites. 3) This site, out of necessity, utilized only five replicates per treatment. It is possible that sufficient statistical power did not exist to detect subtle treatment effects. A larger sample size could be accomplished by using greenhouse experiments instead of field experiments in the future.

	Control	Low	Medium	High	f-value	p-value
EC mS	4.95 (2.84)	2.44 (0.22)	2.51 (0.10)	2.60 (0.16)	0.73	0.55
pH	7.60 (0.02)	7.30 (0.05)	7.28 (0.04)	7.47 (0.06)	11.78	0.00
PMN $\mu g g^{-1} 14 d^{-1}$	64.9 (6.3)	65.8 (4.6)	66.5 (6.4)	63.1 (7.3)	0.05	0.98
$Ca^{++} \mu g g^{-1}$	467.2 (37.9)	515.7 (23.3)	494.7 (45.6)	582.5 (38.0)	1.75	0.17
$Mg^{++} \mu g g^{-1}$	206.2 (16.3)	215.5 (17.5)	192.5 (9.1)	201.8 (12.2)	0.46	0.718
$K^+ \mu g g^{-1}$	265.3 (33.3)	275.0 (21.7)	104.6 (16.2)	174.3 (25.4)	10.50	0.00
$Na^+ \mu g g^{-1}$	221.4 (17.2)	235.6 (107.1)	216.9 (14.2)	207.1 (21.1)	0.17	0.91
% WSA	64.2 (2.4)	61.4 (5.7)	54.2 (8.5)	56.3 (3.8)	0.672	0.582
Biomass $g m^{-2}$	-	-	-	-	-	-

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

^bPMN refers to Potentially mineralizable nitrogen

^cWSA refers to water stable aggregates

Conclusion

Gypsum has some possible use as an amendment to agriculture soils in western Montana; however, it is possible that the inherently high calcium content found in semi-arid landscapes, such as Montana, does not justify the application of additional calcium. Our research thus far supports this argument; however, we feel that several improvements to our initial experimental approach can be made to better test the effects of gypsum addition. Primarily, we believe that greenhouse experiments, rather than field experiments, will provide us with greater statistical power to detect treatment differences by removing unwanted background variation. This approach will also eliminate logistical problems associated with overlaying our experimental plots on working farms, where it is

difficult to leave permanent plot markers, and to control the even distribution of irrigation, fertilization and seeding across experimental plots. Thus, our recommendation for the 2007 field season is to collect soil from working EQIP farms in western Montana, and to conduct greenhouse experiments utilizing this soil that compare the effects of varying gypsum concentration. We further recommend that the greatest potential for gypsum application to soils in western Montana is for restoration of saline seeps, and thus propose that most work in the year 2007 focus on this application, rather than alfalfa and potato production.