PHOSPHATE MANAGEMENT FOR THE CORN SOYBEAN ROTATION

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Abstract

The evaluation of rate, frequency, and placement of phosphorus (P) fertilizer on production in the corn/soybean rotation was evaluated for two contrasting tillage systems. A primary objective of this study was to evaluate both yield and economic response for the full crop rotation. Tillage systems compared were fall chisel plow and no-till. Application rates ranged from 0 to 92 lbs P_2O_5 ac^{-1} yr^{-1} and were fall applied either annually or at double the rate on a biennial basis. The biennial applications were made in the fall after corn harvest and prior to the soybean crop. Placement variables were fall deep band and fall broadcast. All combinations of tillage, rate, application frequency, and placement were replicated three times in a split-split plot design. Soybean yields increased with increasing P rates in both years and averaged 39.6 bu ac^{-1} in 1995 and 36.7 bu ac^{-1} in 1996. Soybean yields were higher for broadcast applied P than for the fall banded P for the chisel system. Neither tillage nor application frequency affected soybean yields. Corn yields also increased with increasing rates of applied P and averaged 97 bu ac^{-1} and 141 bu ac^{-1} for 1996 and 1998 respectively. Corn yields were not different between tillage practice, application frequency, or P placement. Although tillage did not affect yields of individual crops, it did affect economic return over the full rotation with the chisel plow system having a higher return on the P fertilizer cost than the no-till system. Broadcast applied P had an economic advantage to band applications for the full rotation, regardless of tillage. There was no difference in economic return for the biennial and annual application frequencies.

Introduction

The corn-soybean rotation is the dominant farming enterprise in the northern and western Corn Belt. Both corn and soybean respond to phosphorus fertilization on soils low in extractable phosphorus. This response is affected by many factors such as application rate, frequency, and placement. In some cases, the ideal phosphorus management practices differ for the corn and soybean crops and for different soil types and tillage practices. Many phosphorus response studies have focused on a single crop, while less has focused on phosphorus management for the entire corn-soybean rotation. This four-year study evaluates the phosphorus response of corn and soybeans in rotation under a variety of management scenarios. Yields are compared for different phosphorus application rates under combinations of two tillage practices (chisel plow and no-till), two application frequencies (annual and biennial), and two placements (fall broadcast and fall deep banded). In the corn soybean rotation, P is commonly applied prior to corn, allowing the soybean crop to use the residual. This study evaluates biennial P applications applied prior to soybean.

Approach

This study was conducted at the West Central Research and Outreach Center at Morris, Minnesota. The soil is a Barnes Loam with initial soil pH of 7.8, Olsen extractable P concentration of 2.3 ppm, and extractable K of 166 ppm (ammonium acetate). Fertilizer treatments were initiated in the fall of 1994 following the harvest of the previous corn crop. Soybeans were planted in 1995 and alternately rotated with corn in subsequent study years. Both corn and soybeans were planted in 30 inch rows.

The study is a complete factorial, split-split plot design with tillage as the main plots (chisel plow or no-till), P application frequency as the split plots (annual or biennial), and combinations of P application rate and placement as the split-split plots. Application rates evaluated were 0, 23, 46, 69, 92 lbs P_2O_5 ac^{-1} yr^{-1} and each rate was either fall broadcast applied or fall deep banded on an annual or biennial basis. When the banded application was used, the band was placed at a depth of 4 inches below the soil surface with a coulter and knife assembly on 30 inch centers. At this depth, the band was likely disturbed by the chisel plow treatment. Broadcast-applied P was incorporated with the chisel plow, but remained on the surface for the no-till treatment.

Crop management practices besides P application were performed for high yield and uniformity. Soybeans were seeded at a rate of 70 lbs ac^{-1} with Lambert soybean on May 26,1995 and Hendricks soybean on May 16,1997. Corn was seeded at a rate of 30,100 seed ac^{-1} with DK-442 on May 24, 1996 and with Pioneer 38W36 on May 5, 1998. Anhydrous ammonia was sidedressed to corn on June 11, 1996 at a rate of 120 lbs N ac^{-1} and was fall applied prior to the 1998 corn crop at 130 lbs N ac^{-1}.

Grain yield was measured annually and is reported at 13% moisture for soybean and 15.5% moisture for corn. In 1996, corn ear leaf samples were taken at silking and analyzed for P content. Soil samples (0-6 in.) were taken in the fall of 1998 to assess changes in soil extractable P content (Olsen).

