PRODUCT MANUAL

SO4™

PELLETIZED GYPSUM

The Science Behind SO4

CALCIUM PRODUCTS™

OMRI LISTED For Organic Use

calciumproducts.com

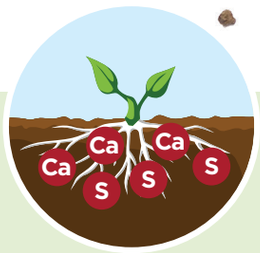
May 18

TABLE OF CONTENTS

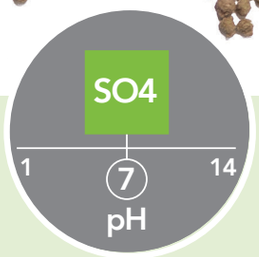
WHAT IS SO4?

Superior Sulfur Release

SO4 is the superior sulfur source that delivers the right amount of sulfur perfectly matching plant needs for yield-maximizing plant growth.



Superior Sulfur Release



pH Neutral

Application Flexibility

- **Superior Sulfur Release.** SO4 supplies a strong initial release of sulfur followed by a steady supply throughout the growing season, perfectly matching plant needs. Ammonium sulfate (AMS) is 300x more soluble than SO4 (Haynes, 2014), releasing sulfur too quickly, while elemental sulfur releases sulfur too slowly, neither meeting the crop's complete needs.
- **pH Neutral.** SO4 is pH neutral, which means it will not acidify the soil, while other sulfur sources. Proper soil pH maximizes a plant's utilization of nutrients promoting good plant health and optimizing yield.
- **Application Flexibility.** SO4's consistent pellet size allows it to be blended and applied with other dry fertilizers and makes it the smart choice for any application scenario.

SO4 is mined and pelletized from a gypsum vein in northwest Iowa, one of the purest sources in the world. The mined gypsum is finely ground to a powder, 80% passing a 100-mesh screen, and then pelletized to achieve ideal reactivity and pellet strength.

Product Specifications

Guaranteed Analysis

Calcium:..... 21%
Sulfur (sulfate):..... 17%
Moisture (max):..... 1.0%
Calcium sulfate dihydrate:... 92%

Average Particle Size Before Pelletizing

4-mesh: 100% passing
8-mesh: 100% passing
100-mesh: 80% passing

Production Details

- SO4 pelletized gypsum is manufactured from mined gypsum in Fort Dodge, IA.
- The binding agent used is calcium lignosulfonate and is a byproduct of the paper milling industry.

Pellet Physical Characteristics

Size Guide Number (SGN)
Averages:
< 200: 3%
200-280: 37%
280-400: 40%
> 400: 20%

Average SGN: 300
Uniformity Index (UI): 50
Compression strength: 9.0 pound-feet (LBF)
Bulk density: 61 lbs/ft^3

What is gypsum?

Gypsum is a soft mineral, chemically composed of calcium and sulfate, and two molecules of water ($CaSO_4 \bullet 2H_2O$), called calcium sulfate dihydrate. Variations of calcium sulfate occur naturally, such as anhydrite ($CaSO_4$) but it has lower solubility compared to dihydrate gypsum due to the lack of bound water in its crystalline structure.

How did SO4 get its name?

The chemical formula for sulfate is SO_4^{2-} and served as the inspiration for the founder of Calcium Products to give the brand name of SO4 to his pelletized gypsum.

SO4 is OMRI Listed®

SO4 is the only pelletized gypsum approved for use in certified organic production. It is certified by the Organic Materials Review Institute (OMRI).

THE NEED FOR SULFUR

The Fourth Major Nutrient

It is widely understood that plant growth is impacted by the three primary macronutrients – nitrogen, phosphorus and potassium. Many agronomists consider sulfur, a secondary macronutrient, to be the fourth major nutrient because of the critical role it plays in healthy plant growth.

