IS POTASSIUM LIMITING NO-TILL CORN YIELDS?

D.L. Karlen and J.L. Kovar
USDA-ARS National Soil Tilth Laboratory, Ames, IA
karlen@nstl.gov (515) 294-3336

ABSTRACT

Potassium (K) was thought to be a limiting factor for no-till and ridge-till corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) in a long-term tillage and crop rotation study at the Iowa State University (ISU) Agronomy and Agricultural Engineering Research Center (AERC). Our objective in this study was to compare 30 lb K_2O/A broadcast, dry subsurface band or liquid surface band applications with a control (0 lb/A). The treatments were applied to the same plots each year for two years, thus providing three site-years of response data for corn and one for soybean. Pre-treatment soil-test status, plant nutrient concentrations and yield were monitored. Sodium-saturated cation exchange membranes also were used to monitor positional availability of the K from the four treatments. Soil-test data confirmed K stratification after several years of reduced tillage, and that K saturation was less than 2% for both the continuous corn and rotated blocks. Although not always statistically significant, whole plant and leaf tissue K concentrations were always lower in check plots compared to those receiving K, and the concentrations for most samples were below the level considered sufficient for the various plant parts. Sodium-saturated exchange membranes were useful tools for characterizing the positional bioavailability of the K following K application. Check-plot yields were significantly lower than those in plots receiving K, except for broadcast treatments on the rotated block, although the response to K was still positive. In 2005, a 16% yield penalty for continuous corn was also observed. Overall, this study confirms that K is a limiting nutrient at this site, and that more attention must be given to K management, especially if corn residues are to be harvested for biofuels production in the future.

INTRODUCTION

The potential for K deficiencies with reduced-tillage, especially for corn production, is a well-documented soil fertility problem (Rehm, 1992; Borges and Mallarino, 2001). Stratification of available soil K is thought to be the cause of this problem. With the increased emphasis on management of N and P because of their potential off-site effects, researchers, consultants, and farmers may now be over-looking the importance of K as compared to N and P.

In 2003, deep placement of preplant K fertilizer had a significant effect on both soil test K and plant growth in long-term tillage plots at the ISU-AERC, suggesting that stratification of exchangeable soil K was a problem. Because some no-till/minimum-till producers would be reluctant to knife K fertilizer into the soil, we hypothesized that a high-volume surface band application of K fertilizer (20 to 30 gal./A application volume) would allow K to move into subsurface soil. This method of supplying additional K would then be just as effective as deep placement. In previous studies (Kovar, 2003), we found convincing evidence that surface band applications of phosphorus (P) fertilizer increased P bioavailability below the soil surface for several weeks after application. The increased levels of bioavailable P in the root zone potentially benefited the plant throughout the growing season. The potential movement of plant-available K into the soil profile following a surface band application was not evaluated in these previous studies. Therefore, our objectives in this study were to evaluate corn and soybean response to three K fertilizer placements in long-term (>30 yr) ridge-till and no-till treatments on Clarion-Nicollet-Webster soils, and to compare the positional availability of K from the fertilizer treatments in these production systems.

MATERIALS AND METHODS

The study was conducted on Clarion-Nicollet-Webster soils in the ridge-till and no-till plots within a long-term tillage and crop rotation study that was established in 1971 at the ISU-AERC in Boone County, Iowa (42.0°N, 93.7°W). After confirming a K deficiency in slow-growing corn in 2003, a more detailed study with four treatments [a control; 0-0-10 liquid dribbled (30 gal/A) on the soil surface two inches to the side of the row; 0-0-60 granular fertilizer applied as a subsurface band (2x2); and 0-0-60 surface broadcast] was initiated in 2004, and repeated in 2005. Fertilizer treatments (30 lb K_2O/A) were applied to the same 12.5 ft. wide by 300 ft. long subplots each year. Continuous corn response was evaluated in one block, while soybean (2004) and corn (2005) response were evaluated in the rotated block. Whole plant corn samples were collected at the V6 growth stage, ear-leaf tissue concentrations were monitored at anthesis, and yield was determined at maturity.

Bioavailable K in the soil profile was measured by inserting a 6-inch by 6-inch sheet of sodium-saturated cation exchange membrane vertically into the soil profile perpendicular to the corn rows, approximately five weeks and nine weeks after fertilizer application. Resin sheets were left in place for 24 hours, removed, cut into 1-inch squares, extracted, and analyzed for K to determine the spatial distribution of bioavailable K within the soil profile. Soil test, plant tissue, and yield data were analyzed with the general linear models (GLM) procedure of SAS (SAS Institute, 1999).

