

Amending soils with Gypsum

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Photo courtesy of GYPSOIL/Ron Chamberlain.



Gypsum has received renewed attention in recent years as a potential soil amendment. Some farmers who've adopted it are finding that its effects on soil physical properties can lead to higher yields and profits, and data are mounting on the mineral's capacity to reduce nonpoint source pollution contributed by agriculture. But is there enough information out there to justify applying it on any one farm? A group of industry representatives, scientists, and growers addressed this question at the Midwest Soil Improvement Symposium this past August.

Gypsum, or calcium sulfate dihydrate, has been used by farmers for a very long time. It was applied extensively as a fertilizer in 18th century Europe, U.S. founding father Ben Franklin touted its benefits—even the Greeks and Romans reportedly used it. More recently, it has become a proven soil amendment to reclaim sodic and other degraded soils. And its use as an economical fertilizer continues to this day.

However, gypsum can seem like a brand new product these days, thanks to the renewed attention it's receiving for several reasons. Gypsum is more plentiful now, for one. It was mostly mined in the past, but today a "synthetic" form is surpassing natural sources: Flue gas desulfurization (FGD) gypsum, a by-product of scrubbing sulfur dioxide gases from the emissions of coal-fired power plants. Production of FGD gypsum doubled from 12 to 25 million tons between 2004 and 2010, according to the U.S. Geological Survey, and it's projected to reach 40

million tons by 2020. Meanwhile, manufacturing markets for gypsum have steadily declined, and the combination of increased supply and reduced demand has sparked efforts to find new applications and expand old ones—including agricultural uses.

Another factor in gypsum's resurgence is its potential to reduce

nonpoint source pollution contributed by agriculture. Through the work of scientists like Darrell Norton, a long-time gypsum researcher with USDA-ARS, data are mounting on the mineral's capacity to curb erosion, improve infil-

Loading gypsum on a truck. Photo courtesy of GYPSOIL/Ron Chamberlain.



tration, decrease runoff, and retain phosphorus in soils. Berms designed to prevent nutrient runoff into the Chesapeake Bay now contain gypsum, and it's being studied as one tool for alleviating other large-scale water quality problems, as well. Meanwhile, farmers who've adopted gypsum are finding that its effects on soil physical properties—better infiltration, for example—can also lead to higher yields and profits.

But is any of this—gypsum's history as a fertilizer, its availability, its positive effects on soils—enough to justify applying the mineral on any one farm? That's the critical question that a group of industry representatives, scientists, and growers tried to answer at the Midwest Soil Improvement Symposium this past August. Hosted and sponsored by the University of Wisconsin (UW)-

University of Wisconsin soil scientists (from left) Dr. Richard Wolkowski and Dr. Birl Lowery describe gypsum trials now underway in Wisconsin during the recent Midwest Soil Improvement Symposium. Photo courtesy of GYPSOIL/Karen Bernick.

Madison College of Agricultural and Life Sciences, UW-Extension, the Conservation Technology Information Center at Purdue University, and GYPSOIL—a leading supplier of synthetic gypsum—the symposium covered everything from how FGD gypsum is first produced at power plants to its ultimate effects on farms. The goal was to present all sides of the gypsum story, said GYPSOIL's president and CEO, Robert Spoerri, in his opening remarks, because even though gypsum has been a part of agriculture for ages, widespread use of it remains controversial.

Roughly 23% calcium and 19% sulfur in its pure form, gypsum comes today not only from mines and coal-fired power plants, but also from recycled casting materials and drywall and as a by-product of citric acid production and phosphorus mining. Importantly, gypsum is also about 200 times more soluble than agricultural lime, or calcium carbonate, allowing it to move readily down the soil profile, where it can provide nutrients to deep plant roots and help alleviate subsoil problems.

Gypsum is not a liming agent, however: It does not neutralize hydrogen ions or change soil pH like calcium carbonate does, stressed Ohio State University professor Warren Dick, although this is a common misconception. Still, one of gypsum's main advantages, emphasized by Dick and several other speakers, is its ability to reduce the aluminum toxicity that often accompanies soil acidity.

