CFAES

OHIO STATE UNIVERSITY EXTENSION

NORTHEAST OHIO AGRI-CULTURE NEWSLETTER

Your Weekly Agriculture Update for
Ashtabula and Trumbull Counties

April 23, 2024

Insects are starting to emerge from their winter slumber!

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Hello Northeast Ohio Counties!

Be alert for a potential frost/freeze event Wednesday night into Thursday morning. Low temperatures may cause significant injury to plants, especially those in full bloom. You can cover small landscape plants with old sheets, but for larger plants there are fewer options. Give me a call to discuss practical options that fit your situation.

We finally had some dry weather that allowed some field work. I saw a lot of fertilizer/lime being applied, some tillage, and oats being planted across NE Ohio. Hopefully, warmer weather later this week will continue the drying process.

Have a great week!

Lee Beers
Trumbull County
Extension Educator

SPRING 2024 WEATHER & SOIL CONDITIONS: UPDATE 4

By Aaron Wilson

Source: https://agcrops.osu.edu/newsletter/corn-newsletter/2024-11/spring-2024-weather-soil-conditions-update-4

Soil Temperatures and Moisture

Though daily average soil temperatures continued to climb most of last week, a late week cold front dropped two-inch and four-inch soil temperatures back down into the upper 40s to upper 50s (Figure 1).

It was yet another active week for severe weather, with five additional confirmed tornadoes (Champaign, Crawford, Delaware, Portage, and Trumbull Counties). This brings the state's total to 35 in 2024, with peak season just beginning. Ohio normally sees about 20 tornadoes per year. Rainfall was plentiful once again (Figure 2). Most of the state rceived 0.5-1.5", with pockets over 2" in southern Hocking and northern Vinton Counties. Small creeks and streams flooded again, with high flows on all the major rivers. Soils remain saturated compared to late winter conditions (Figure 2). Cool conditions will continue early this week, but a warming trend over the weekend should bump soil temperatures up into the 50s to low 60s by early next week.

For more complete weather records for CFAES research stations, including temperature, precipitation, growing

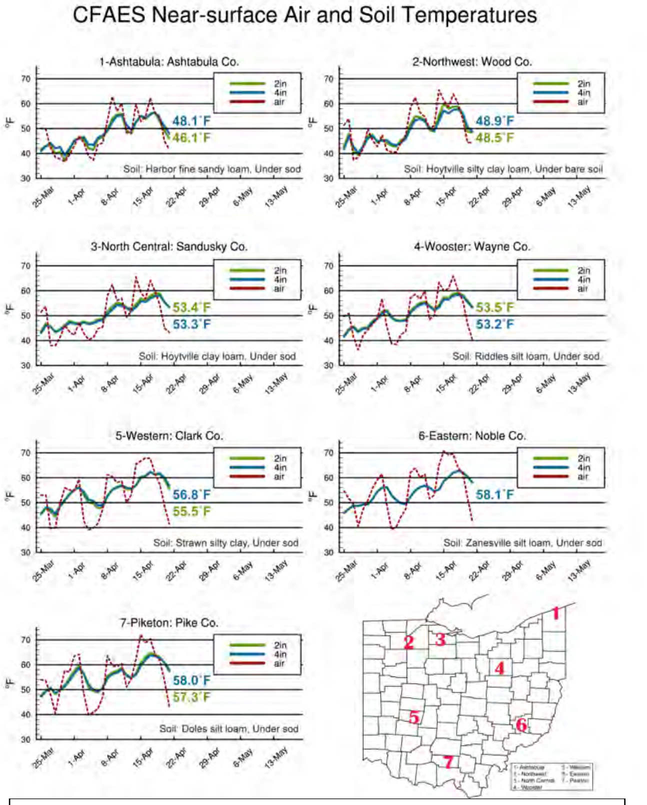


Figure 1: Daily average air temperature (dashed red), two-inch (green) and four-inch (blue) soil temperatures for spring 2024. Soil type and location of measurements (under sod or bare soil) are provided in the lower right corner of each panel. A map of all locations is in the bottom right. Data provided by the College of Food, Agricultural, and Environmental Sciences (CFAES) Agricultural Research Stations located throughout the state.

degree days, and other useful weather observations, please visit https://www.oardc.ohio-state.edu/weather1/.

Weather Forecast

We started Monday morning off chilly, with widespread frost across the state. A beautiful day on Monday has given way to more clouds and an increasing chance of rainshowers on Tuesday with cooler than average highs in the upper 50s to mid 60s. Showers should exit the state on Wednesday, with high pressure settling in and cooler highs in the upper 40s to low 60s (north to south). This will lead to another cold night Wednesday night into Thursday morning. Depending on clouds and location, frost is likely Thursday morning and some areas may fall off into the upper 20s to low 30s. We will see a warming trend beginning on Thursday, with 70s returning for Friday and Saturday. Southern Ohio may see highs in the low 80s by Sunday and Monday. However, scattered showers and storms will be possible Friday through Sunday. Overall, the Weather Prediction Center is currently forecasting 0.55-1.50” of precipitation over the next 7 days, with the heavier amounts across northwest Ohio (Figure 3).

