ASSESSING NUTRIENT STRATIFICATION WITHIN A LONG-TERM NO-TILLAGE CORN SOIL

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INTRODUCTION

Soil testing is a tool to evaluate the fertility status of a soil. The soil samples collected for this evaluation must represent the field. In most instances, representative soil sample within a production field can be collected based on slope and soil type. However, producers often utilize production practices that create a challenge for obtaining a representative soil sample. Production practices that promote nutrient stratification within a field increase the difficulty of collecting a representative sample.

Banding fertilizers stratifies nutrients in a systematic pattern across the field. Collecting a sample that adequately accounts for banded nutrients without either over- or under-estimating nutrient status presents a challenge. Tyler and Howard (1991) reported random sampling should be utilized on soils having banded fertilizers. Nutrient stratification is also promoted in conservation tillage systems from surface applications of non-mobile nutrients (Howard and Tyler, 1987; Tyler and Howard, 1991; Mullen and Howard, 1992). Conservation tillage promotes nutrient stratification when rows are oriented close to the previous years' rows, allowing nutrient recycling from decaying root biomass (Tyler and Howard, 1991; Mullen and Howard, 1992). After seven years, in-row (IR) nutrient stratification as well as nutrient stratification with depth was evident in a no-till corn soil (Mullen and Howard, 1992). Howard et al. (1997) reported higher extractable K levels for the IR sample position than the BR position on three long-term no-till cotton soils. The objectives of this study were to evaluate the differences in nutrient stratification over time in a long-term no-till corn soil fertilized with several surface broadcast P and K rates. An additional objective was to evaluate residual effects of seven years of in-furrow banding P.

MATERIALS AND METHODS

A field experiment was established at the Milan Experiment Station, Milan, Tennessee, in 1983 and continued through 1996 on a Loring silt loam soil (fine-silty, mixed, thermic, Typic Fragiudalf). A wheat (*Triticum aestivum* L.) cover crop was established in October of each year except in 1988 for the 1989 crop. Corn was planted early to mid April each year in 30-in. rows. Individual plots were four rows wide and 30 ft long.

The experimental design was a randomized complete block with a split-plot arrangement of treatments replicated five times. Main plot treatments were surface broadcast P and K rates with N-P_2O_5-K_2O fertilizer starter combinations as the sub-plots. Main plot P and K rates were: unfertilized check, 50-25, 100-50 and 150-75 lb P_2O_5-K_2O/acre. The two starter treatments selected for sampling were an in-furrow application of 15-30-0 lb N-P_2O_5-K_2O/acre and an unfertilized check. Application of the starter treatments was terminated in 1989. Plots were sampled following the 1989 growing season. Main-plot treatments were terminated following production in 1996, and the same plots were sampled in 1997. Treatment effects on the yield of no-tillage corn from these plots have been reported by Howard and Mullen (1991) and Howard and Tyler (1987).

Nitrogen, applied as UAN (32% N), was injected approximately 2 to 3 in. deep and 4 to 6 in. to the side of the row immediately after planting. The total N rate (UAN + starter) applied per plot was 150 lb/acre. Broadcast P+K treatments were applied mid to late March using concentrated super-phosphate and potassium chloride.

The soil sampling protocol consisted of collecting and combining seven sub-samples from within the row (IR) and between the row (BR) positions in the center of each plot. The IR sample was collected by sampling directly in existing stubble while the BR sample was collected approximately 15 in. from the row. Samples were collected to a 12-in. depth and divided into 0 to 3-, 3 to 6- and 6 to 12-in. depth increments. Mehlich-I-extractable P and K (Mehlich, 1953) were evaluated on the 0 to 3- and 3 to 6-in. depth and averaged for statistical evaluations. Statistical analysis was performed to evaluate the effect of year on extractable P and K by sample position (IR vs BR) from the two original starter treatments (15-30-0 and check) within each main plot. These analyses were conducted utilizing Proc Mixed procedures of the Statistical Analysis System (SAS, 1997). Mean separation was evaluated through a series of pairwise contrasts among all treatments. Probability levels greater than 0.05 were categorized as non-significant.

