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LAND TENURE EFFECTS ON PHOSPHORUS MANAGEMENT

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ABSTRACT

A long-term approach to P management is needed due to the residual effects of P additions and the uncertainty of annual rate and response predictions. Soil test calibration data from the northern Great Plains were used to define the relationship between Olsen soil test P level and average relative spring wheat yield. A spreadsheet computer program was developed that uses the calibration function to estimate the optimum soil test P level for wheat based on 7 inputs, including land tenure and yield potential. For a 50 bu/A yield potential, optimum soil test P levels varied from 17 lb/A to 36 lb/A for tenures of 2 and 10 years respectively. Soil test interpretations, based on a long-term approach, that include factors such as land tenure have the potential to increase the profitability of wheat production in the Great Plains.

INTRODUCTION

Economic evaluation of P management decisions is often clouded by the substantial residual value of P additions. Only a fraction of the P applied in any one year is used by the crop in that year. In most soils, the majority of applied P remains in the soil in forms that are available for future uptake. Just as costs of installing tile drainage or irrigation do not need to be recovered in one year, the cost of fertilizer P does not need to be recovered in one year. In many cases, the residual P response is equal to or greater than the first-year response. Thus, the optimum P rate cannot be determined by simply evaluating yield response the year of application.

A second complicating factor for P economics is that P soil tests are indices reflecting the average relative yield or probability of response at a given soil test level and frequently do not accurately predict the rate of P necessary to give a certain yield in any given season. Figure 1 (after Halvorson, 1986) summarizes several long-term spring wheat studies from the northern Great Plains and is typical of P calibration data. At a 20 lb/A (10 ppm) soil test, relative yield varies from 70% to 100%. Response variability at a given soil test P level should not be surprising.

Numerous factors other than soil test P level influence supplemental P needs of a given crop in a given growing season and on a given soil type. Variability in P response among years and the residual effects of P fertilization suggest that P economics should be viewed in the long term and that land tenure is an important factor in making P management decisions.

All commonly accepted P fertilizer recommendation systems maintain soil tests at some level whether intentionally or incidentally from rates recommended for various yield goals. However, systems vary in the rate at which soil tests are increased and also in the extent of the increase. The most critical question in the long term is: At what level should soil tests be maintained?

The objective of this study was to develop an approach to soil test interpretation that focused on the long term with adjustments for land tenure.

MATERIAL AND METHODS

The data set used in this study is the continuous cropping set reported by Halvorson (1986) and graphed in Figure 1. It was selected because it includes information from several long term experiments conducted in the major spring wheat production region. The equation shown in Figure 1 was used to relate soil test level to long-term average relative yield and was selected using the TableCurve statistical software from Jandel. Model selection criteria were r2, lack of pattern in residuals, simplicity, and having a derivative with a direct X solution. Since model predictions slightly exceeded 100% at soil test levels greater than 51 lb/A, the function y=100% was used above 51 lb/A. The error mean square for the model was 0.00626 (df=107) with an F of 122.2.

A Lotus spreadsheet was developed that calculates the ratio of the average value of an additional unit yield increase to the amortized cost of an additional unit of soil test P increase. The target or optimum soil test P level that the individual grower should maintain was calculated as the level at which the ratio defined above is equal to the acceptable marginal rate of substitution input by the user (defined below). The program requires the following inputs:

1. <u>Acceptable marginal rate of substitution</u> - the minimum return per dollar invested acceptable to the individual. A value of 1.00 will cause the program to estimate the level where the last dollar spent increases crop value by one dollar. A value of 1.50 would return $1.50 on the last dollar spent.

2. <u>Annual interest rate or opportunity cost</u> - the actual interest rate if capital is borrowed or an opportunity cost for alternative use of the cash at a similar risk level.

3. <u>Land tenure</u> - the period of time the grower will be farming the field. Since in most soils residual P should not be depleted if removed nutrients are replaced, expected time of ownership or operation in most cases substitutes for the life expectancy of the capital investment in the amortization process.

4. <u>Fertilizer P_2O_5 required to increase soil test level one unit</u> - typically 8 to 12 lb P_2O_5 are required to increase the Olsen P by 1 lb/A.

5. <u>Fertilizer cost</u> - average weighted cost of the fertilizer over the land tenure period.

6. <u>Net crop price</u> - average price of the crop over the land tenure period minus the cost of maintenance P per bushel.

7. <u>Yield potential</u> - the average yield over the land tenure period if P was not yield limiting. The yield potential is used to determine the economic value of a percentage change in relative yield. This is not the same as the yield goal as used in most soil testing programs.

RESULTS AND DISCUSSION

Table 1 shows the effect of yield potential on the relationship between soil test level and bu/A lost from P deficiency. We have commonly viewed a relative yield of 95% as essentially the same as maximum yield. However, a <u>real</u> long term average yield reduction of 5% from P deficiency can be of substantial economic importance to a grower because increasing soil test P levels is relatively inexpensive.

Table 1. Average spring wheat yield loss from P deficiency at various soil test levels based on the calibration data set reported by Halvorson (USDA).

Olsen P	Relative yield	Average Yield 30	50	70
lb/A	%		bu/A lost	
10	78.0	6.6	11.0	15.4
20	90.4	2.9	4.8	6.7
30	95.4	1.4	2.3	3.2
40	98.2	0.5	0.9	1.3
50	99.9	0.0	0.1	0.1

Yield potential and land tenure have dramatic effects on the optimum soil test P level (Figure 2). The three curves represent 30, 50 and 70 bu/A yield potentials. As land tenure increases, optimum soil test P level increases. Land operated on a short-term lease has a lower optimum P level than land that is owned and likely to stay in the family for decades. Also, a farmer who is an excellent manager in a higher rainfall area will have a higher optimum soil test P level than a grower that has a lower yield potential.