The Benefits of Sulfur

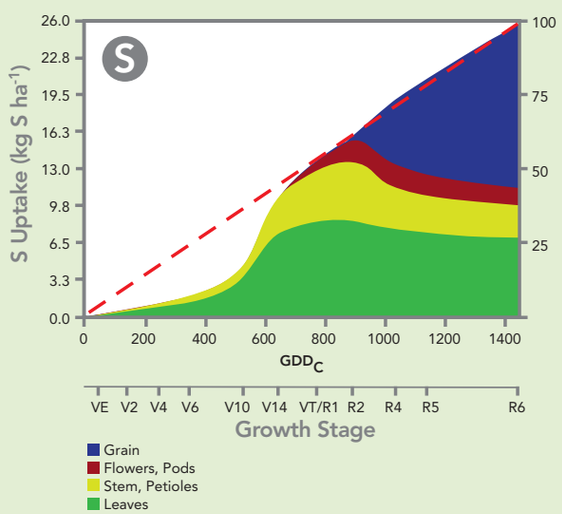
Sulfur is an essential component of plant growth. Key functions of sulfur in the plant include chlorophyll formation, protein production and activation of enzymes. Amino acids such as cysteine and methionine may be deficient in plants where

Sulfur is Needed Throughout the Growing Season

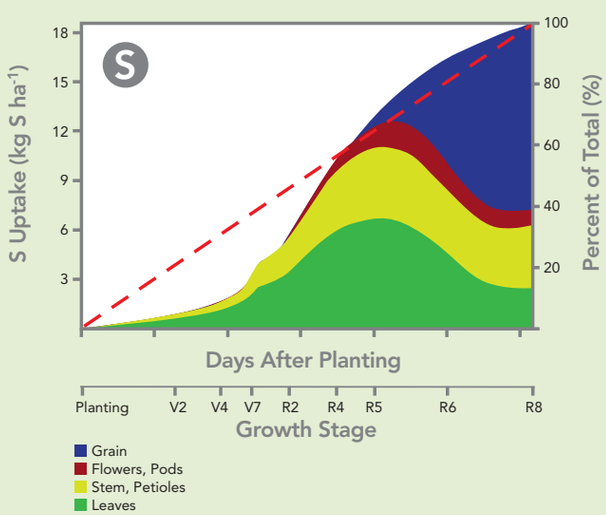
Sulfur uptake in corn has been presumed to be similar to nitrogen. However, a University of Illinois study indicated that more than one-half of sulfur uptake occurs after the transition from vegetative to reproductive processes has begun. This suggests that a season-long supply of sulfur is critical for corn nutrition (Bender et al., 2013).

Sulfur uptake in soybeans is similar to corn, with more than one-half of sulfur uptake occurring after the reproductive phase has begun (Bender et al., 2013). Alfalfa would have a very similar, although greater overall, uptake pattern for sulfur.

CORN



SOYBEAN



sulfur is lacking, negatively impacting the food or feed quality from these plants. Sulfur is also important in nodule formation in legume crops, where it aids rhizobia bacteria in converting atmospheric nitrogen into plant usable forms (Marschner, 1995).

Sulfur deficiency can result in the inhibition of protein and chlorophyll synthesis. Sulfur deficiencies can be difficult to determine from visual observation as symptoms resemble nitrogen deficiency. Sulfur deficiency occurs in younger leaves, causing them to turn light green to pale yellow. Many plants have their growing point at the top of the plant, which can often lead to a visual misdiagnosis of nitrogen deficiency instead of a lack of adequate sulfur (Datnoff et al., 2007).

Recognizing Sulfur Deficiency

1. **Look at leaf color.** Plants with pale green appearance should be inspected closer for nutrient deficiency symptoms. Both sulfur and nitrogen deficiency are marked by yellow striping between the veins of the leaf (interveinal chlorosis), which can cause confusion when diagnosing sulfur vs. nitrogen deficiency. The photo *(above)* shows sulfur deficiency.

2. **Inspect plants' youngest leaves.** Sulfur deficiency appears in the youngest leaves of the corn plant first, while nitrogen deficiency appears in the older leaves first. The difference is related to how each nutrient is mobilized in the plant.

