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Gypsum for Agricultural Use: The State of the Science

Abstract

Soil health is an issue of global concern that influences, among other things, food security and water quality. Certain farming practices, when properly applied, can protect and improve soil health. Research studies and farm management experiences in the U.S. indicate that gypsum is an effective and valuable soil amendment for certain soil types (Chen & Dick, 2011; Chen, Kost, Dick, 2008; Dontsova et al., 2004; Fisher, 2011; Stout et al., 1998; Walworth, 2006; Wolkowski et al., 2000). Gypsum, or calcium sulfate dihydrate ($CaSO_4 \bullet 2H_2O$), has been mined for use as an agricultural amendment for centuries. More recently, it has been produced as a by-product from emission scrubbers in coal-fired power plants, and is known as flue gas desulfurization (FGD) Gypsum. It is a direct source of macronutrients (calcium and sulfur) for plants, and improves soil physical and chemical properties that promote nutrient uptake from soil minerals into plants. Gypsum application has been found to reduce the amount of phosphorus in runoff. By enhancing soil composition and improving water infiltration, gypsum can contribute to enhanced crop growth, improve water conservation, and reduce the loss of soil and nutrients into area waterways.

Introduction

The need to increase crop yields to meet global population growth has led to intensive farming practices, which have depleted soils around the world. Nearly all U.S. agricultural soil is somewhat degraded and much of the soil in the Midwest is classified as very degraded ("Land Degradation", 2010). Poor soil conditions inhibit plant uptake of important nutrients, like phosphorus and nitrogen, reducing yields and producing less healthy plants. To compensate, farmers often over-apply fertilizers and pesticides, which further stress soils and load nearby waterways with excess nutrients. This causes toxic algal blooms, eutrophication, loss of aquatic diversity, water quality degradation and public health concerns. Furthermore, degraded soils retain less water, making farmlands less resilient during drought conditions.

Gypsum

Research indicates that certain soil amendments can aid in remediating soils, resulting in higher yields and reduced sediment runoff (Chen & Dick, 2011; Stout et al., 1998). One promising amendment is gypsum, a sulfate mineral that has been used as a fertilizer for centuries (Chen & Dick, 2011). It is found naturally in sedimentary rocks around the world, including the United States, which has several active gypsum mines. However, mined gypsum is not an economical solution in many locations, in part due to transportation costs (Rhoton, 2011).

FGD gypsum being spread on a cover crop

Gypsum can also be recovered from scrubbers in a coal-fired power plant. This type of gypsum, flue gas desulfurization (FGD) gypsum, contains fewer impurities than mined gypsum, with 90 to 99% purity concentration compared to 66 to 98% concentration for mined gypsum (Chen & Dick, 2011). FGD gypsum has been recognized as a beneficial additive for agricultural application. Compared to mined gypsum, FGD gypsum has more desirable spreading characteristics, which allows for easy application (Dontsova et al., 2004). With more coal fired power plants installing pollution scrubbers to comply with air quality standards, FGD gypsum production has increased and will likely double in the next decade while remaining economical (Wolkowski et al., 2010).

Improved soil composition

In assessing the need for to gypsum application, it is important to understand the stability of the soil by looking at soil aggregates. Aggregates are clusters of soil particles; their size and spacing influences water infiltration. Calcium binds soil particles into more effective aggregates that help with water infiltration (Walworth, 2006). Gypsum particularly improves the physical properties of heavy clay and sodic soils (Chen & Dick, 2011). By improving soil structure, gypsum helps prevent soil particulate dispersion, decreases surface crust formation, aids in seedling emergence, increases water infiltration, and decreases the loss of soil and nutrients due to surface runoff and erosion (Chen & Dick, 2011). When gypsum was applied to fields under no-till practices, it was found to decrease erosion and runoff (Norton, 2011). Due to better infiltration and less surface sealing, the addition of gypsum to soils could help farmers save money on irrigation since more water is available to the crop (Truman et al., 2010).

Gypsum also improves chemical properties of soil such as remedying aluminum toxicity caused by subsoil acidity (Chen & Dick, 2011; Dontsova et al., 2004). Results include better rooting and uptake of water and nutrients, especially during periods of water scarcity (Chen & Dick, 2011). While gypsum addresses subsoil acidity and aluminum toxicity, it is important to note that gypsum is not a liming agent, and does not alter pH levels in the soil (Fisher, 2011).

Improved water quality and quantity

Gypsum can also amend problems associated with excess phosphorus. High phosphorus levels pose a threat to waterways. The calcium in gypsum lowers the amount of phosphorus released in surface runoff. Additionally, gypsum aggregation of soils also reduces the amount of surface runoff.

