Phosphorus Placement for Soybean Production in Reduced Tillage Systems

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Soybean production in the northern Great Plains has steadily increased during the past two decades. In North Dakota alone, acreage has increased from 211,000 acres in 1971 to 640,000 acres in 1989 (ND Crop & Livestock Reporting Service, 1981; ND Ag. Statistics Service, 1991). More than 80 percent of this acreage is grown in the Red River Valley of eastern North Dakota.

Soybeans are usually grown on medium to fine textured soils in a rotation following a small grain crop. In recent years, primary fall tillage of small grain stubble has shifted from moldboard plowing (conventional tillage/low residue) to chisel plowing (reduced tillage/high residue) to reduce the effects of wind erosion. Subsequent spring field preparation involves shallow tillage to incorporate herbicide and preparation of the seedbed with a sweep-type tillage tool or tandem disk.

Previous research on phosphorus placement in conventional tillage has shown soybeans generally respond to broadcast P better than banded P (Hanson, 1977; Ham et al., 1973; Ham and Caldwell, 1978; Rehm and Wiese, 1980). But under certain circumstances, banded P was more effective than broadcast P (Bailey, 1979; Ham et al., 1973; Ham and Caldwell, 1978). Little information on P placement for soybeans in reduced tillage systems is available.

Soybeans generally have a higher P requirement than small grains and P-containing fertilizer is often applied prior to seeding the crop. P is a relatively insoluble nutrient in soils that needs to be incorporated into the soil to be positionally available to crops. In the soybean growing region of North Dakota, P fertilizer is usually applied as a preplant broadcast application. This study was conducted to examine the efficiency of three P application methods in reduced tillage systems using shallow incorporation during seedbed preparation.

METHODS AND MATERIALS

Study sites on farmer-cooperator fields in the Red River Valley were selected on the basis of a preliminary soil test of less than 10 ppm $NaHCO_3$-P (20 pounds of P per acre) at the beginning of the growing season in 1987, 1988 and 1989. The soils and soil test P values are identified in Table 1. All fields were cropped to small grain in the year prior to the study and were fall chisel plowed.

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Table 1. Initial soil test values of the study sites.

	1987		1988		1989	
Soil	P	Zn	P	Zn	P	Zn
	mg kg^{-1}					
Bearden silty clay loam (fine-silty, frigid Aeric Calciaquolls)	3.5	0.4*	4.5	0.4*		
Gardena very fine sandy loam (coarse-silty, mixed Pachic Udic Haploborolls)					6.0	0.6
Glyndon silty loam (coarse-silty, frigid Aeric Calciaquolls)	6.5	0.5	6.0	0.7		

* Zinc sulfate added to correct low soil test.

Plots 25 feet wide by 100 feet long were arranged in a randomized complete block design with four replications. Fertilizer treatments included liquid P solution (10-34-0) applied prior to preplant seedbed preparation as a (1) broadcast (low-pressure spray), (2) dribble banded treatment on the soil surface and (3) knife (deep placement) treatment at a depth of 5 inches. A deep placed nitrogen treatment of UAN solution (28-0-0) was also applied in 1988 and 1989. The P rate was 50 pounds P_2O_5 per acre and the N rate was 15 pounds per acre. Zinc sulfate at a rate of 4 pounds Zn per acre was broadcast at two sites to correct for low (< 0.5 ppm Zn) soil test levels. Preplant seedbed preparation and trifurilan incorporation was done by the farmer-cooperators and consisted of two passes with a field cultivator with sweep shovels or a tandem disk within two days after fertilizer applications.

McCall soybeans were solid seeded in 6- or 12-inch rows with a grain drill at all sites between June 8 and June 12 in 1987 and 1988 and in 30-inch rows on June 20 in the 1989 study.

Soil samples were collected with a hand probe from eight to 10 cores from each plot at three dates: before treatment application, four weeks after treatment application, and after grain harvest. Twelve-inch long soil cores were separated into 2-inch depth increments and like depth increments were composited, air-dried, crushed to pass a 2 mm-mesh screen and analyzed for $NaHCO_3$-P.

Whole plant samples were collected at growth stages 2, 6 and 9 (Hanway and Thompson, 1967) from 1 meter of row. Samples were oven-dried, weighed and ground to pass a 20 mesh screen and analyzed for P. Yield, seed weight, P and protein content of the grain were determined at harvest. Plots were harvested with a plot combine at one site and with the farmer-cooperator's combine at four sites. Grain yield data was corrected to a 13.5 percent moisture basis.

RESULTS AND DISCUSSION

Soil P

Average extractable soil P levels of the various treatments in the surface 12 inches of soil for the five sites are shown in Figure 1. P broadcast or dribbled on the soil surface remained in the surface 2 inches of the soil after two herbicide incorporation tillage operations. In the knife treatment, all of the P was located between 4 and 6 inches deep. In general, extractable soil P decreased by the end of the growing season.