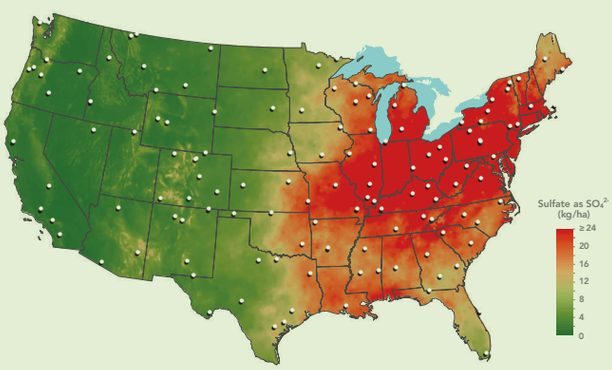
3. **Utilize a tissue test.** Sulfur deficiency can be visually misdiagnosed, even by seasoned agronomists. Collecting tissue from the growing plant and submitting it for laboratory analysis is an excellent way to positively identify nutrient deficiencies and provide quantitative values for any needed corrective actions. Your testing lab can provide threshold tissue test values.

A Rising Need for Sulfur

Agronomically, plants have always needed sulfur. Historically, much of the sulfur need was satisfied from atmospheric deposition of sulfur as a result of coal burning industries. Amendments to the Clean Air Act in 1990 targeted sulfur dioxide emissions and the resulting "free" atmospheric sulfur decreased dramatically. Many areas of the central and eastern Midwest receive less than one-half of the amount of sulfur today compared to 30 years ago.

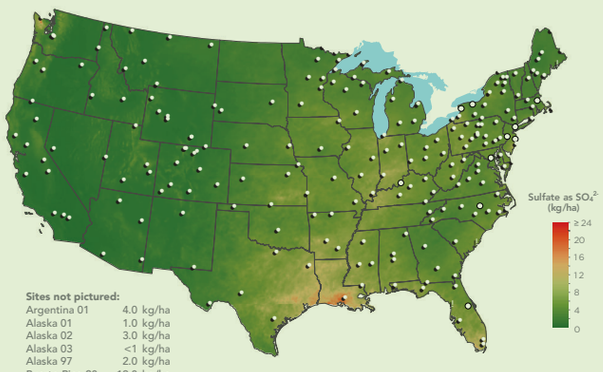
Additionally, modern fertilizers are highly concentrated and contain less sulfur than in the past. Compounded with declining organic matter, less sulfur is naturally available while crop yields continue to climb, resulting in more opportunities for sulfur deficiency to occur.

SULFATE ION WET DEPOSITION, 1985



National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

SULFATE ION WET DEPOSITION, 2016



Sites not pictured:

Argentina 01	4.0 kg/ha
Alaska 01	1.0 kg/ha
Alaska 02	3.0 kg/ha
Alaska 03	<1 kg/ha
Alaska 97	2.0 kg/ha
Puerto Rico 20	19.0 kg/ha
Saskatchewan 20	2.0 kg/ha
Saskatchewan 21	2.0 kg/ha
Virgin Island	6.0 kg/ha

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

COMPARING SULFUR SOURCES

Side-by-Side Comparison

There are several dry sulfur sources available on the market today and comparing them can be a complex task. There are differences to consider such as included nutrients, rate of sulfur release and soil acidification.

	SO4 PELLETIZED GYPSUM	AMS	MAP + AMS + Elemental Sulfur	Pelletized Synthetic Gypsum	Elemental Sulfur
Nutrition					
Total Sulfur	17%	24%	10%	16-18%	90%
Plant Available Sulfate	17%	24%	5%	17%	–
Nitrogen	–	21%	12%	–	–
Phosphorus	–	–	40%	–	–
Calcium	21%	–	–	21%	–
Solubility					
Rate of Sulfur Release	Ideal	Rapid	Rapid then Slow	Slow to Moderate	Slow
Soil Acidification					
Amount of 98G needed to neutralize the acid from 25 units of sulfur/A	None	120 lb/A	100 lb/A	None	80 lb/A
Approved for Use in Organic Farming					
OMRI Listed®	Yes	No	No	No	Yes