Favaretto et al. (2012) found a decrease in dissolved reactive phosphorus in runoff when gypsum was added. This most likely occurs through the conversion of the phosphorus into less soluble compounds. The concentration of water-soluble phosphorus decreased by 50% in one study (Stout et al., 1998). In research conducted by Dr. Darrell Norton, gypsum application was found to mitigate some of the nutrient loading in runoff caused by the addition of manure to fields (Norton, 2008). Gypsum application on soils where poultry litter was used as fertilizer also significantly reduced soluble phosphorus (Sheng et al., 2012). In south Florida where much of the excess phosphorus was from dairy manure application, gypsum resulted in higher retention of phosphorus in the soil and also reduced soluble phosphorus in waterways (Anderson et al., 1995). Grass buffers can also reduce soluble phosphorus runoff and are even more effective when gypsum is applied to the buffers. Watts et al. (2009) showed a reduction in soluble phosphorus by up to 40% when gypsum was applied to the grass buffers in Alabama.

Improved Crops

Improved soil conditions increase crop yields (Chen & Dick, 2011). Calcium is important for strengthening cell walls and membranes and for developing root tips (Fisher, 2011). Gypsum may improve the yields and quality of calcium-dependent crops, such as peanuts, tomatoes and cantaloupes (Baligar et al., 2011). Sulfur is also an essential element. Corn yields, for example, are often limited by inadequate sulfur, which is needed to balance soil nitrogen in producing protein. In fact, sulfur is an often forgotten essential nutrient for plant growth and is rapidly being depleted in soils (Chen & Dick, 2011). A Wooster, Ohio study found that in addition to nitrogen fertilizers, adding sulfur in the form of FGD gypsum boosts corn yields (Chen, Kost, Dick, 2008). The gypsum contributed to the increased uptake of these important elements – nitrogen and sulfur.

The application of gypsum reduces the amount of nitrogen fertilizer needed for producing higher corn yields, making gypsum economically advantageous while reducing the amount of fertilizer runoff (Chen, Kost, Dick, 2008). A Texas study indicated gypsum provided at least three times more available calcium than other tested treatments. A higher level of application was more effective than the lower level (Brauer et al., 2005). Gypsum applications in Kansas increased wheat yields an average of 10 bushels over a five year period (Lamond, 1992).

Gypsum application can produce healthier, more resilient crops

Gypsum application in California avocados groves resulted in a decrease in *Phytophthora cinnamomi* infection; however, it is not fully understood how gypsum reduced the incidence of infection, so further research is needed (Messenger et al., 2000). In California orchards and vineyards, studies have shown gypsum to reduce crop failure associated with the calcium leaching properties of the snow melt (Rouppet, 2008).

Whole systems approach

Gypsum is a proven beneficial soil amendment across the United States and the world for a variety of crops (Fisher, 2011; Brauer, 2005; Peacock; Rouppet, 2008; Miller et al., 1998). While gypsum has a number of benefits when used, best results are achieved when used with other sustainable farming practices, such as no tillage, cover crops, and crop rotation (Fisher, 2011). Farmers in the Midwest have been using gypsum for decades with positive results; including better water infiltration and higher yields (Fisher, 2011).

Application

Some factors should be taken into account when considering gypsum use; the rate and season to best apply gypsum will vary by location and soil type (Dontsova et al., 2004; Peacock). Over-application of gypsum may result in seedling damage and nutrient imbalance. Additionally, when purchasing FGD gypsum it is important that it has been washed in the manufacturing process to remove potentially high levels of boron that can be toxic to certain crops (Dontsova et al., 2004). Low concentrations of trace metals may be found in gypsum, generally at lower concentrations than government regulations, but it is best to test samples before applying (Dontsova et al., 2004). As previously mentioned, gypsum does not remedy all soil problems. Location and soil composition influence gypsum's effectiveness and thus is not suitable for all crops (Franzen, 2008).

Other environmental benefits

In addition to water quality and agronomic benefits, use of FGD gypsum as a soil amendment benefits the environment by avoiding the need to landfill excess material and minimizing the mining and associated impacts of extracting virgin gypsum deposits (Chen & Dick, 2011).

Conclusions

Overall, gypsum is an effective soil amendment, improving soil conditions and their effective nutrient processing capabilities in certain soil types. It helps to restore degraded soils by enhancing water infiltration and improving soil composition, contributing to less erosion and nutrient loading in waterways. For some crops, gypsum can help increase the available nutrients to crops, allowing for greater yields. Gypsum is most effective as one part of a whole systems farming approach that takes into consideration soil type, crop, and hydrology. Not only does a reduction in nitrogen fertilizer benefit the environment, it may also benefit farmers economically (Chen, Kost, Dick, 2008). Gypsum can be an important tool for maintaining healthy, functioning soils, contributing to healthy crops and healthy waterways.

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