Residual Effects of P Fertilization Lessons for the Eighties[1]

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Several states in the North Central Region have established long-term phosphorus studies. These experiments were designed to evaluate the residual effects of P fertilizer and also generate P soil test calibration data in a situation where a range of soil test levels exist on one soil. These data are extremely useful for evaluating year-to-year fluctuations in crop response to soil test P and establishing response probabilities at a given soil test level. Valuable lessons can also be learned from such studies that relate to short-term and long-term P management decisions.

METHODS

The long-term P study in South Dakota is located on the Southeast Experiment Farm near Beresford. The soil is classified as an Egan silty clay loam (*Udic haplustoll*). These are deep, friable, well-drained soils developed in a silty cap over glacial till. From 1964 to 1967 five rates of P (0, 10, 20, 40, and 80 lbs P/A) were broadcast and plowed down annually to establish a range of soil test levels. Varioux crops have been grown in the study with the major ones being corn and alfalfa. A couple years of soybeans and sorghum were included over the 22-year period. Since 1982 the study has been planted to corn and moldboard plowed each fall.

RESULTS AND DISCUSSION

General soil test changes

Table 1 shows the changes that have occurred in selected soil test properties over the past 22 years. Soil pH (0-4") has declined from 6.0 to 5.4 and may be at a point where a small response to lime addition could be seen. These soils normally must be quite low in pH before lime response is measured due to high subsoil pH and abundant exchangeable cations with limited exchangeable or soluble aluminum at any given pH level. Organic matter has remained constant while ammonium acetate extractable K has declined 150 lbs/A (still interpreted as very high).

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Table 1. Changes in soil test results over 22 years.

Year	pH	Organic Matter	Bray & Kurtz No. 1 P	NH_4OAc K
		%	lbs/A	
1964	6.0	2.7	16[1]	597
1986	5.4	2.8	15[2]	455

Depth 0-4". [1]Rep 4 excluded. [2]Check plots only.

Initial soil test P averaged 16 lbs/A for reps 1 to 3 and measured 17, 14, 16, and 27 lbs/A for reps 1 through 4, respectively. Part of rep 4 is a Tetonka soil (Argiaquic argialboll) with a lower pH and with considerably more P initially. The check plot from this rep had dropped to the level of the other reps by 1973. Essentially no change in soil test P levels occurred over the 22-year period for three of the four reps.

Fertilizer effects on soil test P

Soil test P levels following the four fertilizer applications of 1964 to 1967 reflected the amount of fertilizer added (Fig. 1). Check plots showed very little change in soil test P over the 22 years. Soils of this type have an apparent "equilibrium" level of Bray and Kurtz No. 1 extractable P in the 10-15 lb/A range. Once this range is reached, additional draw down seems negligible.

Examination of the draw down curves of Fig. 1 reveals at least two phases of decline following fertilizer addition. An initial phase of more rapid decline that appeared to increase in duration as fertilizer rate increased and a second phase of more gradual decline. The rapid phase lasted about 5 years for the 91 lb rate and increased to at least 16 years for the highest rate.

Table 2 divides the decline rates into soil test categories. The rate of decline increased from 0 in the low category to 5 or 6 lbs/A/year in the very high categores. Although the absolute rate of decline increased wth soil test level, the relative rate remained nearly constant at approximately 8% when soil test was above the "equilibrium" level. This is a useful figure for estimating decline rates on similar soils where decisions are being made concerning the consequences of reducing or ommitting P fertilization for a short period of time (ie. cash flow problems).

