Science Societies

Correcting Sulfur Shortages in Midwest Soils

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Soybeans with 20 lb sulfate sulfur per acre applied prior to emergence (left) and without S (right). Photo by Shaun Casteel, Purdue University.

Declining sulfur depositions from the atmosphere have caused sulfur shortages in soils across the Midwest for more than a decade. Fortunately for growers in regions with noticeable declines in depositions, fixing the problem typically requires minimal amounts of sulfur fertilizer. Earn 0.5 CEUs in Nutrient Management by reading this article and taking the quiz.

Declining sulfur depositions from the atmosphere have caused sulfur shortages in soils across the Midwest for more than a decade. Fortunately for growers in regions with noticeable declines in depositions, fixing the problem typically requires minimal amounts of sulfur fertilizer.

James Camberato, professor of agronomy at Purdue University who studies soil fertility and plant nutrition with colleagues Bob Nielsen and Shaun Casteel, says the trend of declining sulfur atmospheric depositions is likely to persist for the foreseeable future due to ongoing changes in energy generation in the U.S.

"The first impact was implementation of the Clean Air Act, which required power plants to scrub the sulfur out of the smoke stack with lime, so they produced gypsum," Camberato explains. “Most recently, the coal‑fired plants transitioning to natural gas also contributed to lower sulfur emissions.”

The ongoing decline in sulfur atmospheric depositions has had a direct effect on sulfur levels in soils across the Midwest, particularly in the eastern Corn Belt. As recently as 2000, the eastern Corn Belt received 15 lb of sulfate sulfur per acre per year in deposition, says Camberato, noting that a corn yield of 200 bu/ac and a soybean yield of 60 bu/ac remove about 10 lb of sulfur annually.

Sulfur-deficient corn plants may show striping as well as an overall yellow color. Photo by R.L. Nielsen, Purdue University.

“The deposition was more than removal,” he says. “But progressively, the air has gotten cleaner, and now even the eastern Corn Belt, which is where the deposition was the highest, has less than 4 or 5 lb of sulfur per acre per year. That’s half of what the crop would remove.”

Based on soil laboratory studies throughout the Midwest, about 60% of soils today test less low for sulfur, or less than 8 ppm, Camberato notes. In the early 2000s, less than 3% of soil samples tested less than 8 ppm.

Carrie Laboski, forage specialist at the University of Wisconsin–Madison, says sulfur deficiencies in alfalfa started showing up in 2009 with the problem becoming more prevalent over time. However, some soil types are more prone to deficiencies than other soils, she says.

“Some of the places we see sulfur deficiency more frequently tend to be sandier soils because they don’t have an ability to retain sulfur very well,” Laboski explains. “This is in the backdrop of having reduced atmospheric deposition of sulfur. So sandier soils, either topsoil or sandy subsoils that even have a more loamy topsoil, can be problematic.”

Soils that have lower organic matter levels also tend to supply less sulfur to the crop, Laboski notes. Fields that have a history of manure application are less likely to have sulfur deficiency, she adds, noting that manure contains sulfur and acts as a fertilizer.

The direct impact on crop production from sulfur deficiencies is lower yields, Camberato explains. Sulfur deficiencies can also impact crop quality by altering the amino acid composition in grains and oilseeds, particularly with wheat and soybeans.

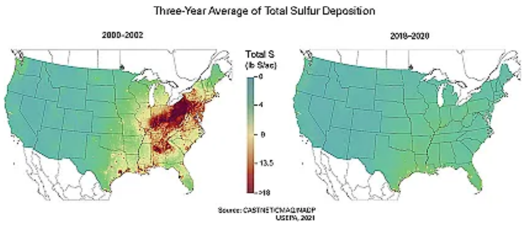
Detecting Sulfur Deficiencies

Agronomists agree that traditional methods of determining fertility programs don’t always apply to sulfur. Rather, field observations and tissue sampling are better indicators of when to fertilize for sulfur.

