FERTILIZER AND MANURE MANAGEMENT COMPARISONS FOR CORN-SOYBEAN ROTATIONS IN MINNESOTA

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Abstract

A study was designed to evaluate the impact of P sources (fertilizer and manure), nutrient application methods (broadcast and subsurface bands), P rates (crop removal and twice crop removal), and tillage systems (no-till and conventional) on corn-soybean response. Results to date show higher yields using manure as compared to fertilizer as the P source. This could be attributed to a higher rate of P being applied using the manure. No-till systems measured greater yields in 1999 and 2000, primarily due to greater control plot yields, but there was apparently no difference between no-till and conservation till in 2001. The higher (twice crop removal) P rate resulted in higher yields than the lower (crop removal) rate across all other variables. Broadcast and subsurface band application methods had no significant effect on yield.

Introduction

Fixation of phosphorus (P) as tricalcium phosphates is a concern when the soil pH is classified as basic. This is the case in western Minnesota, where calcareous, high pH soils create low soil P test results and hence, challenges for fertilizer P management by crop producers. Addition of P to cropland is an essential practice in this region for profitable corn and soybean production. Management of P in the Minnesota River basin has come under increasing scrutiny as studies find non-point agricultural pollution to be a major reason for the decline in the river's health (Westra et al., 2002). Thus, there is a mixed message for crop producers wanting to optimize their P management systems. Several management options exist for maximizing economic benefit of added P while attempting to minimize negative impacts on water quality.

Phosphorus is essentially immobile in soils, therefore P application method and placement can be a major factor in crop response. Research trials with soybeans in Minnesota have shown that higher yields are produced if needed phosphate is broadcast and incorporated before planting. For corn, optimum yields have been achieved when P is either broadcast-applied or subsurface banded. Recent research in Minnesota and neighboring states has shown that placement has had no consistent effect on yield if adequate rates of phosphate and/or potash are applied.

Because it affects particulate-P transport and P transformations, tillage method is an important decision regarding retention of soil phosphorus and prevention of water pollution with phosphorus loaded sediments. Conservation and no-till systems are two management options. Research in Canada found that production of wheat in a no-till system led to a significant increase in total P in the soil (Selles et al., 1999). Pezzarossa et al. (1995) found that minimum-tilled corn plots resulted in higher P content in comparison to conventional tillage.

The rate of P applied can be one of the most important factors for agronomic, economic, and environmental impact. Excess P has direct economic effects on fertilizer purchases for an entire farm enterprise as well as unquantifiable costs associated with degraded public waters. However, inadequate phosphorus will result in lower yields on these soils low in native phosphorus.

Source of P, especially organic P materials, can also create additional risk to a producer. Many producers are using land application of manure as a way to meet their nutrient management and waste disposal needs, as well as increase the organic matter in their soil. Manure, however, can be quite variable in P content of applied manure, and therefore a less exact P rate is applied. Results from a study by Parham et al. (2002), however, suggested that manure-P is relatively more mobile than inorganic fertilizer-P. Long-term application of cattle manure promoted microbiological activities and P cycling, but did not result in P accumulation to levels close to those in inorganic P fertilizer-treated soils. Published research reports are inconsistent in generalizing the impact of source of P on P build-up and losses in soil.

The objective of this project is to evaluate P management scenarios involving tillage system, P source, P rate, and nutrient application method on crop yield, plant P recovery, and soil P test changes in a corn-soybean rotation in western Minnesota.

Materials and Methods

Research plots were established in two separate areas at the Southwest Research and Outreach Center in Lamberton. Both sites were on a Ves loam soil (Calcic Hapludoll) and both tested "very low" for plant available soil P (Olsen test). At each site, a bulk crop of soybean was grown preceding the onset of treatments. Plots were established for a two-year corn-soybean rotation with all the nutrient treatments being applied in the fall before the corn crop. Main plots of tillage systems consisted of a no-till and a conservation tillage system. The conservation tillage system included a fall pass of a combination chisel/disc pass following the corn crop and a spring "finisher" pass before planting.

Nutrient treatments consisted of a factorial combination of P rate, P source, and P application method in addition to a no-P control treatment. Two sources of P were used, inorganic, commercial fertilizer and finishing-barn swine manure. Two application rates of each P source were applied. The baseline P rate was determined by estimating crop P removal in a two-year corn-soybean rotation (designated as the "medium" P rate) whereas the second ("high") rate was twice the estimated crop removal rate. It was estimated that crop removal would be 80 lb P_2O_5/A. Both P sources and rates were applied using two application methods/placement. One method was surface broadcast of the nutrients while the other method was subsurface (6-inch depth) banding of the nutrients. This resulted in a total of eight nutrient treatments and the control within each tillage system.

