Gypsum as a Soil Amendment

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Introduction

Gypsum is calcium sulfate ($CaSO_4 \cdot 2H_2O$) and contains about 22 percent calcium and 18 percent sulfur. There are reports of gypsum being used as a soil amendment or fertilizer dating back to Benjamin Franklin (1740 - 1760). While the primary users of mined and synthetic gypsum are the wallboard, plaster and cement industries, agricultural use has gained interest. This factsheet provides general information about gypsum and its potential benefits for Arkansas crops.

Sources of Gypsum

Gypsum is formed as seawater evaporates from water bodies high in calcium and sulfate. Oklahoma, New Mexico, California, Texas, Utah, and Michigan contain some of the largest gypsum deposits in the US. In other states such as Florida, a form of gypsum called phosphogypsum is generated as a byproduct of phosphorus fertilizer production from rock phosphate. However, the use of phosphogypsum in agriculture is restricted because it may contain radioactive materials. The Environmental Protection Agency (EPA) allows land application of phosphogypsum only if it contains less than 10 picocuries/gram radium (a picocurie is a measure of the radioactivity of one gram of radium), which is common for phosphogypsum from northern Florida. Most phosphogypsum from central Florida, however, exceeds the established threshold and represents the majority of the production.

Flue gas desulfurization gypsum, commonly known as FGD-gypsum, is perhaps the second-largest source of gypsum for industrial and agricultural use. FGD-gypsum is a byproduct of coal combustion power plants. If the coal used to generate power contains significant amounts of sulfur, sulfur dioxide (SO_2) will be produced. The Clean Air Act Amendments of 1990 restrict sulfur dioxide emissions into the atmosphere from coal-fired facilities. This situation prompted the development of flue gas desulfurization (FGD) systems that scrub the sulfur dioxide produced. Basically, with a wet scrubbing process, a slurry of hydrated lime captures the SO_2, initially forming calcium sulfite ($CaSO_3 \cdot 0.5H_2O$). As additional air is forced into the system, the air oxidizes the calcium sulfite and converts it into gypsum ($CaSO_4 \cdot 2H_2O$) (Chen and Dick, 2011). The purity of gypsum varies among sources, with FGD-gypsum being 96 percent or higher calcium sulfate. The purity of mined gypsum is between 70 to 90 percent calcium sulfate, depending of the source.

Potential Benefits from Applications of Gypsum to Agricultural Land

The potential benefits of gypsum applications are well documented in the scientific literature. Such reports include gypsum as a source of the plant nutrients calcium and sulfur (Chen et al., 2008), as a source of electrolytes to remediate soils high in sodium and magnesium (Keren et al., 1983), to reduce soil crust and soil erosion, and improve soil structure (Rhoton and McChesney,

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2011). Gypsum applications may help alleviate the detrimental effects of elevated exchangeable aluminum concentration found in the subsoil of several soil series, particularly those with a fragipan (Sumner et al., 1986).

Using Gypsum as a Source of Sulfur and Calcium for Plants

The reduction in the deposition of sulfur from the atmosphere and fertilizer impurities has increased the incidence of sulfur deficiencies (Michalovicz et al., 2020). While gypsum is considerably less soluble than ammonium sulfate, gypsum is soluble enough to provide plant-available calcium and sulfur in a short time following its application. Figure 1 shows spring soil-test sulfur, in the same plots, at various soil depths before FGD-gypsum was surface-applied (dark bars) and one year after applying 1 t/a (white bars). The study was established on a Calhoun silt loam near Marianna, AR. A significant increase in sulfur concentration occurred down the soil profile in gypsum-treated plots. Research conducted at Michigan State University (DeDecker, 2014) and The Ohio State University (Vijayasatya et al., 2019) showed significant yield responses of soybean and corn when gypsum was the source of sulfur in sulfur deficient soils. Gypsum is the most commonly used source of calcium for peanuts grown in the southern states. Insufficient calcium in the top 6 inches of soil is known to limit the yield potential and grade of peanuts. When the Mehlich 3 calcium concentration in the "pegging" zone is under 600 ppm, gypsum is recommended at the rate of 1500 lb/a.

