ROLE OF LAND TENURE/OTHER FACTORS IN SOIL P INTERPRETATIONS

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ABSTRACT

Soil test interpretation should recognize the residual value of applied P, the inherent limitations of soil P tests, and utilize an approach that can be easily personalized at the local level. These criteria were used to develop an interpretation approach utilizing a computer spreadsheet to estimate the optimum soil test level for an individual grower. The spreadsheet requires the following inputs: a calibration curve, acceptable marginal return, interest rate, land tenure, soil test buffer potential, fertilizer cost, net crop price, and yield potential. Once the calibration curve has been defined, land tenure and acceptable marginal return have the greatest impact on optimum soil test P level. In an example for corn using Clarion-Webster calibration data, estimated optimum soil test P level varied from 29 ppm for an irrigated well established grower to 8 ppm for a renter with cash flow restrictions. This interpretation approach should facilitate the personalization of fertility management that occurs at the local level in a manner that is easily documented.

BACKGROUND

The major objective in soil test interpretation is to offer information useful in making economic decisions about P management. Practical soil test interpretation must recognize the residual value of applied P, the limitations of soil P tests, and the needs of today's soil testing clientele.

Residual Value of P.

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.

Limitations of P Soil Tests.

A second complicating factor for interpretation of soil test P is that P soil tests are indices reflecting the average relative yield or probability of response at a given soil test level. They frequently do not accurately predict the rate of P necessary to give a certain yield in any given season.

The data sets shown in Figures 1 and 2 can serve as examples. Figure 1 (after Halvorson, 1986) summarizes several long-term spring wheat studies from the northern Great Plains and is typical of calibration data. In the 5-10 ppm range, relative yield varied from 62% to 100%. The corn data set in Figure 2 is from a long-term study at the Iowa State University Clarion-Webster Research Center. Although these data were generated by one experiment at one location, we again see a range in relative yield at 5-10 ppm of 62-100% across years. Clearly, 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 management should be viewed in the long term. An accurate estimate can be made of response averaged across years, however, accurate prediction of the rate of P needed in individual years to obtain a given yield level is seldom possible.

The Needs of Today's Soil Testing Clientele.

Today's agriculture has changed markedly from that of the 1940's and 1950's when the common P soil tests in use today were developed. However, the dominant approach to soil test interpretation has largely remained unchanged. Interpretation and recommendation writing are now done by computer rather than by ball point pen but the approach is still the same. A singular soil test level - fertilizer recommendation relationship is assumed to hold for all individuals with adjustments sometimes made for yield level and soil association. A soil test level goes into the black box and a recommendation comes out.

This "black box" approach may not be appropriate for today's grower and crop advisor. The expertise usually exists at the local level to make refinements in fertilizer use that reflect the specific circumstances of the grower. However, the traditional approach to interpretation does not indicate what assumptions have been made by the individual or committee that had the responsibility of translating calibration data and experience into an interpretation and recommendation. This makes refinement of the result difficult.

Much of today's soil testing clientele would be served better by an approach that replaces as many assumptions as possible with user-defined values most appropriate for the individual. The approach discussed here is an attempt to allow for personalization while recognizing the inherent limitations of soil test indices and the residual value of P additions.

Figure 1. Spring wheat response to soil test P level in the northern Great Plains
(Halvorson, USDA).

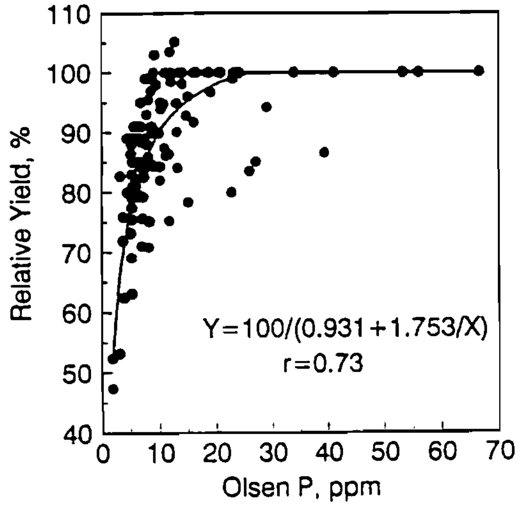


Fig. 2. Corn response to soil test P level on a Webster/Canisteo soil in north central Iowa.
Data courtesy of Webb & Voss, ISU

