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S deficiency in corn. (Dave Franzen, NDSU)

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Limitations of the Sulfate-sulfur Soil Test as a Predictor of Sulfur Response

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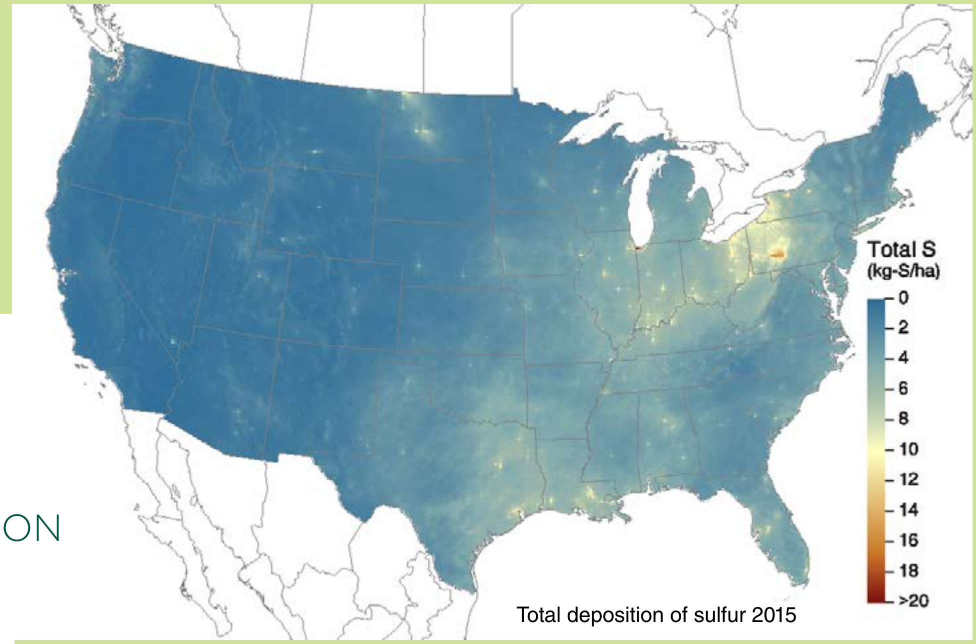
Consistent response to sulfur fertilization in the north-central region of the U.S. has been limited until recently to northwestern Minnesota and North Dakota on farms growing canola (Franzen and Grant, 2008). Yield increases of up to 6,000% have been documented in canola due to applications of sulfur (S) (Deibert et al., 1996).

Sulfur deficiencies also have been documented in field pea and spring wheat (McKay, 1996). In addition, S responses in corn have been observed in Minnesota on sandier soils (Rehm, 2005). Sporadic S responses have been documented in Nebraska and Wisconsin, particularly in sandier soils, as well.

Sulfur deficiency has increased and continues to increase due to continued soil erosion in some areas, increased yields of most regional crops, and perhaps most importantly, the great reduction in atmospheric S deposition as a result of restrictive emissions legislation in Canada and the U.S. A recent map of atmospheric S deposition appears in Figure 1.

Sulfur deficiencies suddenly became common in Iowa beginning in 2005. In 2002, Sawyer and Barker noted that their research at 12 sites in 2000 and 2001 showed no response to S in corn despite having low soil extractable sulfate-S levels. These results were consistent with the 30 years of S research previously conducted in Iowa.

Figure 1. National atmospheric deposition map of total S in kilograms of S per hectare. To convert to pounds of S per acre, multiply the scale by 0.87. (U.S. Environmental Protection Agency image)



Total deposition of sulfur 2015

Source: CASTNET/CMAQ/NTN/AMON/SEARCH

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However, in 2006, six sites with visual symptoms consistent with S fertilization were selected. Sulfur as calcium sulfate (gypsum) was applied sidedress and five of six sites improved significantly in yield, with an average corn yield increase of more than 30 bushels per acre.

In addition, six sites of alfalfa with visual symptoms suggesting S deficiency were selected, and four of the six sites responded to in-season S applications (Sawyer et al., 2009).

Forty-five corn sites were examined in 2007 and 2008 in northern Iowa. Responses were found in 28 sites. Responses in corn on coarser-textured soils averaged about 28 bushels/acre, and responses in finer-textured soils averaged about 11 bushels/acre.

Extractable sulfate-S was not related to yield response in the check plots (Figure 2). Sulfate concentrations higher than 10 parts per million (ppm) would be regarded as nonresponsive, but some of these sites responded to S.

Extractable sulfate-S again was not helpful in a summary of 10 years of sulfur fertilization trials at Brookings and Beresford, S.D. (Gelderman, unpublished data). No response was observed at Brookings for 10 years, despite low S soil test numbers, while at Beresford, about a 4-bushel-acre average response was documented.

The relationship of corn response to sulfate-S soil test levels in South Dakota for 17 years is shown in Figure 3. Sulfur has been a growing nutrient problem in Iowa since 2005.