RESULTS AND DISCUSSION

Analyses of soil samples collected from the continuous corn and corn-soybean plots prior to applying the 2004 fertilizer treatments confirmed that exchangeable K and other soil properties had become stratified during the >30-year study period (Table 1). This stratification was not unexpected since it had been previously reported at this site (Erbach, 1982) and documented for the Clarion-Nicollet-Webster soil association in a nearby on-farm study (Karlen et al. 2002).

Whole-plant analyses in 2004 showed slightly higher K concentrations for all three placement methods, but the differences were not statistically different (data not shown). At anthesis, K concentrations in ear-leaf samples were significantly higher in plots that had received K fertilizer, but there were no differences among the K placements. Soybean leaf samples at full bloom (R4) also had numerically, but not significantly higher K concentrations. The Ca and Mg concentrations in whole plant and ear-leaf samples were also very high for both control and treated plots. Concentrations in soybean leaf tissue were decreased by K applications.

The 2005 whole-plant analyses at growth stage V6 showed that K concentrations in plants from the continuous corn treatment were 0.5 to 1% below the level considered to be a "low rating" (2.5%) for that growth stage (Table 2). Low soil temperature probably contributed to those low levels since the average temperature at 4-inches was 2.5 ºF lower during May 2005 than May 2004. Potassium concentrations for continuous corn in 2004 and for the rotated corn treatment in 2005 were also 2.5% or less except for the liquid- and dry-band treatments (Table 2).

Table 1. Soil-test levels measured in 2004 within the no-till and ridge-till plots of a long-term tillage and crop rotation study at the ISU-AERC in Boone County, Iowa.

Depth	Bulk Density	Organic Matter	pH	Bray P	Exchangeable K
Inches	g/cm3	%		---------- ppm ----------	
Continuous Corn					
0 to 2	1.15	4.38	6.24	50	199
2 to 4	1.35	3.86	6.32	38	119
4 to 8	1.42	3.61	6.16	14	83
$LSD_{(0.1)}$	0.13	0.14	ns	10	18
Corn – Soybean Rotation					
0 to 2	1.16	4.62	6.56	43	192
2 to 4	1.26	4.19	6.49	34	119
4 to 8	1.42	3.95	6.32	17	107
$LSD_{(0.1)}$	0.14	0.46	ns	8	18

Table 2. Average 2005 early-season corn response to K fertilizer (30 lb K_2O/A) placement within the no-till and ridge-till plots of a long-term tillage and crop rotation study at the ISU-AERC in Boone County, Iowa.

Treatment	Growth	N	P	K	Ca	Mg
	--- g/plant ---	-------------------- % --------------------				
Continuous Corn – Whole Plant at V6 – 2004						
Control	8.78	3.81	0.40	2.44	0.79	0.57
Dry band	8.44	3.67	0.39	2.68	0.77	0.55
Broadcast	8.37	3.78	0.40	2.52	0.81	0.58
Liquid band	8.49	3.77	0.39	2.59	0.81	0.54
$LSD_{(0.1)}$	ns	ns	ns	ns	ns	ns
Continuous Corn – Whole Plant at V6 – 2005						
Control	2.95	3.75	0.45	1.53	0.73	0.55
Dry band	3.04	3.70	0.43	1.87	0.70	0.49
Broadcast	3.07	4.01	0.42	1.96	0.69	0.49
Liquid band	3.44	3.73	0.45	1.65	0.74	0.52
$LSD_{(0.1)}$	0.21	ns	ns	0.32	ns	ns
Rotated Corn – Whole Plant at V6 – 2005						
Control	3.66	4.26	0.42	2.33	0.77	0.55
Dry band	3.76	4.16	0.40	2.55	0.75	0.52
Broadcast	4.10	4.24	0.43	2.21	0.81	0.58
Liquid band	3.78	4.18	0.42	2.77	0.77	0.51
$LSD_{(0.1)}$	ns	ns	ns	ns	ns	ns

There were no significant differences in whole-plant N, P, Ca, or Mg concentrations, although Ca and Mg concentrations in 2005 were once again in the "high" range. For reference, whole-plant samples were also collected from the plow treatment even though none of the subplots received K in 2003, 2004, or 2005. The K concentrations in those samples averaged 2.41 and 3.54% for the continuous corn and rotated blocks, respectively, suggesting that early-season K problems may be exacerbated by growing continuous corn. Leaf K concentrations at anthesis were numerically the lowest in plots without K (Table 3), but the differences were not always statistically significant.

Table 3. Average 2005 ear-leaf K concentrations at anthesis in the no-till and ridge-till plots of a long-term tillage and crop rotation study at the ISU-AERC in Boone County, Iowa.

