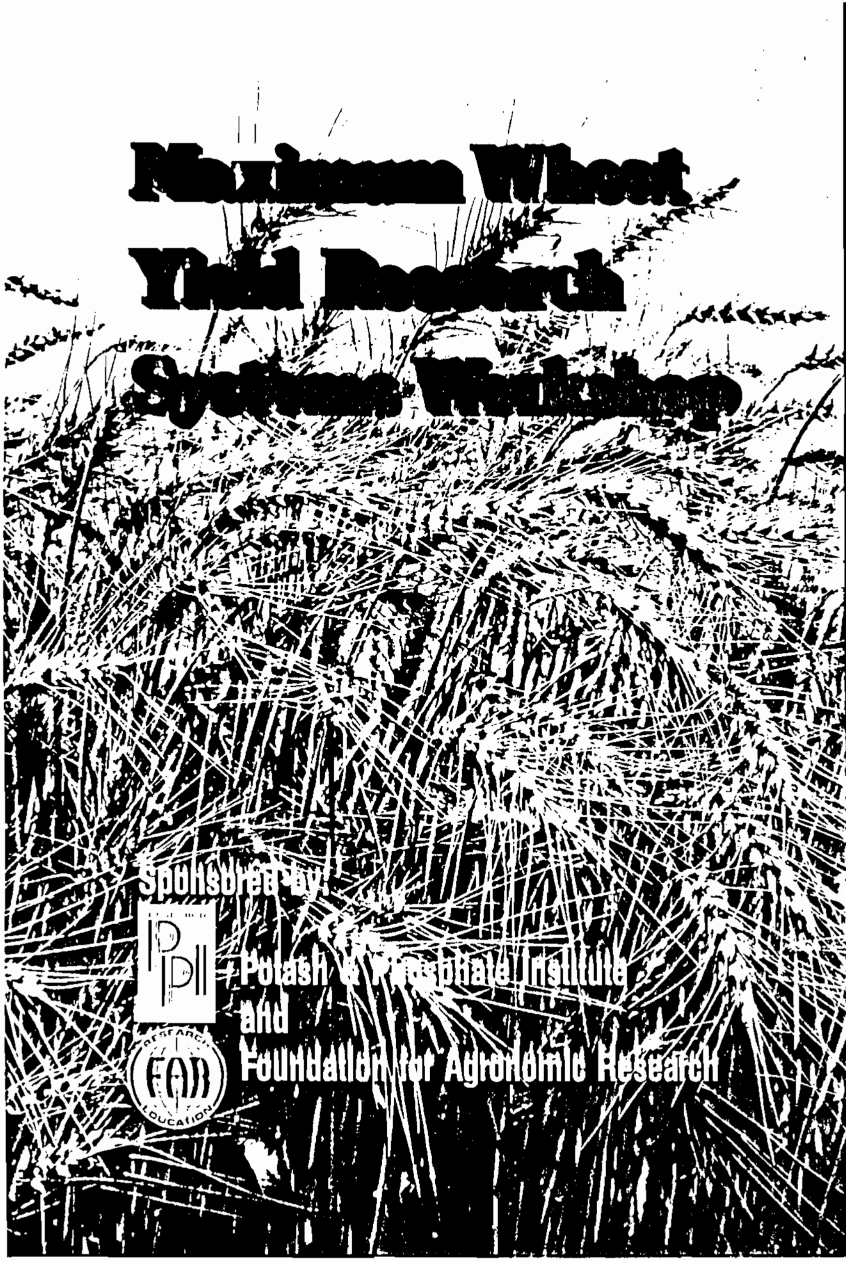
Maximum Wheat Yield Research Systems Workshop



Sponsored by:

Potash & Phosphate Institute

and

Foundation for Agronomic Research

March 5-7, 1986 • Clarion Hotel • Denver, Colorado

SOIL TEST AND P RATE RELATIONSHIPS TO MAXIMUM YIELD: WEST[1,2]

