RESIDUAL P EFFECTS ON SOYBEAN YIELD AND NUTRIENT REMOVAL RATES

Gyles Randall
University of Minnesota, Waseca, MN

Abstract

Long-term experiments were conducted from 1997-2003 on a Nicollet-Webster clay loam soil complex at Waseca, MN to determine the availability of residual P applied for corn on the yield and removal of P by soybeans in the following year. Phosphorus was applied either with the seed at planting as a starter, 5 to 6" deep in a band in the fall, or broadcast and incorporated by tillage. Tillage systems included no till, strip till, spring field cultivation, and chisel plow plus field cultivation. Tillage had no effect on soybean yield or residual P removal on the VERY LOW P-testing soils and only a slight effect on the HIGH P-testing soils. Averaged across the three cropping cycles at both sites (6 site-years), soybean yields were increased 15.7 and 18.7 bu/A by residual P from the 50-lb P_2O_5 starter treatment and the 100-lb broadcast treatment, respectively, on the VERY LOW P-testing soils. Yield responses to residual P on the HIGH P-testing soils ranged between 0.4 and 4.2 bu/A. Phosphorus removal from residual P as a percent of applied P averaged 24, 20, and 18% for the seed-placed starter, deep-band, and broadcast treatments, respectively, on the VERY LOW P-testing soils and 10, 7, and 8%, respectively, on the HIGH P-testing soils. Deep-band placement of P showed no advantage over the seed-placed starter treatment. Economic return to residual P ranged from $61 to $118/A/yr on the VERY LOW P-testing soils and from $2 to $22/A/yr on the HIGH P-testing soils. Highest economic return on the HIGH P-testing soils was obtained for the broadcast P treatment applied to the chisel plow plots. In summary, substantial increases in soybean yield, P removal, and economic return to fertilizer P can be obtained from P applied for corn the previous year.

Introduction

Row-crop agriculture in the Mississippi River Basin is under pressure to reduce sediment and nutrient losses by practicing less tillage and more precise application and placement of nutrients (N and P). No-till, strip-till, and one-pass secondary tillage systems are being proposed as reduced tillage alternatives to conventional tillage.

Use of conservation tillage practices limits the opportunity for incorporation of phosphorus (P) containing fertilizers that are broadcast on the soil surface. Therefore, optimum placement of P fertilizers is essential in reduced tillage systems, especially in soils testing low in P. Thus, the purposes of this long-term study were to: (1) to determine the effect of P placement method in three reduced tillage systems and one conventional tillage system for corn-soybean rotations on: a) P removal and yield of corn and soybeans, and b) residual P availability to subsequent crops and (2) to provide management guidelines on phosphorus placement in very reduced tillage systems to corn producers, crop consultants, local advisors, and the fertilizer industry. This paper will focus on the effects of residual P from the P management strategies applied for corn on uptake of P and yield of soybean in the following year.

Experimental Procedures

The experiments were conducted on a tile drained Nicollet-Webster clay loam soil complex located at the Southern Research and Outreach Center, Waseca, Minnesota. The tile lines were spaced 75' apart and all rows were perpendicular to the tile lines. Two adjacent 3-acre areas were used. One area had been maintained at a high P test (19 ppm Bray P_1) with periodic P fertilizer applications while in a C-C-C-Sb rotation. Continuous corn receiving no fertilizer P for the last 15 years was planted on the other area to mine P and lower the soil test to very low levels (4 ppm Bray P_1). The P rates selected for this study were based on: (1) previous work that showed soil test P in a corn-soybean rotation to be maintained at a high level with about 40 lb of broadcast P_2O_5/A/yr and (2) University of Minnesota recommendations that band rates of P can be optimized at half the broadcast rate. Therefore, the band and broadcast P rates applied prior to corn every other year were 40 and 80 lb P_2O_5/A, respectively, for the HIGH P-testing site and 50 and 100 lb P_2O_5/A for the VERY LOW P-testing site. DAP (18-46-0) was the P source for the deep-band and broadcast treatments, while 10-34-0 was the starter fertilizer. Beginning in the fall of 2000, 10-34-0 was substituted for DAP in the deep-band treatments.

The experiment was started in the fall of 1996 with application of the deep-band and broadcast treatments for corn in 1997 on one set of plots (Site A). Another set of plots (Site B) was started in the fall of 1997 for corn in 1998. This allowed planting of both corn and soybeans each year in a continuous corn-soybean rotation (Table 1). Each plot is 15' wide (6 - 30" rows) by 55' long. The treatments for corn and soybean (Table 2) were replicated four times in a randomized, complete-block design.