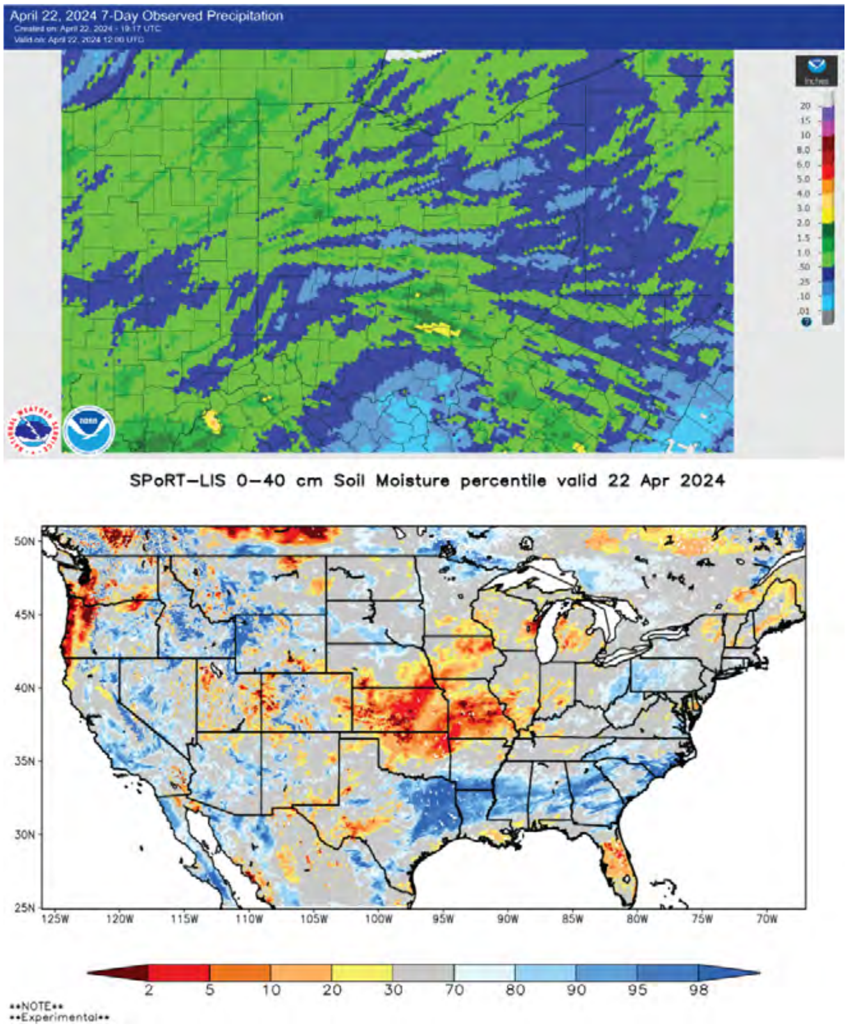


Figure 2: (Top) Precipitation (inches) for the 7-day period ending April 22, 2024 courtesy of the Advanced Hydrologic Prediction Service. (Bottom) Soil moisture percentile for 0-40cm depth as of Calculated soil moisture percentiles as of April 22, 2024, according to the NASA SPoRT-LIS product.

The 6-10 day outlook from the Climate Prediction Center and the 16-Day Rainfall Outlook from NOAA/NWS/Ohio River Forecast Center show strong likelihood for above average temperatures with near to above average precipitation (Figure 4). Climate averages include a high-temperature range of 65-70°F, a low-temperature range of 43-48°F, and weekly total precipitation of 0.90-1.15”.

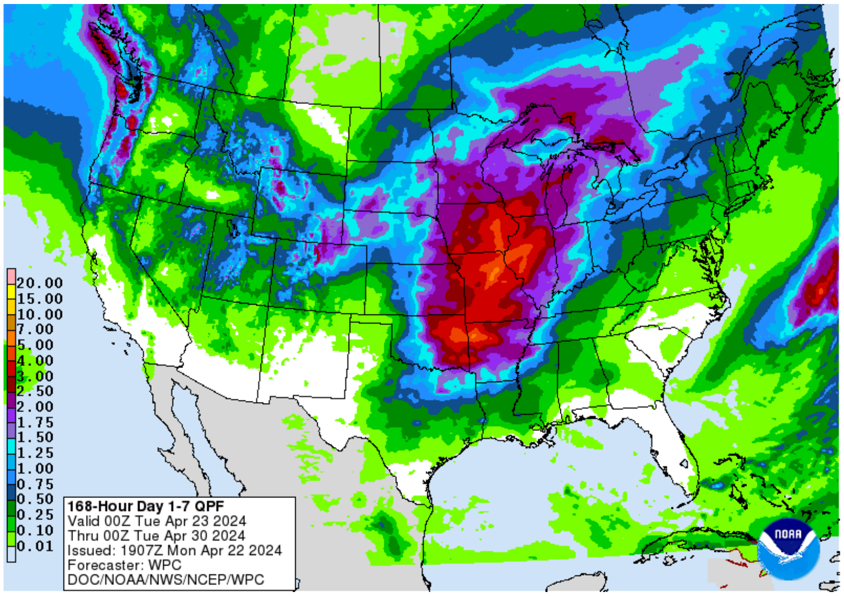


Figure 3). Precipitation forecast from the Weather Prediction Center for 8pm Monday April 22 – 8pm Monday April 29, 2024.

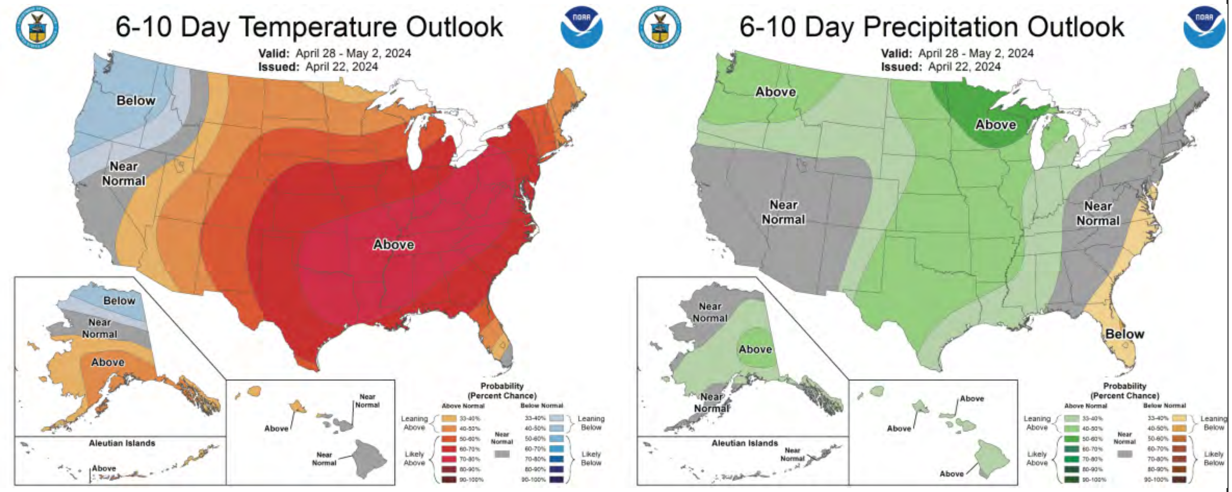


Figure 4) Climate Prediction Center 6-10 Day Outlook valid for April 28 - May 2, 2024, for left) temperatures and right) precipitation. Colors represent the probability of below, normal, or above normal conditions.

