PHOSPHORUS PLACEMENT IN REDUCED TILLAGE SYSTEMS IN KANSAS

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ABSTRACT

A number of questions are being raised concerning phosphorus (P) management as more producers switch to minimum or no-till (NT) systems. These tillage systems conserve moisture below the surface residue creating cooler, and potentially wetter soil conditions at planting, and stratified nutrient concentrations in the soil. The cooler temperatures can result in slower earlier season growth on crops such as corn and wheat, and P stratification can potentially reduce P uptake under dry conditions when the high P surface soil dries, limiting root activity. The objectives of this study were to determine if P availability is reduced due to nutrient stratification, evaluate how P placement could impact P availability in P stratified soils, and determine if starter fertilizer could enhance early season growth and P uptake, and see if that had any impact on final yield of the crop. Four locations were initiated across Kansas using crops and rotations common in those areas, with each crop in the rotation present each year. Treatments consisted of combinations of rates of P applied as starter at planting, broadcast prior to planting or banded under the row in a strip till operation in late fall or winter. The first two years of data show mixed results. Generally, there is a trend for the rain fed locations to yield highest from the deep band treatments, particularly for corn and sorghum. The irrigated location responded to P application, but no response to placement was seen, unlike the trends observed at the rainfed locations. Benefits of P application, both application method and rate, are very field specific and potential advantages need to be evaluated for each location.

INTRODUCTION

No-till and reduced till cropping systems have explicit advantages over conventional till cropping systems including moisture availability (Blevins et al., 1971; Legg et al., 1979), increased soil organic matter concentration near the soil surface (Agboola, 1981; Rosenzweig and Hillel 1998), increased microbial activity (Roldam et al., 2003), and decreased soil erosion (Tiscareno-Lopez et al., 1999). From 1990 to 2004, the United States conservation tillage acres (including NT) increased from 26.1 to 40.7% of cropland. Of these acres, 6.0% was NT in 1990 and 22.6% was NT in 2004 (Peterson, 2005).

It is well documented the increase in NT and reduced till practices lead to nutrient stratification (Blevins et al., 1983, Crozier et al., 1999). Nutrient stratification is caused by surface application of fertilizer (like P) without inversion of the soil to allow adequate mixing and nutrient accumulation from crop residue near the soil surface (Bruulsema and Murrell, 2006).

Western Kansas farmers have moved quickly to adapt NT and reduced till systems, primarily as a means of conserving water. Work at Tribune and other locations show that no-till production generally provides about two inches of additional water to a summer crop. While these tillage systems conserve moisture below the surface residue they also create cooler, and potentially wetter soil conditions at planting. The cooler temperatures can result in slower earlier season growth on crops such as corn and wheat, though the higher P soil tests due to stratification help off-set this through increased nutrient availability near seedlings. But, will starter fertilizer enhance early growth and result in higher yield, or stimulate excess vegetative growth? Phosphorus stratification can potentially reduce P uptake under dry conditions when the surface soil dries, limiting root activity. Would placing these nutrients deeper in the soil through strip tillage enhance availability? This paper will focus on an on-going P placement study that was initiated in 2005 to obtain answers to some of those questions.

The specific objectives of this study are to: 1.) Determine if P availability is reduced due to stratification, 2.) Determine if deep banding of P enhances availability as compared to surface broadcasting , 3.) Evaluate the impact of starter P fertilizer vs. no starter fertilizer on early season growth and final yield.

MATERIALS AND METHODS

This study was established in 2005 at four locations: Manhattan, Tribune, Ottawa, and Scandia, KS. All sites selected had a history of reduced tillage. The design for this experiment was a randomized complete block with three replications at Manhattan and four replications at all other locations. Each site had appropriate rotations and production practices for the respective area (Table 1). All crops were present at each location each year.

Table 1. Experimental locations and crop rotations.

Location	Rotation
Manhattan	Wheat/Sorghum/Soybeans
Tribune	Wheat/Sorghum/Fallow
Ottawa	Corn/Soybeans
Scandia	Corn/Soybeans

All sites were rain fed, with the exception of Scandia, which received supplemental irrigation using a lateral move sprinkler system. Mean annual Rainfall (1971-2001) at each location was: Manhattan, 34.8 in; Tribune, 17.4 in; Ottawa, 39.2 in; Scandia, 28.0 in.

Initial soil samples were taken at each location prior to making the first fertilizer applications or planting the first crop. One 1.25 in diameter core was taken from each plot to a depth of 24 in. Each core was divided into 0-3 in, 3-6 in, 6-9 in, 9-12 in, and 12-24 in segments to estimate initial stratification at the site, with the individual segments combined for each replication and analyzed for Mehlich 3 extractable P content (Mehlich, 1984). Results from each replication were averaged for each depth at each location (Table 2).

Each site had a true check and three basic treatment types: starter (20 lb $P_2O_5 ac^{-1}$) and no starter; low rate (40 lb P_2O_5 ac^{-1}), high rate (80 lb P_2O_5 ac^{-1}), broadcast; low rate (40 lb P_2O_5 ac^{-1}), high rate (80 lb P_2O_5 ac^{-1}), deep band, and combinations of broadcast and deep band with starter to reach a total application rate of 40 lb P_2O_5 ac^{-1} and 80 lb P_2O_5 ac^{-1} (e.g. 20 lb P_2O_5 ac^{-1} starter and 20 lb P_2O_5 ac^{-1} broadcast to total 40 lb P_2O_5 ac^{-1} application).

