LONG-TERM EFFECTIVENESS OF A SINGLE BROADCAST APPLICATION OF P FERTILIZER [1,2]

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INTRODUCTION

Soils in the northern Great Plains are inherently low in plant-available phosphorus (P). Therefore, dryland crops grown in this area generally respond to P fertilization (1, 2, 3, 4, 10). Application of both N and P fertilizer often results in a positive N-P interaction that increases grain yields more than if either N or P is applied alone (5, 6). Several short term studies have shown the residual effects of P fertilization on crop yields and P uptake (1, 2, 7, 8, 9, 10). Most of these studies were conducted for periods of less than 8 years. Information from longer-term P fertilizer studies is limited.

Research was initiated in 1967 to determine the long-term effectiveness of a single broadcast application of P fertilizer as measured by dryland crop growth response. The purpose of this paper is to provide a brief summary of (a) changes in $NaHCO_3$-extractable P levels with time and (b) long-term grain yield responses (1967 to 1983) of dryland crops to single broadcast P fertilizer applications under different levels of N fertilization.

MATERIALS AND METHODS

This study was conducted near Culbertson, Montana on a Williams loam soil having an initial $NaHCO_3$-extractable P level of 6.2 ppm. Duplicate sets of plots were established, one in 1967 and one in 1968. The plots were in a spring wheat-fallow rotation for the first 6 crops, then annually cropped (4 or 5 crops). The seventh crop was safflower, the eighth crop was barley, the 9th crop was wheat, and the yield data for the 10th crop represents an average of barley (1967 plot series) and winter wheat (1968 plot series).

A single application of P was made in 1967 or 1968 at rates of 0, 20, 40, 80, and 160 lb P/acre. No further P applications were made for the duration of the study. Nitrogen fertilizer was not applied to the first two crops following harvest of the 6th crop of the crop-fallow rotation because of a build up of residual NO_3-N in the soil profile of the 40 and 80 lb N/acre treatments (data not shown).

A split-plot, randomized complete block design with 3 replications was used. Nitrogen treatments were main plots and P treatments were subplots. Grain yield summaries reported in this paper represent an average of the data collected from the 1967 and 1968 plot series for the first 10 crops. Soil samples were collected from the 0 to 6 inch depth for $NaHCO_3$-extractable P

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[1] Proceedings, Thirty-fifth Annual Summer Fertilizer Conference of the Northwest Plant Food Association, Pasco, Washington, July 17-18, 1984.

[2] Contribution from USDA-ARS, Akron, CO and Mandan, ND.

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analysis in April or May each crop year. Average soil P values for both plot series are reported in this paper. Total P uptake in the grain and straw was determined each crop year from samples collected at harvest of each crop.

RESULTS AND DISCUSSION

Soil Test P Levels

The application of P fertilizer initially increased the $NaHCO_3$-extractable P levels to 9.4, 11.5, 25.7, and 40.2 ppm in the 0 to 6 inch soil depth for the 20, 40, 80, and 160 lb P/acre treatments, respectively, during the first crop year (Fig. 1). The 1983 $NaHCO_3$-extractable P levels were 5.1, 5.8, 7.5, 9.4, and 14 ppm for the one-time 0, 20, 40, 80, and 160 lb P/acre application rates, respectively. The higher the rate of the initial P application, the greater was the rate of decline in $NaHCO_3$-extractable P level with time. The rate of decline in $NaHCO_3$-extractable P level tended to decrease each year with little change occurring after the 7th crop or 13 years after P application. A new level of soil P chemical equilibrium appeared to be developing at planting of the 8th crop.

