CORN RESPONSE TO STARTER PHOSPHORUS IN ADDITION TO FERTILIZER BANDED WITH STRIP-TILLAGE

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ABSTRACT

Producers often question the need for starter fertilizer application in addition to deep band with strip-tillage. The objective of this study was to evaluate the effect of phosphorus (P) starter on corn (*Zea mays*) in addition to deep-banded application. A study was conducted at two locations, one under supplemental irrigation and one dry land, with a corn-soybean crop rotation established in the spring of 2006. Strip-tillage was completed before corn in the rotation and soybean was planted without previous tillage. The treatments included in this paper include a control, starter only (ST) at 20 lb P_2O_5 ac^{-1}, and two total P rates of 40 and 80lb P_2O_5 ac^{-1} with placements broadcast, broadcast with ST, deep band, and deep band with ST, applied before corn. Results show the effect of P rate and placement on V-6 P uptake, ear leaf and grain P, and yield became more significant over 9 years. Starter placement increased early P uptake when combined with both broadcast and deep band. In Scandia, starter increased yields by 10 and 6 bushel at the 40 and 80lb P_2O_5 ac^{-1} rates with broadcast. With the deep band application, additional starter increased yield by 6 bushel. There is value in long term studies to evaluate placements as crop responses may not be seen in shorter studies.

INTRODUCTION

Strip-tillage can be considered as a popular reduced tillage option for corn production in many regions of the Midwest US. Strip-tillage allows for residue to be incorporated in a narrow band and also prepare soil for planting. The addition of deep band application of fertilizer with the strip-tillage allows for concentrated fertilizer placement directly below the planted seed. Increasing use of plant tissue testing to monitor P uptake has also shown the highest recovery of P with sub-surface band applications (Schwab et al., 2006), however not translating into increase yields compared to broadcast (Barber, 1980; Mallarino et al., 1999).

Surface fertilizer applications can increase P stratification (Eckert and Johnson, 1985; Mullen and Howard, 1992), however several studies have shown that broadcast applications have increased yields (Bordoli and Mallarino, 1998). One explanation is to consider the amount of plant roots that come into contact with the fertilizer with the different placement methods. Kovar and Barber (1987) have shown increased recovery of P occurs when at least five percent of the soil volume was fertilized. Starter and deep bands apply P in a concentrated zone, thus contacting less bulk soil. A consistent response to placement is with the 2x2 (2in to the side and 2in below the seed) starter application (Randall and Hoeft, 1998). The combination of broadcasting and starter banding could improve crop uptake as banding would allow for readily available P and broadcast could increase nutrients in the soil.

Expectations for greater yields can lead to fertilizer applications greater than removal rates, increasing soil P. This create the need for a long term study evaluating fertilizer placement and changes in STP in reduced tillage systems. The objective of this study was to evaluate the long term effect of fertilizer placement of P on corn with emphasis on the use of starter fertilizers.

MATERIALS AND METHODS

A study was established in 2006 and conducted at Scandia and Ottawa, Kansas. The Ottawa site is location at 38°32´19˝N lat.; 95°15´11˝ W long. on the East Central Agronomy Experiment Field. The soil at the Ottawa site is classified as Woodson silt loam. The Scandia site is located at 39°46´23˝N lat.; 97°47´19˝ W long. on the North Central Agronomy Experiment Field. The soil in Scandia is classified as a Crete silt loam. This location had a history of low STP and no-till production practices for more than 5 years before starting this study and therefore, stratification of nutrients was expected. The Scandia location received supplemental irrigation and Ottawa was dryland. Both locations received strip-tillage before corn and soybeans were planted with no prior tillage. Corn and soybeans were both planted on the row of the previous years' crop.