Starter treatments were applied as a 2 by 2 band (2 inches below and 2 inches to the side of the seed) in row crops and with the seed in wheat. Broadcast treatments were applied on the soil surface immediately before planting. Deep band treatments were applied with a strip till unit in row crops. For strip tilling in row crops, conventional strip till units were used that tilled a 7 to 9 inch zone directly over the previous crop row and applied liquid ammonium polyphosphate (APP) at a depth of 6 to 7 inches. In wheat, deep placement was accomplished by using a coulter applicator on 15 in centers and injecting APP 4 to 5 inches deep. In all application methods, nitrogen (N) rate was held constant at an appropriate rate for each crop and location.

RESULTS AND DISCUSSION

The locations in this study can be divided into two groups. The Manhattan and Tribune locations both have P levels greater than the accepted sufficiency level of 20 ppm P (Leikam et al., 2003) with previously established vertical P stratification (Table 2). Due to the high P levels at both locations, P response would not be expected unless stratification of the P would somehow limit P availability. These locations are also rain fed and are better suited for wheat and sorghum (and soybean at Manhattan) production.

The Ottawa and Scandia locations both have soil test levels well below the 20 ppm sufficiency level and have established vertical P stratification (Table 2). The Ottawa location typically receives more timely rainfall and is located in an area where rain fed corn production is commonplace. The Scandia location naturally receives less rainfall, but has supplemental irrigation capabilities. The Ottawa and Scandia locations are in regions where corn/soybean rotations are the norm.

Table 2. Soil test P (ppm) of each site with increasing depth.

Sample Depth (in)	Manhattan	Scandia	Ottawa	Tribune
	--------------------------P (ppm)-------------------------			
0-3 in	55.4	9.5	9.4	74.1
3-6 in	19.9	5.7	5.8	31.3
6-9 in	7.0	5.1	4.8	10.3
9-12 in	4.2	5.4	4.7	13.4
12-24 in	3.4	4.6	4.6	23.5

The wheat at Manhattan and Tribune did not respond to P in three of the four trials (wheat data not shown). At Manhattan in 2007, there was a yield response to P application, probably due to a severe April freeze; however, there was not an affect due to rate or placement. This is to be expected with the high available P at both sites as indicated by soil tests.

At Manhattan, a significant response to P was seen with sorghum in both 2006 and 2007. In 2006, the 40 lb ac^{-1} broadcast and deep band treatments without starter were the lowest yielding fertilized plots. All other plots (80 lb ac^{-1} total application and all treatments with starter fertilizer) had higher yields. Late July rainfall provided good pollination and grain fill in 2006, and good conditions for utilization of nutrients near the soil surface. In 2007, there was a general trend for the deep band treatments to yield higher than the broadcast treatments (Figure 1). Dry conditions during late July and August limited grain fill and yield and would have limited nutrient availability and root activity near the soil surface. At Tribune, sorghum yields in 2006 were very low due to severe moisture stress. Early August rainfall in 2007 resulted in surprisingly good sorghum yields, but no response to P was seen in either year (Figure 1).

The dryland corn at Ottawa yielded substantially lower than the irrigated corn at Scandia in both years. A response to P was observed at Ottawa but there was not a clear difference due to rate or placement. In both years, the highest yielding treatment was 20 lb ac^{-1} starter, 20 lb ac^{-1} deep band (Figure 2). At Scandia, there was no response to P application in 2006. There was a response to P in 2007 however, no response to placement, or higher application rates was observed. With irrigation, the surface soil remained moist, enhancing root activity and availability of surface stratified nutrients. Thus no response to placement would be expected.