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ABSTRACT

The purpose of this paper is to examine the relationship between soil test P level and the maximum yield potential of wheat grown on the calcareous soils of the western U.S. and Canada. The sodium bicarbonate soil test (Olsen test) for P is the main soil test evaluated in this paper. Data from several long-term P fertility studies with wheat were used to develop the relationships between soil test P level (0 to 6 inch depth) and yield potential. Using curvilinear regression, an estimated soil test level of 26.9 ppm P is needed to achieve 100% of the yield potential of wheat in a wheat-fallow system. An estimated soil test level of 20.8 ppm P is needed to achieve 100% of the yield potential of wheat in an annual cropping system. Using the Cate-Nelson Graphical approach, a critical soil test P level of 16 ppm is estimated for wheat grown in both the crop-fallow and annual cropping systems. The 16 ppm critical level was at a 93% yield potential for the wheat-fallow system and a 98% yield potential for the annual cropping system. These critical levels are in agreement with critical levels now being used by many of the University Soil Testing Laboratories. A fertilizer P management system for optimizing wheat yields is proposed: a) Broadcast and apply sufficient fertilizer P to bring the soil test P level in the 0 to 6 inch soil depth up to 16- to 20-ppm; and b) Apply sufficient fertilizer P each crop year thereafter to maintain the soil test P level at 16- to 20-ppm.

INTRODUCTION

Many of the soils in the Great Plains area are deficient in plant-available P for optimum wheat production (Potash and Phosphate Institute Staff, 1985). Therefore, accurately assessing the level of available P in the soil and determining the quantity of P fertilizer to apply to alleviate any P deficiency becomes very important. The objective of this paper is to examine the relationship between soil test P level and the yield potential of wheat.

Several long-term P fertility studies have been conducted in the northern Great Plains and served as the source of data for

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[1] Contribution from the USDA, Agricultural Research Service, P.O. Box K, Akron, Colorado 80720.

[2] Proceedings Maximum Wheat Yield Systems Workshop, March 6-7, 1986, Denver, Colorado. Sponsored by Potash and Phosphate Institute.

the relationships developed in this paper. Only data from those studies that had applied sufficient fertilizer P to raise the soil test level above at least 16 ppm were used. The fertilizer P in all cases was broadcast applied and was incorporated to a depth of 3 to 6 inches. By using those studies where the residual value of fertilizer P was evaluated, I could find data that provided a range of soil test P levels from deficient to more than adequate as well as corresponding wheat yield data. Numerous approaches to interpreting soil test information are available (Dahnke, 1985). Curvilinear regression and the Cate-Nelson Graphical Method (Nelson and Anderson, 1977) were used in this paper to estimate the level of soil P needed to attain optimum wheat yields.

SOIL TEST P vs. WHEAT YIELD POTENTIAL

Wheat-Fallow Cropping System

The relationship between soil test P and relative yield potential shown in Figure 1 was developed from the data of Black (1982) and Halvorson and Black (1985). Only data from P treatments receiving 40 and 80 lb N/acre each crop year were used in this analysis in order to eliminate N deficiency as a variable. This study was conducted on a glacial till, Williams loam soil and provided a range in soil test P values from 5.4 to 40.2 ppm collected over a period of 12 years. A hyperbolic function provided the best fit line (r = 0.92) to this data:

$$Y = 110.5 + (-282.8/X)$$

where Y = relative yield potential (%) and X = soil test P level (ppm) in the 0 to 6 inch soil depth. Using this relationship, a soil test P level of 26.9 ppm in the 0 to 6 inch soil depth would be needed to obtain 100 % of the yield potential. This is considerably higher than most soil testing laboratories would use for making P fertilizer recommendations. Soil test calibration data from the South Dakota State University Plant Science Department supports this soil test level (personnel communication with Dr. Paul Fixen, Plant Science Dept., SDSU). Their soil test calibration data shows that a soil test level of about 25 ppm P is needed to achieve 100% yield potential when using a Mitscherlich function to evaluate the relative yield data as a function of soil test P compared to a critical level of 13.8 ppm P at 89 % relative yield potential for wheat when using the Cate-Nelson approach. Preliminary results of a region wide (multi-state area) effort of the NCR-13 Committee on calibration of P soil tests shows similar high soil test P levels needed to attain maximum yield potential.