The experimental design was a randomized complete-block design with four replications with a one-way treatment structure. Treatments included in this paper include a control, starter only (ST) at 20lb P_2O_5 ac^{-1}, and two P rates of 40 and 80lb P_2O_5 ac^{-1} with placements broadcast, broadcast with ST, deep band, and deep band with ST, applied before corn. Starter fertilizer was applied 2x2 (2in to the side and 2in below the seed) with the planter using ammonium polyphosphate (APP), 10-34-0 (N-P_2O_5-K_2O). Broadcast treatments were applied by hand to the soil surface at planting using triple superphosphate (TSP; 0-46-0). Deep bands were applied with a strip-till operation approximately 6in deep before planting using APP. All other plots were strip-tilled to prevent tillage effects, even if P fertilizer was not applied. Nitrogen (N) was applied as a deep band application with urea ammonium nitrate (UAN; 28-0-0) to balance N in all treatments, therefore preventing a nitrogen effect from the APP application.

Initial soil samples were collected in fall 2005 by collecting one composite sample by depth. Soil water pH was determine on 1:1 (soil:water). Soil test phosphorus (STP) and potassium were determined by Mehlich-3 extraction (Frank et al, 1988). Organic matter was determined by Walkley-Black (Combs and Nathan, 1998). Plant tissue samples were collected during specific growth stages for corn. Ten whole plant samples were taken at V-6 growth stage for early growth and fifteen corn ear leaf tissue samples were collected at silking (VT-R1). Plant samples were analyzed for P concentration and plant uptake was calculated at V-6 growth stage. Plants were dried in a forced air oven at 60 degree Celsius for a minimum of 4 days. After drying, plants were ground with a Wiley Mill grinder to pass a 2mm screen and digested using a sulfuric acid and hydrogen peroxide digest (Thomas et al., 1967). Phosphorus concentration was then determined by inductively coupled plasma atomic emission spectroscopy (ICP-AES).

The center two rows width of each plot was machine harvested. Grain weight was recorded at the end of the growing season and adjusted for 155 g kg-1 moisture for corn. Grain was ground to pass a 2 mm screen and digested following Thomas et al. (1967) and analyzed for P concentration by ICP-AES.

Data was analyzed by year, and across years using year as a random variable for analysis. Corn parameters were analyzed using *proc Glimmix* SAS 9.4 (SAS Institute, Inc.) to determine if there was a significance ($P<0.1$) response to P placements and rates. Placement and rate effects on least square means of corn early P uptake, ear leaf and grain P, and yield were evaluated using repeated measurers at a significant level of $P<0.1$. Comparisons were analyzed individually and significance was tested at $P<0.1$ for each parameter listed above.

RESULTS AND DISCUSSION

The initial 6in soil test results from 2005 show that Ottawa and Scandia had a pH of 5.8 and 6.6, STP of 7.6ppm for both, potassium at 155 and 515ppm, and 2.9 and 2.6% organic matter, respectively. Both locations are categorized as "very-low' in STP according to Liekam et al., 2003.

Over the 9 year study, P fertilizer rate and placement became more significant (Table 1). One possibility for this crop response could be attributed to changes in STP due to crop removal at higher rate than applied P in most years. Table 2 and 3 gives individual year early P uptake, ear leaf and grain P responses to placement for Ottawa and Scandia. Broadcast plus starter and deep band plus starter generally resulted in greater early P uptake and ear leaf P. Placement did not clearly result in greater P concentrations in ear leaf or grain P at either location.

Both Ottawa and Scandia, showed a response to starter (Table 4). In Scandia, starter significantly increase yield compared to broadcast at the 40lb P_2O_5 ac^{-1} rate and deep band in the 80lb P_2O_5 ac^{-1} rate. However, in Ottawa, there was no significant increase in yield at the 40lb P_2O_5 ac^{-1} rate compared to broadcast and a decrease in yield compared to deep band.

Individual comparisons of starter compared to broadcast show an increase in early P uptake and greater concentrations of P in ear leaf samples in Ottawa (Table 5). This increase, however, did not translate into yield at either fertilizer rate. At the high rate, there was no response to starter and the deep band averaged 7 bushel more than starter. In Scandia (Table 6), comparisons of broadcast to broadcast plus starter increased uptake only at the low rate, but increased at both rates compared to deep band. As opposed to Ottawa, corn positively responded to starter by at least 6 bushel per acre compared to both broadcast and deep band in Scandia.