“Soil testing is not a great way to determine if you need to add sulfur, but a fall soil sample is a decent way to assess prevalence of sulfur in the environment,” Camberato says. “It reflects the changes in deposition and the overall sulfur availability. But, you can’t make a decision to fertilize or not fertilize based on it.”

Camberato explains that there are several reasons for the poor relationship between fall soil sulfate measurements and incidence of response of fertilizer needed. Because sulfate is a mobile nutrient, it may be present in the fall when soil samples are taken but may be at a different level in the spring when the crop is growing. Soil organic matter is also an important source of sulfur, which may not be reflected in the fall analysis when temperatures are colder and less sulfur is being mineralized. And, availability of the nutrient depends on the weather and the activity of soil microorganisms, he adds, which also changes from fall to spring.

Tissue sampling during the growing season is a more reliable indicator of sulfur deficiency, he says, with samples ideally taken in the early vegetative stages for corn and soybeans. For alfalfa, Laboski recommends taking tissue samples from the top 6 inches of 20 to 30 stems by the first flower stage just prior to cutting.



Sulfur atmospheric depositions have significantly declined over the last 20 years.

“If you have less than 0.20 to 0.25% sulfur on a dry matter basis, there’s a pretty good likelihood that your crop is sulfur deficient,” Laboski explains.

However, tissue sampling also has its challenges with reliability, Kaiser notes.

“Tissue concentrations are problematic, also, because when you look at some common methods at labs that run tissue analysis, they don’t always agree with each other,” he says.

Pairing tissue sampling with simple field scouting and examining plants for signs of distress increases the reliability in detecting sulfur deficiencies in crops, Camberato adds.

“Symptomology for corn is pretty diagnostic,” he says. “If the plant has a sulfur deficiency, it will be uniformly yellow, whereas with a nitrogen deficiency, the lowest leaves turn yellow, then brown, then wither away and fall off."

Leaves also tend to have interveinal chlorosis, or striping, adds Camberato. However, deficiencies in other nutrients like magnesium, manganese, iron, and zinc can also cause striping. A soil analysis, he notes, can rule out the other nutrients as causes for the striping.

Early detection is crucial in managing for sulfur deficiencies, Kaiser stresses.

"The problem is when you get later in the growing season, it's hard to differentiate between nitrogen and sulfur deficiencies because there tends to be more of a yellowing in the upper canopy, unless you've over-applied nitrogen," Kaiser explains. "It's easier to tell early, particularly around V5 or V6, before it starts interacting with nitrogen."

Organic Matter

To gain a better reading of soil sulfur levels, Kaiser relies on organic matter levels, which he says are a more stable value than tissue samples and a better indicator of the pool of available sulfur.

"It gives you a better idea of the risk assessment for when you're going to be short," he explains.

Pairing tissue sampling with simple field scouting and examining plants for signs of distress increases the reliability in detecting sulfur deficiencies in crops. Photo courtesy of Adobe Stock/Yevhenii Kukulka.

Camberato also points to organic matter is an important indicator of available sulfur. Soil organic matter contains about 100 lb of sulfur per acre per percent organic matter, he notes, with 1 to 3% being available in a growing season. If soil has 3% organic matter, and if conditions are good for mineralization to make the nutrient available to the plant, about 10 lb of sulfur per acre is already provided for the crop.

The timing of mineralization may not coincide with the plant's needs, he warns, resulting in temporary sulfur deficiencies. The plant may have a high demand early in the season when mineralization is slow due to cold temperatures, Camberato explains, resulting in the plant being deficient early in the season.

Kaiser notes this seasonal imbalance is of particular concern in northern climates.

"Since we're cool and early season here in Minnesota, we see a lot of sulfur deficiencies early in our crops. Particularly for corn, one thing I've seen consistently in our studies is we start to get mineralization ramping up around V6. That's a key point in time when the crop's about a foot tall," Kaiser explains. "As long as mineralization can pick up at that point to meet the demand, then the problem isn't that major."

