PHOSPHORUS DISTRIBUTION AFTER LONG-TERM P FERTILIZER PLACEMENT UNDER STRIP-TILLAGE

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ABSTRACT

Long-term phosphorus fertilizer placement under strip-tillage tillage can affect the vertical and horizontal distribution of soil test P (STP). The objective of this study was to evaluate the effect of P fertilizer placement on STP distribution under strip-till. A study was established in Scandia, Kansas in 2006 under a corn-soybean rotation. Treatments included a (1) control (No P); and P applied at 80 lb P_2O_5 ac^{-1} as (2) broadcast, (3) deep band, (4) broadcast with starter 2x2, and (5) deep band with starter 2x2. All fertilizer was applied before planting corn and all plots received strip-tillage. After 10-years of corn and soybean production, soil samples were collected at 0, 3, 6, 9, and 12 in from the row and divided into four depths of 0-3, 3-6, 6-9, and 9-12 in, and analyzed for pH, Mehlich-3 STP, soil test potassium (STK). Data were analyzed for treatment differences by position and depth using depth as a repeated measure. Results show significant treatment differences in STP in the in-row sampling (0 in) at depths 3-6 and 6-9 in. The greatest STP values occurred with deep band, however no differences were found with starter application. Broadcast and broadcast with starter showed significantly greater STP at 9 in from the row at the 0-3 in depth. There were no differences between treatment effects on STK or pH at any position or depth. However, general trends showed greater potassium concentrations for in-row sampling at the 0-6 in sampling depth. Vertical and horizontal STP stratification was increased significantly with long-term fertilizer P placement and minimum tillage. This may require revised guidelines for better soil sampling and management in the field.

INTRODUCTION

With the adoption of fertilizer application with the strip-tillage in corn and soybean production, soil test P variability is becoming a greater issue. Strip-tillage has multiple benefits combining aspects of both no-till and conventional tillage. By incorporating residue in a narrow band, the strip-tillage prepares the seed bed for planting. Improved seedbed conditions with strip-tillage have led to better early crop growth and development, and yield (Randall and Vetsch, 2008). However, having no-till between the rows can decrease P in runoff.

Strip-tillage also allows for deep band fertilizer placement in the same pass. Some studies showed that placing P directly below the plant in concentrated bands, deep band applications have improved nutrient availability, fertilizer use efficiency, and yield (Bordoli and Mallarino, 1998). However, other studies have shown that deep band and broadcast show similar yield (Borges and Mallarino, 2003; Rehm and Lamb, 2004; Farmaha et al., 2011). Overall, the most consistent response to fertilizer placement is using a starter fertilizer (low rate of fertilizer placed in a band at planting) (Randall and Hoeft, 1988). Repeated applications of high rates of P to the soil surface could lead to increased P losses compared to deep banding (Sharpley and Halvorson, 1994). Concentrated bands of fertilizer containing nitrogen (N) can create zones of acidification that can affect nutrient acquisition.

Based on the distribution of P and K in soil, researchers have tried to determine a better sampling protocol for strip-tillage systems. Kitchen et al. (1990) showed that for every sample taken from the band, 20 samples from outside the band were needed to represent soil test P levels. Other researchers have included the range of 15-30 soil cores to accurately describe soil test levels (Shapiro, 1988). Fernandez and Schaefer (2012) determined that a 1:3 ratio of in-row to between-row is adequate to estimate soil test in systems where the band placement is maintained constant. However, one challenge can be to accurately identify the fertilized rows from previous years under field production conditions.

