Title: The impact of phosphorus soil test level differences on crop response, phosphorus leaching, and phosphorus runoff under long-term no-till management in South Dakota

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Summary

Phosphorus, the plant nutrient, is receiving intense scrutiny at the present time due to its potential impact on the degradation of aquatic ecosystems. This requires that everyone involved carefully examine all aspects of phosphorus use in agriculture to assure that every possible effort is made to prevent environmental damage while at the same time optimizing its value as a plant nutrient. Scientific knowledge increasingly indicates that under management systems that promote enhanced biological activity, specifically that associated with mycorrhizal fungi activity, behave differently as compared to traditional systems. There is also evidence that promoting healthy root systems and using fertilizer placement techniques can increase phosphorus (P) crop use efficiency. If all these steps are combined it is probable that soil test P levels (P solubility) can be intentionally maintained at levels lower than those currently recommended without experiencing yield losses due to P deficiency. The net result should be a reduction in the potential for movement of phosphorus to aquatic ecosystems and more efficient use of P fertilizers.

The project was established in November of 2017 at the Dakota Lakes Research Farm. A Corn-Corn-Soybean-Wheat Soybean rotation is being used. The crop in 2020 is the soybeans grown in wheat stubble (seeded to a cover-crop). Two factors are being examined. One is a differential in P soil test level and the other is phosphorus fertilizer placement (soil placed vs surface applied). The soil test differential experiment was in a randomized complete block design with 5 replications. Soil tests that had been drawn to approximately 5 ppm Olsen, received treatments where P soil test level differences were created by applying MAP fertilizer to replicated strips at rates of 0, 100, and 200 lbs of MAP (mono-ammonium phosphate)/acre in 2014 and again in 2017 and 2019. Fertilizer placement impacts are tested in a separate field, with the same crop rotation, and similarly low soil test P levels. Replicated strips of soybeans received 53 lbs of a blend of MAP (90%) and KCl (10%) per/acre placed 3 inches to the side of the seed in the soil test level experiment. The same procedure was used on the placement experiment with the broadcast treatments receiving the same fertilizer applied on the soil surface during the seeding process. Potential of P transport in water and sediment was measured and analyzed using a simulated rainfall event using a Cornell infiltrometer applying approximately 9 to 12 inches of

water in 1 hour, Water samples were collected from the runoff that occurred and from the soil solution extracted by vacuum 30 inches immediately below the infiltration instrument. The water was analyzed for nitrate, sulfate, ortho P and total P. The water sample analysis from the first infiltration run on the soil test portion of the experiment have been completed. Water samples from the placement experiment are in process.

Mid-year results indicate that soil test P values have increased in the treatments that have received an additional 300 and 600 lbs of MAP/acre since 2014 (100 and 200 lbs of MAP/acre three times). The Check has values of 7.7, 5.2, and 3.6 ppm Olsen at the 0-3, 3-6, and 6-12 inch depths. The intermediate rate has 11.2, 5.2, and 3.6 ppm. Olsen. The highest addition produced values of 16.8, 4.9, and 3.7 ppm Olsen. The shallower sampling depth accentuated difference. Normal testing is done to 6 inches. Runoff data from applications of 9 to 12 inches in an hour indicate that the highest runoff of Ortho P was 0.12 lbs/acre and the highest total P runoff was 0.15 lbs of P/acre. Most values were less than .05 lbs of P/acre. The values from the placement study are not complete. We expect some of them to be higher.

Introduction: Phosphorus management in agriculture is receiving substantial scrutiny at the present time due to the role this nutrient can play in degrading aquatic ecosystems. Addressing these concerns requires all involved to examine every aspect of present practice. There is currently an effort to promote the 4 R's of nutrient management. This entails applying the right amount of nutrient, in the right form, in the right place, at the right time. In many cases soil testing is used as a tool in determining the correct amount of nutrient to use. Current recommended P fertilization rates from Soil Testing Laboratories are based on an estimation of the P supplying ability of the soil and the projected need of the crop at the stated yield goal. Recommendations assume P fertilization is done by surface broadcast applications and that conventional tillage practices are used. There is substantial evidence that banding of P near or with the seed increases the efficiency of P crop uptake, subsequently rates can be reduced. However, these P recommendations do not take into account differences in tillage, crop rotations, or mycorrhizal activity. It is probable that under management systems that promote mycorrhizal activity and healthy root systems (i.e. no-tillage, diverse rotations, high crop residue) and fertilization practices that increase P crop use efficiency (banding); soil test P levels (solubility) can be intentionally managed at solubility levels lower than is now common without experiencing yield losses. The total P in the soil will not be reduced significantly since the lower solubility level will be maintained, but the potential for transport of P to aquatic ecosystems should be reduced.