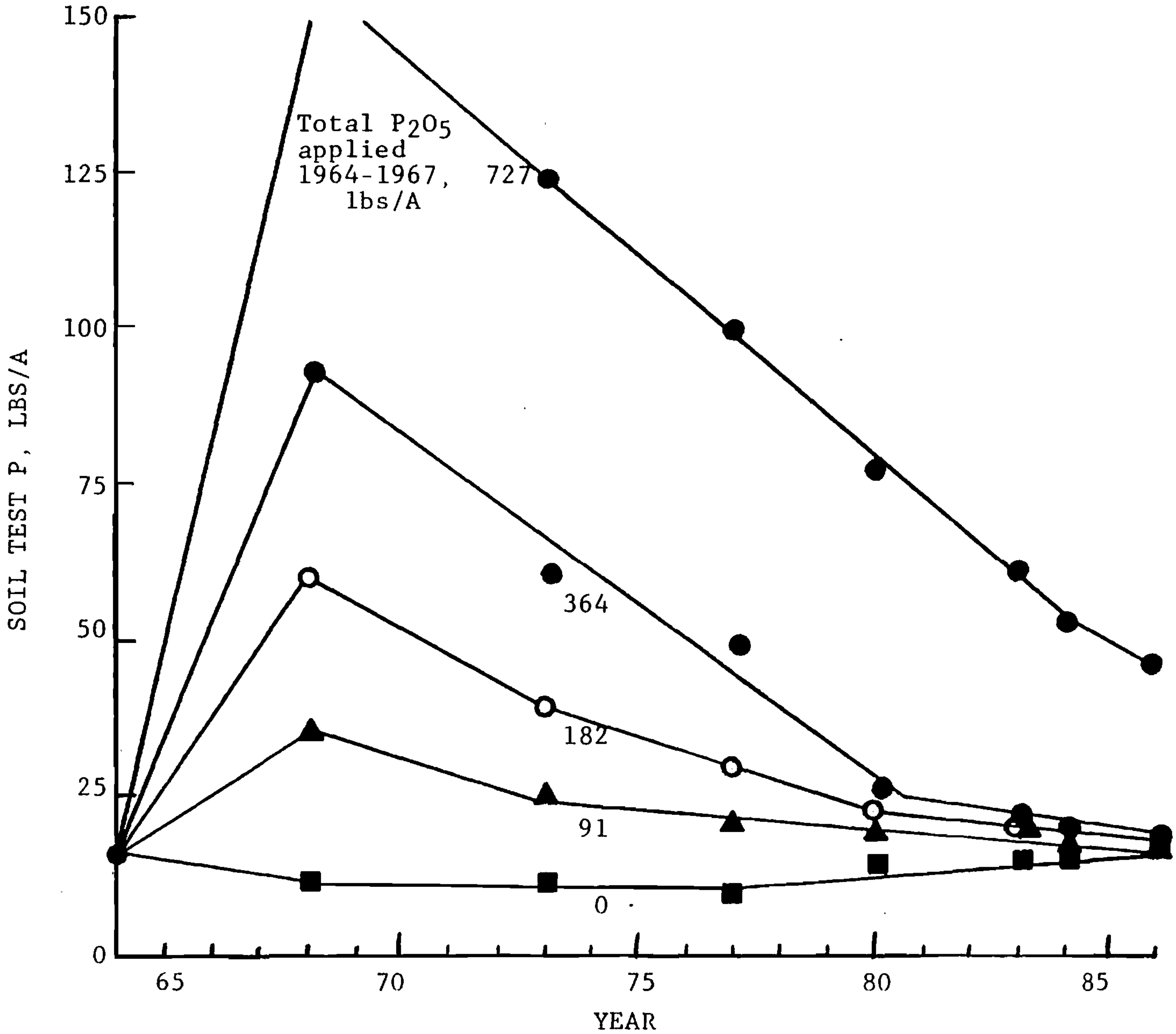

FIG. 1. Influence of fertilizer and time on soil test P levels for an Egan soil.

Table 2. Influence of soil test level on rate of decline of Bray and Kurtz No. 1 extractable P.

S. Dakota category	Soil test level	Annual soil test decline		Drop over 5 years
	lbs/A	lbs/A	%	lbs/A
Low	6-14	0	0	0
Medium	15-25	1.4	7	7
High	26-40	3.0	9	15
V. High	41-80	5.2	9	26
V. High	80-120	6.4	6	32
		Avg. =	8%	

[1] 13-year period 1968-1980.

Consequences for maintenance recommendations

These data can be combined wth data from other long-term P studies from the North Central Region to determine the fertilizer input required to maintain soil P test levels. A commonly accepted belief is that application of a P rate equivalent to the P removed in the harvested portion of the crop will maintain soil test P at its current level. This study and many others have shown that a level of 10-15 lbs/A can be maintained for several decades with no P fertilizer input. Therefore, removal and maintenance cannot be universally equivalent.