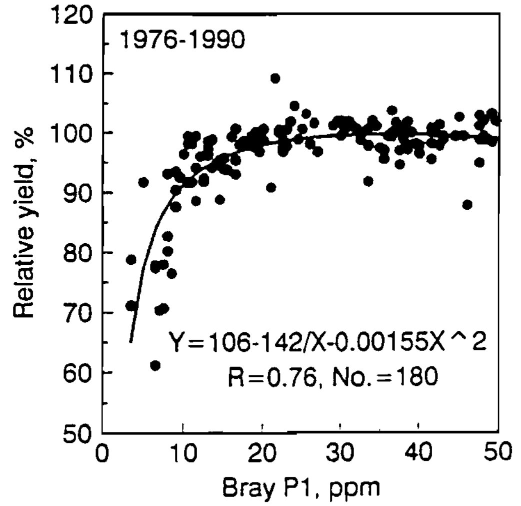
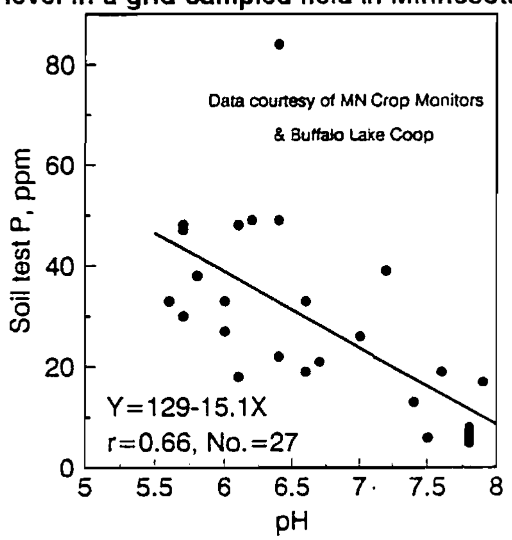


Figure 3. Relationship between pH and soil test P level in a grid-sampled field in Minnesota.



OPTIMUM SOIL TEST LEVELS

All commonly accepted P fertilizer recommendation systems maintain soil tests at some level whether intentionally or incidentally from rates recommended for various yield goals. The soil test level at which the recommended rate is equal to crop removal will be defined here as the optimum soil test level.

Calculating the Optimum Soil Test Level.

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 minimum return on the last dollar spent acceptable to the grower. The spreadsheet has the factors listed below as required input.

Factors Influencing Estimated Optimum Soil Test Levels.

Calibration curve. The calibration curve defines the relationship between soil test level and yield. The calibration data used should be the most appropriate available for the soil and cultural practices of the individual grower. **A limitation in application of this approach today is the availability of such data - a problem that should be a challenge to those responsible for soil test calibration research in each state or province.** It may be necessary to make educated guesses about necessary refinements is general calibration curves to make them more appropriate for the specific grower. For instance, higher soil test K levels are required for reduced till systems on some soils in the northern corn belt.

Required return on the last dollar spent. The minimum acceptable return per dollar invested will vary with the attitude, investment opportunities, and financial condition of the individual. A value of 1.00 indicates that profit from P was maximized and the last dollar spent should increase crop value by one dollar. A value of 2.00 would return $2.00 on the last dollar spent. The goal of a manager with limited capital is to maximize return on the last dollar spent considering all alternative investments and their associated risk.

Annual interest rate for borrowed capital. The actual interest rate applicable if money is borrowed to purchase P.

Land tenure. Land tenure refers to 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.

Quantity of fertilizer required to change the soil test (buffer potential). 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.

Typically 14 to 22 lb P_2O_5 are required to increase the Bray P1 test by 1 ppm to a depth of 6 2/3 inches. A reasonable estimate of P buffer potential for many soils is 18. If a good history of soil tests, crop removal, and fertilizer/manure application is available, this figure can be estimated for the field in question.

When soil specific management is being used and soils of diverse texture, P chemistry, or erosion potential are found within the field, buffer potential should be estimated for each soil within the field. Results of grid sampling of a field in central Minnesota are shown in Figure 3. In this field as pH increased soil test P decreased. Since past fertilization had been constant over the entire field and crop removal was the same or lower for the high pH areas, P buffer potential had to also vary with pH. In the estimation of optimum soil test P level is doesn't matter why the buffer potential appears higher in the high pH areas (ie P chemistry vs erosion). In this case, the apparent buffer potential for the high pH areas was over 4 times as high as in the low pH areas.

Fertilizer cost. The average cost of the fertilizer to be purchased.

Net crop price. The average market value of the crop over the land tenure period minus the cost of maintenance per bushel.

Yield potential. Yield potential is the average yield over the land tenure period if P was not limiting yield. 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 used in most soil testing programs. Yield potential of individual soils would be used in the case of soil specific management.

IMPACT OF SOIL AND GROWER DIFFERENCES ON OPTIMUM LEVELS

The impact of the factors mentioned above on optimum soil test levels will be illustrated using the calibration data for corn in Figure 2 mentioned earlier. Those interested in optimum P levels for spring wheat using the data in Figure 1 are referred to Fixen and Halvorson, 1992.

Raw data to create Figure 2 were provided by Webb and Voss. The maximum yield used to calculate relative yield was determined by fitting a response curve to the data for individual years using the TableCurve statistical software from Jandel. Relative yields for all years were then combined and the equation shown in the figure used to relate soil test level to long-term average relative yield. Model selection criteria were r^2, lack of pattern in residuals, and simplicity. The curve-fit F statistic for the final equation was 123. The x-solution of the derivative was estimated using least squares techniques.

Case Examples

The following 4 examples illustrate the impact grower differences can have on optimum P management. Optimum soil test levels were calculated with the Lotus spreadsheet discussed earlier.