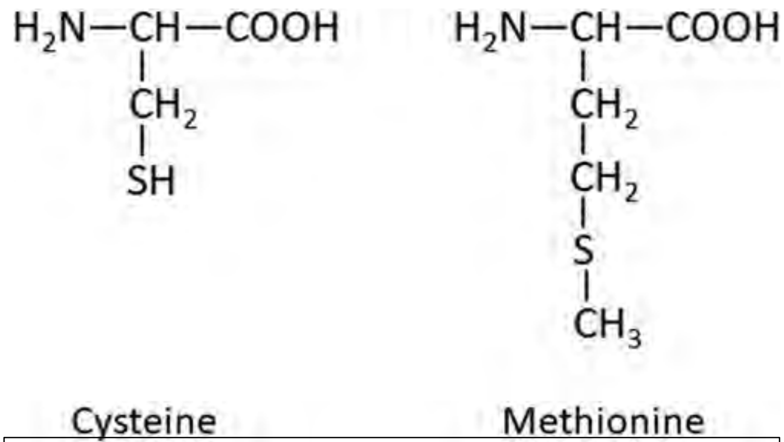
The Role of Sulfur in Meeting 4R Nutrient Stewardship Goals

By Tom Bruulsema, Ron Olson

Source: https://acsess.onlinelibrary.wiley.com/doi/full/10.1002/crso.20360

Sulfur plays several roles in 4R plant nutrition. First, as an essential plant nutrient, it may need to be applied to optimize yields and quality of crops. Second, there may be a need to replenish the sulfur removed from the soil by crop harvests. Third, some forms of sulfur may have additional benefits through their effects on soil pH and on soil nitrogen processes. The three roles combine to support enhanced productivity with lower impacts on the environment. This article reviews basic sulfur nutrition, recent trends affecting the need for fertilizers, and the contribution of sulfur to improving productivity sustainably. Earn 1 CEU in Nutrient Management by reading this article and taking the quiz at https://web.sciencesocieties.org/Learning-Center/Courses.

Sulfur plays several roles in 4R plant nutrition. First, as an essential plant nutrient, it may need to be applied to optimize yields and quality of crops. Second, there may be a need to replenish the sulfur removed from the soil by crop harvests. Third, some forms of sulfur may have additional benefits through their effects on soil pH and on soil nitrogen processes. The three roles combine to support enhanced productivity with lower impacts on the environment.



Cysteine

Methionine

Figure 1. Molecular structure of two of the three sulfur-containing amino acids, cysteine (left) and methionine (right).

This article reviews basic sulfur nutrition, recent trends affecting the need for fertilizers, and the contribution of sulfur to improving productivity sustainably.

Essential Role

Sulfur forms part of three amino acids: cysteine, cystine, and methionine. Plants need sulfur to grow and develop. Amino acids are essential for synthesis of proteins, polypeptides, and enzymes, without which organisms cannot survive. Sulfur atoms are joined with carbon, nitrogen, oxygen, and hydrogen to form the molecular structure of amino acids (Figure 1).

When plants run short of sulfur, the symptoms are like those of nitrogen deficiency. The leaves turn yellow (Figure 2). In contrast to nitrogen, symptoms start on younger leaves. Both yield and quality can be reduced with a shortage of sulfur.

Figure 2. Sulfur deficiency symptoms in canola and soybean.

Trends

Sulfur deposition from the atmosphere was a major pollution concern four or five decades ago in the northeast part of North America. Since then, it has declined to very low levels, owing to the successful implementation of emission controls on fuels used for power generation and transport. Between 2000 and 2022, deposition dropped most dramatically from Indiana to New Jersey (Figure 3) and in the main cropland areas of southern Ontario and Quebec. Across the U.S. Midwest (Ohio to Nebraska to North Dakota), between 1985 and 2015, average rates of sulfur fertilizer application increased from 1 to 4 lb/ac of total cropland as atmospheric deposition declined from 5 to 1 lb/ac (Hinckley & Driscoll, 2022). Deposition of sulfur across the contiguous United States averaged 1.4 lb/ac for 2017 (Hinckley et al., 2000).

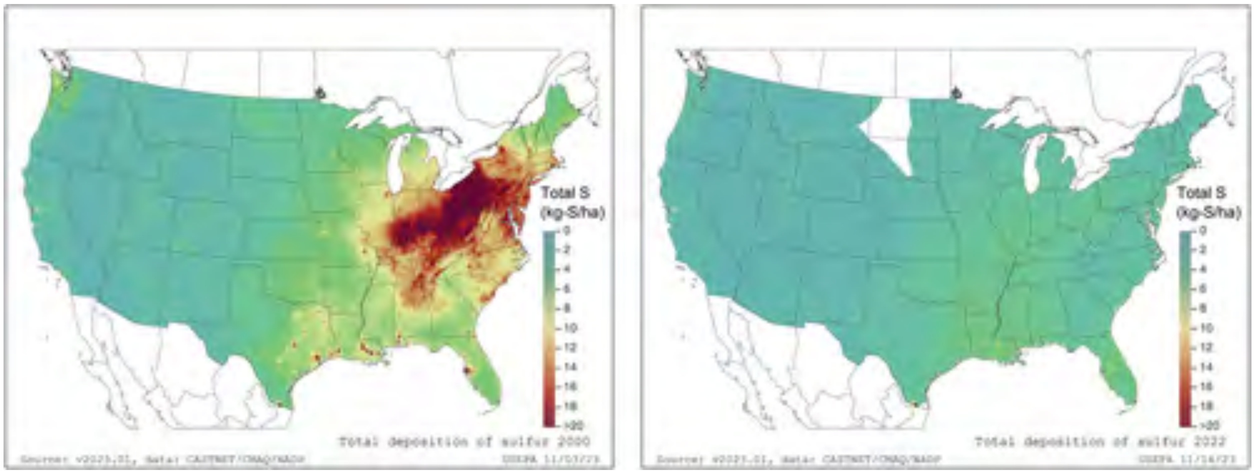


Figure 3. Annual total (wet and dry) deposition of sulfur decreased dramatically in the Eastern Corn Belt between 2000 and 2022. Image from the National Atmospheric Deposition Program, 2024.