The relationship between soil test level and maintenance requirement in terms of crop removal is illustrated in Fig. 2. These data were calculated by the author from studies conducted in Illinois, Indiana, Iowa, Kansas, Minnesota, Nebraska, and South Dakota. In situations where P uptake was not measured, it was estimated at 0.375 lbs P_2O_5/bu for corn and 0.80 lbs P_2O_5/bu for soybeans. Clearly the maintenance requirement is not constant and varies from zero to approximately 100% of removal. In the 30 to 35 lb/A range about 50% of removal was required to maintain the initial P soil test. These data illustrate that when soil test levels for acid or near-neutral soils of medium or fine texture in our region test below 40 lbs/A of Bray and Kurtz P, P rates less than removal are required for maintenance. In other words, application of rates equal to removal should build up, not maintain, soil test P.

The relationship between soil test level and rate of decline and between soil test level and maintenance requirement may seem contradictory. They are not. A soil at a very high soil test level contains a considerable amount of P in unstable forms and has a high degree of supersaturation relative to several inorganic forms. Therefore, adsorbtion reactions that result in strongly

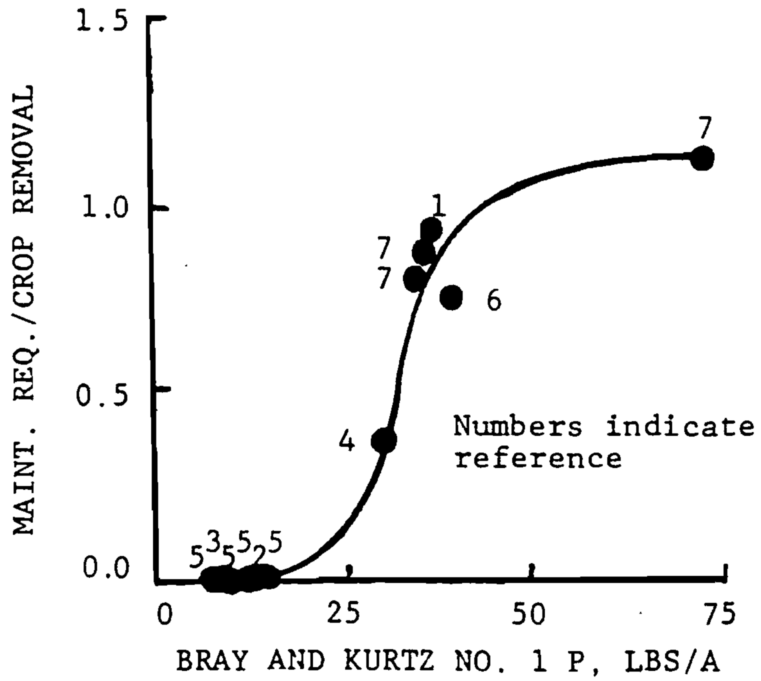

FIG. 2. Influence of soil test P level on maintenance requirements for acid and neutral soils.

bonded P, and precipitation reactions proceed more rapidly and the soil test level drops rapidly. However, in the same soil, more of the high energy bonding sites are already occupied by P and addition of more P results in a greater increase in soil test P. That is why the fertilizer P required to raise a soil test by a given amount tends to decrease as the soil test level increases.

Consequences for short-term vs. long-term soil test P Management

Long-term studies of this type illustrate the high degree of buffering our soils show for P. Because soil P tests don't change markedly from one year to the next, it is frequently suggested that if an individual doesn't have adequate capital to invest in all the fertilizer needed, P can be cut back before N. This study can be used to illustrate the potential long-term consequences of continually underapplying P.

Yield response and grain moisture effects are shown for 1985 in Fig. 3. The difference in grain yield between a 15 lb/A and 32 lb/A soil test level was 12 bu/A. Grain moisture at harvest declined 1.7% from the 15 to the 32 lb/A level. The profitability of this response is illustrated in Table 3. Using typical corn prices and drying costs for 1985, the value of the response was $33. Assuming it takes 9 lbs P_2O_5/lb of soil test level increase and $0.22/lb of P_2O_5, the cost of the soil test increase was $34. Essentially the entire cost of buildup was paid for in one growing season. Responses in other years would be nearly 100% profit (interest charges would need to be covered) on the fertilizer investment.