Corn was planted in 30" rows while soybean was planted in 8" rows with a no-till drill. Corn stalks were not stalk chopped prior to planting soybean in the no-till plots. Soybeans were planted following disking of the corn stalks on the one-pass treatments and field cultivation of the chisel plow treatments. A Tye drill was used to plant all plots. Excellent weed control was obtained on all plots. The soybeans were harvested with a plot combine. Grain samples were saved for moisture and P concentration determinations.

Table 1. Chronological listing of crops and P treatments (applied vs residual) for the two experimental sites.

Year	Site A	Site B
1997	Corn[1/]	Soybean
1998	Soybean[2/]	Corn[1/]
1999	Corn[1/]	Soybean[2/]
2000	Soybean[3/]	Corn[1/]
2001	Corn[1/]	Soybean[3/]
2002	Soybean[4/]	Corn[1/]
2003	Corn[5/]	Soybean[4/]
2004	Soybean[6/]	Corn[5/]

[1/] P treatments applied for corn, cycles 1, 2, & 3
[2/] Residual P for soybean - cycle 1, residual year 1
[3/] Residual P for soybean - cycle 2, residual year 1
[4/] Residual P for soybean - cycle 3, residual year 1
[5/] Residual P for corn-cycle 4, residual year 2
[6/] Residual P for soybean - cycle 4, residual year 3

Results and Discussion

Soil test P

Soil samples (0 to 6" depth) were taken from the 0-P plots for each tillage system from both site A and B at the beginning of the experiment and from all plots during cycle 3 of the study. Bray P_1 soil test P (STP) values averaged across sites were consistently very low (STP = 4 ppm) and high (STP = 19 ppm) among all tillage systems for the "VERY LOW" testing and "HIGH" testing areas, respectively (Table 2). At the end of three cycles of the rotation STP remained at 3 to 4 ppm P at the VERY LOW P-testing area when no P was added, but at the HIGH P-testing area, STP decreased from the initial 19 ppm to 10-12 ppm. On the VERY LOW P-testing soils adding 50 lb P_2O_5/A as seed-placed starter fertilizer three times during the 6-year rotation increased STP up to 10 to 18 ppm but only to 6 to 8 ppm when placed 5 to 6" deep in a band. Apparently, some of the deep band-applied P dropped below the 0 to 6" sampling depth. Furthermore, STP levels for the seed-placed treatments were highest for the no-till and strip-till systems and lowest for the spring field cultivate and chisel plow systems in both the VERY LOW and HIGH P-testing areas. This clearly indicates that surface tillage disrupted the starter bands, resulting in dilution and thus lower STP. On the HIGH P-testing soils, the 40-lb P_2O_5 seed-placed starter treatment maintained STP at 20 ppm for the field cultivate and chisel plow systems but increased STP to between 24 and 29 ppm for the strip-till and no-till systems. Banding 40 lb P_2O_5/A 5 to 6" deep gave STP values of only 17 and 18 ppm. STP ranged from 28 to 30 ppm for the 80-lb broadcast P_2O_5 treatment.

Table 2. Soil test P (Bray P_1) at the initiation of the study (cycle 1, 1997 & 98) and in cycle 3 (2002 & 03) of the study as affected by tillage and P management strategies for corn at the VERY LOW P-testing site and HIGH P-testing site.

Tillage for		P mgmt[1/]	P_2O_5[2/]	VERY LOW P site		HIGH P Site	
Corn	Soybean	Strategy	Rate	Cycle 1	Cycle 3	Cycle 1	Cycle 3
			lb/A	- - - - - - - - Bray P_1, ppm - - - - - - - -			
No till	No till	-	0	4	4	19	12
"	"	Starter	50/40	--	15	--	29
Field cult.	Spr. disk	-	0	4	4	20	10
"	"	Starter	50/40	--	12	--	20
"	"	Fall Band	50/40	--	6	--	17
"	"	Spr. Bdct.	100/80	--	14	--	30
Strip till	No till	-	0	4	3	19	12
"	"	Starter	50/40	--	18	--	24
"	"	Fall Band (f)	50/40	--	8	--	18
Chisel, f.c.	Chisel, f.c.	-	0	4	4	19	10
"	"	Starter	50/40	--	10	--	20
"	"	Fall Bdct.	100/80	--	13	--	28

1/ Starter = seed-placed, 10-34-0; Fall band = 5-6" deep, 10-34-0; Bdct = Broadcast & incorporated DAP.

2/ 50/40 = 50 lb/A for the VERY LOW P-testing soil and 40 lb/A for the HIGH P-testing soil.