Recent Field Testing

As expected considering the decline in sulfur supplied from atmospheric deposition, field trials in the last 10 years show an increased frequency of crop response to applied sulfur. In Indiana corn, sulfur fertilizer applied as sidedress increased yield in 26 of 55 trials from 2017 to 2022 (Camberato et al., 2023). The yield benefit in the responsive trials ranged from 3 to 34 bu/ac, with a mean of 11 bu/ac. Yield responded more frequently to sidedress sulfate than to starter applications of ammonium thiosulfate. Predicting where responses would or would not occur proved elusive.

In the province of Ontario, wheat responded more frequently to sulfur than corn or soybeans over a total of 43 sites from 2018 to 2020. Eight of 13 winter wheat trials from 2018 to 2020 showed a significant positive response–in fact, when averaged over all 13 sites, applying sulfur increased net return by $22 per acre. Generally, applying 18 lb/ac to the wheat sufficed for all three crops in the typical corn–soybean–wheat rotation (GFO, 2024). Even though responses in corn and soybeans were less frequent, these data suggest that any field receiving no other sources of sulfur—for example, those not receiving manure—should receive some sulfur fertilizer.

Recent field testing in Pennsylvania indicates potential for positive corn yield response to sulfur fertilization in the northeastern U.S. About 20% of 27 trials from 2015 to 2017 showed a yield response to applied sulfur. There were no differences among three sources of sulfate: ammonium, potassium, or calcium. The average corn yield increase resulting from sulfur fertilizer at responsive sites was 14% (Brimmer et al., 2018). Despite the decline in deposition from the air, however, not all areas and crops show a high frequency of response to sulfur application. An extensive set of field trials in Ohio from 2013 to 2021 showed less widespread response than expected (Fleuridor et al., 2023). Out of 96 trials, only seven responded positively: 4 out of 50 corn trials, 3 of 34 soybean trials, and none of 12 wheat trials. Thirteen on-farm replicated trials on soybean in New York from 2017 to 2019 showed little response. The researchers concluded that sulfur is not currently limiting New York soybean grain yield (Putman et al., 2021).

Across 18 site-years of field testing of sulfur applications to hard red spring wheat in Minnesota, Kaiser et al. (2019) found that 8 lb/ac of sulfur maximized grain yield and protein concentration on soils with less than 2% organic matter. Soils with higher organic matter showed no crop yield response to sulfur application. In Minnesota, sulfur is recommended for corn on sandy soils and on those with less than 4% organic matter. The Northern Great Plains, including the Canadian Prairie Provinces, received much less sulfur deposition in the past. Over the past two or more decades, farmers have greatly increased the yields of canola and cereal crops in this region. The relatively higher need for sulfur of canola compared with cereals has been known for many decades, and a large body of research supports application of around 20 lb/ac of sulfur for optimum yields of canola (Ma et al., 2015 and literature cited therein).

Crop Uptake and Removal

When making fertilizer decisions for sulfur, it is helpful to know both the expected uptake of sulfur into the plant and the amount removed by crop harvest. The two may differ substantially. Decomposition of soil organic matter, deposition from the atmosphere, and applied organic materials and fertilizers can all contribute to the supply of sulfur for crop uptake. To replenish the soil following harvest on soils where sulfur deficiencies occur frequently, the annual supply needs to balance crop removal. Crop harvest generally removes less sulfur than nitrogen and potassium, but only a little less than phosphorus. Since sulfur concentrations can vary widely, the figures in Table 1 should be treated as general estimates only. Use locally available data wherever possible.

Table 1. Estimated total removal of sulfur (S) in the harvested portion of selected field crops compared with nitrogen (N), P_2O_5 and K_2O, and total uptake.

		Removal[a]				**Uptake[b]**
		N	**P_2O_5**	**K_2O**	**S**	**S**
Crop	**Yield per acre**	**lb/ac**				**lb/ac**
Corn	200 bu	134	70	50	10-16	20
Soybeans	60 bu	195	44	72	11	20
Wheat	60 bu	89	34	20	6	17
Alfalfa	5 ton	255	60	245	27	30
Canola	50 bu	80	40	20	12.5	32

[a] Data from TFI (2020) and Heckman et al. (2003).

[b] Camberato et al. (2022) and Canola Council of Canada.

Fertilizer Sources

Many fertilizers contain sulfate and are moderately to highly water-soluble. Table 2 lists common fertilizer sources, along with their chemical formulas and sulfur contents. Soluble forms also include bisulfites, thiosulfates, and polysulfides. The water-soluble sulfates are immediately available to plants and should be used when sulfur is needed quickly. Elemental sulfur is not water soluble and requires time in the soil for oxidation to the sulfate form. Water-dispersible (S-bentonite) and micronized forms release smaller particles that oxidize more rapidly. Although gypsum (calcium sulfate) is less water soluble than many other sulfate fertilizers, it can be a sufficiently available, effective, and inexpensive sulfur source in some regions.

Table 2. Common sulfur (S) fertilizer sources.

Fertilizer material	Chemical formula	Sulfur content, %	Form
Ammonium sulfate	$(NH_4)_2SO_4$	24	Solid
Ammonium thiosulfate	$(NH_4)_2S_2O_3•5H_2O$	26	Fluid
Ammonium polysulfide	$(NH_4)_2S_x$	40-50	Solid
Potassium sulfate	K_2SO_4	18	Solid
Potassium-magnesium sulfate	$K_2SO_4•2MgSO_4$	22	Solid
Elemental sulfur	S^0	>85	Solid
Gypsum	$CaSO_4•2H_2O$	12-18	Solid
Magnesium sulfate	$MgSO_4•7H_2O$	14	Solid
Potassium thiosulfate	$K_2S_2O_3$	17	Fluid

Note: Fertilizers are expressed on their S content, but plants take up the sulfate ion. To convert S to sulfate, multiply by 3; to convert sulfate to S, divide by 3.

Soil Testing

A survey of soil testing laboratories found that from 2005 to 2020, a greater proportion of soil samples tested low in sulfur (TFI, 2020). The declining trend in soil test sulfur is consistent with lower deposition of sulfate from the atmosphere. Only a few areas, however, show more than 20% of soil samples testing lower than 3 parts per million (ppm) calcium phosphate equivalent sulfur. These include the province of Quebec and the states Georgia, Indiana, Louisiana, Wisconsin, Illinois, Arkansas, Florida, and Mississippi.