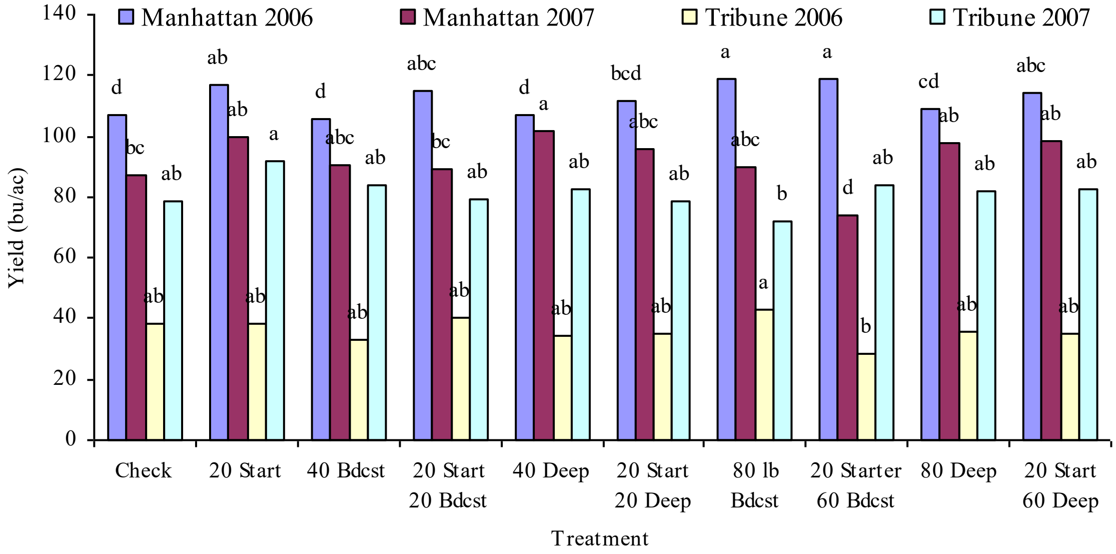

Figure 1. Manhattan and Tribune sorghum yields in 2006 and 2007. Statistical differences were calculated using *proc glm* in SAS with an alpha level of 0.1 (SAS Institute, 2004).

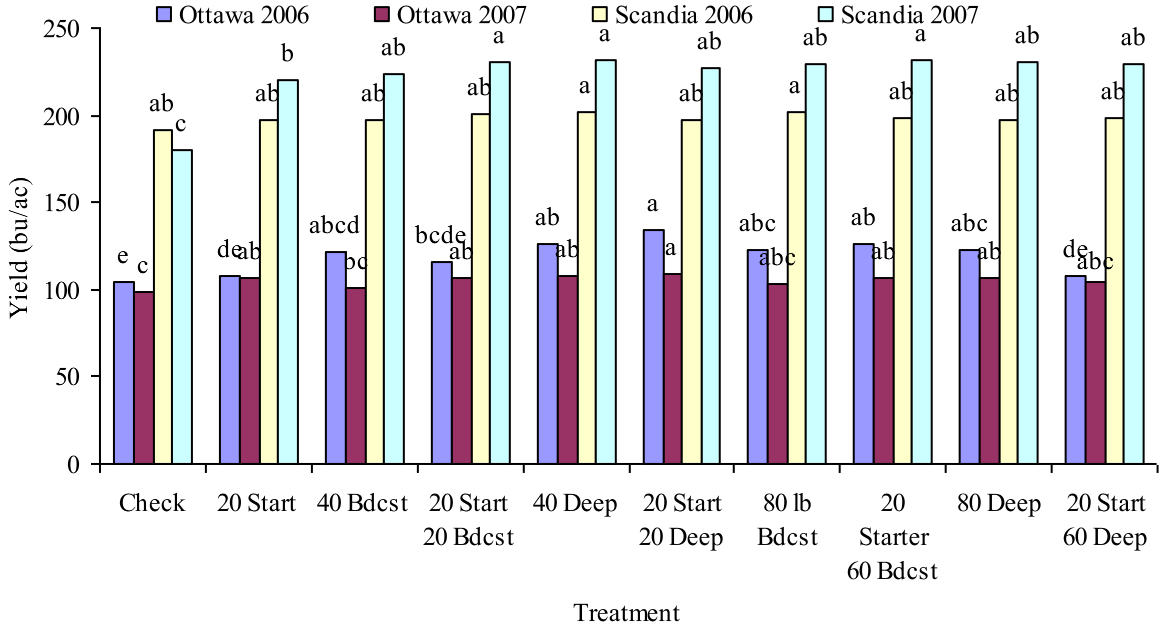

Figure 2. Ottawa and Scandia corn yields in 2006 and 2007. Statistical differences were calculated using *proc glm* in SAS with an alpha level of 0.1 (SAS Institute, 2004).

CONCLUSIONS

There are two key factors which should impact the response to P fertilizer placement in soils where nutrients are highly stratified: soil test P levels and the location of soil moisture. At high soil test P levels, especially when soil tests above the critical level continue to some depth, no consistent response to P would be expected. This is the situation which exists at Tribune.

However in nutrient stratified soils where the lower portions of the "plow layer" are lower fertility, when the top portion of the soil is very dry, root activity in the surface higher nutrient availability zone would be limited, and placing P into more moist soil through deep banding could be beneficial as compared to broadcasting fertilizer on the soil surface. In this study, the rain fed sites at Ottawa and Manhattan have shown a trend for higher yields with deep band treatments for sorghum and corn. Placement didn't have an effect on yield at Scandia where irrigation provided adequate soil moisture to maintain a high level of root activity throughout the soil profile.

While to this point, data on P placement as a tool to overcome nutrient stratification is inconsistent at best, there are some patterns developing which are consistent with our basic knowledge of plant nutrition. Early work throughout the US has shown that band placement is an excellent tool to enhance the availability of P in low soil test, low fertility situations. But studies in the humid Eastern Cornbelt have shown no advantage to P placement as a means of enhancing yield and P uptake at high soil test levels where P has been strongly stratified.

Long-term studies under the drier conditions of the Western Cornbelt and Great Plains focused on nutrient stratification at moderate to high soil tests have not been done. So it will be interesting to see if the soil moisture regime common in the west will give similar results to those obtained in the Cornbelt.

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