Fertilizer Response

Fertility requirements to correct for soil sulfur deficiencies thankfully are low with farmers frequently overfertilizing.

In Camberato's field trials for fertilizing corn, 15 of 40 trials, or 38%, showed a yield response to sulfur applications with detectable differences ranging from 4 to 24 bu/ac. With corn at $6/bu and sulfur in liquid form at about $0.90/lb at an application rate of 10–15 lb/ac, the economics of sulfur applications for deficient fields easily compute.

"You're spending $10 to $15 per acre to make between $24 and $140 if you have a responsive site," he says, adding that sandy soils and low-organic-matter soils are the most likely to be responsive.

Some high-organic-matter and heavier-textured silty clay loam soils that are poorly drained also tend to respond to sulfur fertilizer applications, he adds, explaining that mineralization rates are low and not making available the large reservoir of sulfur in the organic matter.

The most economical rates in Kaiser's field trials were between 5 to 10 lb/ac in spring application. In fields low in organic matter, or 2 to 3%, applying higher rates of 15 to 20 lb/ac is recommended. Slightly higher rates are also recommended for continuous corn, he adds.

"Corn residue tends to be deficient in sulfur, so when it's broken down, it's like nitrogen where it will tie up," he notes. "It will also act like a blanket and cool down the soil, so you end up with situations where your mineralization potential is lower. In that situation, I recommend applying at least 10 lb/ac on an annual basis."

Application rates are similar for soybeans with rates of 10 to 15 lb/ac recommended for deficient fields, Camberato says. Earlier-planted soybeans tend to be more at risk of sulfur deficiency, which can delay nodulation.

"The bacteria in the nodules need sulfur," Camberato points out. "So the bacteria aren't able to nodulate and fix nitrogen until later in the season when there's enough sulfur available. That also causes the plant to be nitrogen deficient as well as sulfur deficient."

In alfalfa, Laboski says a 25 lb/ac sulfur application can increase yield by 1 ton/ac, and in some cases, raise yields by nearly 2 tons/ac over multiple cuttings in a growing season.

"When you look at the economic value of a ton of hay versus the cost of the sulfur, it's definitely of economic benefit," she says.

Laboski notes that response tends to be higher with fertilizer in sulfate forms, such as potassium sulfate, ammonium sulfate, and calcium sulfate, or gypsum, which are readily available for a plant. Elemental sulfur, though, takes longer to be made available to the plant as it requires soil bacteria to convert it to sulfate form. In alfalfa, applying sulfur in sulfate form will have an immediate impact on yield in the following cutting.

The best fertilizer growers and CCAs can apply is their time, Camberato says. By investing the time to scout fields early in the growing season, growers and CCAs will have the best knowledge for planning their fertility program.

“Observing the crop early in the season is really important because the soil sampling is not a good tool for detecting sulfur deficiencies,” he says. “You actually have to have the plant there to tell you whether it’s going to be sulfur deficient or not. That puts an emphasis on the role of CCAs and scouting and giving farmers advice so they can do better.”

Self-study CEU quiz

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1. **Sulfur has been declining in soils because of**
   a. ongoing changes in energy generation in the U.S.
   b. the Clean Air Act.
   c. recent coal‑fired plants transitioning to natural gas.

d. All of the above.

2. **In 2000, the eastern Corn Belt received 15 lb of sulfate sulfur per acre per year in deposition. How does that compare to recent deposition rates?**
    a. It’s about 5 lb more than current rates.
    b. It’s about 5 lb less than current rates.
    c. It’s about 10 lb less than current rates.
    d. It’s about 10 lb more than current rates.
3. **Sandier soils are more likely than other soil types to have a sulfur deficiency.**
    a. True.
    b. False.
4. **What’s the best method of determining fertility programs for sulfur?**
    a. Field observations.
    b. Soil testing.
    c. Tissue sampling.
    d. Both A and C.
5. **Striping in leaves is a sure sign of sulfur deficiency.**
    a. True.
    b. False.

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