EFFECT OF PHOSPHORUS AND POTASSIUM FERTILIZATION ON CORN DEVELOPMENT AND ROOT DISTRIBUTION IN CONSERVATION TILLAGE

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Abstract

In conservation tillage systems, like no-till (NT) and strip-till (ST), phosphorus (P) and potassium (K) typically become vertically and/or horizontally stratified in the soil. This stratification has the potential to make P and K less available and to limit corn yield. The objective of this study is to determine the influence of tillage and P and K placement and rate on soil P and K content, soil water status, root and shoot development, and grain yield of corn. The experiment was arranged in a split-split-block design with three replications in a corn-soybean rotation. Tillage/placement— NT broadcast (NT-BC), NT deep placement at 15 cm (NT-DP), and ST deep placement (ST-DP)— as the main plot, P rate (0, 23, 46, and 68 kg P_2O_5 hectare^{-1} year^{-1}) as the subplot, and K rate (0, 41, 82, and 164 kg K_2O hectare^{-1} year^{-1}) as the sub-subplot. Soil and plant samples were collected through the season. Soils P and K concentrations decreased with increasing soil depth. Corn grain yield was not influenced by tillage-placement method or K rate. The 68 kg P_2O_5 hectare^{-1} produced 690 kg ha^{-1} increase in grain yields over the control (no P added), with the greatest response in NT-BC. Soil water was not influenced by treatment, but at the end of the season, the in-row positions had more soil water compared to the between-rows position. Dry matter accumulation at R3 development stage was increased by 1,214 kg ha^{-1} with the highest K rate compared to no K application and by 2985 kg ha^{-1} in NT-BC compared to NT-DP. Root analysis indicates no influence of treatment on root distribution in the soil profile. There was a two-fold decrease in root length density for each successive depth increment from the 0-5, 5-10, 10-20, and 20-40 cm depths.

Introduction

In 2008, producers in the United States planted 87.3 million acres of corn, the second highest acreage on record since 1944 (USDA, 2008). This acreage makes it the most widely planted crop in the United States. In recent years, a majority of fertilizer research has investigated the optimum rates of nitrogen fertilizer to maximize economic yield of corn and reduce the environmental impact of agricultural inputs. Phosphorus (P) and potassium (K) are two very important plant nutrients that also represent a large annual investment by producers. With the rising cost of fertilizer and fuel and increased interest in conservation tillage it is important to investigate the efficiency of P and K rates and placement methods. Broadcast surface application in no-till is a common application method of granular P and K. This often leads to vertical stratification of the nutrients, limiting their availability to crop plants. This is especially true of soil P due to its limited mobility. Deep band applications in strip tillage lead to horizontal stratification with enriched nutrient areas in the band and deficient areas between the bands (Buah et al., 2000; Holanda et al., 1998; Rehm, et al., 2002).

In addition to a need for more P and K work, there is also a need for addition characterization of seasonal corn root growth (Amos and Walters, 2006). Tillage methods have proven to affect multiple soil conditions and properties, such as soil temperature, available soil water, and macropore continuity, that impact corn growth, including rooting depth and root distribution (Dwyer et al., 1996). In years where there is inadequate soil water, vertical stratification can be a major problem for corn plants as their roots are exploring deeper soil depths in search of soil water. Deep band placement can take advantage of greater soil water in the subsurface, but, again, in years where rainfall is limiting, there may only be enough water to moisten the soil surface, making the subsurface P and K unavailable to the plant.

Taking these factors into consideration, the objective of this study is to determine the influence of tillage, P, K placement, and rate on soil P and K content, soil water status, root and shoot development, and grain yield of corn.

Methods and Materials

This study started Spring 2007 at the Crop Sciences Research and Education center on a field that was not tilled the previous fall after the removal of the corn crop. The site has both Flanagan silt loam soil (Fine, smectitic, mesic Aquic Argiudolls) and Drummer silty clay loam soil (Fine-silty, mixed, superactive, mesic Typic Endoaquolls). The following characteristics were present in the field at the start of the experiment: CEC-14.2cmol (+) kg^{-1}; organic matter-3.6%; pH-5.7; available P-16.2 mg kg^{-1}; available K -185 mg kg^{-1}; Ca-1564 mg kg^{-1}; Mg-253 mg kg^{-1} . Both P and K were highly stratified by previous agricultural practices. The 0-5:5-10 cm layers ratio was approximately 2:1 for both nutrients. Dividing the field in half created a corn-soybean rotation with 144 plots on each side of the field. The fertilizer treatments consisted of all possible combinations of four P rates (0, 23, 46, 68kg P_2O_5 ha^{-1} $year^{-1}$) and four K rates (0, 41, 82, and 164 K_2O ha^{-1} $year^{-1}$) applied by either broadcast or deep-band under the row (76 cm apart and 15 cm deep).