SUMMARY

The value of long term studies was shown here, as single year comparisons may not show differences in placement, particularly starter fertilizers. The 9 year application of P in broadcast with starter band has shown yield benefits as a long term management system. This placement has shown increased early P uptake and yield. With the long term placement on soil surface and the amount of root-soil contact, bulk soil P would be increased. The addition of starter application would allow for readily available P close to the seed. Further long term research is essential for understanding the effect of different management systems over time, helping producers know which management systems are agronomic and environmentally beneficial.

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Table 1. ANOVA for the effect of treatment on early phosphorus (P) uptake in whole plant samples taken at V-6 growth stage, P concentration in ear leaf samples taken at silking (VT-R1) and grain samples collected following harvest, and corn grain yield at Ottawa and Scandia for the 9 year study and averaged over years.

	Year									
Sample	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
	---------- P < F ----------									
	Ottawa									
V-6 P (mg plant^{-1})	---	0.520	0.541	0.001	---	0.001	0.219	0.001	0.001	0.001
Ear Leaf P (%P)	0.516	0.036	0.048	0.002	0.001	0.001	0.001	0.001	0.001	0.001
Grain P (%P)	0.049	0.589	0.009	0.001	0.001	0.583	0.199	0.001	0.001	0.001
Yield (bu ac^{-1})	0.003	0.271	0.715	0.013	0.011	0.568	0.992	0.430	0.068	0.081
	Scandia									
V-6 P (mg plant^{-1})	---	0.001	0.001	---	---	0.001	0.001	0.001	0.001	0.001
Ear Leaf P (%P)	0.575	0.223	0.003	0.003	0.015	0.001	0.001	0.006	0.001	0.001
Grain P (%P)	0.873	0.518	0.160	0.003	0.021	0.017	0.302	0.038	0.086	0.001
Yield (bu ac^{-1})	0.878	0.001	0.001	0.001	0.010	0.001	0.006	0.001	0.010	0.001

Table 2. Average early phosphorus (P) uptake in whole plant samples taken at V-6 growth stage, and P concentration in ear leaf samples taken at silking (VT-R1) and grain samples collected following harvest for corn at Ottawa.