Soybean yield

On the VERY LOW P-testing soils, soybean yield responses to residual P applied for corn the previous year were found in all tillage systems and in all three cycles (Table 3). Responses to residual P were greatest in cycle 3 (approx. 20 bu/A) and least in cycle 1 (approx. 10 bu/A). Soybean yields were increased by 15.7 bu/A for the 50-lb seed-placed starter treatment when averaged across tillage systems and across the three cycles (six site-years). A difference in response to residual P was not found between the seed-placed starter and deep-band treatments. The 3 bu/A additional response to residual P from the broadcast 100-lb P_2O_5 treatment was statistically significant. Tillage had no significant effect on soybean yield.

On the HIGH P-testing soils, soybean yield response to residual P was not significant in cycle 1 but showed some slight responses in cycles 2 and 3 (Table 4). When averaged across the three cycles (six site-years) and across tillage systems, yield responses to the 40-lb seed-placed and deep-band treatments ranged from 0.4 to 3.6 bu/A. The response to residual P from the 80-lb broadcast treatment ranged from 1.7 to 4.2 bu/A. Greatest response to residual P occurred with the chisel plow system, which along with the spring field system gave slightly greater yields compared to the no-till and strip-till systems.

Table 3. Soybean yield in a C-Sb rotation on a VERY LOW P-testing soil as affected by tillage and residual P from P management strategies for corn.

Tillage for		P Management Strategy[1]		Soybean Yield			
				Cycle 1	Cycle 2	Cycle 3	3 Cycle/6-Yr
Corn	Soybean	Placement[2]	P_2O_5 rate	1998 & 99	2000 & 01	2002 & 03	Avg.
			lb/A	bu/A			
No till	No till	-	0	38.6	31.0	28.0	32.5
"	"	Starter	50	46.8	48.7	47.7	47.7
Field cult.	Spr. disk	-	0	38.1	34.0	30.3	34.1
"	"	Starter	50	46.8	49.6	49.4	48.6
"	"	Fall Band	50	49.1	46.8	49.2	48.4
"	"	Spr. Bdct.	100	52.8	52.3	51.7	52.2
Strip till	No till	-	0	40.2	35.6	30.2	35.3
"	"	Starter	50	49.2	49.2	48.4	48.9
"	"	Fall Band (f)	50	48.2	47.4	45.4	47.0
Chisel, f.c.	Chisel, f.c.	-	0	34.2	30.6	25.3	30.0
"	"	Starter	50	48.7	53.0	47.0	49.6
"	"	Fall Bdct.	100	53.7	53.6	50.2	52.5
		LSD (0.10) =					2.6

1/ Applied for corn grown in year before soybean.

2/ Starter = seed-placed, 10-34-0; Fall band = 5-6" deep, 10-34-0; Bdct. = Broadcast & incorporated. DAP.

Table 4. Soybean yield in a C-Sb rotation on a HIGH P-testing soil as affected by tillage and residual P from P management strategies for corn.

Tillage for		P Management Strategy[1]		Cycle 1	Cycle 2	Cycle 3	3-Cycle/6-Yr
Corn	Soybean	Placement[2]	P_2O_5 rate	1998 & 99	2000 & 01	2002 & 03	Avg.
			lb/A	bu/A			
No till	No till	-	0	52.3	50.0	49.3	50.5
"	"	Starter	40	53.2	51.8	52.0	52.3
Field cult.	Spr. disk	-	0	54.9	54.4	50.3	53.3
"	"	Starter	40	55.0	54.8	52.6	54.2
"	"	Fall Band	40	54.2	54.8	53.0	54.0
"	"	Spr. Bdct.	80	54.0	56.1	54.8	55.0
Strip till	No till	-	0	51.4	54.4	49.6	51.8
"	"	Starter	40	51.4	52.2	53.0	52.2
"	"	Fall Band (f)	40	53.2	54.4	50.8	52.8
Chisel, f.c.	Chisel, f.c.	-	0	53.7	51.3	47.0	50.6
"	"	Starter	40	53.6	55.6	53.2	54.2
"	"	Fall Bdct.	80	54.2	57.7	52.5	54.8
		LSD (0.10) =					1.9

1/ Applied for corn grown in previous year.

2/ Starter=seed-placed, 10-34-0; Fall band = 5-6" deep, 10-34-0; Bdct. = Broadcast & incorporated, DAP.

