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# Sulfur, the secretive limiting factor for alfalfa

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*USDA photo by Preston Keres*


Sulfur is not one of the “big three” nutrients growers think about with their crops. But for a forage crop like alfalfa, it’s at least as important if not more important than nitrogen, phosphorus, and potassium. Sulfur is both yield and protein limiting for alfalfa, especially in sandier soils and in colder regions, where many of North America’s dairy farms are and much of the alfalfa crops are grown. This article will discuss why sulfur is needed for alfalfa crops, how much is needed, and in what form it is best to apply it.

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Sulfur is not one of the “big three” nutrients growers think about with their crops—those are nitrogen, phosphorus, and potassium (NPK). But for a forage crop like alfalfa, it’s at least as important if not more important than NPK. Sulfur is both yield and protein limiting for alfalfa, especially in sandier soils and in colder regions, where many of North America’s dairy farms are and much of the alfalfa crops are grown.

Yet sulfur is not a nutrient that can be reliably tested for in soils, its deficiency can present a lot like nitrogen or potassium deficiency, and truth be told, it’s just not a nutrient most people think about. That’s because for a century or longer, soils have not been deficient in sulfur throughout most of North America. Sulfur was in the air, thanks

to industries spewing out the pollutant in bulk. For decades, it rained down on plants and soils, creating plenty of the nutrient for alfalfa. But in the 1990s, when we started halting sulfur's release from industry and power plant smokestacks and auto tailpipes in order to decrease acid rain, the nutrient's environmental distribution began decreasing.

In the 1980s, annual atmospheric sulfur deposition on soils across the northern half of the U.S. ranged from 9 to 25 lb/ac, with most on the higher sides, especially those downwind of major cities and industries. The lower peninsula of Michigan, for example, received more than 25 lb/ac of sulfur annually in the mid-1980s. Kentucky averaged 9–16 lb/ac. Over the last two decades, annual atmospheric sulfur deposition has dropped to 0–5 lb/ac. It's starting to affect crop production, says Christine O'Reilly, a forage and grazing specialist with the Ontario Ministry of Agriculture, Food, and Rural Affairs. Some research suggests in the early 1990s less than 5% of soils were sulfur deficient. Today, more than half to three-quarters likely are deficient for crops like alfalfa.

"We didn't used to have to think about sulfur, but now we do," O'Reilly says. Nowadays, anyone who doesn't add manure, which contains sulfur, to their alfalfa fields should probably be adding the nutrient, she says.


*If you fertilize your fields with manure, it's unlikely you'll see a significant sulfur deficiency since manure contains sulfur. Photo courtesy of Flickr/Kelly Colgan Azar and reproduced under this license.*

## How much sulfur is needed?

Alfalfa is responsive to sulfur, so it makes sense to think about applying the nutrient annually, notes Daniel Kaiser, a soil extension specialist at the University of Minnesota. How much sulfur an alfalfa crop needs depends on the type of soil, how much organic matter is present in the soil, and whether you fertilize with manure or phosphates.

First, soil type: Sandy soils tend to hold onto the least sulfur as it can leach out with rain or irrigation. Clayey soils hold onto more. Silt loams with lower organic matter also tend to need more sulfur because the nutrient is more mobile. This is just a generalization though, Kaiser says. Recent research suggests we don't actually see as much leaching in

forage production systems as we thought, he says. For example, in one plot he studied, some sulfur is still measurable four years after application in a silt loam soil. But generally speaking, he says, the sandier the soil, the more likely you are to need sulfur.

That directly relates to organic matter: Soils with higher organic matter concentrations tend to need less sulfur than soils with lower organic matter concentrations, Kaiser says. In Minnesota, for example, if soil organic matter concentrations are less than 3%, the recommendation is to apply 15–25 lb S/ac to alfalfa fields. "I typically tell my growers that 3–5 pounds of sulfate-sulfur can be mineralized for each 1% organic matter per acre per year," he says.

If you fertilize your fields with manure, it's unlikely you'll see a significant sulfur deficiency since manure contains sulfur, O'Reilly says. Likewise, if you fertilize with phosphates, you are putting on some sulfur, so deficiency is less likely. But you should still watch your fields for signs of deficiency. The predominant symptom is yellowing of the plant and/or stunted growth. The symptoms can look similar to potassium and nitrogen deficiency though, Kaiser notes, so if you see yellowing, you should take some plant tissue samples to determine what nutrient is needed. Sample the top 6 inches of stems, roughly where you'd mow. If the results come back with sulfur at less than 0.22%, O'Reilly says, "we would consider that deficient and likely to respond to an application" of sulfur.

*How to take a tissue sample in alfalfa.*

No matter how deficient your field is though, you don't need to go above that 25-lb application rate, Kaiser says. Research and anecdotes have both shown that max forage yield and protein concentrations are produced with 25 lb/ac applications and do not increase with greater application rates. By overapplying, you could unintentionally acidify your soil, especially if your soil is already prone to acidification, he says. Alfalfa

should have a higher-pH soil in general, he adds, and if you overapply sulfur and lower the pH, you could end up with poor growth.

## What does sulfur do?

The two primary reasons for ensuring your alfalfa field has sufficient sulfur are yield and protein content.

Typical alfalfa yields are around 3 tons/ac, according to the USDA. Adding up to 25 lb of S/ac/yr, especially at sites with lower organic matter concentrations, can increase alfalfa yields by 1 to 2 tons/ac—a significant economic benefit. At one site Kaiser studied in Minnesota, from four cuttings of alfalfa over a season, the researchers got about 5500 lb of additional forage—that was with an application of about 20 lb of sulfur after the first cutting.