When using the Cate-Nelson Graphical Method (Nelson and Anderson, 1977) to determine a critical soil test level, a value of 16 ppm P was estimated to be needed to obtain a 93% relative yield potential (Figure 2). This value is in close agreement with many of the University Soil Testing Laboratories located in the Great Plains (ND, MT, CO). Using the hyperbolic function given above, a soil test level of 16 ppm would have an estimated 93% yield potential. Therefore, both methods for interpreting a critical soil test P value are in close agreement for the wheat-fallow system.

Annual Cropping Systems

Data from Halvorson and Black (1985), Wagar et al. (1986), Bailey et al. (1977), Read et al. (1977), Ridley and Tayakepisuthe (1974), and Alessi and Power (1980) were used in developing the relationship between soil test P and relative yield potential shown in Figure 3. Soil textures ranged from clay loams to sandy loams. A good range in soil test values (1.8 to 66.5 ppm P) with corresponding yields was obtained. A hyperbolic function gave the best fit line (r = 0.83) to the soil test P vs. relative yield data plotted in Figure 3. The equation was:

$$Y = [X/(1.845 + 0.911*X)]*100$$

where Y = relative yield potential (%) and X = soil test P level (ppm) in the 0 to 6 inch soil depth. The four data points that are circled were excluded from the regression analysis because they tended to move the regression line to much to the right. A soil test level of 20.6 ppm would be needed to obtain 100% of the yield potential. This is slightly less than the 26.9 ppm P level needed for maximum yield potential in the wheat-fallow system. This should probably be expected since yields under recrop conditions are generally slightly lower than those obtained with a wheat-fallow system. Soil water supply under annual cropping conditions may be slightly less than with wheat-fallow, which may account for the slightly lower yields with annual cropping when N has been adequately supplied. Thus with a lower yield level, the need for P is slightly less. North Dakota State University (Dahnke et al. 1985) makes P fertilizer recommendations for wheat based on soil test value and expected yield level, with more P fertilizer being recommended for increasing yield level.

The Cate-Nelson Graphical Method was also use to estimate a critical soil test P level for the annual cropping system (Figure 4). A critical level of 16 ppm P with a 98% yield potential was estimated using this method. This is the same critical level estimated for the wheat-fallow system (Figure 2) with a yield potential of only 93%. Thus is would appear that a higher level of available P would be needed in a crop-fallow system to attain maximum yield potential than in an annual cropping system.

The Cate-Nelson approach estimates a soil test P level of at least 16 ppm is needed to obtain optimum wheat yields in either the wheat-fallow or annual cropping systems. This agrees with the original work of Olsen et al. (1954) in developing the sodium bicarbonate soil test. They also found that when the soil test level reach about 18 ppm P, no responses to fertilizer P were obtained. However, the data presented in Figures 1 and 3 shows that to attain maximum wheat yield potentials, critical soil test P levels above 20 ppm may be required.

Phosphorus Fertilization

Method and rate of fertilizer P application can greatly affect the response of wheat to P fertilization (Leikam et al. (1983), Bauer et al. (1970), Wagar et al. (1986), Read et al. (1977), Alessi and Power (1980). If low rates of fertilizer P are to be applied to soils testing "low" in plant-available P, then banding the fertilizer P below or with the seed is generally more efficient and results in greater yield increases than broadcast P applications. However, if sufficient fertilizer P was to be added to attain maximum wheat yields on a soil testing "low" in P, then method of placement may not be as critical. The recent work of Wagar et al. (1986) supports this theory. They found that a single, broadcast P application of 80 kg P/ha had a greater cumulative yield after 5 years than 20 kg P/ha applied each crop year with the seed. Thus the broadcast treatment produced at or near optimum yields each year whereas the seed place P treatment produced at less than optimum yield potential during the first several years. They also found that a combination of a residual 40 kg P/ha broadcast one time plus 10 kg P/ha applied each crop year with the seed produced near maximum wheat yields. The latter treatment would be desireable from the stand point of spreading the P fertilizer costs out over a longer time frame and still being able to maintain near maximum yield potential.