A number of studies have described nutrient distribution in soil with broadcast and deep band applications under various tillage and no-till systems (Kitchen et al, 1990; Rehm et al., 1995; Borges and Mallarino, 2003; Farmaha et al., 2012; Fernandez and Schaefer, 2012). Farmaha et al. (2012) described the distribution of P and K with deep banding fertilizer in strip-tillage systems and Fernandez and Schaefer (2012) described both deep banding and broadcast applications in strip-tillage. However, studies including a split applications of fertilizer in a starter band at planting are needed. Furthermore, previous studies evaluated the short-term effect of fertilizer placement and most studies are limited to 1-2 years. The objectives of this study were to (i) determine the distribution of soil test P, K, and pH after a decade of fertilizer placement as broadcast, broadcast plus starter, deep band, and deep band plus starter compared to the control (No P) under strip-tillage and (ii) develop soil sampling procedures to improve estimating soil P and K test levels.

MATERIALS AND METHODS

Site description

The study was conducted at Scandia, Kansas, starting in 2006. The Scandia site (39°46´23˝N lat.; 97°47´19˝ W long.) is located on the North Central Agronomy Experiment Field. The soil in Scandia is classified as a Crete silt loam (fine, smectitic, mesic Pachic Argiustolls) (Soil Survey Staff, 2016). This location had a history no-till production practices for more than 5 years before the establishment of this study. The Scandia location received supplemental irrigation. The corn-soybean crop rotation is common for this region and each crop was present every year in the study with adjacent fields. Strip-tillage was performed before corn and soybeans were planted with no prior tillage. Corn and soybeans were both planted on the row of the previous years' crop.

Treatments

The experimental design was a randomized complete-block design with four replications. Treatments included (1) control, starter fertilizer at 20 lb P_2O_5 ac^{-1}, and total P rates of 80 lb P_2O_5 ac^{-1} with four placement combinations: (2) broadcast, (3) broadcast with starter, (4) deep band, and (5) deep band with starter applied before planting corn. Starter fertilizer was applied 5 cm to the side of the seed dribble banded on the surface. All starter was applied using ammonium polyphosphate (APP), 10-34-0. Broadcast treatments were applied by hand to the soil surface at planting using triple superphosphate (TSP; 0-45-0). Deep bands were applied with a strip-till operation approximately 6 in deep before planting using APP. The strip-till implement in Scandia was a straight chisel point shank knife, wavy coulter, rolling basket, and fertilizer application with a John Blue electric pump using speed and pressure. All plots in the study 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. In Scandia, a blanket application of 200 lb N ac^{-1} using anhydrous ammonia (AA; 82-0-0) and 24 lb N ac^{-1} to balance N in the deep band for a total of 224 lb N per acre.

Sampling

Initial soil samples were collected at random prior to establishing treatments by plot and averaged for Scandia. After 10-years of fertilizer placement, soil Samples for P, K, and pH were collected from each plot in the spring of 2016 before corn planting following sampling techniques outlined by Fernandez and Schaefer (2012). A composite of 8 cores (1-inch diameter each) for each of the 4 replicated plots were made for each of six positions with respect to the crop row: In-Row (IR) and Between-Row (BR) at 3 inch increments from IR (BR-3, BR-6, BR-9, BR-12, and BR-15). Each sample was partitioned into 0-3, 3-6, 6-9, and 9-12-inch depth increments. The composite 8 soil core samples were collected one per each of the positions with respect to the crop-row within the 10 by 30 ft plot area. To ensure consistency in sampling position with respect to the row, a board with pre-drilled holes at centers for each designated distance was used.

Soil samples were dried for a minimal of 4 days at 100 degrees Fahrenheit and ground to pass a 2-mm diameter sieve. Samples were analyzed for P using the Mehlich-3 extraction and concentrations determined colorimetrically (Frank et al., 1988). Potassium was determined using the ammonium acetate extraction method (Warncke and Brown, 1998) and analyzed with an inductively coupled plasma optical emission spectrometry (ICP-OES). The soil pH was determined using a 1:1 (soil:water). Organic matter was determined by Walkley-Black (Combs and Nathan, 1998).