Treatment	Continuous Corn		Soybean – Corn Rotation	
	2004 – Corn	2005 – Corn	2004 – Soybean	2005 – Corn
	---------- % -----------			
Control	1.38	1.17	1.79	1.20
Dry band	1.65	1.26	1.81	1.47
Broadcast	1.66	1.31	1.86	1.26
Liquid band	1.68	1.34	1.80	1.36
$LSD_{(0.1)}$	0.15	Ns	ns	0.17

Measurements of bioavailable K with the resin sheets were successful in 2004. Higher concentrations of K were measured near the soil surface for all three of the K placements 28 days after application (Fig. 1). Similar results were recorded 50 days after application (data not shown). The highest concentration of bioavailable K was found at a depth of one to two inches below the surface for the 0-0-30 dribble treatments; however, higher concentrations of K also were measured throughout the one to two-inch soil layer after broadcast application of 0-0-30 as dry material (Fig. 1). In contrast, only small increases in bioavailable K concentrations were measured in plots in which 0-0-30 was applied as dry material in a subsurface band. The reason for this is unclear. Perhaps, there was significant variation in measurable soil K in the direction of the application band, so that even with three replications, additional measurements may be necessary to identify areas with more bioavailable K. Measurements of bioavailable K 41 and 76 days after planting in 2005 (data not shown) also provided evidence that surface-applied K had moved one to two inches into the soil profile.

In the continuous corn plots, grain yields increased in response to all three K treatments in both 2004 and 2005, but there were no significant differences among the methods of application (Table 4). In the rotated plots, both soybean (2004) and corn (2005) yields increased in response to the banded K treatments. Broadcast application of the additional 30 lb K_2O/A also increased grain yield for both crops compared to the control, but the average increase was small. Nevertheless, these results confirm that K is an important factor contributing to the slow early-season growth and lower grain yield from the reduced tillage plots at this research site. Another point regarding grain yield, which is important primarily because of the renewed interest in growing more continuous corn, is the 16% lower yield for continuous corn than for corn grown in rotation with soybean in 2005. In plots that received no K fertilizer, the yield decline was even greater at 21%. This response was consistent with previous studies conducted throughout Iowa and other Midwestern states (e.g Crookston et al., 1991; Karlen et al., 2006), but is important considering the increasing interest in growing more continuous corn, so that residues can be removed for biofuels production.