In soils below pH 5, aluminum becomes soluble Al^{3+} , which is extremely toxic to plant roots. So harmful is aluminum, in fact, that plant roots bend away from regions of subsoil acidity and wind up restricted to a shallow depth. Gypsum corrects this by moving into the subsoil, where its calcium ions (Ca^{2+}) displace aluminum ions from the soil's exchange sites. Sulfate ions (SO_4^{2-}) supplied by gypsum can also react with the free aluminum ions to produce aluminum sulfate complexes that are less toxic and more capable of being leached away.

In studies in Ohio, root growth in the acidic subsoil has been found to increase as a result, Dick said, allowing plants to tap deep reserves of moisture and nitrogen that would otherwise be unavailable. Gypsum has also been used to treat aluminum toxicity in the South, added Harry Schomberg, a cropping systems ecologist with USDA-ARS in Georgia, where many soils exhibit acidity below about 12 inches. In a study by Schomberg's USDA-ARS colleague, Fred Rhoton, for example, adding gypsum at 3 tons/ac substantially reduced concentrations of soluble, subsoil aluminum over three years, compared with 0 and 1 ton/ac applications.

The forgotten nutrients

Gypsum is also a source of calcium and sulfur, or what Dick called



the “forgotten nutrients.” Nitrogen, phosphorus, and potassium get most of our attention, but plants also need calcium and sulfur in relatively large amounts, he explained. Plant cell walls and membranes require calcium for proper functioning, and growing root tips and developing fruits also need a lot of the nutrient. Sulfur, meanwhile, is critical to making protein because the amino acids methionine and cysteine both contain sulfur atoms. The nitrogen-fixing enzyme, nitrogenase—important in alfalfa and soybean—also has a very high requirement for sulfur.

But are these nutrients deficient in soils? This certainly wasn't the case historically with sulfur. Previously, nitrogen and phosphorus fertilizers contained sulfur as a by-product. More significantly, coal burning releases sulfur into the atmosphere that subsequently returns to earth in precipitation, providing a free source of sulfur to many areas of the country, Dick said.

Sulfur impurities have been mostly eliminated from fertilizers today, however. And now that sulfur is being scrubbed from flue gases, much less is coming from the atmosphere, as well. In Wooster, OH, for example, deposition dropped from 30 lb/ac in 1971 to 17 lb/ac in 2002. Add to these changes the greater sulfur requirements of today's high-yielding crop varieties, Dick said, and sulfur deficiency is emerging in the Midwest.

He proceeded to present several studies from the 1980s to 2000s in which adding sulfur as gypsum or other forms corrected sulfur deficiency and boosted yields of corn and forages. In a 2002 to 2005 study near Wooster, OH, for instance, average corn yield increased from 182 bu/ac without gypsum to 193 bu/ac when sulfur was supplied (as FGD gypsum) at 30 lb/ac. “It will



pay, if you get that kind of boost,” Dick said.

Another key finding of that study was that nitrogen use efficiency improved significantly with gypsum addition, Dick added, suggesting “if you don't satisfy the sulfur requirement of the crop, it can't really use the nitrogen either.” Likewise, applying gypsum won't help if the crop doesn't have enough nitrogen, added UW-Madison emeritus extension soil scientist Richard Wolkowski. In research plots at Arlington, WI, his group found that grain yield didn't respond to the sulfur in FGD gypsum until adequate nitrogen was provided. In fact, gypsum actually lowered yields when nitrogen was applied at sub-optimal rates.

“So, like Warren said, you need both adequate nitrogen and where you have a sulfur responsive situation, you need the sulfur,” Wolkowski said. “The interaction [between them] is highly significant.”

Although Wolkowski reiterated that “sulfur really has become a nutrient of interest that 10 years ago we didn't think too much about,” he also cautioned that it should still be treated like any other. This includes testing for sulfur deficiency

Dr. Meghan Buckley, assistant professor in the College of Natural Resources at the University of Wisconsin–Stevens Point, demonstrates aggregate stability from soil samples treated with FGD gypsum at the Midwest Soil Improvement Symposium. Photo courtesy of GYPSOIL/Karen Bernick.