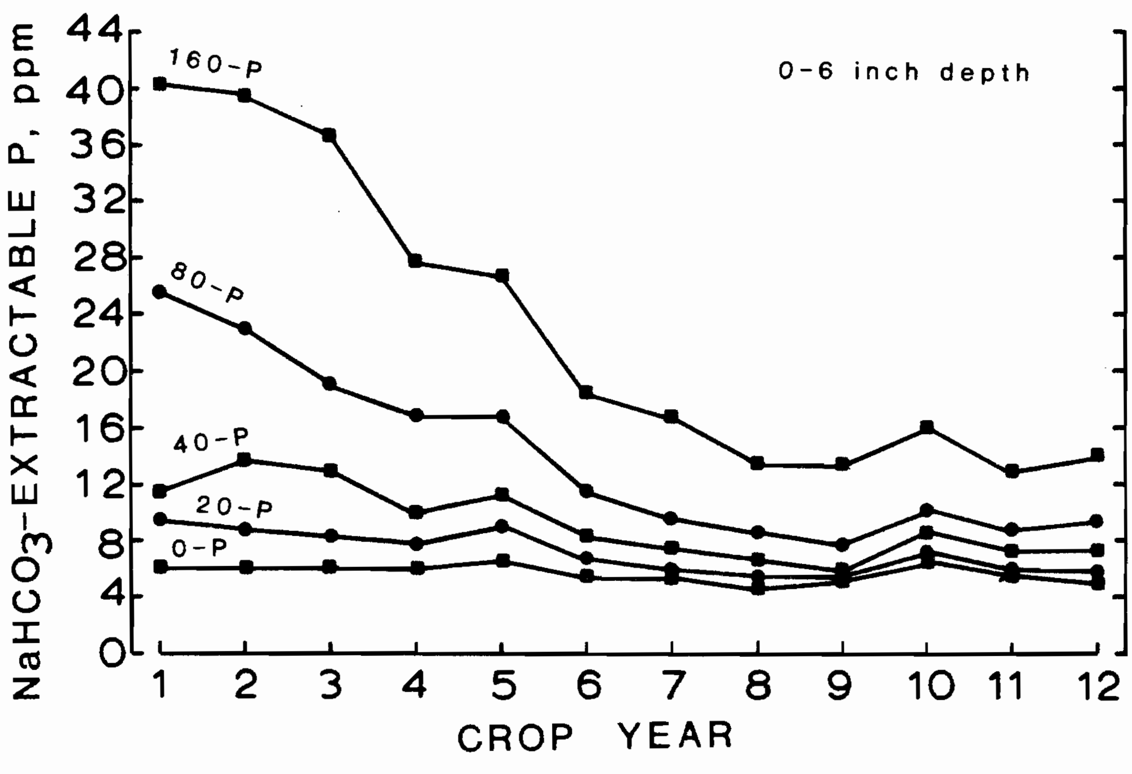

Fig. 1. Soil $NaHCO_3$-extractable P levels each crop year for each P treatment averaged over N rates.