	0	20 lb P_2O_5	40 lb P_2O_5				80 lb P_2O_5			
Year	Control	ST†	B	B+ST	DB	DB+ST	B	B+ST	DB	DB+ST
	V-6 whole plant (mg P plant^{-1})									
2007	27.3	25.2	26.0	25.2	28.2	27.6	28.5	29.6	29.8	31.5
2008	41.6	51.5	50.5	45.9	54.6	59.2	66.2	53.7	51.9	58.9
2009	7.9f	14.0bc	8.6f	9.9ef	12.5cd	15.8b	11.7de	14.3bc	13.0cd	19.6a
2011	7.7g	11.1f	12.9def	12.6def	12.6ef	15.4abc	11.8ef	14.9bcd	11.5ef	16.6ab
2012	11.3b	13.6ab	12.1b	12.0b	13.2ab	13.9ab	12.6b	15.7a	15.8a	13.1ab
2013	25.9f	33.5de	29.6ef	34.2de	37.0cd	40.5bc	42.8abc	47.8a	43.1abc	48.0a
2014	13.1f	18.7cde	17.2ef	18.9cde	20.5bcde	18.8cde	19.7bcde	28.7a	22.0bcd	23.7b
	Ear leaf (%P)									
2006	0.23	0.20	0.23	0.21	0.20	0.23	0.24	0.23	0.19	0.21
2007	0.40cde	0.43bcd	0.39de	0.51a	0.43bcd	0.46abc	0.36e	0.44bcd	0.44bcd	0.47ab
2008	0.23d	0.26cd	0.28cd	0.28bcd	0.30bc	0.30bc	0.30bcd	0.32bc	0.35b	0.42a
2009	0.23c	0.26bc	0.25bc	0.27b	0.26bc	0.27b	0.26bc	.27b	0.32a	0.33a
2011	0.20i	0.25gh	0.24h	0.28def	0.27fg	0.28def	0.28ef	0.30cde	0.31bc	0.32ab
2012	0.23i	0.28fgh	0.27gh	0.30def	0.32cd	0.29efg	0.27h	0.32cde	0.38a	0.36ab
2013	0.17g	0.19efg	0.18fg	0.21defg	0.25bc	0.25bcd	0.20efg	0.22cdef	0.31a	0.27ab
2014	0.20f	0.26de	0.23ef	0.28cd	0.29bcd	0.28cd	0.28bcd	0.28bcd	0.31b	0.39a
	Grain (%P)									
2006	0.22e	0.24cde	0.25bcd	0.23de	0.26abc	0.27ab	0.26abc	0.27ab	0.28a	0.27ab
2007	0.23	0.25	0.26	0.27	0.23	0.23	0.28	0.27	0.24	0.25
2008	0.22d	0.23d	0.27bc	0.26bc	0.25cd	0.27bc	0.30a	0.27abc	0.27bc	0.27bc
2009	0.21g	0.22fg	0.25de	0.26bcd	0.25de	0.24ef	0.26cde	0.30a	0.28ab	0.28bc
2010	0.23f	0.26e	0.29bcd	0.28Cd	0.28d	0.29abcd	0.29bcd	0.30abc	0.30abc	0.30abcd
2011	0.24	0.27	0.26	0.26	0.26	0.27	0.28	0.27	0.29	0.28
2012	0.27	0.24	0.26	0.22	0.24	0.25	0.26	0.26	0.25	0.25
2013	0.26h	0.29g	0.28h	0.32ef	0.34def	0.35bcd	0.32f	0.34cde	0.37ab	0.39a
2014	0.16f	0.19e	0.20de	0.22cd	0.20e	0.20de	0.23bc	0.23bc	0.24ab	0.25a

† Placements ST, 2 in by 2 in starter band; B, broadcast; DB, deep band 6 in deep with strip-tillage.

Table 3. Average early phosphorus (P) uptake in whole plant samples taken at V-6 growth stage, and P concentration in ear leaf samples taken at silking (VT-R1) and grain samples collected following harvest for corn at Scandia.