Statistical Analysis

Data were analyzed by position with respect to the row and depth using block as a random variable in the model. Soil test P were analyzed using *proc Glimmix* SAS 9.3 (SAS, 2011) to determine if there was a significant ($P<0.10$) response to P placement under strip-tillage. Treatment effects on least square means of STP were separated using repeated measure at a significant level of ($P<0.10$).

RESULTS AND DISCUSSION

Initial soil samples were taken before establishing the study in the Spring of 2006. One composite sample was collected at random by 6-inch depth and averaged for Scandia. The Scandia location had a pH of 6.6, STP of 7.6 ppm, STK of 515 ppm, and 2.6 percent organic matter. Based on STP, Scandia is categorized as “very-low” and should respond to fertilizer application below 20 ppm (Liekam et al., 2003).

Fertilizer placement was found to significantly affect STP levels at various positions and depths (Table 1). Significant differences were observed in the top 0-3 inches at all positions and at all depths at BR-3 position. Significantly higher levels of P were observed with long-term broadcast and broadcast with starter applications (Table 2). Higher P levels were observed IR and BR-3 with all fertilizer applications compared to the control. With the incorporation of soil and residue with the strip-tillage unit, higher levels would be observed IR and BR-3 from the row.

With the strip-tillage application, deep banding fertilizer in the same pass can decrease fertilizer application costs. However, concentrated bands create levels of high P levels. After 10-years of banding, higher P levels were observed BR-3 at all depths. This includes deep banding and deep banding with starter. Soil sampling for the top 6 inches, these concentrated bands can generate an overestimation for STP levels for the bulk soil. Phosphorus levels with deep band and deep band with starter were above 50 ppm if samples were taken either IR or BR-3 inches from the row (Table 2). Soil sampling these bands would greatly affect fertilizer recommendations.

Table 3 show corn grain and soybean seed yields for the 10-year study. As the study progressed, greater separation between treatments occurred. Increased significance treatment effects on yield could be explained by changes in soil test (Table 3). The use of starter fertilizer in combination with broadcast or deep-band show small average increase in yield. However, fertilizer placement showed no statistically significant effect on corn and soybean yield.

SUMMARY

Vertical and horizontal STP stratification was increased significantly with long-term fertilizer P placement and minimum tillage. This may require revised guidelines for better soil sampling and management in the field. By mapping the distribution of different fertilizer placements, we can make better decisions in regards to application rates.

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Table 1. ANOVA for the effect of treatment on soil test phosphorus (STP) after 10-years of corn-soybean rotation under strip-tillage.

	Position†					
Depth	IR-0	BR-3	BR-6	BR-9	BR-12	BR-15
inch	- P-value -					
0 – 3	0.063	0.006	0.049	0.097	0.015	0.001
3 – 6	0.291	0.062	0.431	0.522	0.068	0.478
6 – 9	0.342	0.042	0.258	0.223	0.109	0.423
9 - 12	0.180	0.082	0.212	0.131	0.031	0.045

† Sampled positions as related to the row: In-Row (IR) and Between-Row (BR) at 3, 6, 9, 12, and 15 inches from the center of the row.

Table 2. The effects of fertilizer placement on soil test phosphorus (STP) after 10-years of corn-soybean rotation under strip-tillage.