Nutrient treatment application occurred in late October following soybean harvest in the rotation. Because the start of each plot area was staggered by one year, one crop of corn and soybean are grown each year. One plot area was initiated in 1998 and the other in 1999. The inevitable confounding of nutrient source in this project caused by the N applications in the manure was minimized by blanket applications of commercial N to all corn plots in the rotation. This does not alleviate the impact of manure-N on corn (and soybean) yet does eliminate the N rate impact on the yield response. Plot size was 20 ft wide by 30 ft long. Four replicates were used in this randomized complete block design.

Crop seed/grain yields were measured following each crop. Herbage and seed/grain samples were collected from each crop in the fall of the year to quantify total plant P uptake and removal. Soil P test values (Olsen) were measured in incremental (4-inch) soil depths to 12 inches in the fall following soybean harvest.

Results

Corn grain yields and soybean seed yields are combined across site-years and listed in Tables 1 and 2, respectively. No significant climatic effects impacted yields since the beginning of this project. No plant P concentration analysis have been conducted, thus only yields are presented at this time. Discussion of yields will be categorized by main effect, noting however, that interactions are of great importance to crop producers in management decisions.

No-till systems resulted in greater grain yields for corn (157 bu/A average corn yield with no-till compared to 153 bu/A with a conservation tillage system). Soybeans had greater yield with conservation tillage (43 bu/A average soybean yield with conservation compared to 41 bu/A with no-till). The major contributing data to these differences was the control treatment yields; there was a 14.3 bu/A increase with no-till systems for corn while there was no measurable differences for soybean. Interactions with other treatment variables were inconsistent when averaged across site years.

The source of P applied, manure or fertilizer, was generally an important factor in grain yields. When averaged over all other factors, manure applications onto corn resulted in 169 bu/A yields whereas fertilizer applications resulted in 160 bu/A. Likewise with soybean, manure as a P source resulted in average yield of 45 bu/A while yields averaged only 43 bu/A when commercial P was used. Although these increased yields with manure may be because of a difference in available phosphorus between the two sources, this cannot be a definitive conclusion as the method used to determine manure applications led to an unequal amount of P being applied by the two sources for the first two sets of nutrient applications. Manure P applications were greater than fertilizer P because manure P concentrations were greater than estimated each year (as manure samples were collected at application time for analysis), thus greater amounts of P were actually applied than with the fertilizer.

There was a significant effect of P rate on all crop yields in this study. While the initial response of the crop removal rate would be predicted based on soil test P levels, the consistent yield increases between the medium and high nutrient application rates was duly noted. This response to P rate was consistent across all other variables. The plots with a P rate of twice crop removal (160 lb P_2O_5/A) had consistently higher yields than those with a rate of crop removal (80 lb P_2O_5/A) for all site-years (168 bu/A average corn yield with high rate compared to 161 bu/A with medium, 45 bu/A average soybean yield with high rate compared to 43 bu/A with medium).

Acknowledging that the manure treatments had slightly higher P rates, the response to these levels were different for more important for soybean than corn. For corn, there was a 7.1 bu/A increase with the high rate of nutrients (compared to the medium rate) for the manure treatment while there was a 7.5 bu/A increase from the medium to the high rate for the fertilizer treatments. In contrast, fertilizer treatments increased yields 1.4 bu/A between the medium and high P rate while manure treatments increased yields 4.8 bu/A from the medium to high P rates. This supports earlier research by these authors of significant soybean yield increases from manure applications due to nitrogen and/or non-nutrient effects from the manure, the high rate of manure treatments may have contributed to enhanced yields with non-P factors.

There was no consistent effect from application method on either corn (166 bu/A average corn yield with broadcast, 164 bu/A with subsurface band) or soybean yields (44 bu/A average soybean yield with broadcast, 44 bu/A with subsurface band) for any of the site-years (Tables 1 and 2). There was only a two bu/A maximum range between these methods without a consistent pattern of which method was superior. Most surprising was the lack of difference measured between placement methods with the no-till tillage system due to the relative immobile nature of P. Broadcast application showed no difference from subsurface banding even at the lower P rate, when P was likely limited and placement would traditionally be considered an important factor.