P concentration and removal

On the VERY LOW P-testing soil, P concentration in the soybean seed was lowest for the O-P control (0.34%), intermediate for the 50-lb seed-placed starter and band treatments (0.43%), and greatest for the 100-lb broadcast treatments (0.48%) (Table 5). There was no difference in P removal among the four tillage systems. Phosphorus removal above the O-P control treatment ranged from 5.2 lb P/A/yr for the 50-lb starter treatments to 7.6 lb/yr for the 100-lb broadcast treatments. Phosphorus removal from residual P as a percent of applied P averaged 24, 20, and 18% for the seed-placed starter, deep-band, and broadcast treatments, respectively.

On the HIGH P-testing soil, P concentration in the soybean seed was significantly greater in the 40-lb starter and deep-band treatments (0.58%) and 80-lb broadcast treatments (0.59%) compared to the O-P control (0.53%) (Table 6). There was no difference among the tillage systems in P removal, although P concentration was slightly less for the chisel system. Phosphorus removal over the O-P control treatment within each tillage system ranged from 1.2 to 1.7 lb/A/yr for the 40-lb deep-band and seed-placed starter treatments to 2.8 lb/A/yr for the 80-lb broadcast treatments. Phosphorus removal from residual P as a percent of applied P averaged 10, 7, and 8% for the seed-placed starter, deep-band, and broadcast treatments, respectively.

Table 5. Six-year average P concentration, P removal, and P removal as a percent of applied P in the soybean seed as influenced by residual fertilizer P from P management strategies applied for corn in the previous year on an initially VERY LOW P-testing soil.

Tillage for[1]		P mgmt.[2]	Six-Yr Avg.		Avg. P removal above O-P control	P	P removal as a percent of
Corn	Soybean	strategy	P conc.	P removal	within tillage	applied	applied P
			%	lb/A/yr	lb/A/yr	lb/A/yr	%
NT	NT	-	0.351	6.0	--	0	--
"	"	SF	0.434	10.9	4.9	21.8	22
SFC	SD	-	0.353	6.2	--	0	--
"	"	SF	0.445	11.5	5.3	21.8	24
"	"	Band	0.427	11.0	4.8	21.8	22
"	"	Bdct.	0.483	13.2	7.0	43.6	16
ST	NT	-	0.333	6.2	--	--	--
"	"	SF	0.433	11.1	4.9	21.8	22
"	"	Band	0.404	10.0	3.8	21.8	17
CP+	CP+	-	0.321	5.0	--	--	--
"	"	SF	0.414	10.7	5.7	21.8	26
"	"	Bdct.	0.481	13.2	8.2	43.6	19
		LSD (0.10) =	0.030	1.0			

[1] NT = no tillage, SFC = spring field cultivate, SD = spring disk, ST = strip tillage, and CP+ = chisel plow and field cultivate.

[2] SF = starter fertilizer (seed-placed, 10-34-0), Band = 5-6" deep (10-34-0), and Bdct. = broadcast DAP.

Table 6. Six-year average P concentration, P removal, and P removal as a percent of applied P in the soybean seed as influenced by residual fertilizer P from P management strategies applied for corn in the previous year on an initially HIGH P-testing soil.

Tillage for[1]		P mgmt.[2]	Six-Yr Avg.		Avg. P removal above O-P control	P	P removal as a percent of
Corn	Soybean	strategy	P conc.	P removal	within tillage	applied	applied P
			%	lb/A/yr	lb/A/yr	lb/A/yr	%
NT	NT	-	0.542	14.1	--	0	--
"	"	SF	0.598	16.4	2.0	17.5	11
SFC	SD	-	0.535	15.0	--	0	--
"	"	SF	0.574	16.3	1.3	17.5	7
"	"	Band	0.581	16.4	1.4	17.5	8
"	"	Bdct.	0.595	17.1	2.1	35.0	6
ST	NT	-	0.538	14.6	--	0	--
"	"	SF	0.578	15.8	1.2	17.5	7
"	"	Band	0.566	15.6	1.0	17.5	6
CP+	CP+	-	0.500	13.5	--	0	--
"	"	SF	0.556	15.8	2.3	17.5	13
"	"	Bdct.	0.588	16.9	3.4	35.0	10
		LSD (0.10) = 0.022		0.9			

[1] NT = no tillage, SFC = spring field cultivate, SD = spring disk, ST = strip tillage, and CP+ = chisel plow and field cultivate.

[2] SF = starter fertilizer (seed-placed, 10-34-0), Band = 5-6" deep (10-34-0), and Bdct. = broadcast DAP.