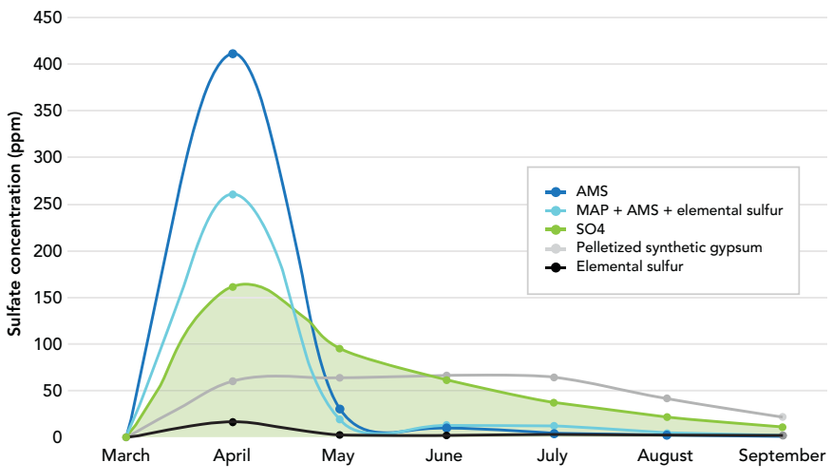
Rate of Sulfur Release

In 2017, a study was conducted in the Calcium Products laboratory to evaluate the sulfur release rate of several sulfur sources. Analysis of sulfur release was completed by Midwest Laboratories in Omaha, NE.

Study Findings

- SO4 supplies the best balance of initial sulfur release and steady supply throughout the growing season perfectly matching plant needs.
- Ammonium sulfate (AMS) has an extreme initial release of nearly all its sulfur, leaving it susceptible to leaching throughout the remainder of the growing season. AMS is 300x more soluble than SO4.
- Sulfur release of ammonium thiosulfate (ATS) would be similar to or greater than the sulfur release of AMS.
- Products combining AMS and elemental sulfur provide an initial release from the AMS but very little, if any, further release from the elemental sulfur. The released sulfur from the AMS is then susceptible to leaching in subsequent months.
- Products containing AMS and elemental sulfur also degrade soil quality by acidification due to nutrient transformations.
- Elemental sulfur needs significant time to release its sulfur. Very little sulfur was released from elemental sulfur in this study. Further, it is nearly impossible to predict exactly when sulfur will be fully released from elemental sulfur due to several environmental factors.
- Synthetic pelletized gypsums include additives and extra binding agents, slowing initial breakdown and preventing full solubility during the growing season. They can also contain heavy metals not suitable for land application.

Study Results



SO4 APPLICATION, HANDLING AND STORAGE

Application Timing and Rate

SO4 can generally be applied spring or fall, depending on soil type, making it a flexible sulfur source in fertilizer recommendations.

The application rates in the table are general recommendations. Application rates are best determined by either:

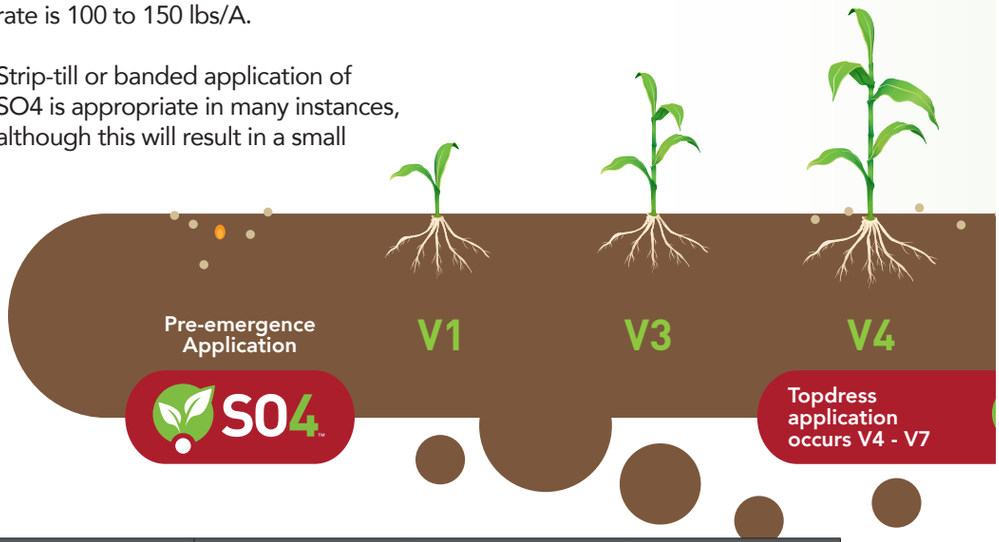
1. Incorporating equations from Calcium Products into your precision software, or
2. Using the SO4 application rate calculator on our website - http://www.calciumproducts.com/ag-products/ag-calculators