Table 3. Profitability of soil test P responses in 1985.

Grain yield response, bu/A	12
Grain moisture reduction, %	1.7
Grain value increase[1]	$24.00
Grain drying savings[2]	$ 8.91
Total value of response	$32.91
Estimated cost of soil test increase[3]	$33.66

[1] $2.00/bu.
[2] ($0.04/bu/%) x 131 bu/A.
[3] (32 lbs/A - 15 lbs/A) x 9 lbs P_2O_5/lb of soil test level = 153 lbs P_2O_5; 153 lbs x $0.22/lb = $33.66.

SUMMARY

Long-term P experiments can be used to predict the consequences of fertilizer P management decisions. Studying the data generated by these studies will improve our ability to predict and therefore enhance credibility and the accuracy of our recommendations. These studies also demonstrate the need for separating short-term emergency management practices from long-term planning for successful crop management programs that maximize profit over the long-term.

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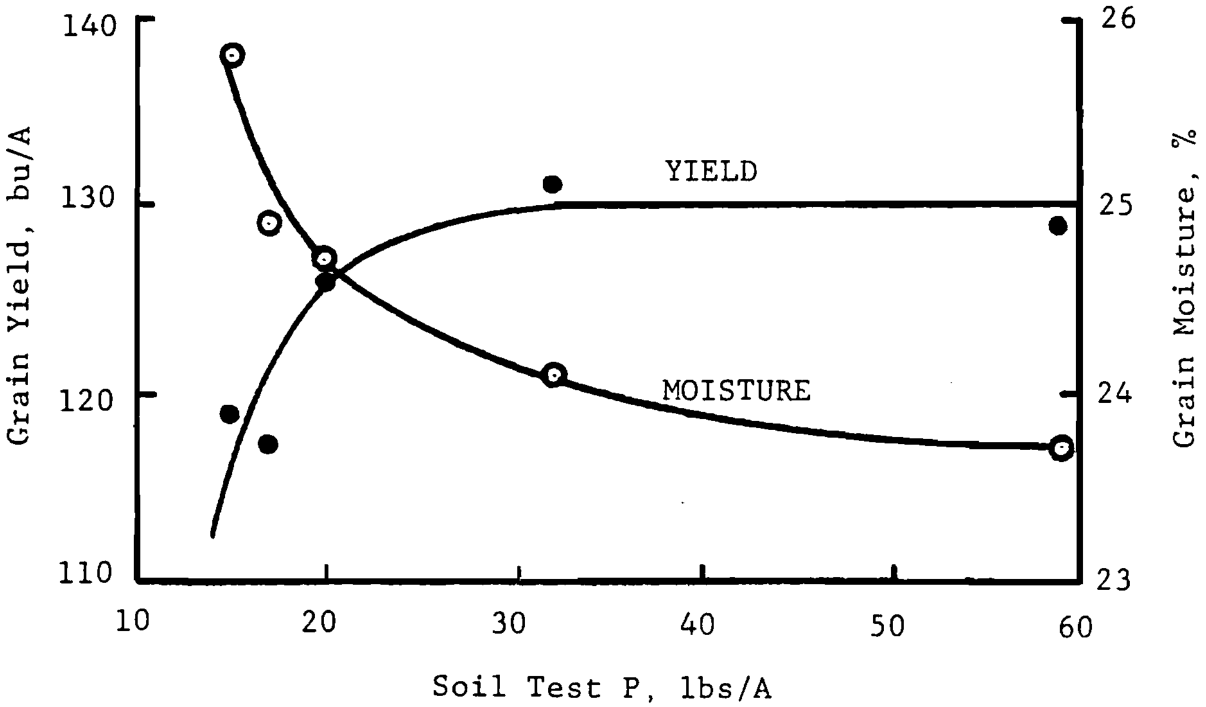

Fig. 3. Influence of soil test P level on grain yield and grain moisture content, 1985.

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