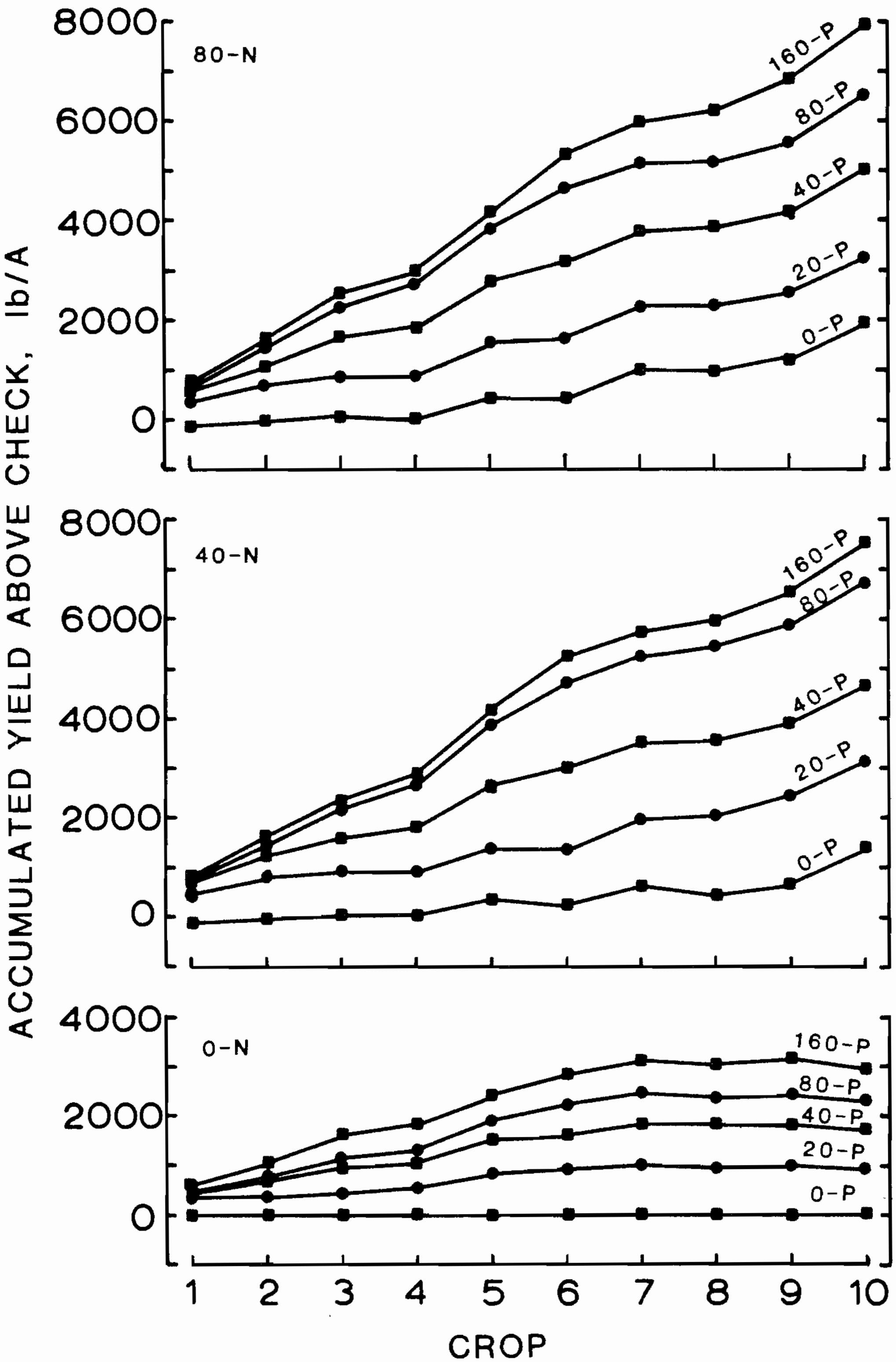

Fig. 2. Average accumulated yield above that of check (no N or P) treatment for the first 10 crops as a function of N and P fertilization.

Accumulative Yields

The accumulated yields above that of the check (zero N and P fertilizer treatment) are shown in Fig. 2 for the various N and P treatments. With each additional crop, differences in accumulated grain yield due to P treatment increased. Application of 40 or 80 lb N/acre resulted in greater differences between P treatments or a significant N-P interaction. No yield increases were observed with increasing residual P levels for the 8th, 9th, and 10th crops when no N fertilizer was applied. In fact, there was a tendency for grain yields to decrease with increasing residual P levels without N fertilization under annual cropping conditions. However, when sufficient N was present, either as residual or applied N, grain yields increased with increasing residual P levels under the annual cropping conditions. In contrast, yield increases due to increasing soil P levels were evident every crop year following a fallow period with or without N fertilization.