Application Timing on Corn

As you can see from the table *(below)*, SO4 can be applied to corn in the spring pre- or post-emergence. If you identify a sulfur deficiency post-emergence and need to apply SO4 as a rescue application, a response to SO4 can be expected within a week, provided adequate moisture is present.

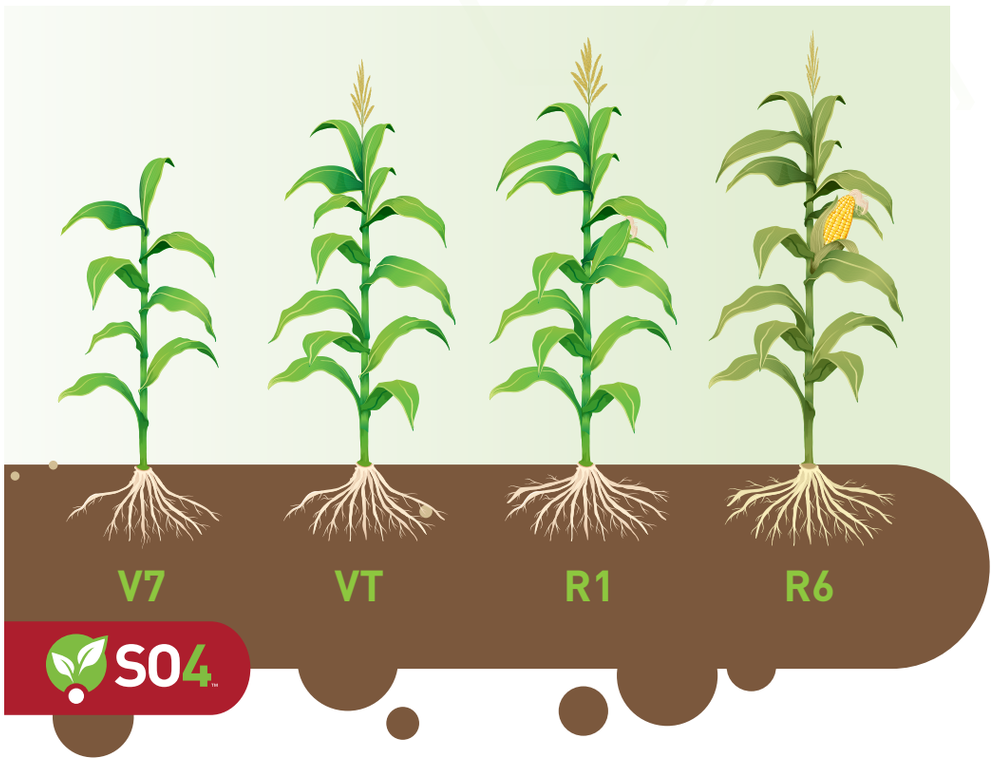
Another option for applying SO4 post-emergence is to topdress SO4, at V4-V7. A common SO4 topdress rate is 100 to 150 lbs/A.

Strip-till or banded application of SO4 is appropriate in many instances, although this will result in a small volume of soil being impacted compared to a broadcast application. Rates for strip-till or banded application are often determined by the capacity of the equipment being utilized, in combination with frequency of desired refill. This often results in a rate from 50 to 100 lbs/A.