	0	20 lb P_2O_5	40 lb P_2O_5				80 lb P_2O_5			
Year	Control	ST†	B	B+ST	DB	DB+ST	B	B+ST	DB	DB+ST
	V-6 whole plant (mg P plant^{-1})									
2007	12.3d	26.5b	20.3c	26.6b	26.1b	27.8b	23.0bc	24.6bc	27.9b	33.6a
2008	40.8f	48.7de	47.3def	72.0a	46.5def	53.0cd	61.1b	43.2ef	56.4bc	68.1a
2011	9.5g	14.0ef	13.7f	17.1de	16.7def	17.7d	18.9cd	25.4a	21.5bc	23.8ab
2012	38.9f	52.9de	51.3ef	73.4bc	61.1cde	67.2bcd	62.3bcde	76.7b	5207bcde	90.9a
2013	31.1f	48.6e	43.3e	51.2de	52.8de	52.8de	56.9cd	73.2a	63.3bc	76.5a
2014	32.7g	51.3ef	47.0f	64.2bcd	50.6ef	65.2bc	55.0def	61.1cd	65.0cd	70.3ab
	Ear leaf (%P)									
2006	0.20	0.22	0.23	0.22	0.22	0.22	0.23	0.23	0.23	0.22
2007	0.22	0.27	0.28	0.27	0.26	0.27	0.27	0.30	0.26	0.30
2008	0.22d	0.25bc	0.25bc	0.26ab	0.27ab	0.27ab	0.28a	0.28a	0.23cd	0.26ab
2009	0.21f	0.25bcde	0.23ef	0.23cdef	0.23ef	0.25bcd	0.24cde	0.26ab	0.23def	0.26bc
2010	0.23e	0.25de	0.26cd	0.25cd	0.26cd	0.26cd	0.29a	0.27abcd	0.25cd	0.27bcd
2011	0.21f	0.23e	0.25cde	0.25bcd	0.25cde	0.25cde	0.27bc	0.27ab	0.25cde	0.24de
2012	0.19d	0.20cd	0.22bc	0.21bc	0.20cd	0.20cd	0.24a	0.24ab	0.21cd	0.22bc
2013	0.21d	0.22bc	0.21cd	0.23bc	0.21cd	0.24ab	0.23bc	0.23bc	0.21cd	0.24ab
2014	0.16d	0.18cd	0.21bc	0.21bc	0.17d	0.18cd	0.22ab	0.23ab	0.18d	0.21bc
	Grain (%P)									
2006	0.23	0.24	0.23	0.23	0.22	0.22	0.23	0.25	0.24	0.25
2007	0.26	0.26	0.23	0.25	0.22	0.24	0.26	0.25	0.26	0.23
2008	0.24	0.26	0.26	0.26	0.27	0.28	0.30	0.27	0.28	0.29
2009	0.18d	0.22bc	0.22c	0.24abc	0.24abc	0.25a	0.22c	0.24abc	0.22c	0.25a
2010	0.22d	0.22d	0.24bcd	0.23cd	0.24bcd	0.25abc	0.27a	0.27a	0.24bcd	0.26ab
2011	0.21c	0.22bc	0.21c	0.25a	0.22bc	0.25ab	0.25a	0.25a	0.25ab	0.25ab
2012	0.21c	0.21c	0.25ab	0.21c	0.22bc	0.22bc	0.26a	0.24abc	0.23bc	0.23abc
2013	0.18c	0.19bc	0.18c	0.21ab	0.24a	0.23a	0.21ab	0.23a	0.23a	0.22a
2014	0.23e	0.26cde	0.26bcd	0.25de	0.27abcd	0.27abcd	0.26ab	0.27abcd	0.27abcd	0.29abc

† Placements ST, 2 in by 2 in starter band; B, broadcast; DB, deep band 6 in deep with strip-tillage.

Table 4. Average corn grain yield response to fertilizer placement and rate at Ottawa and Scandia.

Year	0	20 lb P_2O_5	40 lb P_2O_5				80 lb P_2O_5			
	Control	ST†	B	B+ST	DB	DB+ST	B	B+ST	DB	DB+ST
	Ottawa (bu ac^{-1})									
2006	81.6f	83.9ef	96.1abcd	93.1bcde	97.7abc	101.2ab	99.6ab	100.1ab	102.0a	89.0def
2007	94.2	102.4	95.8	103.3	103.6	105.4	99.5	103.5	103.6	100.9
2008	129.9	141.3	142.2	152.6	150.2	140.6	144.1	142.9	134.4	138.6
2009	139.3de	140.0de	142.4bcde	141.7cde	152.9a	142.2bcde	150.0abc	147.8abcd	141.7cde	138.7e
2010	88.0b	89.4b	99.5a	102.0a	102.0a	106.5a	100.0a	100.9a	101.7a	99.5a
2011	71.9	76.2	78.1	80.4	75.6	84.5	83.7	87.2	85.9	82.3
2012	11.6	10.5	13.6	13.9	13.7	10.8	12.9	11.2	12.4	13.7
2013	97.3	95.8	86.1	92.8	90.2	84.7	78.8	72.4	77.2	71.7
2014	114.0abc	98.5bcd	117.8ab	99.3bcd	92.3cd	112.6abc	125.0a	116.4ab	120.5ab	81.2d
	Scandia (bu ac^{-1})									
2006	178.6	186.5	188.1	191.3	192.9	188.1	192.9	189.7	188.1	189.7
2007	181.8c	221.6b	223.2ab	231.2ab	231.2ab	228.0ab	229.6ab	231.2ab	229.6ab	229.6ab
2008	191.3e	228.0abc	220.0cd	236.0a	223.2bcd	232.8ab	216.8d	229.6ab	228.0abc	236.0a
2009	223.2c	258.3ab	256.7ab	271.0a	253.5b	271.0a	263.1ab	267.9a	255.1ab	264.7ab
2010	188.1b	218.4a	220.0a	218.4a	224.8a	226.4a	223.2a	231.2a	215.2a	218.4a
2011	178.6d	207.3c	215.2bc	221.6abc	210.5c	220.0abc	218.4abc	228.0ab	220.0abc	220.0abc
2012	105.2c	124.4b	124.4b	124.4ab	129.1ab	126.0ab	132.3ab	127.6ab	127.6ab	132.3ab
2013	110.0g	129.1cde	116.4fg	133.9bcde	126.0ef	143.5ab	127.6def	140.3abc	126.0ef	135.5bcde
2014	159.4e	199.3a	172.2de	192.9abc	177.0cde	188.1abcd	184.9abcd	197.7ab	180.2bcd	194.5ab