(there are tools available for doing so) and looking at factors such as soil type, farm location, and history of manure. “There's not always an automatic need for sulfur,” he said.

Gypsum also provides calcium. Calcium fertilization is generally unnecessary for crops and soils in Wisconsin, Wolkowski said. However, work by UW soil scientists in the 1980s found that gypsum can increase the yield and tuber quality of potatoes grown on sandy soils with low organic matter. Moreover, stored potatoes are frequently bumped and bruised when handled, Wolkowski explained, and the added calcium “tends to build stronger cell walls that allow the potato to maintain its integrity, improving storability.”

Dick also noted that growing root tips are especially sensitive to

calcium deficits. They require a lot of the nutrient, to start, and they depend entirely on the soil to get it since calcium can't be transported to them from other plant tissues. This is an important reason to supply calcium as gypsum rather than lime, Dick said. Because of its greater solubility, gypsum moves into deeper soil layers within three to four years, whereas lime typically remains in the top 6 to 10 inches even after a decade or more. His final recommendation was to add the two together: Lime to bring soils to the proper pH and gypsum to deliver nutrients into the root zone.

Improving soil structure

But nutrition isn't the most important thing calcium offers. All the speakers agreed its greater value is as a "flocculating" agent that can improve soil structure. Flocculation, or the aggregation or clumping together of soil particles, depends largely on which positively charged ions are present on the exchange sites in soil. Large concentration of ions with more than one positive charge, such as calcium (Ca^{2+}) and magnesium (Mg^{2+}), help soil particles hold together in stable aggregates. In contrast, high levels

of single-charge ions, especially sodium (Na^+), will cause soil particles to disperse, or separate. Put another way, if sodium's relative flocculating power is set at 1, potassium's (K^+) is 1.7, magnesium's is 27, and calcium's is the highest, at 43.

Lack of aggregation, or dispersion, in turn, causes poor soil structure—and a number of problems. Soils erode easily when particles don't hold together well. A lack of stable aggregates also means fewer pore spaces for water to move through, leading to rapid waterlogging and poor infiltration when it rains and surface-crusting and cement-like compaction when soils dry out. Plant roots have a hard time penetrating poorly structured soils. And less infiltration, of course, causes greater runoff, erosion, and loss of nutrients.

Especially well documented is gypsum's ability to improve the structure of soils containing high sodium ion concentrations, or sodic soils. As it does with aluminum, gypsum adds calcium ions that knock sodium ions off exchange sites, helping sodium leach from the soil and consequently improving aggregation, infiltration, crop rooting, and so on. Gypsum is commonly used to reclaim sodic and saline

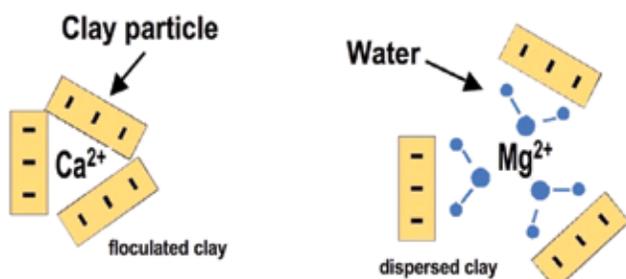
soils in arid and semi-arid regions, for example, especially where salty water is used for irrigation.

Gypsum has also been shown to increase aggregation, reduce surface crusting, improve crop rooting, and boost yields in soils of the Southeast's Piedmont and Coastal Plain regions. There the problem isn't so much sodicity, Schomberg said, as highly weathered, often clayey soils with minimal capacity for cation exchange or nutrient and water retention. Because of the region's low soil organic matter levels, in particular, clay particles disperse easily unless the right flocculating ions are present, he said. "So, that's one of things that we're really interested in utilizing gypsum for."

Along similar lines, Wolkowski and his co-investigator, University of Wisconsin-Stevens Point assistant professor Meghan Buckley, have found that gypsum has a greater effect on the physical properties of soils that are high in clay or poorly structured. In on-farm studies in 2010, for example, adding gypsum at rates of 0.5, 1, and 2 tons/ac didn't affect the porosity of three Wisconsin loam soils, but did seem to increase porosity slightly in two clay loams. Likewise, gypsum increased infiltration in one clay loam (but not the other) while failing to boost infiltration substantially in the three loams.