Unfortunately, soil tests for sulfur are not well correlated to probabilities of yield response, so agronomic interpretations are not very clear. The most used soil test is the calcium phosphate method. The critical level for sulfate-S by that method is often taken to be 3 ppm, or an equivalent of 6 ppm for a Mehlich-3 soil test.

Additional Benefits

Ammonium sulfate as a form of nitrogen generates more soil acidity—about 50% more per unit of nitrogen applied—than other common forms of nitrogen fertilizer like urea, anhydrous ammonia, and ammonium nitrate. This can be a concern in acidic soils but may be a benefit in soils of higher pH where the acidity generated may increase the availability of nutrients like phosphorus, manganese, and zinc, particularly when applied in a band.

Elemental sulfur also generates substantial acidity as it oxidizes. Each pound applied neutralizes about 6 lb of calcium carbonate. While this is twice as much acidity, pound for pound of sulfur versus nitrogen, typical agronomic rates have minimal effect on bulk soil pH in calcareous soils with pH of 7.5 or higher. The 4R nutrient stewardship framework includes monitoring soil pH and applying lime where needed. Lime is more likely to be needed to counter the acidifying effects of nitrogen and sulfur fertilizers in sandier soils with pH below 7. Gypsum and other sulfate forms that contain no ammonium generate no acidity and neither increase nor reduce soil pH. In cropland soils, the degradation that sulfur depositions created on forest soils may be mitigated through liming practices and the application of other fertilizers (Hinckley et al., 2020).

The thiosulfate forms have been shown to inhibit nitrification and nitrous oxide (N_2O) emissions and to a lesser extent slow ammonia loss by inhibiting urea hydrolysis. Cai et al. (2018) demonstrated in a laboratory incubation that rates of potassium thiosulfate supplying 45 to 180 lb/ac sulfur could reduce N_2O emissions by 25%–48%. Several field studies on rice, wheat, and tomatoes in India have reported N_2O emission reductions of 9%–35% in response to mixing thiosulfate with urea. These studies generally had low rates (<1 kg/ha) of N_2O emission, however. Compared with other nitrification inhibitors, thiosulphates show less efficacy in reducing emissions. In the meta-analysis of Akiyama et al. (2010), thiosulfates showed 40% and 65% of the efficacy of DMPP and DCD, respectively. Nevertheless, inhibition of nitrification in many situations may additionally reduce nitrate leaching as well as losses of nitrate by denitrification.

Summary

Sulfur nutrition is important to the yield and quality of crops. Deficiencies are most likely on soils of sandier texture, where crops are irrigated, and where amounts of sulfur deposited from the air have declined relative to the 1970s and 1980s. As yields of crops increase, the amount of sulfur removed increases as well and may need replenishment. Various forms of sulfur fertilizer can be used to control soil pH for better soil health and to control nitrogen transformation processes to limit losses of nitrate and nitrous oxide, reducing the environmental footprint of crop production. Crop sulfur nutrition therefore plays several important roles in 4R nutrient stewardship.

Industry concerns with liver abscesses in finishing cattle

By Jerad Jaborek

Source: https://www.canr.msu.edu/news/industry-concerns-with-liver-abscesses-in-finishing-cattle

Liver abscesses increase costs with reduced efficiency of production and increased liver condemnation.

Example beef livers scoring 0) for no abscesses, A-) for 1 or 2 small abscess, A) for multiple little or 1 or 2 large abscesses, A+) for multiple large abscesses. Photo by Elanco Liver Check Service.

The United States beef industry has a renewed interest in trying to understand what causes the development of liver abscesses in cattle and their subsequent effect on the growth performance of cattle raised for beef. In a recent issue of the Veterinary Clinics of North America: Food Animal Practice journal, liver abscesses in cattle were reviewed. Liver abscesses are not a new problem for the beef industry and have been associated with feeding cattle primarily grain-based diets dating back to the 1930's. Liver abscess prevalence rate varies considerably by region, presumably due to different feedstuffs fed, different feed management, and different cattle types (e.g., beef steers and heifers, beef x dairy steers and heifers, dairy steers, cull beef cows, cull dairy cows). Cattle livers containing abscesses are condemned at slaughter and represent an economic loss to the U.S. beef industry of approximately $61.2 million a year (25.5 million fed cattle, 30% liver abscess rate, $8 per liver), not including reduced carcass weight from the additional trimming required, reduced marbling deposition, and reduced feedlot performance. For many cattle producers, the effect of reduced feedlot performance caused by liver abscesses goes unnoticed and is only discovered at the time of slaughter. Severe liver abscesses (i.e., livers containing multiple smaller abscesses or larger abscesses) have been associated with a 5% reduction in average daily gain for feedlot cattle.

Liver abscesses have long been associated with feeding cattle diets with large amounts of fermentable carbohydrates (i.e., grains). Digestive upsets that result from the fermentation of readily fermentable carbohydrates are in response to a subsequent decline in rumen pH. Cattle consuming a forage diet typically have a rumen pH just under 7 or neutral, and cattle consuming a concentrate-based diet, typical of finishing beef cattle, may have an average rumen pH just above 6. Fermentation of feed in the rumen produces volatile fatty acids (VFAs), which are absorbed and used for energy, and lactic acid, but these acids cause the rumen pH to decrease. When the rumen pH remains below 5.8 or 5.6 for an extended period of time, the condition is called subacute ruminal acidosis, and the more severe case, when the pH is less than 5.2, is called acute acidosis. Low rumen pH can insult the epithelia cells lining the rumen and compromise barrier function to cause rumenitis and inflammation. It has been believed that the low rumen pH causing rumen barrier disfunction may allow bacteria access into the portal blood stream and thereby access the liver. Recently, it is being speculated that compromised gut barrier function in the small and (or) large intestine may be another route for bacteria to infiltrate into the blood stream and for bacteria to colonize in the liver to form liver abscesses. Abrasive objects, such as hair consumed from grooming and/or splinters from wood chewing, can be irritants to the rumen epithelium as well.