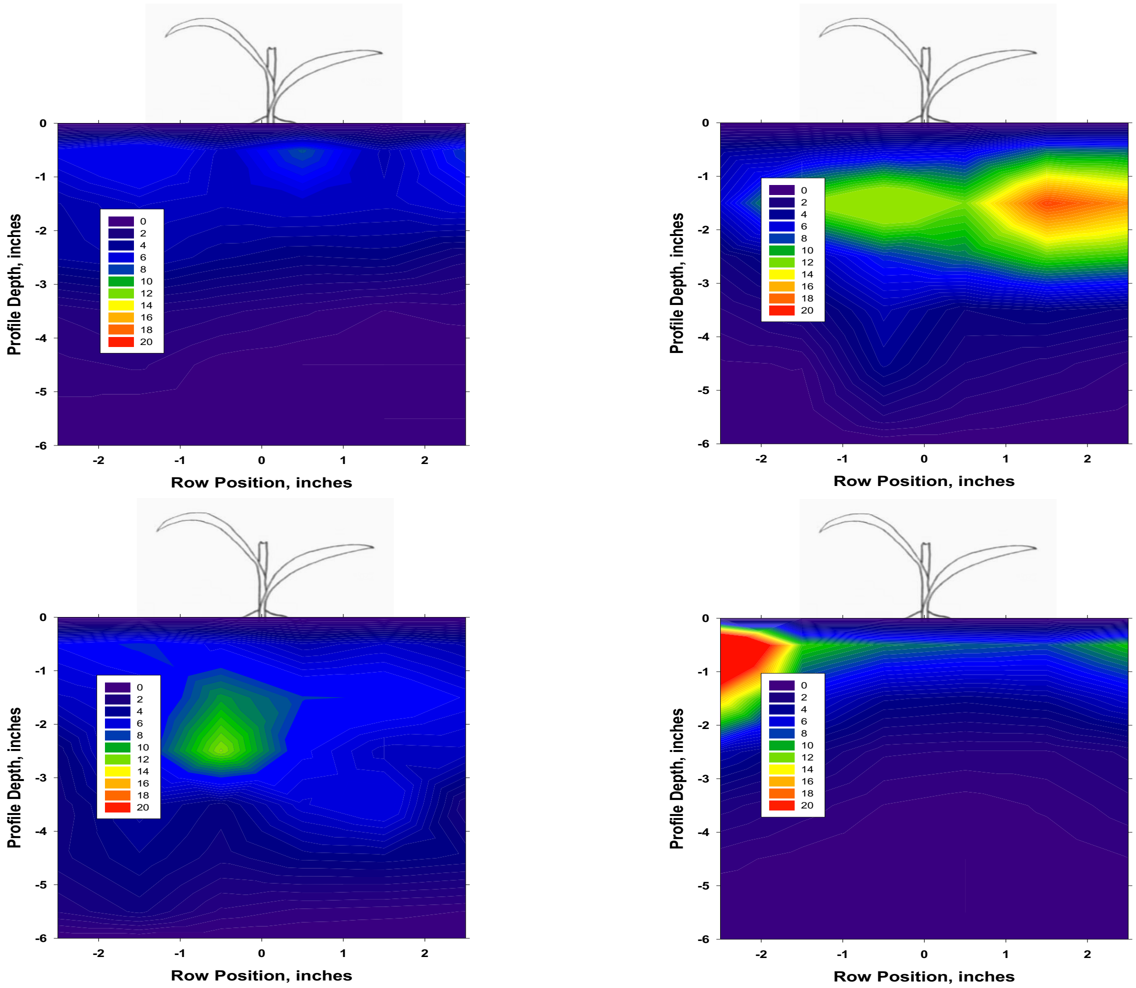

Fig. 1. Profile distribution of bioavailable K 28 days after broadcasting dry material (top right), subsurface banding dry material (bottom left), or surface band application of liquid material (bottom right) approximately two inches to the side of the corn row in 2004. For comparison, the distribution of bioavailable K in the control plots also is shown (top left). Potassium concentrations are (x10^{-8}) lb. actual K/inch^2, and were determined by extraction with sodium-saturated exchange resin membranes.

SUMMARY

After two years of field trials, this project has demonstrated that low K is a major factor contributing to the slow early-season growth, development and lower yield within long-term ridge-till and no-till treatments on Clarion-Nicollet-Webster soils. Stratification of K appears to be the primary cause of the problem. Band application of K fertilizer may be a beneficial practice to help producers implement no-till agriculture on these soils. Use of cation exchange resin sheets to track the movement and relative availability of surface applied K was successful in both years, and demonstrated that surface band applications of liquid K fertilizer increased K bioavailability below the soil surface for several weeks after application. The study reconfirmed that grain yield may decrease by 15% or more if corn is grown continuously, rather than in a two year rotation with soybean. This potential yield penalty for continuous corn and the need for additional K are two important management factors that producers interested in using no-tillage and harvesting corn stover for biofuels must consider.

Table 4. Grain yield response to K fertilizer (30 lb K_2O/A) placement within the no-till and ridge-till plots of a long-term tillage and crop rotation study at the ISU-AERC in Boone County, Iowa.

Treatment	Cont. Corn '04	Soybean '04	Cont. Corn '05	Corn '05
	-------------------- bu/A --------------------			
Control	165	50.3	148	180
Dry band	171	52.4	164	193
Broadcast	171	51.1	158	184
Liquid band	173	52.5	161	188
$LSD_{(0.1)}$	3	1.6	8	6

ACKNOWLEDGEMENTS

This research was supported in part by a grant from the Fluid Fertilizer Foundation. The authors are grateful to Rich Hartwig, Larry Pellack, and Jay Berkey of the USDA-ARS National Soil Tilth Laboratory for the field and laboratory assistance.

REFERENCES

Borges, R., and A.P. Mallarino. 2001. Deep banding phosphorus and potassium fertilizers for corn managed with ridge tillage. Soil Sci. Soc. Am. J. 65:376-384.

Crookston, R. K., J. E. Kurle, P. J. Copeland, J. H. Ford, and W. E. Lueschen. 1991. Rotational cropping sequence affects yield of corn and soybean. Agron. J. 83:108-113.

Erbach, D.C. 1982. Tillage for continuous corn and corn-soybean rotation. TRANS. ASAE 25:906-911, 918.

Karlen, D.L., K.A. Kohler, D.A. Laird, R.L. Thompson, and D.D. Buhler. 2002. Soil-test dynamics throughout a five-year 'Thompson Farm' rotation in Iowa. Am. J. Altern. Agric. 17:9-17.

Karlen, D.L., D.G. Hurley, S.S. Andrews, C.A. Cambardella, D.W. Meek, M.D. Duffy, and A.P. Mallarino. 2006. Crop rotation effects on soil quality at three northern corn/soybean belt locations. Agron. J. (in press) accepted 11-15-05.

Kovar, J. L. 2003. Effective starter fertilizers for corn in conservation tillage systems. Fluid Fert. Foundation Res. Symp. Proc. 20:230-240.

Rehm, G.W. 1992. Response of ridge-till corn to potash fertilization. P. 139-143. In: Proc. North Central Extension-Industry Soil Fert. Conf., St. Louis, MO. 18-19 Nov. 1992. Univ. MN, St. Paul, MN.

SAS Institute. 1999. Statistical Analysis Software. Version 8. SAS Institute, Cary, NC.