Results and Discussion

Soybean Yields

Soybean yields in 1995 averaged 39.6 bu ac^{-1} (C.V.=19%) over all P rates and treatments and yields increased with increasing phosphorus application rate (Fig. 1). In 1997, soybean yield averaged 36.7 bu ac^{-1} (C.V.=21%) and increased with P application rate (Fig. 1). Neither tillage practice (p=0.260) nor application frequency (p=0.250) had a significant effect on soybean yield in either year. For the soybean years, the application frequency variable actually represented a difference in rate, since both annual and biennial applications were made prior to soybeans. Broadcast-applied P resulted in higher yields than the banded treatment for the chisel plow system, but not for no-till (Fig. 2). This observation is supported by a significant tillage by placement interaction (p=0.036). Other research has shown no yield advantage for banded P application for soybean in tilled soils (Ham and Caldwell, 1978).

Corn Yields and Tissue P Concentration

Average corn grain yields for all treatments was 97 bu ac^{-1} in 1996 and 141 bu ac^{-1} in 1998. Although the two years differed widely in average yield due to different weather conditions, there was a significant increase in yield with increasing rates of P for both 1996 and 1998 (Fig 3). Application frequency did not affect corn yield (p=0.724). This suggests that there was no reduction in yield when corn was managed with residual P from a biennial application compared to an annual application. The tillage by application frequency interaction was also not significant (p=0.110). However, there was a trend of lower average yields for biennial compared with annual application for the no-till system and not for the chisel plow system. Other research has shown that biennial P applications prior to corn resulted in similar soybean yields to an annual application (Randall et al., 1997; McCallister et al., 1987). Those results, combined with results of this study suggest that biennial P applications could be made prior to either crop in the corn-soybean rotation.

Tillage did not affect corn yields in either year. Similarly, there was no significant effect of P placement on corn yield (p=0.301). This differed from the expectation that band applying P would produce higher corn yields than a broadcast application for the no-till managed soil. Corn yields averaged for the no-till system in this study were 118 bu ac^{-1} and 122 bu ac^{-1} for the band and broadcast treatments respectively and there was not a tillage by placement interaction (p=0.295).

Ear leaf samples were collected at silking in 1996 to monitor the effect of treatment on P uptake by corn. The effects of the various treatments on the P concentration in ear leaf tissue were similar to the effects of these treatments on grain yield (Table 1). The P concentration in ear leaf tissue increased with rate of phosphate applied (Figure 4). The average P concentration in ear leaf tissue was 0.196% and 0.189% for the chisel plow and no-till systems respectively. Differences in P concentration due to tillage were not significant. However, data in Table 1 suggests that ear leaf P content was higher for the chisel plow system than for the no-till system for the biennial P application. Placement of P had no significant effect on ear leaf P concentration for either tillage system.

Changes in Soil Test P

Soil samples (0-6 inches) were collected following harvest in 1998 and analyzed for P content. Table 2 shows the effects of tillage and application frequency on soil P change for the 46 lbs P_2O_5 ac^{-1} yr^{-1} application rate and the broadcast treatment. For both tillage systems, the annual application rate resulted in a higher level of extractable P after corn harvest than the biennial applications. These differences were greatest in 1996 when corn yield was low relative to the 1998 season. Extractable P from soil sampled in the fertilizer band was similar to the broadcast treatment. Soil test P also increased with increasing rates of P application (data not shown).

Economics of P Application

An economic comparison of the P management approaches evaluated in this study was made to compare treatment effects on the entire rotation. For this comparison, corn and soybeans were valued at \$2.00 and \$5.00 per bushel, respectively. The value of the phosphorus fertilizer was placed at \$0.25 per pound of P_2O_5. The economic comparison was made by determining the value of the yield increase for each treatment relative to the control and comparing it with the cost of the P_2O_5 applied. For simplicity, no adjustments were made for differences in application costs for the different placement and frequency treatments.

The value of the yield increase from added P varied with application rate ($p=0.033$), tillage practice ($p=0.012$), and with P placement ($p=0.031$), but was not affected by application frequency ($p=0.560$). Although tillage did not affect yields of individual crops, the economic return for the full rotation was significant for each level of P addition, with greater return for the chisel plow system than for the no-till system (Fig. 5). This occurs because the economic comparison reflects differences in the full rotation and is a more complete comparison than yields for individual crops. For either tillage system, the optimum application rate based on economic return was nearest the 46 lbs P_2O_5 ac^{-1} yr^{-1} rate (\$11.5 ac^{-1} yr^{-1}). Across all rates, broadcast P application had a higher economic return than the band application (Fig. 5) and this was true for both tillage systems. Applying a biennial rate of P prior to soybeans did not increase the economic return on P costs compared to an annual application.