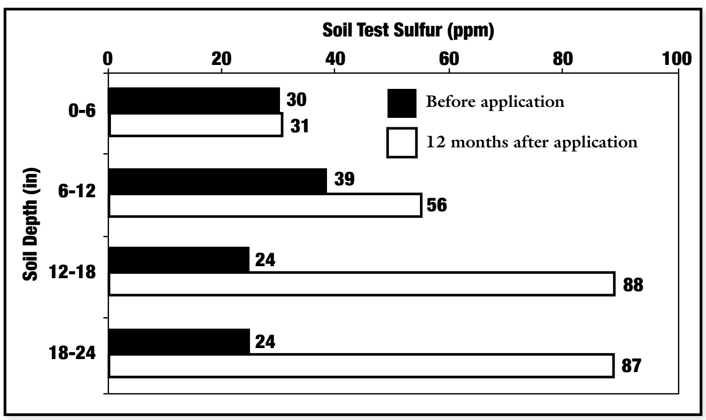

Figure 1. Average Mehich 3 sulfur concentration (ppm) at four depths before FGD-gypsum application (dark bars) and after one year of a surface application of 1 t/a FGD-gypsum (white bars) on a Calhoun silt loam near Marianna, Arkansas (n=4).

The Use of Gypsum to Remediate Sodic Soils

High concentrations of sodium in soil, compared to calcium and magnesium, may be toxic to plants and cause soils to disperse. Dispersion refers to the breakdown of soil into tiny particles, resulting in the formation of a soil crust, thus restricting the movement of water and oxygen. When the exchangeable sodium in a soil occupies more than 15 percent of the cation exchange capacity (CEC), the soil is classified as "sodic." Sodicity, which should not be confused with salinity, may appear at the surface but also in subsurface horizons, making their management more complicated.

Gypsum application has traditionally been the treatment of choice in the reclamation of sodic soils (Ogeen, 2015). The amount needed would depend on the initial exchangeable sodium percentage (ESP), the desired ESP, the CEC of the soil and the purity of the gypsum to be used.

Example of calculation of the gypsum requirement to alleviate sodicity:

CEC of the soil is 20 cmolc/kg of soil.
The exchangeable sodium of the soil is 15 percent.
Desired exchangeable sodium 5 percent.
Gypsum to be used is 100 percent pure.

10 percent of exchangeable sodium needs to be replaced by calcium: 0.1 x 20 = 2.0 cmolc/kg.

So 2 cmolc/kg of sodium need to be replaced.

As a rule of thumb, 1.7 tons of gypsum are required to replace 1.0 cmolc /kg of sodium.

So, 1.7 x 2.0 = 3.4 tons of gypsum needed to replace 2.0 cmolc/kg of sodium.

However, before applying gypsum, a source of good quality water needs to be available so the sodium can be leached out of the desired depth. Remediation gets complicated when there is no water of good quality and/or when there are problems with internal drainage. This calculation assumes the use of gypsum having 100 percent purity. If the source of gypsum is, for example, 70 percent pure, then extra gypsum would need to be added to compensate for the purity of the material to be used. If the calculated rate is 3.4 tons, the rate when using a source of 70 percent purity would be 3.4 x (100/70) = 4.8 tons of gypsum.

The Potential Effect of Gypsum to Improve Infiltration

Surface crusting in some silt loam soils, particularly those with up to 70 percent silt, is a significant problem preventing seedling emergence and reducing water infiltration. Research in Georgia reported substantial increases in water infiltration and reduction in runoff in

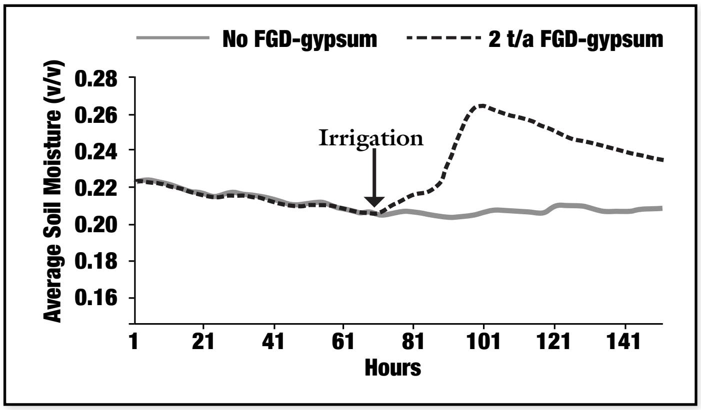

Figure 2. Average soil volumetric moisture content, 7 inches deep, after an irrigation event on control plots and those that received 2 t/a FGD-gypsum, 12 months previously. The test was established in a Henry silt loam planted to cotton near Marianna, Arkansas (n=3).

typical soils of the southeast United States that received gypsum (Miller et al., 1987). Figure 2 shows the results of a test evaluating the effect of gypsum on water infiltration on a Henry silt loam near Marianna, Arkansas, planted to cotton. The arrow represents an irrigation event (about 130,000 gal. of water per acre). The average volumetric soil moisture of soil that received 2 t/a FGD-gypsum (dotted line) increased after the irrigation event. In contrast, the soil moisture content for the soil that received no FGD gypsum (solid line) remained unchanged due to poor water infiltration caused by crusting. The observed soil moisture trends are specific to the conditions of the study and do not indicate a beneficial response to gypsum applications for all soils. The probability of improved soil structure and increased water infiltration is higher in soils with a significant amount of silt since "silty" soils are prone to surface crusting after rain or irrigation.