The experimental design is a split-split plot arrangement in a randomized complete block design with 3 replications. Tillage/placement is the main plot, which consists of no-till broadcast (NT-BC), no-till deep placement (NT-DP), and strip-till deep placement (ST-DP). The subplot is the P rate and the sub-subplot is the K rate. NT-DP applications utilized a low disturbance knife to minimize disruption to the soil surface. All of the treatments have been spring applied. Sprayer applied urea ammonium nitrate at a rate of 196 kg N ha^{-1} were applied prior to planting.

Prior to initial fertilization soil samples were taken from each plot at 0-5, 5-10, 10-15, 15-20, and 20-50 cm depths. Samples were collected at the same depths after harvest, but the sampling was divided into between the crop rows and in the crop row positions. At the V12 and R2 growth stages plant, soil, and root samples were taken from selected intensive plots (P0-K0, P0-K164, P68-K0, P46-K82, and P68-K164). The soil and root samples were again taken from two locations, in-row and between-rows at 0-5, 5-10, 10-20, and 20-40 cm depths. Root samples were cleaned using an elutriator and stored in a 10% ethanol solution. The samples were further cleaned by hand and analyzed for physical parameters with WIN-RHIZO software. Both plant and soil samples were analyzed for P and K content. Decagon ECH_2O soil water sensors were installed in both in-row and between-rows positions in the P68-K164 plots to monitor soil water throughout the growing season. Probes were installed at 0-5, 5-10, 10-15, 15-20, and 20-40 cm depths and readings were taken every hour. Grain yields were collected at harvest by combine. All data was analyzed in PROC GLM using SAS 9.1 with an alpha value of 0.05.

Results and Discussion

Root Parameters

Root length density (RLD) decreased with soil depth from the surface to the 10-20 cm depth increment. (Figure 1). The top 5 cm of the soil had 50% of the RLD measured at both development stages. At the V12 development stage, greater ($p<0.05$) RLD were observed at the in-row position compared to the between-rows position at the top 5 cm of the soil (indicated by *) (Figure 2). This preliminary observation could indicate that applying fertilizers in the row position may be advantageous. However, at this time the soil P and K data is not available to determine whether nutrients are been taken up readily in this portion of the soil with the greatest RLD. No differences in RLD were observed due to treatment variables (tillage/placement, P rate, and K rate). The fact that roots did not proliferated in response to a concentrated P fertilizer in the band application suggests that sufficiently high P levels were present in the soil volume.

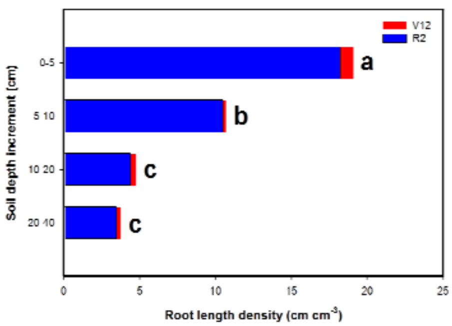

Figure 1. Root length density (RLD) by depth. RLD followed by the same letter are not significantly different ($p>0.05$).

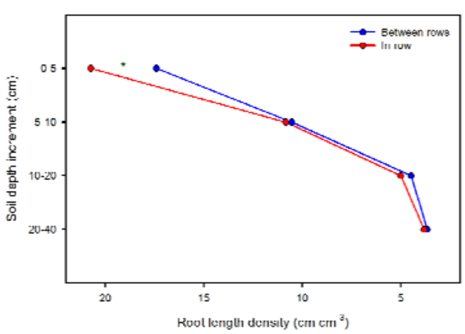

Figure 2. Root length density (RLD) by row position. * indicate RLD difference ($p<0.05$).

Mean root diameter was greater for the soil surface layer, while the diameter did not change significantly with depth in the subsurface layers (Figure 3). This is probably related to the normal morphological development of roots with more primary roots at the base of the plant and subsequent greater number of secondary and tertiary roots as the distance from the base of the plant increases. Also, the inclusion of some brace roots in the surface sample likely caused some of the increase in root diameter.

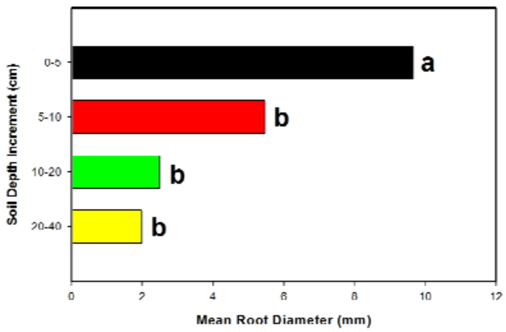

Figure 3. Mean root diameter (MRD) by depth. MRD followed by the same letter are not significantly different (p>0.05).

Soil Water Parameters

Averaged across the entire growing season for each soil depth increment, there was more water present at the in-row than the in-between rows position (Figure 4). This may be related to the funneling effect the corn plant has in capturing rain and dew. The difference between the positions was greater in the later part of the growing season when water uptake is highest. Greater RLD (Figure 2) and water content at the in row position may suggest that placement of fertilizer at the in-row position could increase nutrient availability.