Based on the studies of Wagar et al. (1986), Read et al. (1977), Jose (1981), and Alessi and Power (1980), I would like to suggest that the following P management system be used to optimize wheat yields in the Great Plains and western U.S.:

a) Broadcast and incorporate sufficient fertilizer P to bring the soil test P level up to 16- to 20-ppm in the 0 to 6 inch soil depth.
b) Apply sufficient fertilizer P by banding, with or below the seed, each crop year thereafter to maintain the soil test P level near 16- to 20-ppm. A broadcast P application would probably produce equal results in a conventional tillage system, but banding would be preferred for reduced tillage systems.

This approach to P fertilization would probably provide the potential for optimum and near maximum wheat yields each crop year. In dry years, a high level of soil P will not hurt yields and in the wet years, a high level of soil P will provide that opportunity to utilize more efficiently the available water supply, providing that N is not limiting.

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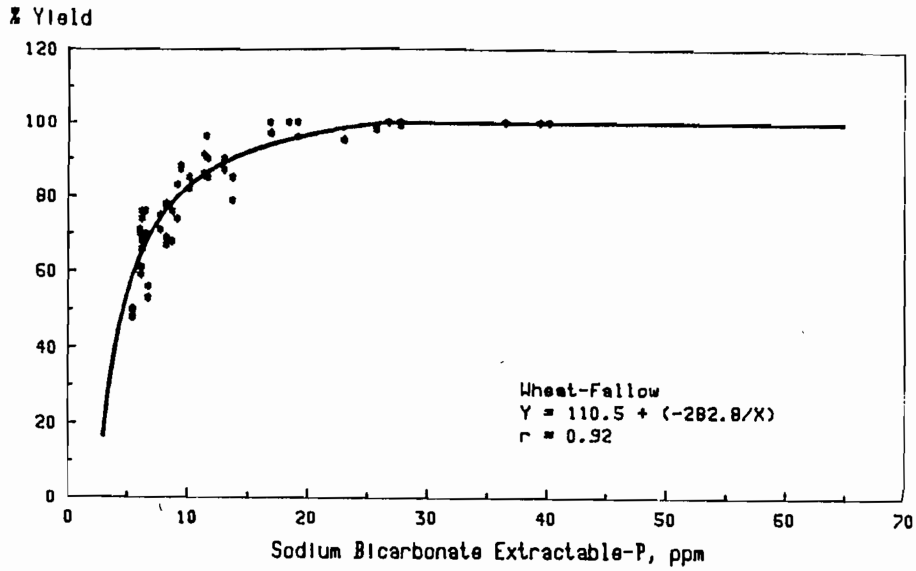

Figure 1. Relative yield potential as a function of soil test P level in a wheat-fallow system expressed as a hyperbolic function.

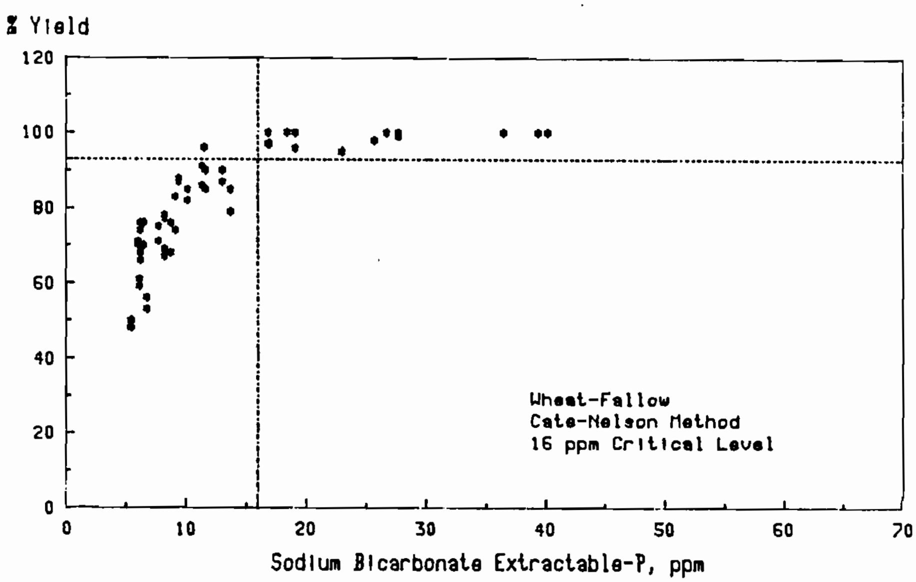

Figure 2. Use of the Cate-Nelson Graphical method to estimate a critical soil test level for P in a wheat-fallow system.