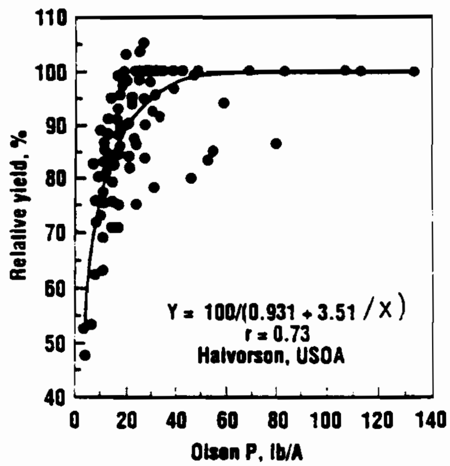

Figure 1. Spring wheat response to soil test P level in the northern Great Plains.

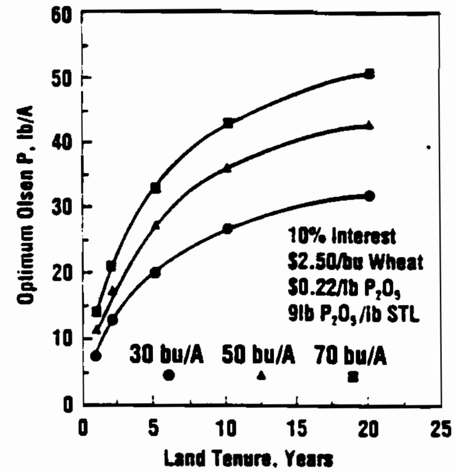

Figure 2. Land tenure affects optimum Olsen P level for wheat.

Fertilizer price, crop value, and interest rates also influence optimum P levels but not as much as yield potential and land tenure. For example, increasing net wheat price from $2.50 to $3.50/bu increases optimum soil test P level by only 5 to 8 lb/A. When one considers that these should be long-term average prices or rates rather than current market conditions, the effect of these factors on optimum soil test P levels is dampened further.

Soils differ in the amount of P required to change soil test P levels. Soil test P levels are typically easier to change on coarse textured sandy soils than on medium or fine textured soils. Some low pH and some high pH soils fix applied P readily and increasing soil test P levels is more costly, decreasing the optimum level. This assumes such soils have the same P yield response relationships as normal soils.

When a long-term basis is used in making P rate decisions, the focus should be on soil test P level. Therefore, the first step in determining optimum P fertilizer rate is determination of optimum soil test P level considering the factors discussed earlier. Then, a P rate-soil test level relationship needs to be used that maintains soil test P levels at the optimum point. In other words, if the current soil test P level is less than the optimum, the fertilizer P rate should be greater than the quantity of P removed by the crop to allow soil test P levels to increase. If the current soil test P level exceeds the optimum, the P rate should be less than P removal which will allow soil test P levels to decline to the optimum point. A detailed example of one approach to determining optimum P rates with various placement methods is offered by Fixen and Halvorson (1991).

Researchers in Saskatchewan have compared one-time broadcast applications to annual seed-placed P and to various combinations of broadcast and seed-placed P over a 5-year period (Wagar et al., 1986). At low P rates, seed placement appeared to have a slight advantage over broadcast application, however, at optimum rates, broadcast application produced higher yields over the 5-year period even though the initial soil test P level was very low. The most effective treatment was where an initial broadcast application was made that elevated soil test levels followed by small annual applications applied with the seed. Such data suggest that regardless of placement methods, it is important to maintain an optimum soil test level to experience the full yield potential of the system.

Similar effects are being measured in an ongoing Colorado study on no-till winter wheat (A.D. Halvorson & J.L. Havlin, Personal communication). Cumulative response to seed-placed P leveled off at about 100 lb/A P_2O_5 and produced a total response of 14 bu/A over 3 years. The broadcast treatments continued to increase yield to rates exceeding 200 lb/A P_2O_5 and produced a total response over 3 years of 28 bu/A, twice that of the seed-placed treatments. As in the Saskatchewan study, there was a decided advantage to correcting soil test levels quickly. These studies and others indicate that a soil testing at its optimum level will often have a higher yield potential than one testing low even though P fertilizer is applied. Land tenure is critical to determining that optimum.

SUMMARY

A long-term approach to P management is needed due to the residual effects of P additions and the uncertainty of annual P rate and response predictions. Land tenure and yield potential are important factors when a long-term approach is used. Refinement of soil test P interpretation programs to include these parameters will likely increase the profitability of wheat production in the Great Plains and improve the credibility of P soil testing and the resulting P recommendations. Computer spreadsheet programs can be easily developed to aid in this refinement.

REFERENCES

Fixen, Paul E. and Ardell D. Halvorson. 1991. Optimum phosphorus management for small grain production. Better Crops 75 (Summer): 26-29.

Halvorson, Ardell D. 1986. Phosphorus management for MEWY and quality. In Proceedings of the Hands on Workshop for Implementing Maximum Economic Wheat Yield Systems, July 8-11, 1986, Bismark, ND.

Wagar, B.I., J.W.B. Stewart, and J. L. Henry. 1986. Comparison of single large broadcast and small annual seed-placed phosphorus treatments on yield and phosphorus and zinc contents of wheat on Chernozemic soils. Can. J. Soil Sci. 66: 237-248.