Guidelines for the Application of Recycled Gypsum as a Soil Amendment in Western and Central Montana Agricultural Soils

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Introduction

Gypsum ($CaSO_4$) has a long history of use as an agricultural amendment; in highly weathered soils, it provides the plant nutrients calcium (Ca^{2+}) and sulfate (SO_4^{2-}) and improves plant growth through ameliorating deficiencies of these plant nutrients. In alkaline soils, it provides Ca^{2+} without increasing pH as liming compounds do (CaO and CaOH); increases in pH are generally undesirable in neutral to alkaline soils since most plant nutrients are more chemically available at neutral to slightly acidic pH levels (Brady and Weil, 2004). Gypsum has also been used to remediate saline-sodic soils (USDA, 1983); once the gypsum dissolves, the Ca^{2+} helps to displace excess sodium (Na^+) from the soil cation exchange complex and clay particles which were formerly dispersed by Na^+ are then able to aggregate thereby improving soil structure. Well-developed soil structure allows water infiltration and gas exchange which are vital to healthy plant growth; water-stable aggregates do not disperse under wet conditions but maintain their structure and allow water infiltration into and drainage through the soil. Poor infiltration may cause drought stress in crop plants due to lower soil moisture levels, and poor gas exchange under wet conditions deprives plant roots of oxygen (O_2) needed for root respiration while exposing them to high levels of CO_2.

Montana Soils

Field research on the application of recycled gypsum to agricultural soils was carried out during May to August of 2006 through 2008. Initial research in 2006 investigated 4 levels of gypsum application to typical agricultural soils in Western Montana planted to crops with high calcium requirements. Soils in Western Montana are relatively unweathered and apparently contain sufficient levels of Ca^{2+} and SO_4^{2-} for crops such as alfalfa and potatoes; due to this relatively unweathered state, field research in 2006 showed no significant differences in the soil characteristics measured or in biomass harvested in plots sown to alfalfa and potatoes (Gundale 2006).

Due to this lack of response to gypsum applications in typical agricultural soils, in 2007, research focused on sodic soils (Hot Springs, MT and Logan, MT) and suspected saline/sodic soils (Deer Lodge, MT). Four levels of gypsum application were again applied to plots (Brimmer and DeLuca, 2007). Soils at the Hot Springs plots were heavily sodic due to the surrounding geology and did not respond to gypsum application; soil exchangeable sodium percentages (%ESP) were in excess of 60% at this site.

Research results for the Deer Lodge plots indicated that the soils there were not saline or sodic, but were more likely impacted by heavy metals due to flooding from the collapse of tailing holding ponds at Opportunity, MT. Gypsum applications at Deer Lodge did not significantly impact the majority of soil properties measured; exchangeable Ca^{2+} was significantly increased, however, this simply indicates that the gypsum dissolved due to the irrigation frequency applied to the plots.

Soils at the Logan, MT plots had been culturally salinized due to fifty years or more of flood irrigation. Statistically significant improvements in pH, increases in electrical conductivity (EC) and exchangeable Ca^{2+} were observed in these plots. While not statistically significant, trends of increasing water stable aggregates (% WSA) and lowered % ESP with gypsum treatment were observed in these soils. Due to significant results, encouraging trends, and landowner enthusiasm, field scale plots (one-eighth acre) were established at the Logan site in 2008. Recent literature has recommended addition of organic matter in combination with gypsum for remediation of saline-sodic soils (Hanay et al., 2004), so plot treatments in 2008 included control, gypsum (2 tons $acre^{-1}$), manure (4 tons $acre^{-1}$) and gypsum + manure (same rates as above treatments) treatments. Gypsum treatments decreased pH from the control plot and increased EC due to dissolution of the gypsum. Interestingly, the combination gypsum and manure treatment increased sub-surface soil EC measurements, indicating this combination enabled salts to leach further down in the profile.

Recommendations for Gypsum Application to Agricultural Soils in Montana

Due to lack of response to any tested soil qualities, gypsum applications are not recommended for typical Montana agricultural soils. If soil fertility is good and there are no indications of soil salinity or sodicity, gypsum application is unlikely to provide any measurable benefit. Likewise, gypsum application is not recommended for non-irrigated sites due to Montana's dry climate which does not supply enough moisture to significantly dissolve the gypsum and mobilize Ca^{2+} ions in the soil.

Salt-affected soils that are not severely saline-sodic and are under irrigation may benefit the most from gypsum application. These may be saline seep soils created by upland crop fallow practices or soils salinized by poor irrigation practices as in our 2007 and 2008 studies. Gypsum application rates should be tailored to sites; our 2008 control plot in Logan had an ESP of 25.4%. Sites with significantly higher ESP may not respond to gypsum applications due to the greater excess of Na^{+} in the soil. Sites with lower ESP may be able to decrease gypsum applications and still obtain improvements in soil characteristics. Due to the site-specific nature of this research, gypsum application is not recommended on any soil with an ESP in excess of 30%. More research is needed to determine if gypsum application is able to generate positive effects in more heavily sodic soils.

In moderately sodic soils, (ESP 15-30%) we recommend gypsum application rates in the range of 2 tons $acre^{-1}$ in combination with manure (4 tons $acre^{-1}$). This treatment appeared to mobilize salts and move them lower in the soil profile while also decreasing pH and ESP (Brimmer and DeLuca, 2008). Both calcium and organic matter are known to improve soil structure; the two materials may also work synergistically to mobilize and leach Na^+ from the soil profile. It is important to note that there must be adequate drainage in the soil to leach the salts out of the profile, otherwise salts may build up lower in the soil profile and continue to cause problems.

Research results so far have only yielded a few significantly different parameters; however, variation in agricultural fields is high due to uneven applications of fertilizers, organic matter and irrigation water. Soil texture and type gradients may also be present and introduce greater variation into results. Treatments in 2008 plots were applied with farm equipment and may not have been distributed evenly. A second year's worth of research is planned on the 2008 field scale plots; with another addition of each treatment type, variations in applications may be diminished and more effects of the treatments may be observed. Though the second year's worth of research has not been done, it is likely that soils with ESP more than a few percent higher than the sodic criteria (15% ESP) will benefit from more than one application. Once 2009 field research has been completed, these guidelines will be updated to reflect any changes in application recommendations.

References

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Brimmer, R.J. and T.H. DeLuca. 2007 Summary Report for Field Experiments Evaluating Crushed Drywall Application to Agricultural Fields in Western Montana. Web document located at http://www.constructionsiteservices.net/pdfs/2007Report.pdf

Gundale, M. 2006 Summary Report for Field Experiments Evaluating Crushed Drywall Application to Agricultural Fields**.** Web document located at: http://www.constructionsiteservices.net/pdfs/2006FieldReport.pdf

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Saline-Seep Diagnosis, Control and Reclamation. 1983. USDA, Agricultural Research Service, Conservation Research Report Number 30.

Web Resources on Montana Soil Salinity:

http://agnotes.org/AgNotes/docs/72.htm

http://dnrc.mt.gov/cardd/consdist/salinity_control.asp