The nonrelationship of the current sulfate-S soil test with corn yield is shown in Figure 3. Recent Minnesota research also found a lack of relationship between sulfate-S soil test and corn yield (Figure 4).

Sources of Plant-available Sulfur

Schoenau and Malhi (2008) recently summarized the sources of sulfur available to crops. Soil sulfur originates from inorganic and organic forms. Plant-available sulfur is the sulfate (SO_4^{-2}) form, which is the oxidized state of S.

Sulfate ions are deposited annually in soils in the north-central region through rainfall. However, the amount of atmospheric deposition has decreased recently (Franzen and Grant, 2008) as a result of U.S./Canadian air emission legislation, as previously stated.

In the drier areas of the north-central region, some soils contain significant sulfate salts, particularly gypsum, magnesium sulfate and sodium sulfate. In more humid regions, significant sulfate comes from the mineralization of organic matter and residues, combined with microbial oxidation of sulfide bonds to sulfate ions.

Due to the mobile nature of sulfate ions and the limited S that can be mineralized in low-organic-matter soils, sulfur deficiencies often are most severe on coarse-textured, low-organic-matter soils (Harvard and Reisenauer, 1996; Rehm and Caldwell, 1968).

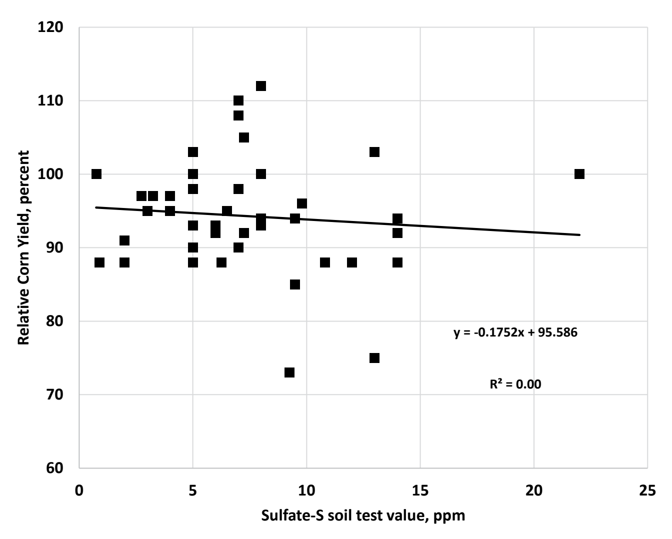

Figure 2. Relative corn yield in relation to sulfate-S soil tests, Iowa. (Sawyer et al., 2009)

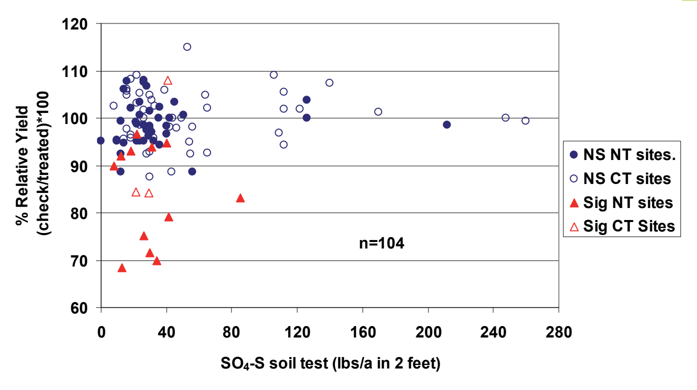

Figure 3. Relative corn yield in relation to sulfate-S soil tests, South Dakota, 1990-2007.

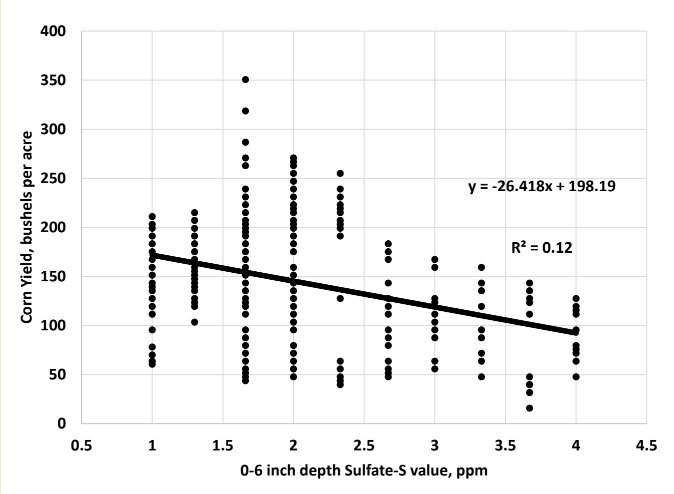

Figure 4. Relationship between Minnesota corn yield and sulfate-S soil tests. (Adapted from Kim et al., 2013)

North-central Region S Tests

In North Dakota, extractable sulfate-S was one of the most variable nutrients analyzed in site-specific nutrient management experiments, with 2-foot soil core values varying from less than10 pounds of S/acre to nearly 1,000 pounds of S/acre within a 40-acre field (Figure 5). Therefore, regardless of the laboratory method used to predict the plant-available S status of soils, we advise considering S mobility when sampling.