Summary

Phosphorus management approaches for the corn/soybean rotation were evaluated on a low P-testing soil. Both corn and soybean crops were responsive to increasing rates of P fertilizer. Tillage practice did not affect yields of individual crops in the rotation but did affect the economic return on the P fertilizer cost for the full rotation. Economic return was greater for the chisel plow system than for the no-till system. Broadcast-applied P resulted in better return of P fertilizer cost than fall deep-banded P. This is mostly due to the improved soybean yields associated with broadcast applications. Application frequency had no effect on individual crop yield or on the economic return for the cost of P fertilizer, but no consideration was made for differences in application costs.

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Table 1. The effect of P fertilizer placement, application frequency, and tillage on average P concentration of corn ear leaf tissue.

	Annual	Frequency Biennial	Average
		----% P----	
Fall Chisel Plow			
Broadcast	0.178	0.216	0.197
Band	0.180	0.201	0.195
Average	0.179	0.209	0.196
No-Till			
Broadcast	0.203	0.188	0.196
Band	0.195	0.170	0.183
Average	0.199	0.179	0.189

Table 2. Impacts of tillage practice and application frequency on the concentration of extractable P in soil (Olsen method) for the 46 lbs P_2O_5 ac^{-1} broadcast application treatments.

	1994	Sample Year 1996	1998
		ppm P	
Fall Chisel Plow			
Annual	4.7	15	10
Biennial	4.7	7.5	7
Average	4.7	11	8.5
No-Till			
Annual	5.3	11	9
Biennial	5.3	6.7	7
Average	5.3	8.9	8.0

