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Developing ecologically sound and profitable alternative fertilizer and manure phosphorus management strategies

Abstract: Revised guidelines for the Iowa State University (ISU) phosphorus (P) recommendations and ISU P management may be needed. This project utilized fertilizer and poultry manure P and experiments at research farms and producers' fields with corn-soybean or alfalfa-corn rotations to evaluate several P management practices and provide new knowledge about P management.

Question & Answer

Q: Are there new ways to achieve optimal phosphorus management?

A: This project provides information needed to improve phosphorus management recommendations.

Background

Results from research conducted from the 1970s through the 1990s provided the basis for current P recommendations in Iowa. These were the best available "one-fits-all" recommendations at that time. Changes in public perceptions and regulations about water quality impairment and escalating crop and fertilizer prices have lead to a need for more knowledge and more flexible guidelines that are better adapted to a broad range of management philosophies and production conditions. The project was intended to evaluate and develop ecologically friendly, flexible, and profitable alternative P management strategies and recommendation systems.

Specific objectives were to:

- Evaluate long-term impacts of a strictly response-based, low-input P fertilizer management strategy for corn-soybean and alfalfa-corn rotations on soil-test P, yield, and profitability of fertilization;
- Assess crop availability of poultry manure P for early corn growth and early P uptake; and
- Use the Iowa P index to estimate the impact of the alternative P management practices on risk of P loss from fields.

Approach and methods

The project evaluated fertilizer and/or poultry manure P management strategies for corn-soybean and alfalfa-corn rotations by measuring soil-test P and crop yields from plots of six long-term experiments at five ISU research farms and 18 single-year experiments in producers' fields. The project also evaluated early crop growth and P removal with grain harvest at selected experiments.

Some long-term experiments were modified to accommodate the work objectives and evaluate P application rates, placement methods and timing of P in corn-soybean and corn-alfalfa rotations to measure long-term soil-test P trends, and P removal with harvest. New experiments in producers' fields focused on the availability of manure P shortly after application by using various methods to measure early corn growth, P uptake and soil P.

Results

Corn-soybean rotation. A key result of this segment of the project affirmed the currently recommended P application rates for no-till and chisel-plow in Very Low and Low soil-

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test categories are appropriate. Results also showed that removal-based P recommendations for the Optimum soil-test category work well over time when crop yield estimates are appropriate. Results also showed that use of lower P application rates for the Optimum category often achieves higher crop yields. Therefore, soil-test P maintenance rates are appropriate to maintain long-term productivity, reduce risk of yield loss due to P deficiency, and maintain profitability over a long term, but lower rates may be more profitable for one crop. This may be helpful to producers when economic decisions must be made about application rates for fields that test in the Optimum category, especially when land tenure is not secure.

The research confirms that there are no large or consistent differences between band and broadcast P fertilizer placement methods for no-till and chisel-plow tillage, and that the currently recommended sampling depth of 6 inches is appropriate. A shallower sampling depth did not improve the soil test assessment of plant P availability in no-till. Also, the three soil-test methods recommended in Iowa to assess plant P availability were similarly effective in most soils, except for some high-pH and calcareous plots.

Corn-alfalfa rotation. Alfalfa had a very large response to P in this low-testing soil, and additional yield responses to rates higher than those currently recommended were not statistically significant. Once the system was established, different methods of P fertilizer distribution had no statistical effect on yield responses. An important result was that the lowest P rate applied during the three years of alfalfa (which maximized hay yield) also maximized corn grain yield and additional nitrogen (N) and P seldom were needed. Therefore, corn might need additional P or N only occasionally after appropriate P fertilization during the alfalfa phase, but on average responses will be small and may not offset application costs depending on corn and fertilizer prices.