Grain Yields

Table 2 shows grain yields for all sites and years and treatment averages for all three years. Overall, no significant difference between treatments was observed for the three-year period, although the dribble and knife treatments tended toward higher yields. Signficiant differences were observed for the broadcast and knife treatments on Bearden soil site in 1987 ($P \leq 0.06$) but the yields were low due to 50 to 60 percent hail damage to the crop in July. The higher yielding treatments appeared to have a greater pod fill prior to the hail storm, reducing pod loss due to hail damage.

The 1988 growing season was one of the hottest and driest on record, resulting in lower yields, especially on the Glyndon soil site.

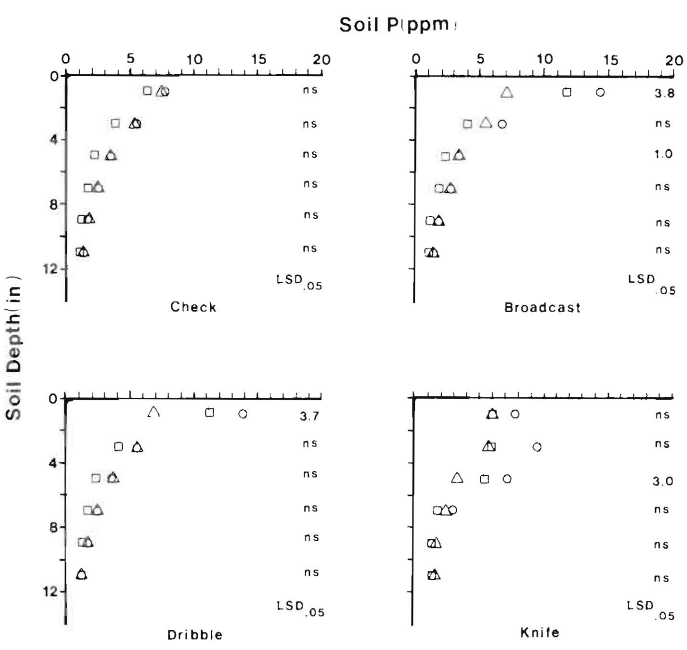

Figure 1. Distribution of available soil P as affected by placement treatment averaged over five sites for (△) pre-treatment, (O) post-treatment, and (□) end-of-season sampling dates.

Plant Tissue P

1987. The effects of the phosphorus treatments on P content of the above ground portion of the plants and total P uptake per plant in 1987 are shown in Table 3. At stage 2, the knife treatment gave significantly higher tissue P content and P uptake on the Bearden soil. At stage 6, results varied, with the dribble treatment providing higher P uptake values on the Bearden soil and both the broadcast and dribble treatments resulted in higher tissue contents on the Glyndon soil. No significant differences were observed for any treatment at stage 9.

All treatments gave significantly higher grain P values as well as P uptake on the Bearden site. The Glyndon site showed no significant differences between treatments although the P treatments were numerically higher.

1988. The 1988 growing season was extremely dry with rainfall in the study areas being less than 60 percent of normal from April through August. The only significant differences observed were for the tissue P content of plants at stage 6 on the Glyndon soil site. Here, the broadcast treatment showed lower P levels than the other treatments including the unfertilized control. This site exhibited greatest drought stress. This stress appears to be responsible for the variability in results from both sites.

1989. The effects of phosphorus treatment on soybean plant tissue P for 1989 are shown in Table 5. The dribble treatment gave significantly higher tissue P content levels

Table 2. Effects of phosphorus treatment on soybean grain yield.

	Grain yield*		
P Treatment	Bearden soil	Gardena soil	Glyndon soil
	bu/acre		
1987			
Unfertilized	14.0 a		30.9 a
Broadcast	16.6 b		31.1 a
Dribble	15.2 ab		32.1 a
Knife	16.4 b		32.5 a
1988			
Unfertilized	29.5 a		16.8 a
Broadcast	28.1 a		17.5 a
Dribble	28.4 a		20.3 a
Knife	29.2 a		18.8 a
N Only	28.0 a		18.9 a
1989			
Unfertilized		31.7 a	
Broadcast		27.9 a	
Dribble		24.1 a	
Knife		31.7 a	
N Only		27.4 a	
3-Year Averages (all soils)			
Unfertilized		24.5 a	
Broadcast		24.2 a	
Dribble		26.0 a	
Knife		25.7 a	
N Only		24.7 a	

* Values followed by the same letter are not significantly different at $P \leq 0.06$.

Table 3. Effects of phosphorus treatment on soybean plant tissue phosphorus — 1987.

P Treatment	Bearden Soil[1]		Glyndon Soil[1]	
	P Content	P Uptake	P Content	P Uptake
	...... %	-- g/plant --	...... %	-- g/plant --
Stage 2				
Unfertilized	0.283 a	0.37 a	0.405 a	0.66 a
Broadcast	0.293 ab	0.40 ab	0.393 a	0.62 a
Dribble	0.275 a	0.44 ab	0.348 a	0.66 a
Knife	0.313 b	0.49 b	0.410 a	0.71 a
Stage 6				
Unfertilized	0.158 a	0.78 a	0.250 a	2.12 a
Broadcast	0.153 a	1.05 ab	0.308 b	2.14 a
Dribble	0.183 a	1.17 b	0.295 b	2.00 a
Knife	0.168 a	0.90 ab	0.265 ab	2.02 a
Stage 9				
Unfertilized	0.218 a	1.43 a	0.255 a	3.92 a
Broadcast	0.248 a	1.83 a	0.238 a	2.74 a
Dribble	0.220 a	2.21 a	0.265 a	3.47 a
Knife	0.250 a	2.15 a	0.268 a	4.28 a
Grain[2]				
Unfertilized	0.415 a	3.1 a	0.450 a	7.3 a
Broadcast	0.467 b	4.1 b	0.510 a	8.3 a
Dribble	0.475 b	3.8 b	0.492 a	8.3 a
Knife	0.462 b	4.0 b	0.470 a	8.0 a

[1]Values followed by the same letter are not significantly different at $P \leq 0.05$.