Tabatabai (1996) reviewed a large number of methods for S determination in soils. Due to relationships found by Probert (1976) between $Ca(H_2PO_4)^2$ extracted sulfate and plant uptake, researchers generally accept the monocalcium phosphate extraction procedure as the one that would be most related to crop production. This is the procedure laboratories in the north-central U.S. region use most often as a guide to growers for soil S status.

Several other studies in the 1960s and early 1970s supported this extractant to some degree (Fox et al., 1964; Hoeft et al., 1973). Hoeft et al. (1973) found that of the extractants examined, the monocalcium phosphate with 2-N acetic acid performed the best and the monocalcium phosphate alone was not as good at predicting alfalfa yield as a sulfate-S extractant.

However, through time, the acetic acid version of the extractant was abandoned by soil laboratories because it not as practical to use as the water-based monocalcium phosphate extractant. Despite laboratories overwhelmingly adopting the monocalcium phosphate extractant, the extractant is nondiagnostic in regard to most crops.

The relationship of extractant and canola yield response to S is low (Lukach, personal communication). Previously, cited research showed corn from Iowa and South Dakota has similarly low relationships. Therefore, the test procedure should be used with caution with the understanding that the soil texture, organic matter and recent rainfall/snowfall patterns may be more predictive of future S needs than the soil test.

Alternative Prediction of Crop S Deficiency – N-sufficient Area

When crops have lower than optimal available N, S deficiency is not as severe because plants have the ability to deconstruct N-compounds in older leaves and tissues and transport them to new growth for seed production. Sulfur, as a component of many of these N-compounds, also is transported to newer plant tissues.

However, if adequate N is available for the crop, no signal occurs within the plant that results in the same deconstruction of N-compounds with their S components and their transport to newer tissues. Therefore, the severity of S deficient is increased with adequate N.

In corn N-rate trials, when S deficiency was not realized at time of establishment, the highest N-rate corn was the most yellow due to S deficiency. The 0-N plot was the greenest in the plot (Figure 6).

Growers can use this knowledge to apply an N-rich "sentinel" strip in their field with an additional 100 pounds of N per acre. If this strip appears more yellow than the surrounding crop, S deficiency is highly likely and supplemental S fertilizer should be applied as soon as practical (Franzen et al., 2016).

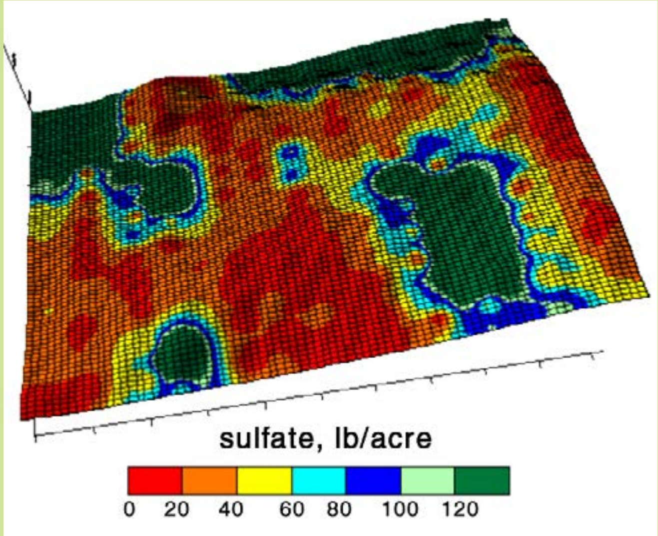

Figure 5. Variability of sulfate-S analyzed from a 110-foot grid over a 40-acre field near Valley City, N.D. High-sulfate areas tend to be local depressions, and the lowest sulfate was in low-organic-matter upland soils, usually, but not always, associated with coarser-textured soils.

Figure 6. S deficiency symptoms related to N rate in corn near Oakes, N.D., 2013. Yellower plots received 200 pounds of N per acre, while greener plots, such as the one the researcher in the dark shirt is in, are lower-N-rate plots. The tallest corn in the foreground is outside the plot area, and it received an S application in the starter band from the cooperating farmer. (Dave Franzen, NDSU)

The recent explosion in the frequency of sulfur responses in historically nonresponsive soils in not only Iowa, but in many other examples in the north-central states, provides an opportunity to finally find improvements to the current soil testing procedures. The north-central region's currently recommended plant-available sulfate-sulfur analysis procedures should be used with caution if they are meant to be predictive of crop response. As they are written, the results probably will underestimate or overestimate the chance of crop response.

S deficiency in spring wheat. (Dave Franzen, NDSU)

Early season S deficiency in canola. (Dave Franzen, NDSU)

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