Sulfur is also a key component for protein, O'Reilly says. Across the sulfur-deficient plots Kaiser has been studying, adding up to 25 lb of S/ace has increased protein content by 2 to 6%—"that's a lot," he says.

Low sulfur can also hinder symbiotic nitrogen fixation, research has suggested.

## How much sulfur should I add—and in what form?

For best results, if you know your field is likely to be deficient—for example, you're not in the habit of applying manure or phosphates and/or you know you have sandy soils—apply sulfur to alfalfa fields in early spring in a sulfate form. There's not enough microbial activity in cold early-spring soils in places like Minnesota and Ontario to oxidize elemental sulfur, so the plants wouldn't be able to take much up, Kaiser says. Fields in such locations see a lot of sulfur deficiency early in the growing season, he says.

In Minnesota, the general recommendation is to apply 15–20 lb of S/ac to soils with organic matter of less than 3%. In Ontario, the government recommends 5 lb of S/ac unless a plant tissue sample shows deficiency, in which case you'd add more.

If organic matter is higher in your field but you suspect a sulfur deficiency, applying 10–15 lb of S/ac could help improve yield and protein. You can also apply it later in the year—after first cutting tends to be a good time, Kaiser says, because you have three or so cuttings after that for the crop to take advantage of the nutrient and little risk for leaching loss.


*Sulfates like potassium sulfate, ammonium sulfate, and calcium sulfate are easier for alfalfa plants to absorb than elemental sulfur.Photo courtesy Sara Bauder/South Dakota State*

*University and originally published here.*

There's a lot of debate about whether to apply sulfates or elemental sulfur. Either way, "you need to know what you're applying," Kaiser says. Elemental sulfur is often cheaper and more common, especially because people worry about sulfates leaching through the system faster and not being available to the plants. Kaiser's research though has shown very little sulfate leaching unless sulfate is applied in the fall. In general, he says, sulfates like potassium sulfate, ammonium sulfate, and calcium sulfate are easier for plants to absorb than elemental sulfur. Many growers prefer elemental sulfur, but if you apply that early in the year and then test your plant tissue, the plants may show a deficiency because the elemental sulfur isn't readily available to the plant. You run the risk of overapplication, then, he says. And if you overapply ammonium sulfate or elemental sulfur, you could acidify your soils as well. If you need predictable, readily available sulfur, it has to be sulfate, he says.

Kaiser and his team have been testing some elemental sulfur products like MST—Sulvaris' micronized sulphur technology—which is marketed to be a readily available elemental sulfur. He says if the elemental sulfur is super finely ground like MST is, then it tends to be more readily available to plants than coarser sulfur, which is more widely available. Experiments have shown that MST eventually increases yield about the same as sulfates do, but it appears to take time. The plants "don't seem to pick it up in the initial application" so the yield doesn't increase in first cuttings, "but in the end, if you look at the yield over four cuttings, it's roughly the same," Kaiser says. "So it seems to be more of an availability and timing thing. It just takes more time for that stuff to become available" to the plant. If further tests reach the same results, it would hedge a bit against leaching, he notes. Kaiser presented his team's results on optimizing alfalfa sulfur management at the 2023 International Annual Meeting of the American Society of

Agronomy, Crop Science Society of America, and Soil Science Society of America.

“In Ontario, a lot of farmers are surprised to see that alfalfa needs at least as much sulfur as canola,” O’Reilly says.

***“If you’re in a canola-growing region, and your neighbors are applying sulfur to the canola, maybe consider some sulfur on your alfalfa because that requirement is very similar.”***

Likewise, she says, if your neighbors are applying sulfur to their wheat, you definitely should apply it to your alfalfa (wheat needs less sulfur, so if a wheat crop needs it, you can bet your soils are deficient).

Many farmers are also surprised that sulfur can be yield limiting for the crop, O’Reilly notes. Most forage growers use the crop onsite for their livestock, so there are rarely hard numbers on how much forage was produced in a given year. The usual assessment is “Did I have enough to feed my animals this year?” If not, you make a change, and if so, you don’t worry about it, she says. If your yield was lower than you needed, think about adding sulfur.

*Most forage growers use the crop onsite for their livestock, so there are rarely hard numbers on how much forage was produced in a given year. Photo by M. Rehemtulla for QUOI Media Group. Published under this license.*

Protein content in forage is usually tracked by nutritional consultants, O'Reilly says. Most dairy farmers work with nutritionists so they should be able to tell the farmers whether adding sulfur might increase protein. It's a good question to ask the nutritionists, O'Reilly notes.

Alfalfa is a sulfur-hungry crop, she says. "It's definitely something we're raising awareness of and helping growers stay on top of."

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**1. Sulfur is ___ for alfalfa.**

a. protein limiting

b. yield limiting

c. not necessary

d. both protein and yield limiting

**2. Over the last 20 years, annual atmospheric sulfur deposition has dropped to**

a. 0–5 lb/ac.

b. 9–16 lb/ac.

c. 9–25 lb/ac.

d. 25 lb/ac.

**3. How much sulfur an alfalfa crop needs is not dependent on how much organic matter is present in the soil.**

a. True.

b. False.

**4. Which of the following sulfur application rates would be overapplying?**

a. 15 lb/ac.

b. 20 lb/ac.

c. 30 lb/ac.

d. There is no risk of overapplying sulfur.

**5. Elemental sulfur is often**

a. more expensive than sulfates.

b. less common than sulfates.

c. easier for plants to absorb than sulfates.

d. more readily available to plants when it is coarser than when it is finely ground.

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