	Application Timing		Application Rate		
	Sandy soils	Other soils	Fine-textured soils	Coarse-textured soils	All soils
 Corn	Spring	Fall/Spring • Pre-emergence • Post-emergence	100 lbs/A (17 units S)	150 lbs/A (25 units S)	–
 Soybeans	Spring	Fall/Spring	75 lbs/A (12 units S)	100 lbs/A (17 units S)	–
 Alfalfa	–	Spring and/or summer, applied prior to or after first cutting and additional applications after subsequent cuttings as desired.	–	–	175 lbs/A total: • After first cutting, apply 100 lbs/A (17 units S) • After third cutting, apply additional 75 lbs/A (12 units S)

The sulfur rates above are based on recommendations from Iowa State University.



Handling and Storage Best Practices

To best maintain the integrity of the SO4 pellet, there are a few handling and storage best practices to keep in mind.

1. Handling equipment such as conveyor belts or bucket elevators (legs) are conducive to maintaining good product quality. Augers and drag conveyors are not ideal for product handling, as they create numerous opportunities for abrasion and wear between the material and handling equipment. Maintaining all handling equipment and keeping it in good repair will result in satisfaction with product quality and less downtime due to breakdown.
2. Product should be stored in facilities kept in good repair. Minimizing exposure to moisture from rain or snow will aid in maintaining product integrity. SO4 does not absorb moisture from the atmosphere, unlike many other fertilizers such as urea, which are hygroscopic.
3. Product should be stored as close to the receiving location and equipment as practical. This will result in less interaction with the handling equipment due to shorter distances and time.

Mixing Best Practices

SO4's consistent pellet size allows it to be blended and applied with other dry fertilizers. To best maintain the integrity of the SO4 pellet, there are a few best mixing practices to keep in mind.

1. SO4 pellets will begin to break down or degrade after contact with water or other liquids. While this is a desired trait after soil application, it can create problems where liquid materials are present, such as impregnation of pesticides into mixtures containing SO4, or when improper application of nitrogen or phosphorus stabilizers occurs prior to or during blending with SO4. When labeled rates, directions and mixing practices are followed, problems should not arise. In cases where application volumes exceed labeled rates and carryover wetness contacts SO4 pellets, breakdown can occur and cause gumming or buildup on the application and/or blending equipment. If higher than normal rates are expected, we recommend a small scale blend test to determine how these rates will affect SO4 breakdown and subsequent problems.
2. While no adverse or damaging effects have been noted between SO4 and other pesticides, additives, etc., it is the responsibility of the end user to consult with the manufacturer of other products on any concerns or questions regarding product efficacy, product interactions, etc.

SOIL AMENDING

Improving Soil Drainage

Gypsum has been used for hundreds of years in remediating and amending soils, particularly sodic soils. Through ion exchange, calcium displaces sodium from the soil colloid, allowing the sodium to leach and the clay particles to aggregate.

Using variable rate equations to calculate SO4 rates for soil amending needs is highly recommended. We have worked with several software providers to include specific parameters and product recommendations in their systems.

Soil testing combined with variable rate technology will result in the most accurate and cost-effective application of SO4.

Sodium remediation

- Soils with sodium levels in the range of 3% to 15% base saturation are prone to negative effects from sodium. Geography influences what level of sodium warrants action, so make sure to check with local extension guidelines to determine baseline thresholds.
- Irrigation water quality should be monitored and analyzed regularly for the presence of sodium. This is often a significant contributor to sodium accumulation in the soil.
- The addition of soluble calcium aids in maintaining good soil structure and offsetting the negative effects of sodium.

Magnesium remediation

- High levels of magnesium, which are less problematic than sodium but more widespread, can also lead to adverse effects on soil structure.
- Magnesium levels exceeding 20% base saturation can negatively impact soil physical properties. However, there is no established rule regarding a threshold magnesium base saturation value that warrants corrective action. We recommend partial field applications to determine effectivity before widespread application.