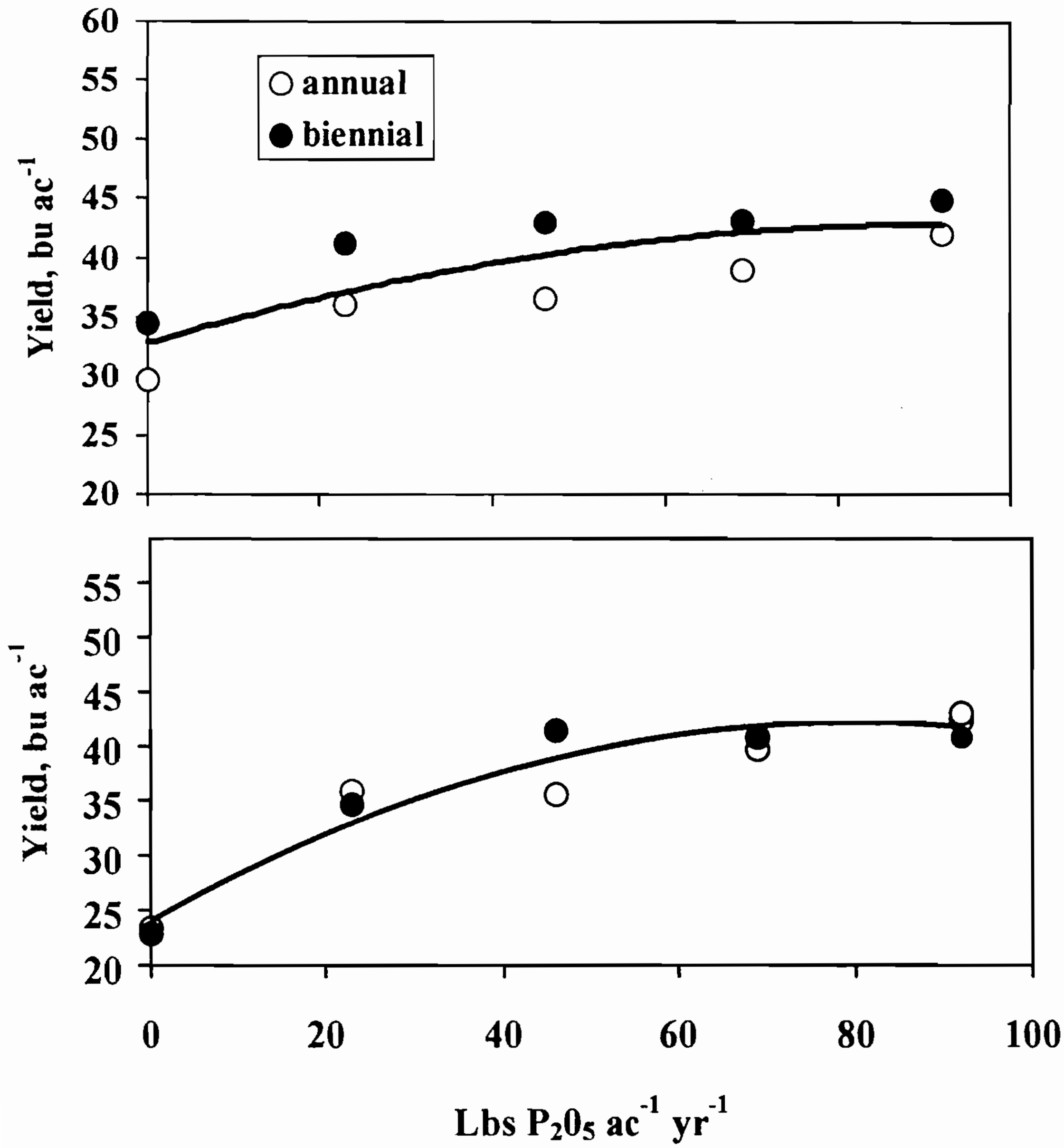

Figure 1. The effect of P application rate and frequency on 1995 (above) and 1997 (below) soybean yields.

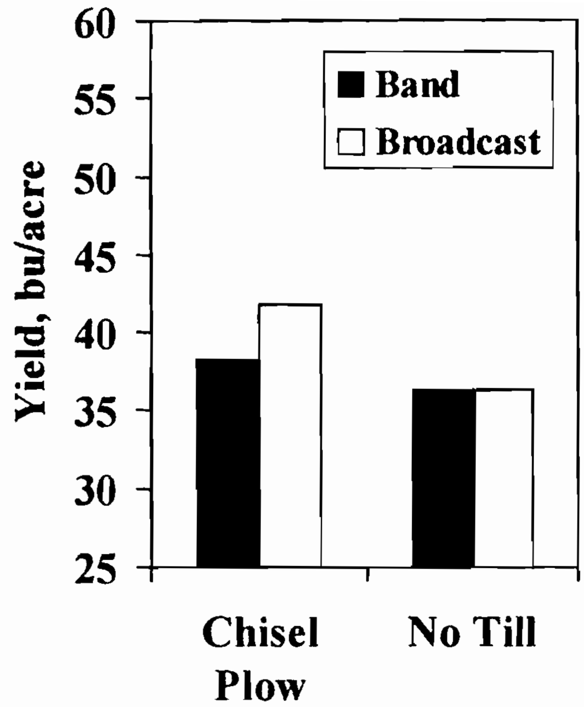

Figure 2. The effect of tillage practice and placement of P fertilizer on average soybean yield.