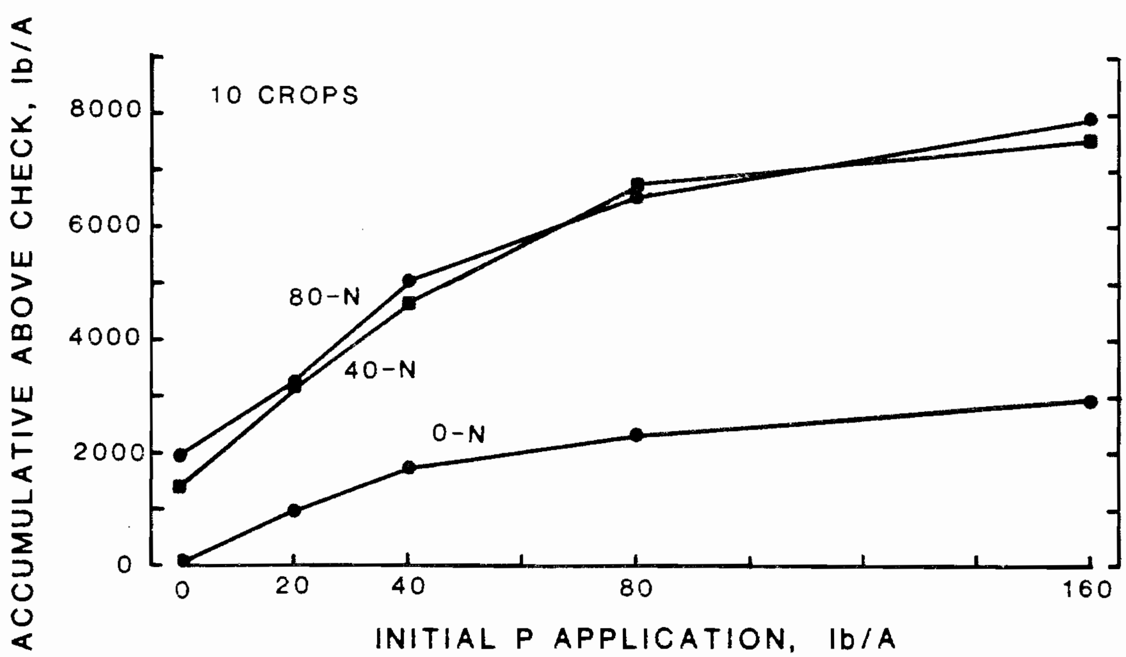

Fig. 3. Total accumulated yield (10 crops) above that of check (no N or P) treatment for the 0, 40, and 80 lb N/acre treatments as a function of P added (only one P application).

Total accumulated yields (10 crops) above that of the check plot (zero N and P) for each of the N and P treatments are shown in Fig. 3. Grain yields for the 40 or 80 lb N/acre treatments did not differ significantly at any P treatment level. Grain yields increased with increasing residual P levels with or without N fertilization (Fig. 3); however, most of the increase without N fertilization occurred with the first 6 crops which were grown following a fallow period (Fig. 2). The significant N-P interaction shown in Fig. 3 demonstrates the importance of having a good balance in available N and P for optimizing grain yields under dryland conditions in the northern Great Plains.

Increases in grain yield due to P fertilization alone were greater following fallow than under annual cropping conditions, 37% compared to 6% for the 80 lb P/acre treatment, respectively. Conversely, increases in grain yield due to N fertilization were greater under recrop than following fallow, 34% compared to 13% for 40 lb N/acre treatment, respectively. The accumulated grain yield after 10 crops was nearly two-fold greater with 40 lb N/acre than with no N fertilizer added.

P Recovery

Phosphorus uptake per crop increased with increasing residual soil P level and with N fertilization (data not shown). Application of 80 lb N/acre did not increase the level of P uptake over that of the 40 lb N/acre treatment. Percent fertilizer P recovery in 10 crops decreased as the level of applied P increased. Phosphorus recovery in grain plus straw after 10 crops averaged 36, 30, 26, and 15% for the 20, 40, 80, and 160 lb P/acre treatments, respectively, with no N added. Adding 40 lb N/acre each crop year, except two, increased the P recovery to 52, 43, 43, and 28% for the 20, 40, 80, and 160 lb P/acre treatments, respectively. Thus, P fertilizer recovery was increased 40 to 80% by the addition of N fertilizer.

Economics

An estimated net dollar return per acre above that of the fertilizer cost was calculated (Fig. 4) using the data shown in Fig. 3 and assuming a grain price of $0.05/lb, a P fertilizer cost of $0.70/lb of P, and $0.27/lb of N applied. Over the 10 crops, 320 and 640 lb N/acre were applied to the 40 and 80 lb N/acre treatments for an estimated total N fertilizer cost of $86.40 and $172.80/acre, respectively. Estimated P costs were $14, $28, $56, and $112/acre for the 20, 40, 80, and 160 lb P/acre treatments, respectively. This economic analysis does not consider the interest on borrowed money, the savings from income tax deductions, and/or other production costs.

A single application of 40 lb P/acre without N fertilization resulted in a net return of $58/acre more income in 10 crops or $5.80/acre more income per year than the no N and no P treatment. Application of either 40 or 80 lb N/acre without P fertilization resulted in an income loss. The 40 lb N/acre plus 80 lb P/acre treatment resulted in the greatest estimated total net return, $194/acre, or an average of $19.40/acre per crop year. The 160 lb P/acre treatment had an estimated accumulated net income of $111/acre when 80 lb/acre was applied each crop year vs $177/acre with 40 lb N/acre each crop year vs $36/acre without N fertilization. These data demonstrate the importance of a balanced N and P fertility program for optimizing economic returns of dryland crops in the northern Great Plains. With continued cropping and no further P application, the 160 lb P/acre treatment with N fertilization would probably become the more economical P treatment instead of the 80 lb P/acre treatment with N fertilization. On the short term, the 40 and 80 lb P/acre treatments would be the more economical.