The presence of a fragipan complicated the conditions at the study site. A fragipan is a subsurface horizon present in several of the most common soil series in eastern Arkansas, including the Henry, Grenada, Calloway, and Loring series. A fragipan is strongly acidic (pH <5) and prevents root growth due to high concentrations of exchangeable aluminum. Roots suffering from aluminum toxicity tend to be short and chubby. Gypsum can be used to alleviate aluminum toxicity since it is much more soluble than agricultural lime. However, gypsum will not change the soil pH; gypsum will only alleviate aluminum toxicity, according to the reaction between the soluble-soil aluminum with gypsum (figure 3). The calcium molecules (from gypsum) replace the exchangeable aluminum, while the sulfate associates with aluminum to form a soluble compound with lower toxicity that can be easily leached down the soil profile.

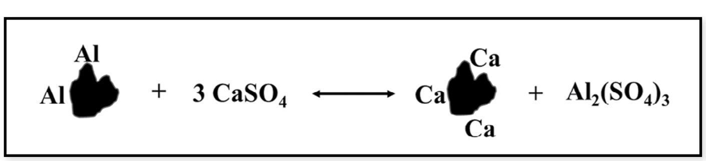

Figure 3. Reaction between gypsum and aluminum in soil to form alum.

The thickness of the fragipan layer can be 3 feet or more, and thus, it may be too costly to alleviate the toxicity any deeper than 12 inches. Figure 4 shows exchangeable aluminum concentrations 18 months after surface application of 1 and 2 t/a FGD-gypsum. Both the 1 and 2 t/a rates were equally effective at reducing the exchangeable aluminum concentrations at the 6-12 inches depth, close to the commonly accepted threshold of 25 ppm exchangeable aluminum. Exchangeable aluminum levels at the 12-18 inch depth were also lowered, but not enough to reduce exchangeable aluminum's toxic effects. There was no significant yield difference among the treatments, but gypsum application could have saved 1 to 2 irrigations. How long this effect will last is not known. Producers need to be aware that excessive applications of gypsum could potentially remove some of the essential nutrients like potassium from exchange sites, in the same manner that the calcium in gypsum displaces exchangeable aluminum or sodium from the solid phase. Regular soil sampling is recommended when using gypsum as a soil amendment.

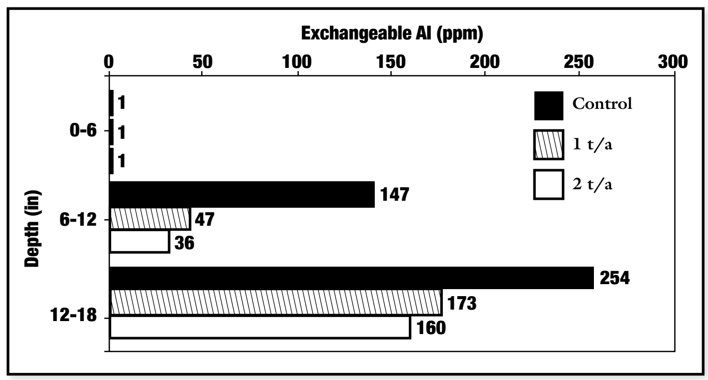

Figure 4. Average exchangeable aluminum concentrations at three depths 18 months after application of 1 and 2 t/a FGD-gypsum and for control plots on a Henry silt loam near Marianna Arkansas (n=3).

Summary

1. Two forms of gypsum can be land applied: mined and FGD-gypsum.
2. Gypsum can be used as a source of sulfur and calcium.
3. Gypsum will not change the pH of the soil.
4. Gypsum can be used to remediate sodic soils, provided there is a source of good quality water and the sodium can be leached out of the root zone.
5. Gypsum can potentially reduce surface crusting in soils with a high percentage of silt.
6. Gypsum can aid in the leaching of aluminum out of a fragipan.

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