Because liver abscesses are commonly associated with ruminal acidosis, increasing the roughage content of the diet can stimulate salvia production during rumination, resulting in a buffering effect of ruminal pH decline. As a likely result, increasing the roughage concentration in the diet has been demonstrated to reduce the incidence of liver abscesses in feedlot cattle. Examples include increasing chopped/ground alfalfa hay from 10 to 30% of the diet resulting in a reduced liver abscess prevalence of 15 to 2%; increasing corn silage concentration from 0 to 15% resulting in a reduced liver abscess prevalence of 29 to 15%; increasing corn silage concentration from 15 to 45% resulting in a reduced liver abscess prevalence of 35 to 12%. However, there are other instances where research has failed to detect a reduction in liver abscess prevalence due to increasing dietary roughage inclusion. For example, research published in the Journal of Animal Science reported increasing chopped grass hay from 8% to 16% of the diet did not reduce the incidence of liver abscesses but increasing the chop length of hay from 1 to 3 inches reduced liver abscess prevalence from 12.5 to 0%. Increasing the physical effectiveness of the roughage in the diet increases chewing, rumination time, and saliva production to help buffer the rumen pH. Roughage inclusion can also increase passage rate of digesta, therefore reducing the acid load experienced in the rumen over an extended period of time. Therefore, determining the balance needed between grain and effective forage in concentrate-based finishing diets is needed for maximum growth performance and animal health. Other feed management practices that regulate feed intake

Tylosin-phosphate is the most commonly used antibiotic feed additive approved for controlling liver abscesses in feedlot cattle. There are other antibiotics approved for controlling liver abscesses in feedlot cattle, such as chlortetracycline, virginiamycin, and bacitracin methylene disalicylate. If you are considering feeding any of these products to reduce the incidence of liver abscesses in your feedlot cattle, speak with your veterinarian to get antibiotic use approval and develop a plan for feeding medicated feed. Ionophores and essential oils with antibacterial properties have shown less conclusive evidence of consistently reducing liver abscesses in feedlot cattle. In the future, vaccines for preventing liver abscesses may become commercially available as research continues to improve their efficacy.

A Menace Reconsidered, Part 4: Losing Nitrogen

By Jonathan Coppess, Shae Ruppert, and Marin Skidmore

Source: https://farmdocdaily.illinois.edu/2024/04/a-menace-reconsidered-part-4-losing-nitrogen.html

Amid the wind and rain of Midwestern April, the Farm Bill faithful may detect stirrings of a possible start to the long, difficult reauthorization process (Clayton, April 16, 2024; Hagstrom, April 17, 2024; Baethge, April 17, 2024; Abbott, April 16, 2024; Downs, April 8, 2024). Alexander Pope famously wrote that "Hope springs eternal in the human breast" and the line continues to resonate (Pope, 1732; Matteo, March 26, 2022). The challenges inherent in soil erosion seem also to spring eternal and this article continues that discussion by incorporating an exploration of the research on nitrogen losses, seeking to further build risk-based perspectives (*farmdoc daily*, March 14, 2024; March 21, 2024; March 28, 2024; see also, December 7, 2023; January 4, 2024; and January 15, 2024). In the spirit of the season, it may be hoped that applying research to develop a wider, more comprehensive perspective on farm risk—one that incorporates natural resource risks—can inform the development of more effective farm polices.

Background

Soil erosion adds risk to farming. It can magnify complications in farm management. It also carries significant cost implications. These realities are supported by a substantial body of research (*farmdoc daily*, March 14, 2024; March 21, 2024; March 28, 2024). Soil erosion possesses a long history and has menaced many societies, persisting as a perennial complication of farming and the production of food (Dotterweich, 2013; Brevik, 2018; Gibbard and Mead, 2020). Among the many challenges of soil erosion is designing effective policy responses. Soil erosion is a complex menace and the loss of nitrogen from fields helps demonstrate the point. One of the most critical nutrients for plant growth, and a major component of topsoil fertility, nitrogen is exported from farm fields in a different process than soil erosion. The two are connected in important ways, however. Erosion of fertile topsoil, for example, requires applications of nitrogen to compensate. Together, they can drive self-feeding cycles, compounding and complicating the challenges. Additionally, neither constitutes actual loss but rather misplacement or displacement, deposited in waterways or somewhere other than the fields where they are needed for crops.

Summarizing the research on the topic is daunting. Humans have likely doubled the amount of reactive nitrogen that cycles through ecosystems across the planet, a substantial portion of which is not consumed as intended. Organic nitrogen abounds in soils but is not available for plants to consume. Bacteria and other microorganisms produce inorganic, plant-available, nitrogen, while ammonium forms of nitrogen are generally added by fertilizer inputs. Nitrogen fertilizers are subject to rapid nitrification to nitrate, the form of nitrogen favored by plants but also the one most soluble and easily transported such as being leached through the soil with water. Nitrate is especially mobile and susceptible to being leached, a risk that is most prominent early in the season when crop growth and nitrogen uptake is low, but mineralization of nitrogen (especially from fertilizer) is high. The complex system of artificial drainage contributes by quickly moving water from precipitation and snowmelt out of farm fields. That water, however, carries significant quantities of nitrates to lakes, reservoirs, and natural waterways such as the Mississippi River and the Gulf of Mexico. The result is that nutrients intended for crops degrade water quality and contribute to hypoxic or dead zones (Gentry et al., 2024; Li et al. 2022; Myrold, 2021; Cao, Lu and Yu, 2018; Fernández, Fabrizzi and Naeve, 2017; Pittlekow et al., 2017; Christianson and Harmel, 2015; Robertson et al., 2013; Dessureault-Rompré et al., 2011; David, Drinkwater, and McIsaac, 2010; Gentry et al., 2009; Robertson and Vitousek, 2009; Robertson and Groffman, 2007; Paul et al., 2003; Cassman et al., 2002; Smil, 2002; Williams, Hutchinson and Fehsenfeld, 1992; Kladivko et al., 1991; Russel and Williams, 1977; see also, *farmdoc daily*, February 8, 2024; March 10, 2016; March 17, 2016; February 17, 2021).