Goals and Objectives: The main goal of this project is to provide South Dakota producers with information on optimum application methods and rates of P fertilizer to increase crop yields while reducing risks of P transport to aquatic ecosystems. Specific objectives of the project are to:

1. Assess the impacts of different soil test P levels on crop yields and P use efficiency.
2. Document the impact of nutrient placement in improving P use efficiency and reducing potential off-site movement.

3. Quantifying P movement associated with soil test level and fertilization practices.
4. Document the relationship between arbuscular mycorrhizal (AMF) fungi activity and crop P use efficiency.
5. Perform cost/return analysis related to these factors.

Work Plan

The project is being conducted at the Dakota Lakes Research Farm (18 miles southeast of Pierre) on an irrigated field in a no-till, Corn-Corn-Soybean-Wheat/cover crop-Soybean rotation. This site has been strictly no-till since 1990. Replicated strips with differing soil test P levels were established in 2014 by applying zero, 100, and 200 lbs of MAP (mono-ammonium phosphate)/acre on soils where the Olsen P soil levels had been lowered to approximately 5 ppm. The experiment was in a randomized complete block design with 5 replications. Dimensions for each plot at the site were 20 ft by 450 ft. A crop of soybeans and two crops of corn were grown on this area during the 2015, 2016, and 2017 years respectively.

In the fall of 2017 and the fall of 2019 (after wheat harvest) applications of MAP were again made at rates of 0, 100, and 200 lbs of MAP/acre to the same replicated strips that were treated in 2014. A no-till drill was used to place the nutrient 1.5 inches deep in 7.5-inch rows.

In the soil test field, a cover-crop of winter wheat was seeded following fertilizer applications. Small portions of this cover-crop were terminated before frost to allow testing P runoff as impacted by cover crops that freeze. These data have been collected but more analysis is required.

The P placement portion of the study is conducted in a separate field that has been in the same rotation and has similarly low P soil test values. In this area a cover-crop of oats, barley, and German millet was seeded immediately after wheat harvest. The cover-crop was swathed when the oats was in the milk stage. These swathes were grazed during the winter and spring by beef cattle. A cover-crop of oats was seeded early in the spring on this field.

Both fields were seeded to soybeans using a row-crop seeder with 20-inch spacing. Fertilizer (MAP 90% and KCl 10%) at 53 lbs/acre was applied at seeding either placed 3 inches to the side of the seed or on the surface depending on the protocol. The cover crop was terminated after seeding.

Mid-season Results and Impacts

Objective 1: Crop yields and P use efficiency
Early season leaf samples have been collected and submitted for analysis. Whole plant samples will be collected and analyzed to determine total P uptake before the crop is harvested.

Objective 2: Impact of phosphorus placement on P use efficiency, P uptake and yield

It is too early to assess this factor. Leaf samples have been collected and are being analyzed.

Objective 3: Soil P and P from water runoff and sediment

Cornell infiltrometers were used to quantify potential P transport in water and sediment as impacted by soil test P levels and placement differences. Long-term no-till history made it necessary to apply water at very high rates on 9 to 12 inches/hour for 1 hour to produce sufficient runoff to allow analysis. Water samples were collected from the runoff that occurred and from the soil solution extracted by vacuum 30 inches immediately below the infiltration instrument. The water was analyzed for nitrate, sulfate, ortho P and total P. The water sample analysis from the first infiltration run on the soil test portion of the experiment have been completed. Water samples from the placement experiment are in process.

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Objective 4: Mycorrhizal activity and crop P use efficiency

Samples for determination of AMF populations will be collected and used by Dr. Lehman to conduct greenhouse/laboratory studies to determine most probably numbers. We will also subject these samples to Phospholipid Fatty Acid analysis and DNA evaluation. These samples need to be collected when plants are actively growing. Results from last year's AMF sampling have been prepared but need to be "read" when the USDA center reopens. Samples form 2018 indicated the most probably number was over twice as high where no MAP was applied in 2014 or 2017 as compared to were 100 and 200 lbs of MAP/acre were each of these years (200 and 400 lbs of total product).

Objective 5: Economics

Efficient use of P in crop production is important for economic and environmental reasons. Obviously obtaining comparable yields with less total nutrient applied is beneficial. Yields need to be obtained before economics can be calculated.

Changes in Project or Personnel

Brennan Lewis was hired in May to be a MS student working on this project. The open soil scientist position has been open since May 2019. It is hoped that will be filled before fall. Dr. Dwayne Beck has taken over primary duties for directing field activities for this research until a replacement is hired.

Products (publications, presentations, disclosures/patents)
This study was a featured stop on the June 25, 2020 DLRF Virtual Field Day Videos are online.

Budget
This fund has a remaining balance of $36,496 as of June 30, 2020. That is the entire budget for this year. Brennan is being paid by DLRF until his assistantship begins. Most of the soil design and analysis work has not been processed. The Covid issue resulted in our secretary working from home part-time. This will continue through the summer.