Average grower. The average grower in this case is described as an individual that grows 150 bu/A corn on owned land (Table 1). This grower is well established and really has no cash flow problems. A $1.50 marginal return on investment is considered acceptable. The optimum soil test P level is estimated at **21 ppm.** In other words, a maintenance rate of P should be applied at 21 ppm for this grower to be most profitable. Below this soil test level, more than maintenance P should be applied while less than maintenance may be applied at higher soil test levels.

Well established irrigated grower. This grower is also well established and an excellent manager (Table 1). With the stabilizing influence of irrigation, yields average near 200 bu/A. Due to good marketing and purchasing skills, fertilizer is a little cheaper and grain is sold a little higher. No operating capital is borrowed, instead it is taken from either a money market or savings account set up for operating costs. Alternative investments are such that a $1.10 marginal return is considered quite acceptable. In this case the grower would be most profitable by maintaining a P soil test of **29 ppm.**

Young renter. In this case a young grower is in the early stages of a farming career (Table 1). A reputation has not been established and land is operated on a 3-year lease with no written or verbal commitment for renewal. Cash flow is very tight and insufficient capital is available to support all farm enterprises at an optimum level. The investment goal is to maximize return on the last dollar invested and the best estimate is that alternatives will return close to $3.00 per dollar. In such a situation, profit is optimized for the individual with very conservative P use. With existing restraints and uncertainties about future land use, it would be unwise to build P levels and the optimum soil test level is estimated at just **8 ppm**.

Crop advisors working with this grower would be wise to assist in removing profit reducing restraints. Removing those restraints would liking involve both the lender and the landlord as more capital is sought and an equitable arrangement is set up with the landlord to share in the costs of land improvement and resulting profits.

Table 1. Examples of the potential range of optimum soil test levels among growers.

Factor	Grower type		
	Average	Irrig.	Renter
Required return ($/$):	1.50	1.10	3.00
Annual interest (%):	9.0	3.0	10.0
Land tenure (yrs):	10	10	3
Buffer potential (lb P2O5/ppm):	18	18	18
Fertilizer price ($/lb P2O5):	0.20	0.18	0.22
Net corn price ($/bu):	2.00	2.30	1.75
Avg Yield Potential (bu/A):	150	200	130
OPTIMUM SOIL TEST (PPM)	21	29	8
MAINTENANCE RATE, (LB P2O5/A)	66	88	57

<u>Soil specific manager.</u> The soil test interpretation approach outlined here is quite applicable to soil specific management. This approach allows the user to establish target soil test levels based on yield potential and soil test P buffer potential for each soil area or grid section. Table 2 is a hypothetical illustration using the soil test P data graphed in Fig. 3. The long term goal would be to minimize the difference between optimum levels and existing levels.

Table 2. Optimum soil test P levels in a grid-sampled field intended for variable rate application.

Soil area	Yield potential	Buffer potential	Soil test level	
			Current	Optimum
	bu/A	lb P_2O_5/ppm	---- ppm ----	
A	160	12	39	24
B	150	18	24	21
C	110	40	9	13

Value of other factors equal to the average grower in Table 1.

Influence of Land Tenure and Acceptable Marginal Return

Except for unusual cases, optimum soil test level is most sensitive to land tenure and acceptable marginal return (Table 3). These factors must be defined or assumed before any reasonable estimate of optimum soil test level can be made. Yield potential is also influential but not as much as land tenure and acceptable marginal return.

Table 3. Impact of land tenure and acceptable marginal return on optimum soil test P levels.

Land	Minimum acceptable marginal return			
Tenure	1.00	1.50	2.00	3.00
Years	--------------	ppm	-------------	
3	17	14	12	10
5	20	17	15	12
10	24	21	19	16
20	26	24	21	18

Value of other factors equal to the average grower in Table 1.

FERTILIZER RATE DETERMINATION

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 is 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). In this approach, the amount of P that must come from fertilizer is estimated as the difference in P content between the crop yield expected without P application (from the calibration curve) and the P uptake of a crop at its full yield potential. Fertilizer P to apply is calculated by dividing the resulting number by the expected first year fertilizer P recovery assumed for the placement method planned. The rate vs soil test level relationship is defined such that the rate needed for maintenance is recommended at the optimum soil test level.

SUMMARY

The soil test interpretation paradigm may need to be shifted to better accommodate the more sophisticated needs of today's growers and crop advisors. The new model needs to recognize the short term limitations of soil tests and the residual effects of P additions while allowing for personalization at the local level. Thus, a long-term approach to P management seems most appropriate that focuses on an economically defined optimum soil test level. Land tenure and acceptable marginal return are critical factors when such an approach is used.

Much of the personalization discussed here has been taking place for many years as growers and local experts mold the fertility program recommended by a lab into an action plan that seems most appropriate. The approach outlined here uses computer technology and simple spreadsheets to systematically facilitate local fine-tuning in a manner that is easily documented. It also shows the linkage between research data and fertility management decisions and reveals all the assumptions in between. That revelation in itself can be very helpful in directing future research efforts to strengthen the weak links in the process.

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