† Placements ST, 2 in by 2 in starter band; B, broadcast; DB, deep band 6 in deep with strip-tillage.

Table 5. Comparisons of placement within total application rates for early phosphorus (P) uptake in whole plant samples taken at V-6 growth stage, P concentration in ear leaf samples taken at silking (VT-R1) and grain samples collected following harvest, and corn grain yield at Ottawa averaged over 9 year study.

Comparison†	V-6 Whole plant‡	Ear leaf	Grain	Yield
	mg P plant^{-1}	----- %P-----		bu ac^{-1}
Control vs ST	(-4.2)*	(-0.03)*	(-0.02)*	ns
		40 lb P_2O_5 ac^{-1}		
B vs B+ST	(-2.5)*	(-0.03)*	ns	ns
DB vs DB+ST	(-2.3)*	ns	ns	ns
B vs DB	(-4.1)*	(-0.03)*	ns	ns
B+ST vs DB+ST	(-3.9)*	ns	ns	ns
		80 lb P_2O_5 ac^{-1}		
B vs B+ST	(-3.7)*	(-0.03)*	ns	ns
DB vs DB+ST	ns	(-0.02)*	ns	(+7.0)*
B vs DB	(-5.5)*	(-0.06)*	ns	ns
B+ST vs DB+ST	ns	(-0.05)*	ns	(+7.0)*

† Placement of fertilizer ST, 2in by 2in starter band; B, broadcast; DB, deep band at 6in deep applied with the strip-tillage.
‡ Values in parenthesis are differences in comparisons; *, Indicates significance at $P \leq 0.1$ level; ns, indicates non-significant comparisons.

Table 6. Comparisons of placement within total application rates for early phosphorus (P) uptake in whole plant samples taken at V-6 growth stage, P concentration in ear leaf samples taken at silking (VT-R1) and grain samples collected following harvest, and corn grain yield at Scandia averaged over 9 year study.

Comparison†	V-6 Whole plant‡	Ear leaf	Grain	Yield
	mg P plant^{-1}	----- %P-----		bu ac^{-1}
Control vs ST	(-9.6)*	(-0.03)*	(-0.01)*	(-28.7)*
		40 lb P_2O_5 ac^{-1}		
B vs B+ST	(-3.5)*	ns	(-0.01)*	(-9.6)*
DB vs DB+ST	(-2.7)*	(-0.01)*	ns	(-6.4)*
B vs DB	(-6.5)*	ns	ns	ns
B+ST vs DB+ST	(-5.6)*	ns	ns	ns
		80 lb P_2O_5 ac^{-1}		
B vs B+ST	ns	ns	ns	(-6.4)*
DB vs DB+ST	(-7.4)*	(-0.02)*	ns	(-6.4)*
B vs DB	ns	(+0.03)*	ns	ns
B+ST vs DB+ST	(-9.4)*	(+0.10)*	ns	ns

† Placement of fertilizer ST, 2in by 2in starter band; B, broadcast; DB, deep band at 6in deep applied with the strip-tillage.
‡ Values in parenthesis are differences in comparisons; *, Indicates significance at $P \leq 0.1$ level; ns, indicates non-significant comparisons.

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