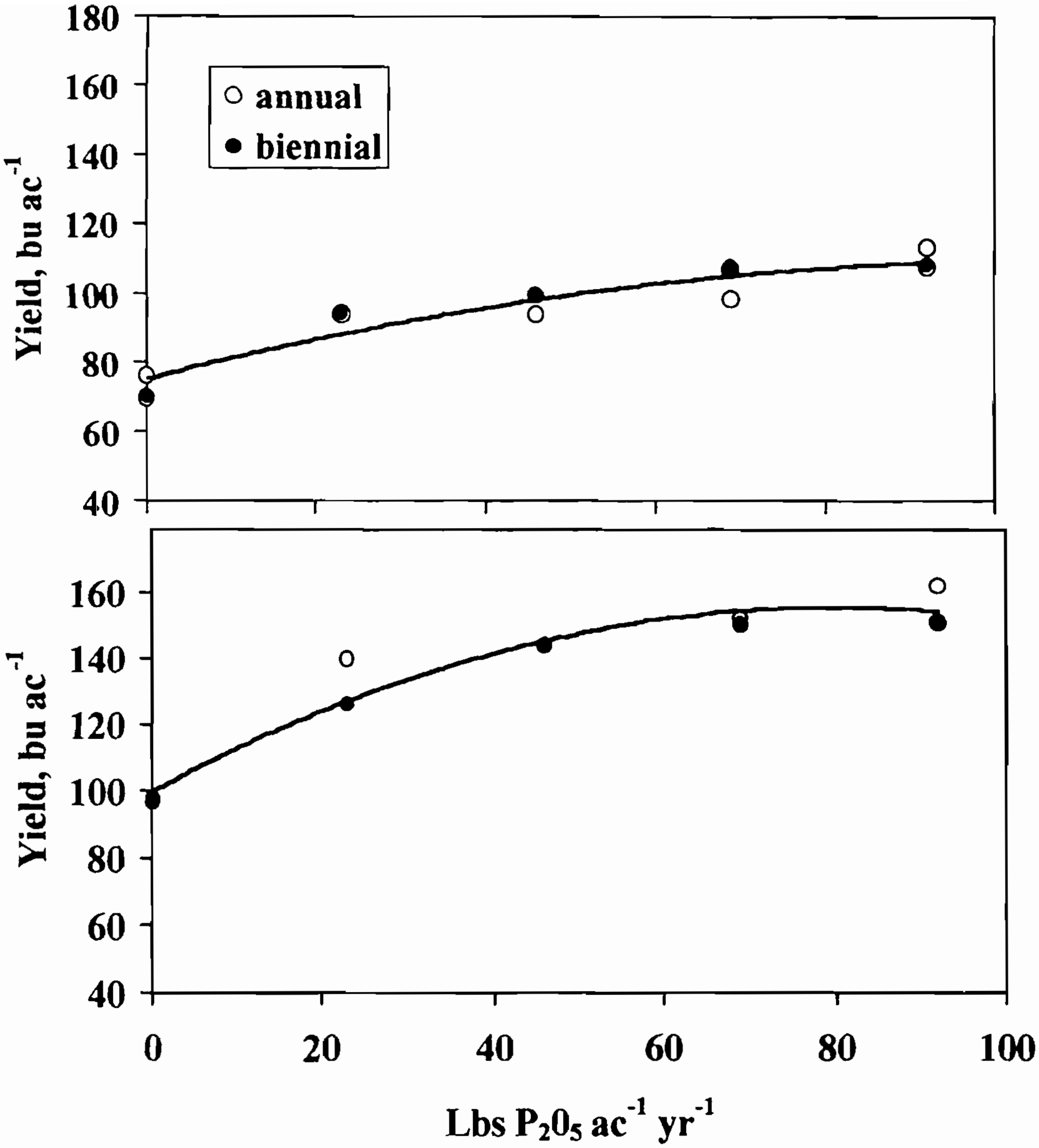

Figure 3. The effect of P application rate and frequency on 1996 (above) and 1998 (below) corn yields.