[2]P uptake values for grain are reported as lbs/acre.

at stages 2 and 9 but no significant differences were observed in plant total P uptake. The N only treatment significantly depressed the grain phosphorus content and gave the lowest (but nonsignificant) P uptake values.

SUMMARY

This study showed that regardless of how P fertilizer is applied, it can be incorporated into the plant rooting zone with normal field preparation in reduced tillage farming systems and be available for plant utilization.

Although soil test P levels were low at all study sites in this study, soybean yield response to applied P was small, most likely due to droughty conditions. The application rate recommended by NDSU for 35 bushel soybeans is 40 pounds P_2O_5 per acre for a soil test of 0 to 9 pounds P per acre and 25 pounds P_2O_5 per acre for a soil test of 10 to 19 pounds P per acre (Dahnke et al., 1981). Responses occurred more often with the dribble or knife application procedures than with the broadcast treatment. Whether or not P was applied appeared to be of greater importance to the plant than the method of P application.

When applied alone, N appears to have no effect on increasing P uptake and may actually have decreased it in one case.

Table 4. Effects of phosphorus treatment on soybean plant tissue phosphorus — 1988.

P Treatment	Bearden Soil[1]		Glyndon Soil[1]	
	P Content	P Uptake	P Content	P Uptake
	...... %	-- g/plant --	...... %	-- g/plant --
Stage 2				
Unfertilized	0.285 a	0.50 a	0.285 a	0.36 a
Broadcast	0.275 a	0.45 a	0.285 a	0.30 a
Dribble	0.288 a	0.48 a	0.298 a	0.45 a
Knife	0.298 a	0.46 a	0.293 a	0.40 a
N Only	0.300 a	0.48 a	0.298 a	0.38 a
Stage 6				
Unfertilized	0.203 a	1.13 a	0.180 b	0.81 a
Broadcast	0.203 a	1.46 ab	0.158 a	0.66 a
Dribble	0.220 a	1.39 a	0.188 b	0.99 a
Knife	0.218 a	1.40 a	0.195 b	0.86 a
N Only	0.208 a	1.49 a	0.175 ab	0.78 a
Stage 9[2]				
Unfertilized	0.188 a	1.10 a	0.163 a	0.75 a
Broadcast	0.148 a	0.91 a	0.163 a	0.78 a
Dribble	0.208 a	1.29 a	0.175 a	1.02 a
Knife	0.170 a	1.22 a	0.190 a	0.82 a
N Only	0.193 a	1.37 a	0.155 a	0.82 a
Grain[3]				
Unfertilized	0.483 a	7.43 a	0.440 a	1.83 a
Broadcast	0.490 a	7.15 a	0.438 a	1.88 a
Dribble	0.493 a	7.30 a	0.433 a	2.18 a
Knife	0.498 a	7.57 a	0.445 a	2.06 a
N Only	0.483 a	7.06 a	0.453 a	2.10 a

[1]Values followed by the same letter are not significantly different at $P \leq 0.05$.

[2]Values at this date were affected by leaf loss due to drought.

[3]P uptake values for grain are reported as lbs/acre.

Table 5. Effects of phosphorus treatment on soybean plant tissue phosphorus — 1989.

P Treatment	Gardena Soil[1]	
	P Content	P Uptake
	...... %	-- g/plant --
Stage		
Unfertilized	0.272 ab	0.31 a
Broadcast	0.270 ab	0.30 a
Dribble	0.295 b	0.31 a
Knife	0.280 ab	0.30 a
N only	0.242 a	0.26 a
Stage 6		
Unfertilized	0.227 a	0.80 a
Broadcast	0.245 a	1.09 a
Dribble	0.257 a	1.27 a
Knife	0.255 a	1.09 a
N Only	0.217 a	0.73 a
Stage 9		
Unfertilized	0.155 a	1.50 a
Broadcast	0.177 ab	2.01 a
Dribble	0.182 b	1.87 a
Knife	0.172 ab	1.68 a
N Only	0.155 a	1.45 a
Grain[2]		
Unfertilized	0.453 a	7.50 a
Broadcast	0.460 a	6.69 a
Dribble	0.455 a	8.13 a
Knife	0.455 a	7.53 a
N Only	0.435 b	6.19 a

[1]Values followed by the same letter are not significantly different at $P \leq 0.05$.

[2]P uptake values for grain are reported as lbs/acre.

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