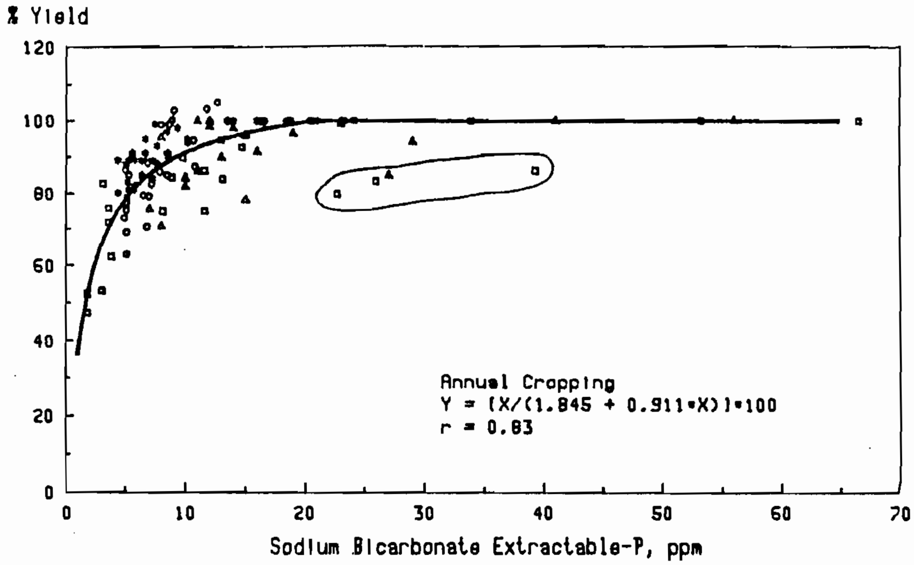

Figure 3. Relative yield potential as a function of soil test P level in an annual cropping system expressed as a hyperbolic function.

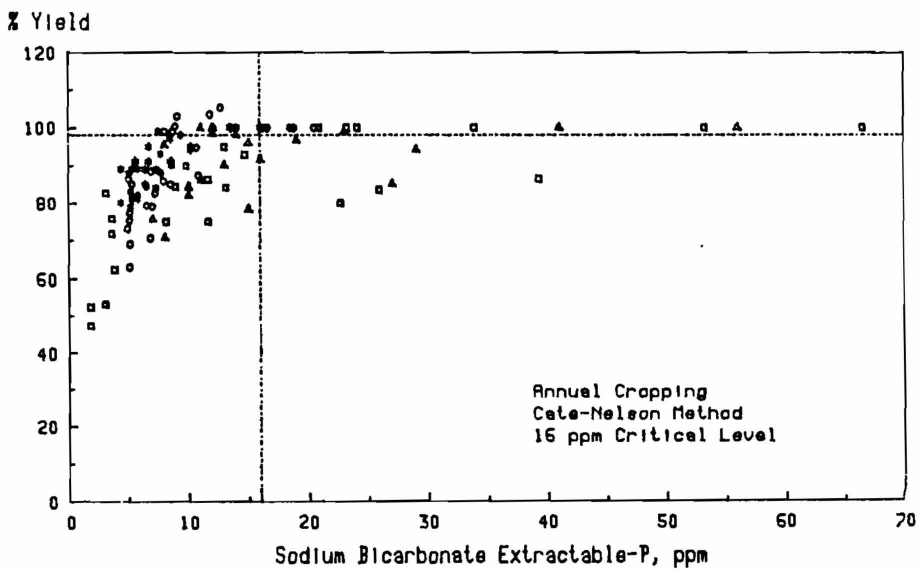

Figure 4. Use of the Cate-Nelson Graphical method to estimate a critical soil test level for P in an annual cropping system.