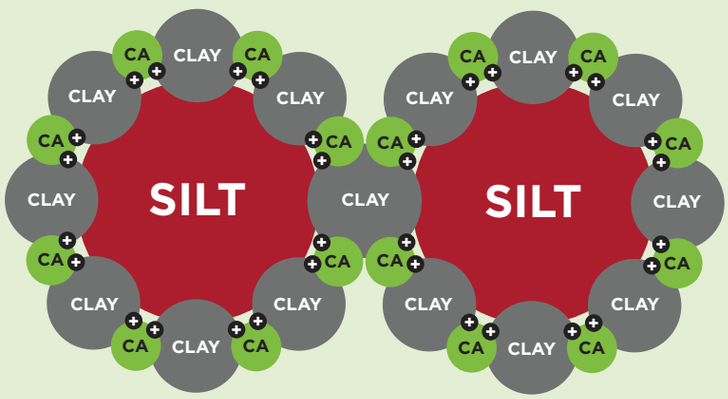
Soil structure, tilth and quality effects

- Due to the complex nature of soil chemistry, it is often difficult to predict which soils will benefit from SO4 application. However, soils that are prone to surface crusting, are difficult to till, don't maintain proper soil moisture levels and/or exhibit poor soil structure can be considered for SO4 application to improve these problems.
- SO4 is a versatile tool for use in many difficult soil conditions. There are many other tools such as cover crops and no-till that can also be used.

IMPORTANCE OF CALCIUM

A Needed Macronutrient

Calcium is categorized as a secondary macronutrient, along with sulfur and magnesium. It plays a major role in the plant through the formation of cell wall membranes, which provide stiffness and rigidity. Calcium is an activator of several enzyme systems in protein transfer and carbohydrate transfer. It also acts as a detoxifying agent by neutralizing organic acids in plants (Marschner, 1995).



Calcium in the Soil

Calcium in the soil flocculates clay particles, promoting soil porosity. Good soil porosity improves soil aeration, which provides an environment for adequate drainage and root growth (Brady and Weil, 2008).

Calcium and sodium have opposite effects on soil structure. Calcium is beneficial to good soil structure, providing flocculation and aggregating very small soil particles into loose aggregations. Sodium is detrimental to soil structure, causing soil particles to disperse, which can clog pathways for air and water to enter and exit the soil easily, leading to difficult growing conditions (Brady and Weil, 2008).

SELLING THE VALUE OF SO4 TO GROWERS

Maximize Yield

At the end of the day, we all know growers are looking to maximize yield. Ask your Territory Sales Manager if we have SO4 yield data in your area.

From 2006 to 2016, Iowa State University conducted 53 trials in 21 counties comparing SO4 at 100 lbs/A to no sulfur. The trials' average yield increase was 16 bu/A. See the full SO4 Iowa Yield Summary Research Brief for more details. Research briefs are available for other states and crops.

Plant-Available Sulfur When the Plant Needs It

Not only is the sulfur in SO4 already in the form the plant uses – sulfate, the release pattern of SO4 perfectly matches plant needs. SO4 supplies the best balance of initial sulfur release and steady supply throughout the growing season.

pH Neutral

SO4 is pH neutral, which means it will not acidify the soil, lowering soil pH, like other sulfur sources. Proper soil pH maximizes a plant's utilization of nutrients promoting good plant health and optimizing yield.

Literature Cited

Bender, R., Haegele, J., Ruffo, M. and F. Below. 2013. Modern Corn Hybrids' Nutrient Uptake Patterns. Better Crops 97:2013-1.
Brady, N. and R. Weil. 2008. The nature and properties of soils. 14th ed. Pearson Education, Inc. Upper Saddle River, New Jersey.
Datnoff, L., Elmer, W., and D. Huber. Mineral Nutrition and Plant Disease. The American Phytopathological Society. St. Paul, Minnesota.
Haynes, W.M. 2014. CRC Handbook of Chemistry and Physics. 95th ed. CEC Press LLC, Boca Raton, Florida.
Marschner, H. 1995. Mineral Nutrition of Higher Plants. 2nd ed. Academic Press, Inc. San Diego, California.