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

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Background and Objectives: Magnesium is a critical nutrient for crop development and grain production that is commonly found to be in moderate to high ranges 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 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.

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. This data served as initial justification for further investigation through this project. The second piece of evidence suggesting a closer look into magnesium is associated with the Mississippi River Alluvial Aquifer (MRVA). Historic analysis of over 2,000 MRVA multi-state water quality samples show a mean magnesium concentration of 25.8 ppm. Using this concentration, we estimated 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. 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. In addition to gypsum, several Delta area growers expressed interest in liquid calcium applied via broadcast spray and through irrigation water to improve soil tilth. This project was modified to incorporate that objective.

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 factors driving situations where soil magnesium negatively impacts soybean yield.
2. Assess irrigation water magnesium levels across different zones of aquifer decline.
3. Evaluate fall applied gypsum in conjunction with deep tillage versus cover crop systems
4. Evaluate liquid calcium applied via broadcast and irrigation water in cover crop systems.

Report of Progress/Activity

Objective 1 – Assess factors influencing situations where soil magnesium negatively impacts soybean yield.

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 geodatabase containing spatially referenced soil sample data points representing over 12,000 acres with magnesium base saturation levels ranging from 10% to 52% has been created. Soil data is from years 2017-2020. Soybean yield data from the same farms was compiled for 2018-2020 crop years. For the initial phase of analysis, 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). 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, considerable variation in the strength of that relationship by both year and farm were observed. In general, the negative effect and relationship between BS-Mg and yield was stronger in years where average soybean yields were lower. This preliminary analysis supports the general hypothesis that high base saturation magnesium negatively impacts yield.

Given the large data set and multi-factor analysis desired, collaboration for Machine Learning (ML) based analytics on this geodatabase was initiated with Drs. Brian Smith and Nazanin Morshedlou in the Department of Industrial and Systems Engineering at MSU. The initial phase of ML analytics has been completed and a meeting for review is scheduled for April 1, 2022.

Objective 2 - Assess irrigation water magnesium levels across different zones of aquifer decline.

In year one of the project, 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. Water sampling efforts were expanded in year two to include wells located across different zones of aquifer decline. Preliminary spatial analysis of this data set does not suggest a relationship between zone of decline and irrigation water magnesium levels. Final analysis and reporting of this data set will be conducted in 2022.

Objective 3 - Evaluate fall applied gypsum in conjunction with deep tillage versus cover crop systems

In year one 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 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.

Additional gypsum trials were established in the fall of 2021 on two farms with differing farming system strategies. The rationale behind this is that for the sulfur in gypsum to bind with magnesium and leach it out or downward in the soil profile, there must be ample internal water movement in the soil. A cover crop system achieves this over the long-term by creating pore space via roots and increased microbial activity which are stabilized by root exudates and carbon-based substances. This approach is contrasted by mechanical deep tillage which temporarily creates soil pore space which is subsequently lost through consolidation and compaction associated with soil wetting and drying cycles. These trials will be followed to yield during the 2022 cropping season.

Objective 4 - Evaluate liquid calcium applied via broadcast and irrigation water in cover crop systems.

On-farm trials evaluating a liquid calcium carboxylate product were established in 2021. For the irrigation delivery component, side by side fields were selected utilizing the same well but different irrigation sets. Liquid calcium was metered into irrigation water at a rate delivering 1 gallon of product per acre per irrigation event. Three irrigation events were performed in 2021. An electric over hydraulic penetrometer was used to measure soil strength/compaction in 0.25 inch increments for the top 24 inches of soil at planting prior to liquid calcium application. These penetrometer measurements will be repeated at planting of the 2022 crop. However, physical inspection following the calcium applications in-season noted dramatic differences in soil tilth and hardness following the calcium treatment. The treated soil was very mellow and friable when dry, whereas the untreated was hard and brick like. A similar trial was established in the fall of 2021 where the same liquid calcium product was broadcast applied behind the combine prior to cover crop planting. This trial will be followed through the 2022 cropping season.

Impact and Benefits to Mississippi Soybean Producers

Potassium is a critical nutrient for soybean production. The antagonistic relationship between magnesium and potassium has been well documented, and the standard recommendation to address the situation is to increase the amount of potassium fertilizer applied. With potash fertilizer prices dramatically increasing in recent months, the logic of applying more may not be the most profitable strategy for soybean growers moving forward. This project evaluates alternative strategies to support profitable decision making of soybean producers facing high soil magnesium scenarios.