Results from this study show that benefits from a single application of P fertilizer can be expected for several crop years, especially at rates greater than 40 lb P/acre on soils with low $NaHCO_3$-extractable P levels. A single, high rate application of P fertilizer may be an effective way to satisfy the P needs of crops under reduced and no till conditions for several crop years.

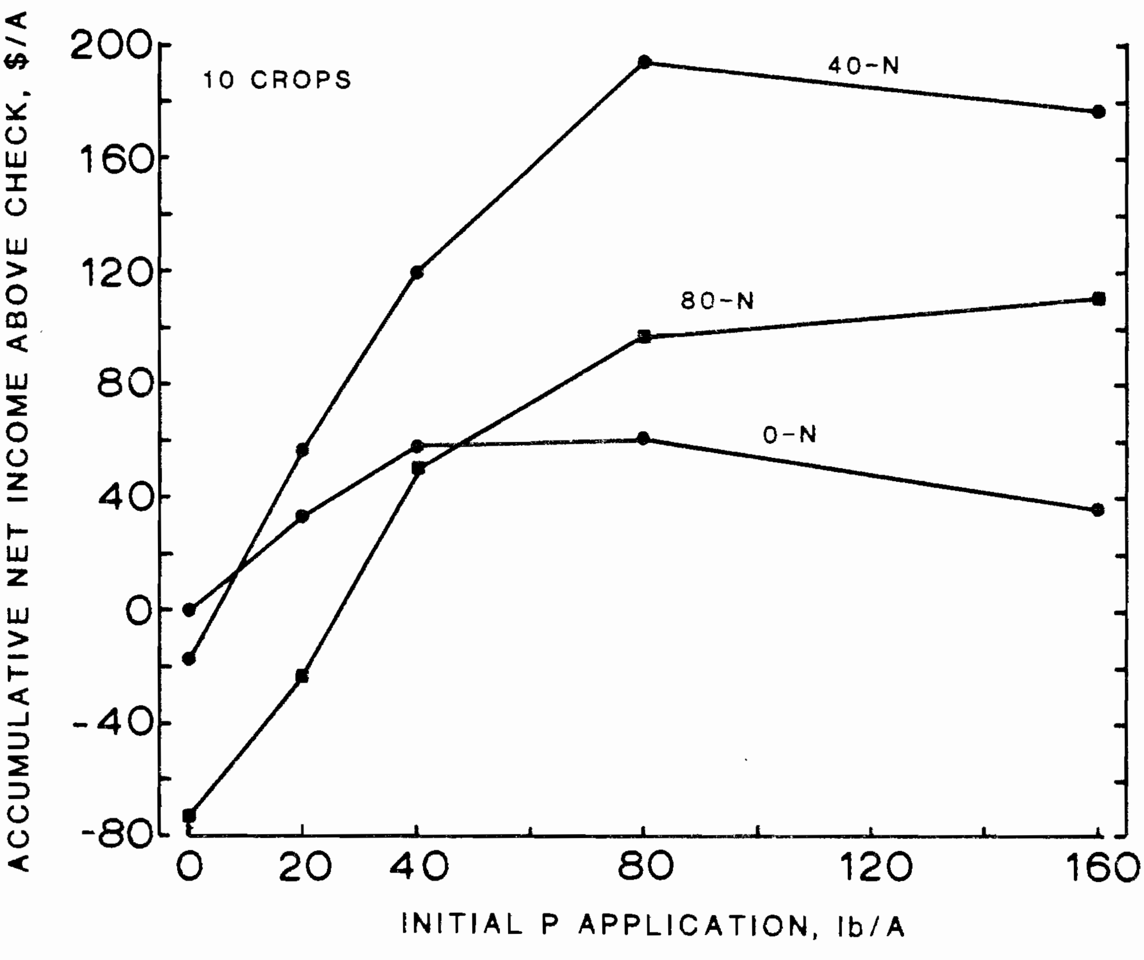

Fig. 4. Estimated accumulated net income above that of check (no N or P) treatment after 10 crops as a function of N and P added.

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