	Position†					
Treatment‡	IR-0	BR-3	BR-6	BR-9	BR-12	BR-15
			0 – 3 inch§			
Control	6.1c¶	5.5c	6.4b	5.4b	5.5c	5.6b
BC	19.5ab	13.1b	16.6a	14.1ab	12.3ab	14.8a
BC+ST	27.7a	12.7b	17.1a	20.3a	17.2a	20.4a
DB	12.8bc	21.5a	7.4b	7.0b	7.2bc	8.3b
DB+ST	23.2ab	12.3b	8.0b	7.1b	8.3bc	8.4b
			3 – 6 inch			
Control	4.2	4.9b	4.7	4.3	4.1c	4.2
BC	7.6	6.9b	5.8	4.8	4.8abc	4.8
BC+ST	6.7	9.3b	5.6	5.2	5.6a	5.1
DB	53.6	58.8ab	5.3	8.7	4.3bc	4.5
DB+ST	54.1	95.3a	46.0	4.9	5.2ab	4.5
			6 – 9 inch			
Control	2.9	3.6b	3.8	3.5	3.3c	3.2
BC	4.2	4.4b	4.8	4.3	4.2ab	4.0
BC+ST	4.3	4.7b	4.8	4.7	4.4a	4.2
DB	14.9	14.4a	4.3	4.5	3.4bc	3.6
DB+ST	10.7	18.4a	11.9	4.9	4.5a	3.6
			9 – 12 inch			
Control	2.2	2.6b	2.7	2.8	2.3c	2.4c
BC	3.1	3.0b	3.4	3.7	3.2ab	3.3ab
BC+ST	3.2	3.4b	3.7	3.6	3.5a	3.2ab
DB	3.5	3.6b	2.8	2.6	2.8bc	2.7bc
DB+ST	3.8	5.1a	3.9	3.2	3.3ab	3.6a

† Sampled positions as related to the row: In-Row (IR) and Between-Row (BR) at 3, 6, 9, 12, and 15 inches from the center of the row.

‡ Fertilizer placement treatments: Control, no P applied; and fertilizer applied at 80 lb P_2O_5 ac^{-1} BC, broadcast application made before planting; ST, starter as 2 inch from the seed, dribble band at planting; DB, deep band application made 6 inches deep with the strip-tillage prior to planting.

§ Depths at 0-3, 3-6, 6-9, and 9-12 inches deep at each position.

¶ Different letters in columns by depth indicate significant differences at the $P \leq 0.1$ level.

Table 3. The effects of fertilizer rate and placement on corn grain and soybean seed yields in and soil samples taken at random in 2014 following corn and soybean harvest in Scandia.

Year	Control†	BC	BC+ST	DB	DB+ST
	- Corn (bu ac^{-1}) -				
2006	178	193	189	188	189
2007	181b‡	229a	231a	229a	229a
2008	191d	216c	229ab	228ab	235a
2009	223b	263a	267a	255a	264a
2010	188b	223a	231a	215a	218a
2011	178b	218a	228a	220a	220a
2012	105b	132a	127a	127a	132a
2013	110c	127b	140a	126a	135ab
2014	159b	185a	197a	180a	194a
2015	180b	229a	235a	220a	235a
	- - - - - - - - - - - - - - - - - - - Soybean (bu ac^{-1}) -				
2006	44c	47bc	53a	45bc	48b
2007	53d	62cd	66a	62bc	60c
2008	61bc	63ab	59c	64ab	64ab
2009	59c	71a	66b	58c	68ab
2010	48b	62a	68a	63a	59a
2011	55d	69a	65ab	60bc	64bc
2012	47b	60a	63a	61a	61a
2013	39c	50a	46b	49ab	47b
2014	73b	88a	90a	86a	91a
2015	56c	68ab	71a	65b	68ab
	- - - - - - - - - - - - - - - - - - -Soil Test P (ppm)- - - - - - - - - - - - - - - - - - -				
Soil Test P	5.6d	22.0a	16.2b	8.0cd	10.5c

† Treatments Control, 0 lb P_2O_5 ac^{-1}; Placement of fertilizer at a total of 80 lb P_2O_5 ac^{-1} as BC, broadcast; DB, deep band at 6 in deep applied with the strip-tillage; and split applications of broadcast and deep band at 60 lb P_2O_5 ac^{-1} and ST, 2 in to the side dribble banded on soil surface as a starter band at 20 lb P_2O_5 ac^{-1}.

‡ Different letters in rows by year indicate significant differences at $\alpha=0.10$ level.

§ Soil Test P, phosphorus using Mehlich-3 extraction averaged over plots receiving treatment following corn and soybean harvest in 2014.

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