Poultry manure P field demonstrations. In low test soils, both plant and soil P test results indicated large responses to both manure and fertilizer P as measured by early plant growth, P uptake, and soil-test P. There was a good deal of variability among replications, which is expected in manured fields, however there were no consistent differences in plant or soil P measurements between standardized fertilizer and manure P rates. Manure P often increased growth further than comparable P fertilizer rates, even though uniform high rates of N and potassium (K) were applied. With commonly used poultry manure rates (two to four tons/acre), corn producers supplied enough P to maximize early growth, P uptake of corn and grain yield, and additional P fertilizer was not needed. Results confirmed that poultry manure applied at rates to supply 50 percent or more of the N needed for corn will result in over-application of P and sharp increases in soil test P.

Iowa P index ratings. Preliminary results indicated that fertilizer P or manure P treatments used in the study did not significantly affect P index ratings or increase risk of P loss to water resources. However, results clearly suggest that continued application of poultry manure rates to supply N for continuous corn or corn after soybean will result in a sharp soil P buildup, increasing the risk of P loss especially in fields with relatively higher erosion and surface runoff.

Conclusions

The project resulted in practical information that will be useful to improve fertilizer and manure P management and the ISU P guidelines. Results showed that P fertilization effects on yield of corn and soybean managed with no-till or chisel-plow tillage are statistically similar for band and broadcast application, and that a 6-inch soil sampling depth is appropriate for both tillage systems in spite of significant soil P stratification. The results confirmed that current P recommendations for corn, for corn-soybean rotation, and for alfalfa-corn rotation are appropriate for most production conditions. They minimize risk of yield loss due to P deficiency and maintain desirable soil P levels over time, so that P application and crop production are profitable over the long term and minimize adverse effects on water quality. However, soil-test P results clearly demonstrated that continued application of poultry manure rates that supply the N needed by corn, even in rotation with soybean, will result in sharp soil P buildup that will increase the risk of P loss to high levels in a few years.

Project results also suggest some changes to make the recommendations more flexible, broadly applicable and user-friendly. Regarding current recommendations for using P removal at harvest to guide soil P maintenance, the recommendations are effective as long as farmers' estimates of yield are appropriate. For producers, another

related point is that the P application rates and P removal don't have a good year-to-year correlation, but do correlate well over a few years. Therefore, producers should not make drastic changes in P application rates based on yield of one crop. Also, results showed that since P recommendations for the optimum soil-test category are designed to eliminate expected minor deficiencies and to maintain soil P levels, lower rates (even starter rates) often result in similar yield response from one crop. This means that a producer has more management flexibility than previously thought and could reduce P in one year without necessarily risking yield. Only if a producer maintains a reduced rate over time will there be a significant negative impact on soil P levels that can result in reduced yield. This introduces some economic flexibility for producers with uncertain land tenure or unstable economic situations.

Impact of results

The field experiments of the project have provided a large amount of data, much of which continue to be analyzed. Preliminary results have been shared with cooperating producers, scientists and nutrient management planners. While major outcomes have been calculated, other information from the project continues to be interpreted for future inclusion in appropriate publications and recommendations.

Education and outreach

Fifteen published articles, abstracts or theses were generated by this project. Some reports appeared in ISU Extension publications and ISU Research Farms reports, others were published in American Society of Agronomy publications, and related conference proceedings.

Thirty-seven ISU Extension presentations related to the project results were given in 2006 and 2007. Many were part of ISU Extension short courses or certification programs. Results will be repackaged to be added to the "current topic" section of the ISU soil fertility web page at http://www.agronext.iastate.edu/soilfertility/.

Leveraged funds

Funding to enhance the scope of this project was obtained from the Iowa Department of Land Stewardship (IDALS) and was applied during three years for measurement of grain yield, post-harvest soil-test P, and P loss with surface runoff (using field rainfall simulations) when fertilizer or poultry manure were applied to corn. Funding from the Iowa Egg Council was used with the same purpose during the last year of the project. Also, this project leveraged funding from the Foundation for Agronomic Research to include analysis of P concentration in grain samples that had been collected and stored for nine years.

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