Economic return to residual P

On the VERY LOW P-testing soil, economic return to residual P ranged from $71 to $103/A/yr for the 50-lb seed-placed treatments, from $61 to $75/A/yr for the 50-lb deep-band treatments, and from $84 to $118/A/yr for the 100-lb broadcast treatments (Table 7). Averaged across the conservation tillage systems, 9.6 and 5.4 bu/A of soybeans were obtained to residual P for 100 lb P_2O_5/A applied to corn as a starter or broadcast, respectively. Economic return to residual P on the HIGH P-testing soil was poor, ranging from $2 to $19/A/yr for the 40-lb seed-placed starter treatments, $4 to $5/A/yr for the 40-lb deep-band treatments, and $9 to $22/A/yr for the 80-lb broadcast treatments. Economic returns were approximately three times greater for the chisel plow system compared to the three conservation tillage systems. Averaged across the conservation tillage systems, <1 bu/A was obtained to residual P for 100 lb P_2O_5 applied to corn, regardless of placement strategy on this HIGH P-testing soil.

Table 7. Economic return to residual fertilizer P applied to corn by soybean (3 cycles, 2 sites) as affected by P management strategies within tillage systems on initially VERY LOW and HIGH P-testing soils.[1/]

Tillage for[2/]		P mgmt.[3/]	VERY LOW P-Testing Site		HIGH P-Testing Site	
Corn	Soybean	strategy	Yield increase within tillage	Economic[4/] return	Yield increase within tillage	Economic[4/] return
			bu/A/yr	$/A/yr	bu/A/yr	$/A/yr
NT	NT	-	-	0	-	0
"	"	SF	15.2	80.	1.8	9.
SFC	SD	-	-	0	-	0
"	"	SF	14.5	76.	0.9	5.
"	"	Band	14.3	75.	0.7	4.
"	"	Bdct.	16.1	84.	1.7	9.
ST	NT	-	-	0	-	0
"	"	SF	13.6	71.	0.4	2.
"	"	Band	11.7	61.	1.0	5.
CP+	CP+	-	-	0	-	0
"	"	SF	19.6	103.	3.6	19.
"	"	Bdct.	22.5	118.	4.2	22.

1/ Residual P from corn, no cost to soybeans.

2/ NT = no tillage, SFC = spring field cultivate, SD = spring disk, ST = strip tillage, and CP+ = chisel plow and field cultivate.

3/ SF = starter fertilizer (seed-placed, 10-34-0), Band = 5-6" deep (10-34-0), and Bdct. = broadcast DAP.

4/ Soybean = $5.25/bu.

2004 Soybean yield

Soybean yields in 2004 (cycle 4, residual P year 3) were affected by tillage system in both the VERY LOW and HIGH P-testing areas and by residual P in the VERY LOW P-testing area (Table 8). Yields were poor, especially in those treatments receiving no tillage prior to growing soybeans in this cool and very wet year. Highest yields (46.0 to 49.7 bu/A) were obtained in the chiseled plots that received broadcast P. On the VERY LOW P-testing soils, yield responses to residual P averaged 6.4 and 11.6 bu/A for the 50-lb deep-band and seed-placed starter treatments, respectively, and 17.4 bu/A for the 100-lb broadcast treatments. On the HIGH P-testing soils, yields were not affected by residual P for any of the treatments. However, yields were consistently lower with no-tillage (35.6 bu/A) compared to the spring disk and chisel plow treatments (45.5 bu/A).

Table 8. Soybean yields in 2004 (cycle 4, residual year 3) as affected by tillage and P management strategies for corn on initially VERY LOW P-testing and HIGH P-testing soils.

Tillage for		P mgmt	P_2O_5[1/]	P-testing soil	
Corn	Soybean	Strategy	Rate	VERY LOW	HIGH
			lb/A	- - - - - - - - bu/A - - - - - - - -	
No till	No till	-	0	24.5	34.4
"	"	Starter	50/40	31.1	34.2
Field cult.	Spr. disk	-	0	30.0	44.3
"	"	Starter	50/40	39.2	44.8
"	"	Fall Band	50/40	37.3	43.8
"	"	Spr. Bdct.	100/80	43.2	43.3
Strip till	No till	-	0	23.4	37.1
"	"	Starter	50/40	35.0	36.9
"	"	Fall Band (f)	50/40	29.8	37.2
Chisel, f.c.	Chisel, f.c.	-	0	24.3	47.4
"	"	Starter	50/40	43.5	45.5
"	"	Fall Bdct.	100/80	46.0	49.7

[1/] 50/40 = 50 lb/A for the VERY LOW P-testing soil and 40 lb/A for the HIGH P-testing soil.

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Program Chair:
Bob Hoeft
University of Illinois
Urbana, IL 61801
(217) 333-9480

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