Investigating high magnesium soils and the impacts on soybean production. Project # 04-2020

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RATIONALE/JUSTIFICATION FOR RESEARCH: Magnesium is a critical nutrient for crop development and grain production that is typically found to be in adequate supply throughout the Mississippi Delta. Typically, the percentage of readily available potassium is low and limited to that held on cation exchange sites on clay colloids and what is dissolved in the soil solution. High soil magnesium exacerbates the already low percentage of available potassium by super-saturating exchange sites with its double positive charge and essentially crowding out the potassium ions. This magnesium induced antagonism is known and generally addressed by increasing potassium rates in fertility recommendations. New knowledge suggests that high magnesium levels could be could be a more widespread issue than previously considered, with negative effects extending beyond that of simple potassium antagonism. High magnesium can also negatively impact soil structure and related functions. Recent studies point towards magnesium induced soil *disaggregation* as the underlying process. As clay particles disaggregate (i.e. disperse) under high magnesium conditions soil pore space decreases resulting in crusting and compaction thereby reducing soil aeration and water infiltration/internal drainage. In the field, these conditions are particularly expressed in medium to fine textured soils through symptomology such as: 1) prolonged soil wetness; 2) soft soil easily subject to compaction; 3) rapid transition from "wet" to "dry"; and 4) extreme soil "hardness" when dry. While this may or may not influence yield, it does significantly influence field operations.

Of 17,204 soil samples collected by Southern Ag in 2019, 60% had base saturation magnesium levels greater than 20%, which may be considered "high". Similarly, 66% of samples exhibited base saturation potassium levels less than 2%, which may be considered "low". Preliminary results from year one data analysis of approximately 12,000 soybean acres suggests a general trend of declining yield once base saturation magnesium exceeds approximately 21-23%, supporting the 25% base saturation magnesium threshold previously suggested. However, high variability associated with the data suggests there are other factors influencing this relationship.

The second piece of evidence suggesting a closer look into magnesium is associated with the Mississippi River Alluvial Aquifer (MRVA). Irrigation withdrawals exceeding recharge over time has resulted in declining water levels, which is also known to concentrate and increase salt and nutrient contents in irrigation water. The United States Geological Survey (USGS) has been testing the quality of irrigation water from numerous wells throughout the MRVA (MS-AR-LA-MO) for many years. Analysis of over 2,000 MRVA multi-state water quality samples show a mean magnesium concentration of 25.8 ppm. Using this concentration, we estimate the amount of magnesium added to be 56.3 lbs/acre/year using some basic water use and yield assumptions.

Gypsum (calcium sulfate dihydrate) is a by-product commonly used to remediate soils by improving soil structure and infiltration. This is achieved as sulfur contained in the gypsum binds with magnesium freeing up exchange sites which are replaced by calcium. The Natural Resource Conservation Service recognizes gypsum as a conservation practice suitable for soils with base saturation magnesium greater than 13%. Mississippi NRCS has approved this practice and has established payment rates ranging between $28.49 and $48.68 per acre. Although gypsum may be a viable option for improving soil properties under high magnesium conditions the effect or potential improvement in soybean yield is unknown. 2020 on-farm trials utilizing gypsum as an in-season soil amendment did not result in a positive yield response. However, the typical yield drag in high magnesium areas of the field was not observed during this growing season, likely due to non-excessive rainfall and/or irrigation. Similar to gypsum, there are several liquid calcium products on the market that have shown positive, yet mostly inconsistent, yield responses in the field. The basic science behind using calcium and sulfur

products to remediate high magnesium soils is sound, it is a matter of determining which product to apply in which situation to generate a positive ROI.

OBJECTIVE(S): The overall aim of this project is to determine the situations and extent that high magnesium is impacting soybean yield and to support location specific management strategies that generate a positive ROI.
1) Determine relationships between soybean yield and base saturation magnesium levels.
2) Determine relationships between irrigation water magnesium and soil test magnesium.
3) Evaluate the use of gypsum to improve soil conditions and soybean yield.

APPROACH AND EXPERIMENT CONDUCT:

Objective 1 – Southern Ag Services manages soil test and crop yield data for producer clients throughout the Mississippi Delta. Southern Ag will identify client cooperators willing to provide their soil test and crop yield data for anonymous analysis in order to implement this objective. This analysis will target fields with soil test base saturation magnesium levels exceeding 25%. This project aims to include a minimum of 10,000 acres in this analysis where soybean yield and soil test parameter correlations are calculated in order to determine whether high base saturation magnesium appears as a yield limiting factor.