Buckley cautioned that the results represent just one year's worth of data while it can take many years to change soil physical properties. Still, the data seem to suggest that "some of the troublesome soils—the tighter soils, the denser soils, the clayey soils—are where we're seeing some effects initially," she concluded. "But we're not seeing many wide-ranging effects." The pair also attributed the yield responses they've seen to better sulfur nutri-

Soil dispersion is mainly caused by highly hydrated ions, such as Na^+ or Mg^{2+} , attracted to the surface of clay particles



Addition of soluble Ca can overcome the dispersion effects of Mg or Na ions and help promote flocculation and structure development in dispersed soils. Illustration courtesy of Dr. Jerry Bigham, the Ohio State University (OSU), and reprinted with permission from the OSU Extension Bulletin 945: *Gypsum as an Agricultural Amendment*.

tion, rather than improved soil properties.

That has been the experience of the researchers so far, but a trio of corn and soybean growers got the last word on gypsum near the symposium's end. "We don't think you can ever say with confidence that something will work (or won't) until you try it on your own farm," said fourth-generation Indiana farmer Rodney Rulon, which is why he and his co-presenters have been doing their own experiments with gypsum. And although their levels of experience with it varied, they all reported gains in soil health, crop rooting, infiltration, and yield.

For example, Nick Miller, who farms 3,500 acres near Oconomowoc, WI, said his soybean yields hit 65 bu/ac the first year he applied gypsum compared with the previous 10-year average of 45. He also described a 1-ac low spot in a field where standing water prevented him from sowing crops in previous years. "With one application of gypsum, the water filtered right through, the roots got air, and the beans in that one acre went 110 bushel," he said.

Jack Maloney, Rulon's neighbor in Indiana and another fourth-generation farmer, also emphasized gypsum's value in helping regulate drainage, a critical issue on his farm. "We're on a soil type that's rated somewhat poorly drained, and I guarantee you when it's wet, it's *really* poorly drained," he said. But, he added, his real "aha" moment with gypsum came five years ago, during a drought. To prepare for a meeting with Purdue soil scientists, he dug a 4.5-ft-deep soil pit the evening before and was surprised to see corn roots extending all the way down. By the morning, too, the bottom was filled with water, despite the dry conditions. "So, the water was down there, and the roots were



down there," he said. "That corn never gave up all summer."

For his part, Rulon highlighted the tremendous improvement in soil color, texture, and quality he has seen over the years. "[The soil] is a testament to how this system works," he said. But there's a caveat here, and it lies in the word "system," he cautioned. He, Maloney, and Miller use gypsum as part of a suite of practices designed to protect and build the soil, including no-tillage, cover cropping, and intercropping. And when you do that, "you start getting one plus one equals three," Miller said, making it tough to identify any one component as *the* factor making the difference—gypsum included.

Indiana growers Rodney Rulon (left) and Jack Maloney (right) look on as Nick Miller explains how he uses gypsum to add sulfur and improve soil structure at his Oconomowoc, WI farm. Photo courtesy of GYPSOIL/Karen Bernick.

That point underscored what seemed to be the take-home message of the day: Gypsum is not a stand-alone, magic bullet solution to improving soils, or boosting crop yields and profits. True, it can have dramatic impacts in some cases, such as when soils are sodic. But, in general, farmers will need to weigh gypsum's benefits against the costs of buying and applying it—just as they do with everything else on the farm. 🌱

Additional Resources

For more information on gypsum, including the latest research results and management guidelines, visit:

- GYPSOIL: www.gypsoil.com
- National Research and Development Network of FGD Products in Agriculture: www.oardc.ohio-state.edu/agriculturalfgdnetwork
- National Soil Erosion Research Laboratory, gypsum fact sheet: www.ars.usda.gov/Services/docs.htm?docid=18103
- Ohio State University Extension Bulletin 945, *Gypsum as an Agricultural Amendment*: <http://ohioline.osu.edu/b945/b945.pdf>