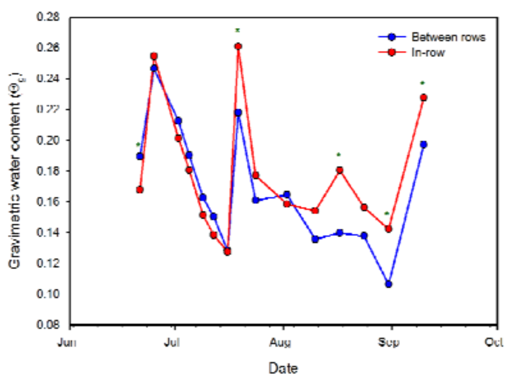

Figure 4. Gravimetric water content by position during the season. * indicate difference (p<0.05) for the specific date.

The 2007 growing season was fairly dry for some periods. Averaged across the growing season, soil water content differed significantly (p<0.05) between all soil layers except for the 5-10 and 10-20 cm layers. As soil depth increased, so did water content (Figure 5). After a substantial precipitation event or series of events, the pattern was reversed and water content decreased with increasing soil depth. This indicates that the surface layer recharges to a greater extent than the subsurface after a precipitation event greater than at least 20 mm. This indicates that in a season with intermittent precipitation it is possible to have water available at the soil surface for the crop to take up nutrients present there.

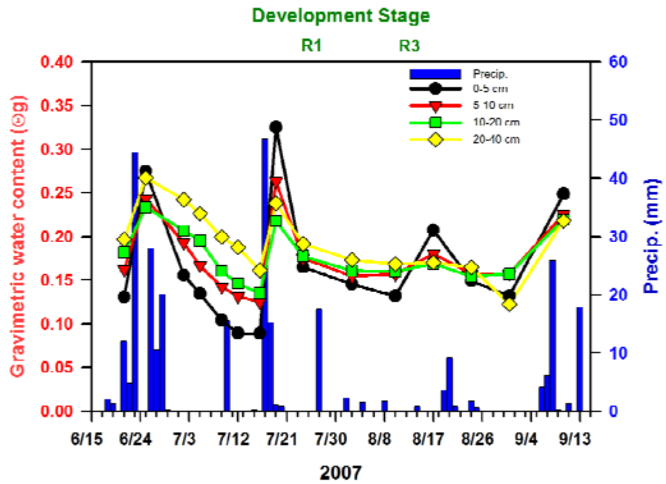

Figure 5. Gravimetric water content changes with precipitation

Grain Yield

Grain yield was significantly increased from the control by adding at least 46 kg P_2O_5 hectare^{-1} (Table 1). The tillage/placement and K treatment variables had no influence in yield. The response to P and not K was expected since initial P test levels were slightly limiting, whereas K levels were high. The significant 2-way interactions between tillage-placement and P rate indicated a yield decrease in NT-DP check (zero rate) compared to all other tillage-placement and P rate combinations except for the NT-DP 23 kg P_2O_5 ha^{-1} rate. The significant 2-way interaction between tillage-placement and K rate indicated a slight yield increase for the high K rate in no-till as a broadcast application compared to a deep placement application.

Table 1. Grain yield by treatment and statistical analysis of main effects

Rate	Tillage-Placement treatment		
	NT-BC	NT-DP	ST-DP
	--------------kg ha^{-1} --------------		
P-0 K-0	7780	6400	7905
P-0 K-41	7717	6274	7780
P-0 K-82	6525	7027	7529
P-0 K-164	7905	5898	7968
P-23 K-0	7278	7654	7403
P-23 K-41	7654	6525	7968
P-23 K-82	8094	7780	6901
P-23 K-164	7843	7215	8282
P-46 K-0	7905	8156	7403
P-46 K-41	8533	6839	8282
P-46 K-82	7466	7780	8031
P-46 K-164	8784	7592	7403
P-68 K-0	8345	7968	7466
P-68 K-41	8533	7529	7717
P-68 K-82	7968	7466	8282
P-68 K-164	8282	7529	7843

Variable	Corn Grain Yield
	-------kg ha^{-1}--------
Tillage-Placement (TP)	
NT-BC	7905a
NT-DP	7215a
ST-DP	7780a
P Rate (P)	
0	7215b
23	7529ab
46	7843a
68	7905a
K Rate (K)	
0	7654a
41	7592a
82	7592a
164	7717a
Interactions (P>F)	
TP x P	0.068
TP x K	0.025
TP x P x K	0.293
CV (%)	9.8

Within variables values followed by the same letter are not significantly different ($p>0.05$).

Conclusions

Phosphorus applications increased grain yield because the starting soil P levels were yield-limiting. Although band application did not improved yields, greater soil water and root proliferation at the in-row position compared to the between-rows position indicates that in-row nutrient placement could be more advantageous for increasing nutrient availability. These results are preliminary, but indicate the need for further investigation on the potential effects of nutrient placement on the crop.

Additional years of data coupled with soil P and K information will enhance our ability to address the objective of this study.

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