Only soil tests from one plot area have been analyzed (Table 3). The removal rate (medium) treatments resulted in soil test P increases after this 2-year rotation of 2-3 ppm. Doubling the application rate with the high rate resulted in soil test P increases, with the increase a function of P source. Fertilizer addition showed relatively small soil test P increases (1.6 ppm) above the medium rate whereas the manure treatments had a 7.0 ppm increase. This can be attributed to the increased total P applied with the manure treatments due to the underestimation of P concentrations in the manure. Due to the variability in the dataset, differences due to tillage or application method were of minor significance.

Summary

Based on the limited dataset compiled so far, the optimum P management scenario for a corn-soybean rotation is not confined to one set of management practices. While the no-till system resulted in greater overall corn yields, the majority of the increases were with no nutrient additions, thus, with adequate P rates, either tillage system produced optimum yields. Phosphorus rate was the most important management practice for yield response. Although this study was not intended to develop response curves for P rates, the application of the high rate of P (twice removal rate) was best. The additional P with the high rate resulted in additional yield and significant soil test P increases. On these calcitic soils, the environmental risks of this rate are predicted to be minor.

While manure has consistently provided increased yields for both corn and soybean, the noted confounding of greater P rates with the manure must be acknowledged. Method of application appears to be of inconsequential importance so far in this study. While the majority of the preliminary discussion has focused on agronomic parameters, the environmental ramifications will be a crucial component of this study. This will be evaluated when plant P analyses are conducted and additional soil test P information is integrated so that the fate and efficiency of applied P can be determined.

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Table 1. Average corn yields as influenced by tillage system, P source, P application method, and P application rate from three site-years in Lamberton, 1999-2001.

			P Rate			
Tillage	**P Source**	**Method**	**0**	**med[1]**	**high[2]**	**average**
			bu./acre			
Conservation	Fertilizer	Broadcast		155.6	167.4	161.5
		Subs. Band		156.0	161.8	158.9
		Average	*108.8*	*155.8*	*164.6*	
	Manure	Broadcast		162.6	172.3	167.5
		Subs. Band		162.6	171.6	167.1
		Average	*108.8*	*162.6*	*172.0*	
No-Till	Fertilizer	Broadcast		158.7	163.4	161.0
		Subs. Band		154.8	162.6	158.7
		Average	*123.1*	*156.7*	*163.0*	
	Manure	Broadcast		170.2	175.1	172.7
		Subs. Band		167.4	171.9	169.6
		Average	*123.1*	*168.8*	*173.5*	

[1] medium rate = crop removal (80 lb P_2O_5/A)
[2] high rate = twice crop removal (160 lb P_2O_5/A)

Table 2. Average soybean yields as influenced by tillage system, P source, P application method, and P application rate from two site-years in Lamberton, 2000-2001.

Tillage	P Source	Method	0	med[1]	P Rate High[2]	average
				————	bu./acre	————
Conservation	Fertilizer	Broadcast		44.0	46.2	45.1
		Subs. Band		43.1	44.4	43.8
		Average	*33.4*	*43.6*	*45.3*	
	Manure	Broadcast		44.2	45.5	44.9
		Subs. Band		44.8	48.9	46.8
		Average	*33.4*	*44.5*	*47.2*	
No-Till	Fertilizer	Broadcast		42.1	42.5	42.3
		Subs. Band		39.4	41.2	40.3
		Average	*33.4*	*40.8*	*41.9*	
	Manure	Broadcast		41.6	44.7	43.1
		Subs. Band		41.5	48.6	45.1
		Average	*33.4*	*41.6*	*46.6*	

[1] medium rate = crop removal (80 lb P_2O_5/A)
[2] high rate = twice crop removal (160 lb P_2O_5/A)

Table 3. Soil test P (Olsen) as influenced by tillage system, P source, P application method, and P application rate, 2000. Soil test values are a 12-in. depth.

Tillage	P Source	Method	0	med[1]	P Rate High[2]	average
				————	ppm	————
Conservation	Fertilizer	Broadcast		4.6	7.4	6.0
		Subs. Band		3.8	4.1	4.0
		Average	*2.8*	*4.2*	*5.8*	
	Manure	Broadcast		6.2	13.4	9.8
		Subs. Band		5.8	10.0	7.9
		Average	*2.8*	*6.0*	*11.7*	
No-Till	Fertilizer	Broadcast		4.5	7.7	6.1
		Subs. Band		5.3	5.1	5.2
		Average	*3.1*	*4.9*	*6.4*	
	Manure	Broadcast		6.1	15.6	10.9
		Subs. Band		6.5	14.7	10.6
		Average	*3.1*	*6.3*	*15.2*	

[1] medium rate = crop removal (80 lb P_2O_5/A)
[2] high rate = twice crop removal (160 lb P_2O_5/A)

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