Discussion

Agriculture, especially row crop agriculture, is the largest contributor of nitrogen to the environment in the United States, previously reported as contributing 54 percent of nitrate emissions (Ribaudo, September 1, 2011). Today's loss of nitrogen has been linked to the huge wave of investment, research, infrastructure, market development, and policy under the rapid technological changes in farming known as the Green Revolution (1966-1985) (see, Pingali, 2012; Mann, 2018; Anderson, 2006). For example, commercial and manure fertilizer application increased from 1 million metric tons in 1951 to 13 million metric tons in 2017 (Del Rossi et al., 2023). Figure 1 illustrates the total U.S. consumption of nitrogen as last reported by USDA's Economic Research Service (ERS) in 2019 through year ending June 30, 2015 (USDA-ERS, Fertilizer Use and Price, October 30, 2019). It also includes the acres planted to corn and other feed grains (sorghum, oats, and rye), wheat, upland cotton, and rice.

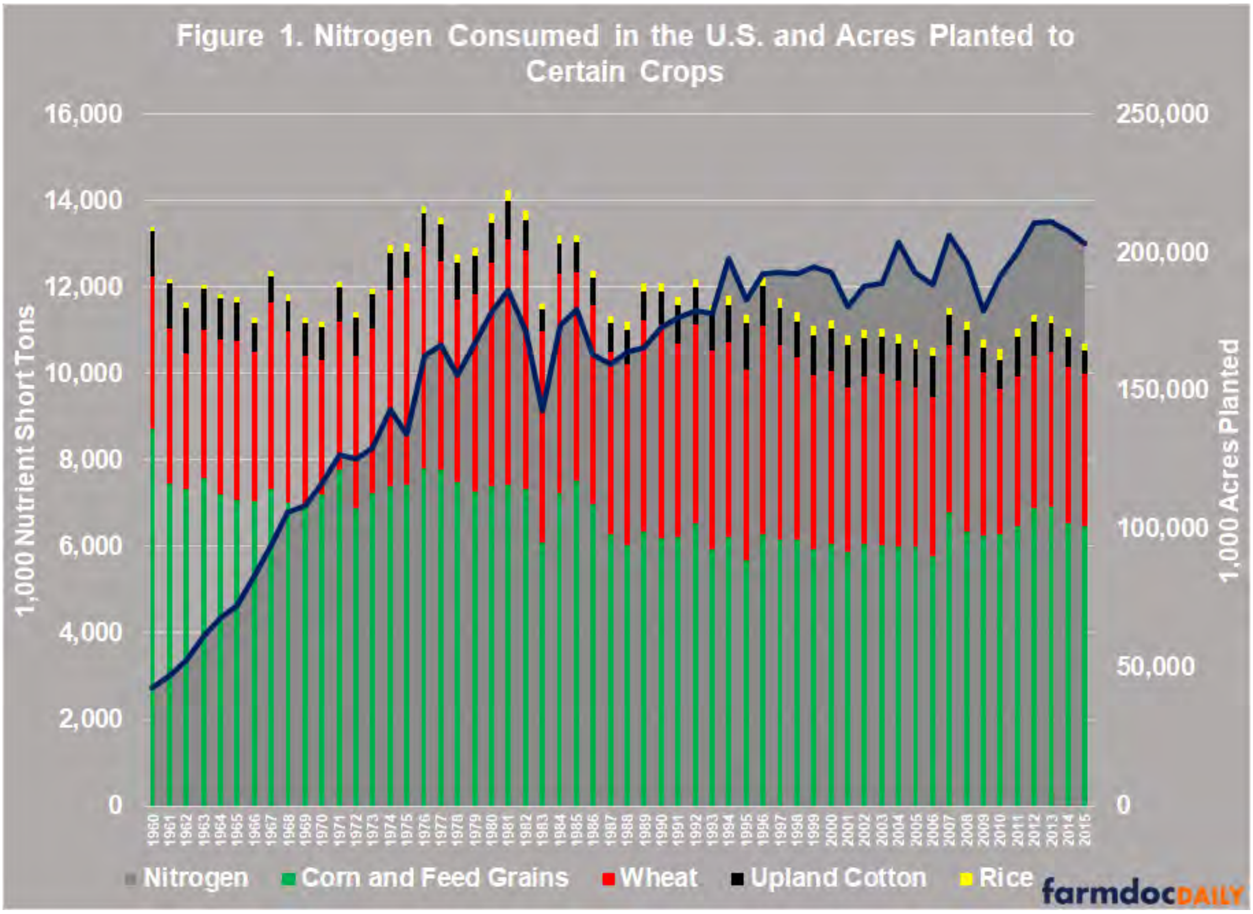


Figure 1 raises tough questions about whether farmers are overapplying nitrogen for these crops. Total nitrogen consumption has generally increased (and remained at elevated levels) even as acres planted to these crops initially decreased and have remained relatively constant in the later years of the reported data. Overapplication of nitrogen, as well as application of nitrogen in the fall after harvest, contributes to water quality degradation. As discussed above, the research is clear that nitrogen fertilizer not consumed by the plants accumulates in the soil and that the mobile nitrate form is easily transported out of the fields, carried by water. For example, one study in Iowa found residual nitrate in the soils after corn harvest that ranged in amounts equal to between 16% and 26% of the applied rate of nitrogen in 2002 and 2004 (Jaynes and Covin, 2006).

As with soil erosion, we begin by applying the research on nitrogen losses to estimate this complex issue in terms of risk of loss. Nitrogen loss is extremely variable, which makes sense given the extent to which the transport of the nitrate form depends on water. For example, USDA previously estimated a range from less than 20 pounds per acre to more than 70 pounds per acre each year from 2003 to 2006 (USDA-NRCS, 2017). Figure 2 is the first attempt at illustrating the risk of nitrogen losses in farm fields each year based on a compilation of research findings over multiple years and sites in the Midwest (Gentry et al., 2024; Waring et al., 2022; Preza-Fontes et al., 2021; Pittlekow et al., 2017; Jaynes, 2015; Jaynes, 2013; Randall et al., 2003). Specifically, Figure 2 charts ranges of nitrogen loss measured as a percentage of the annual nitrate load measured in subsurface tiles relative to the amounts of nitrogen applied as fertilizer. It compares four different nitrogen application practices: fall-applied, spring-applied, split application in the spring, and side-dress (nitrogen applied between the rows of the growing crop).