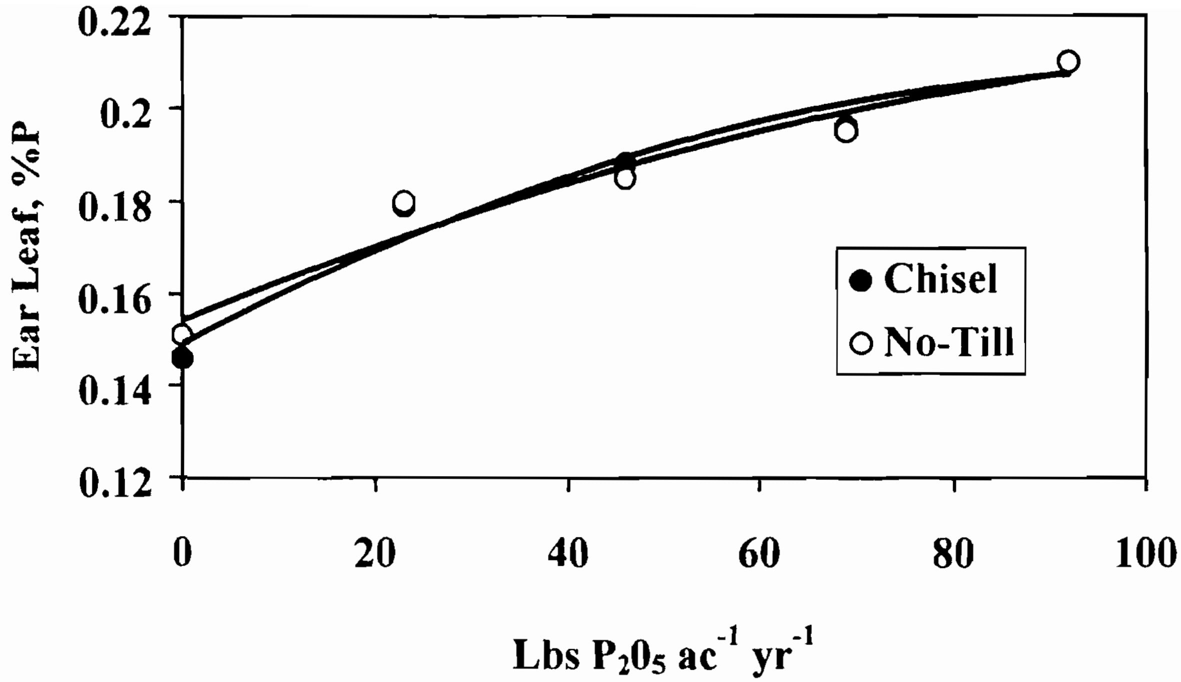

Figure 4. Phosphorus concentration in ear leaf tissue of corn as affected by rate of phosphate applied for two tillage systems.

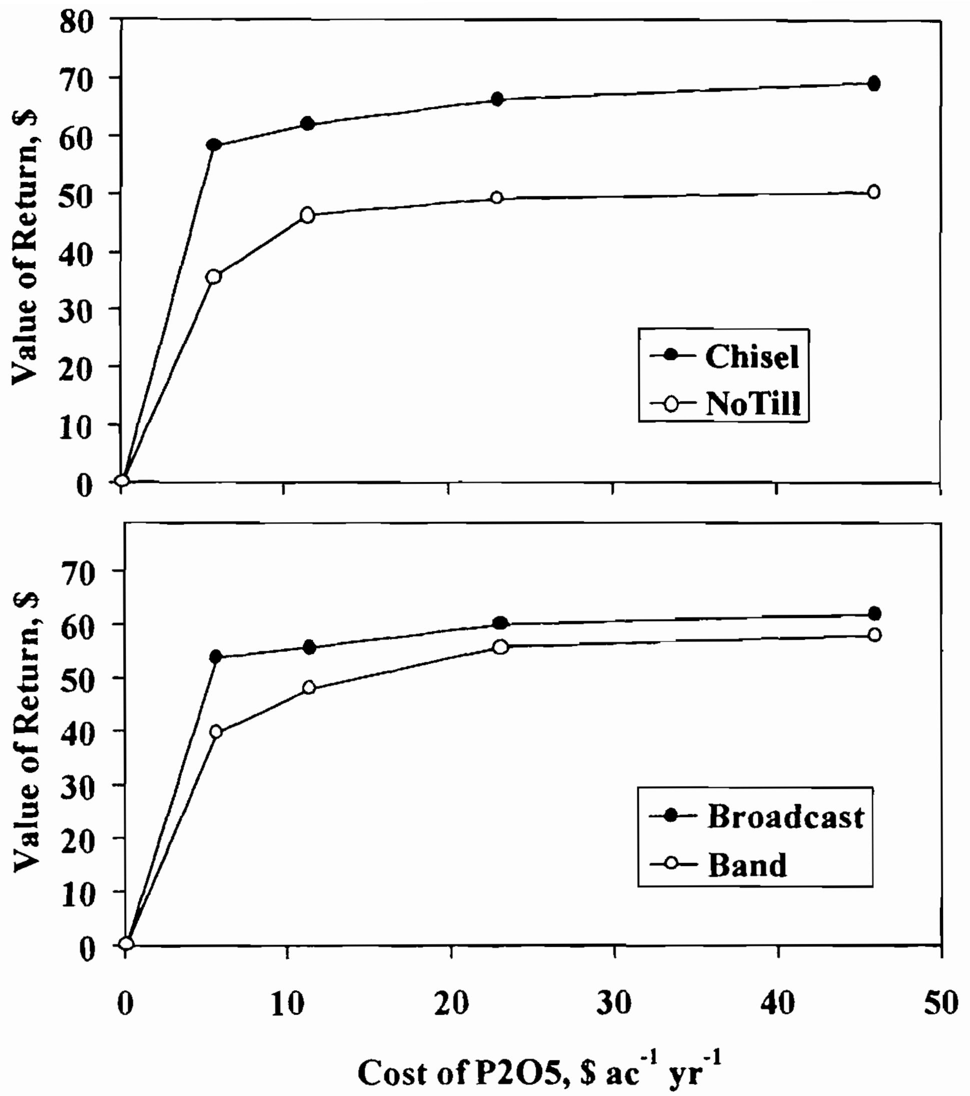

Figure 5. Impact of tillage practice (above) and P placement (below) on the economic return on the cost of applied P fertilizer.

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