Objective 2 – Irrigation wells associated with fields described in objective 1 will be identified. The first phase of this analysis will involve querying the U.S. Geological Survey MRVA irrigation well water quality database and extracting magnesium concentration data for analysis against soil test magnesium in associated fields. The second phase will involve sampling of irrigation water during the 2020 growing season where historic data is lacking. Approximately 50 wells will be sampled, once at the beginning of irrigation season and once at the end. Irrigation water and soil test magnesium levels will then be plotted to test for relationships.

Objective 3 – One field will be selected which exhibits a range of soil test base saturation magnesium levels. The field will be mapped and zoned using electromagnetic induction technology and soil sampled by textural zones. Randomized Complete Block Design (RCBD) will be utilized to implement replicated strips of zero, low, medium, and high rates of gypsum. Gypsum application will be made in the spring of 2020 and prior to soybean planting. Calibrated and spatially referenced yield data will be collected at harvest and plotted against application rates by zone to determine the level of crop yield response.

REPORT OF ACTIVITY / ACCOMPLISHMENTS:

Objective 1 - Determine relationships between soybean yield and base saturation magnesium levels.

- Activities undertaken for this objective are based on historic soil test and soybean yield data from three farms in the Mississippi Delta located in Sunflower and Leflore Counties. A database of 3,744 spatially referenced soil sample data points representing 9,360 acres with magnesium base saturation levels ranging from 10% to 52% has been created. Soil data is from years 2017-2019. Soybean yield data from these farms was compiled for 2018 and 2019 crop years, and cleaned to eliminate erroneous and outlier data points. Yield data points were aggregated and averaged within a 38 ft buffer (combine header width) of each soil sample data point and combined into a master file for analysis with JMP Software (statistics program from SAS). Initially, bivariate analysis of soybean yield versus all typical soil test parameters (pH, CEC, OM, Ca, P, K, Mg, Mn, B, S, Fe, Na, Zn, BS-Ca, BS-Mg, BS-K, BS-H, and BS-Na) was performed and parameters ranked by goodness of fit. BS-Mg (base saturation magnesium) consistently ranked in the top three variables negatively correlated with yield. However, there is considerable variation in the strength of that relationship by both year and farm. In general, the negative effect and relationship

between BS-Mg and yield was stronger in years where average soybean yields were lower. This initial analysis supports the general hypothesis that high base saturation magnesium negatively impacts yield. Additional steps are currently underway to hone in on the range of soil conditions in which negative impacts to yield are most likely. These steps include: 1) addition of 2020 soybean yield data to create two-year average yield values for analysis against soil test parameters; and 2) multivariate analysis (clustering and principal component).

Objective 2 - Determine relationships between irrigation water magnesium and soil test magnesium.

- Groundwater wells were identified near locations of high base saturation magnesium soil and irrigation water samples were collected. Lab analysis indicated a mean magnesium concentration of 31.2 ppm which equates to 70.2 lbs/acre/year magnesium contribution based on conservative irrigation use and efficiency assumptions. Spatial analysis of irrigation water magnesium versus soil test magnesium will be conducted.

Objective 3 - Evaluate the use of gypsum to improve soil conditions and soybean yield.

- An on-farm trial was conducted in Bolivar County to evaluate soybean yield response to an in-season gypsum application. The field was mapped and zoned using electromagnetic induction technology. Soil samples were collected, composited, and analyzed by zone, the results of which indicate base saturation magnesium ranging from 20% to 38%. Four treatments (0 lbs/ac, 1,000 lbs/ac, 2,000 lbs/ac, and 3,000 lbs/ac) were randomly applied within three block replications. Combine yield data was spatially aggregated from 12 rows for each treatment whereas the spreader ran the middle of the 12 rows from which yield data is reported. No significant differences in yield were observed. Average yields by treatment across all replications were: 0 lbs/ac = 87.1/bu/ac, 1,000 lbs/ac = 87.8/bu/ac, 2,000 lbs/ac = 85.2 bu/ac, and 3,000 lbs/ac = 88.7 bu/ac. Interestingly, the study field (Mg base saturation ranging 20%-38%) did not have the typical yield drag (20-30 bushels) in the high magnesium areas during this production season, which is consistent with findings discussed in Objective 1. Soil sampling will be repeated in April 2021 using the same protocol to evaluate soil test parameter response to the gypsum treatments.