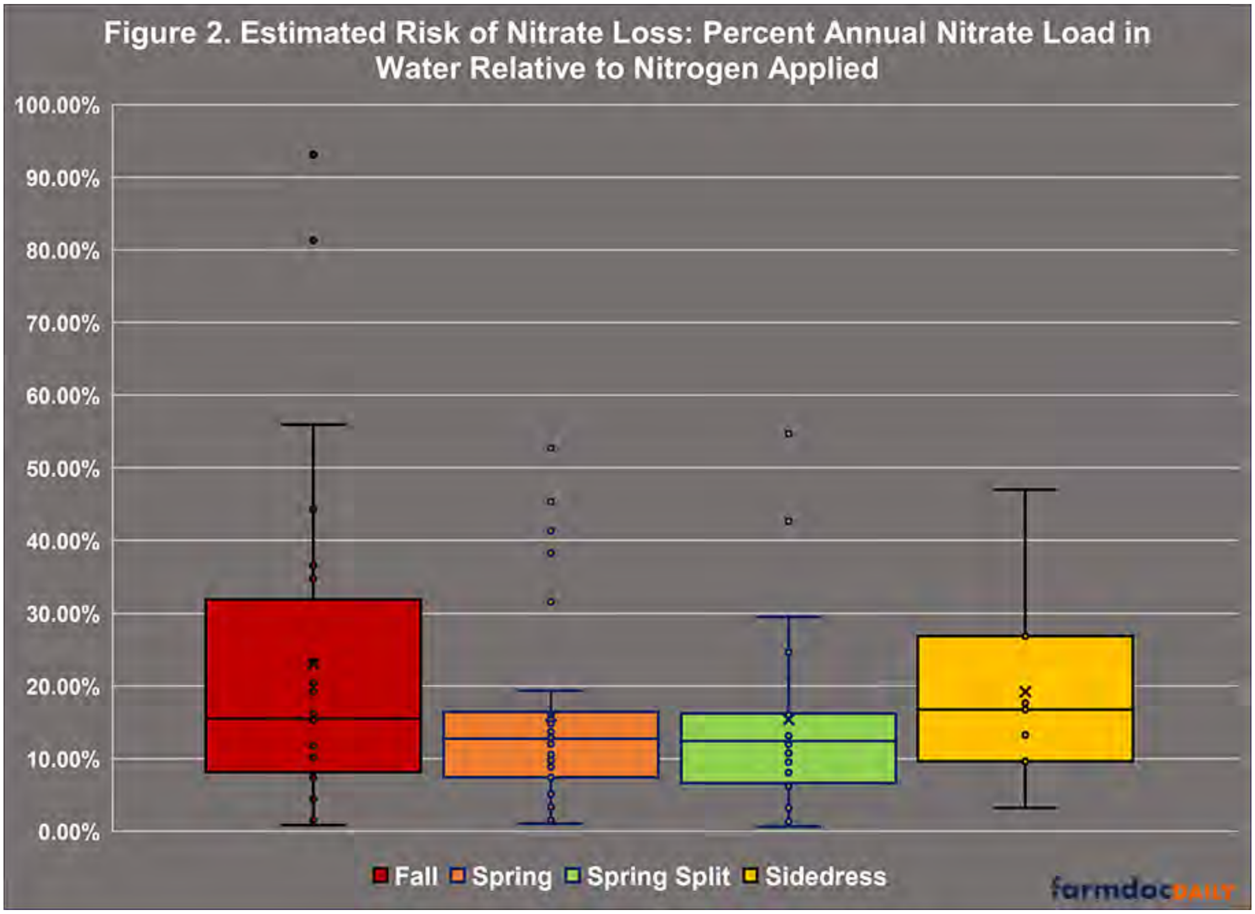


Figure 2. Estimated Risk of Nitrate Loss: Percent Annual Nitrate Load in Water Relative to Nitrogen Applied

Residual N pools, present in the soil of farm fields after commercial crop harvest, cost the farmer and society. Because of the nearly guaranteed loss of nitrogen, farmers are spending income for some amount of nitrogen that will not be utilized by the plant. Additionally, farmers are potentially absorbing extra costs that outweigh any benefits in crop yield. This concern has been magnified in recent years with the skyrocketing cost of nitrogen (see e.g., *farmdoc daily*, August 15, 2023; September 12, 2023). While overapplication of this expensive input means farmers have sunk in more cost than needed and diminished profitability, it also creates burdens on (and costs to) society in the form of drinking water contamination by excess nitrates, presence of cyanotoxins (cultivated by harmful algae blooms), and excess turbidity (Del Rossi et al., 2023). These costs include negative health effects, recreational and aesthetic damages, remediation actions for contaminated wells, installing filtration or treatment systems, as well as avoidance behaviors like purchasing bottled water. These costs are more intensely felt by the 43 million, mostly rural households, who source their water from a private well and live near the source of this nonpoint source of pollution, agricultural lands (Del Rossi et al., 2023). Another deep well of complex issues to be explored further.

Concluding Thoughts

This article expands upon the complex, complicated challenges of soil erosion by incorporating those of nitrogen losses from farming. Congress first proclaimed soil erosion to be a menace to society in 1935 in response to the Dust Bowl and Great Depression catastrophes; soil erosion, however, has a much longer history. It has menaced many societies throughout human history, persisting as a perennial complication of farming and the production of food. The Dust Bowl was a dramatic example of soil erosion and offers critical lessons. Ironically, its prominent position in history risks obscuring many of them. It can be narrowed to a single dimension in the popular imagination, isolated in time and place to moving mountains of soil across the drought-ravaged and wind-swept southern Great Plains. Soil erosion is a much more complex menace and the challenges are especially acute for designing effective policy responses. As discussed herein, the risks of losing nitrogen help demonstrate the point. One of the most critical nutrients for plant growth, and a major component of topsoil fertility, nitrogen is exported from farm fields in a different process than soil erosion. The two are connected in important ways, however. Erosion of fertile topsoil, for example, requires applications of nitrogen to compensate. Together they can drive self-feeding cycles, compounding and further complicating the challenges of each. The common ground is bare soil; farm fields left fallow and exposed after harvest are at an increased risk of both soil erosion and nutrient loss, critical consequences that result when the bare soils of farm fields are exposed to the elements. To initial evaluations of the risks of soil erosion, this article adds evaluation of the risks of nitrogen losses; applying research to develop a wider, more comprehensive perspective of farm risk that incorporates natural resource risks and in turn, accepts the multi-dimensional realities which could inform the development of more effective, multi-dimensional farm polices.