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RESULTS

Extractable Phosphorus

The level of Mehlich-I-P varied with year of sampling, sampling position (IR vs BR) and starter treatment (Table 1). Extractable P within the 0-P_2O_5 main plot was over twice as high in 1989 as in 1996 (Table 2). Mehlich-I-P was also higher in 1989 than in 1996 for samples collected from the 50-lb P_2O_5 main plot. However, Mehlich-I-P differences between years were not significant for the two higher P_2O_5 fertilizer treatments. In-furrow application of 30 lb P_2O_5/acre to the starter plot resulted in higher Mehlich-I-P from the 0-, 50- and 100-lb P_2O_5 main plots compared with Mehlich-I-P from the check plot. Broadcasting 150 P_2O_5/acre eliminated Mehlich-I-P differences due to starter applications. Extractable P was higher in the IR position relative to the BR position in the 0- and 50-lb P_2O_5/acre main plots, but the reverse occurred in the 100- and 150-lb P_2O_5 main plots. The year-by-starter-by-position interaction affected extractable P within each P_2O_5 main plot (Table 1). Mehlich-I-extractable P within the unfertilized main plot (0-lb P_2O_5 rate) was greater in the 1989 IR position of the starter plot compared with the other treatments (Table 3). In-furrow applications of 30 lb P_2O_5/acre clearly impacted extractable P. In 1996, differences in Mehlich-I-P due to sampling position were not detected. Seven years after terminating the in-furrow starter applications, extractable P in the IR position had decreased from 30 to 7 lb/acre, a change from a high (H) to a low (L) soil test level. There is a possibility that the in-furrow-applied P_2O_5 was not intersected in 1996 sampling, but planting within the same 10-ft plot should have allowed sampling of one of the seven in-furrow P_2O_5 applications. This observation suggests that the soil has high P buffering capacity.

As expected, broadcasting 50 lb P_2O_5/acre resulted in greater Mehlich-I-P relative to the unfertilized main plot (Table 2). Application of the 50 lb P_2O_5 rate to a main plot changed the pattern of Mehlich-I-P based on sampling protocol (Table 3). As was observed for the 0-lb P_2O_5 main plot, extractable P from the 1989 IR starter sample was greater than that extracted from the other treatments. By 1996, Mehlich-I-P in the BR starter position was greater than that of either sampling positions within the check. Extractable P within this main plot ranged from a high of 68 lb/acre to a low of 15 lb/acre.

Once again, the extractable P pattern changed when sampling a higher P_2O_5 rate (100 lb). The in-furrow application of 30 lb P_2O_5 was detected in the 1989 IR starter sample (Table 3). The extractable P in the IR position had not changed by 1996 (74 and 63 lb). However, extractable P in the BR position had increased by 1996. Extractable P from the starter BR position was higher in 1996 than the extractable P from either sample position within the check plot. Broadcasting 100 lb P_2O_5/acre for 14 years increased Mehlich-I-P levels well into the H soil test rating.

Broadcasting 150 lb P_2O_5/acre over the 14 years once again changed the pattern of extractable P in this soil when compared with the other main plot fertilization rates (Table 3). The 1989 IR starter position was higher in extractable P than the BR position but the reverse was observed in the check sample. By 1996, extractable P was unaffected by sampling position of the starter. As was observed in 1989, extractable P from the 1996 BR position in the check was higher than the IR position. Differences in extractable P between the 1989 and 1996 samples due to sample positions (IR vs BR) were similar, 29 and 31 lb P/acre, respectively.

These data indicate that Mehlich-I-P was vertically stratified within a long-term no-tillage corn soil. Stratification was dependent on fertilization applied either as surface broadcast rates or in-furrow starter treatments. Nutrient stratification would affect fertilizer recommendations on those soils having low fertilizer applications for M or L Mehlich-I-P soil test levels.

Extractable Potassium

Mehlich-I-extractable K was affected by sampling time, position (IR vs BR) and starters within the 0 and 50 lb K_2O/A main plots (Table 1). Extractable K within the 0 and 25 lb K_2O fertilized main plots was lower in 1996, indicating depletion by crop removal (Table 2). The check plot had higher extractable K than the starter within the 0-lb K_2O main plot, but the reverse was observed for the 50-lb K_2O/acre main plot. This is interesting since K was not in-furrow applied as a starter fertilizer. Sampling the IR position resulted in higher extractable K relative to BR sampling of main plots.

Mehlich-I-extractable K within the 50- and 75-lb K_2O main plots was affected by a year-by-starter-by-sample position interaction (Table 1). Extractable K of the 1989 starter plot within the 50-lb K_2O main plot was unaffected by sample position (Table 3). But extractable K was greater in the check IR position compared with the BR sample. The level of extractable K in the 1989 IR or BR positions was the same for both starter plots. The levels were the same for the BR position within the starter and check plots. By 1996, IR-extractable K was greater in both starter treatments compared with the BR position sample, but 1996 extractable K in the starter IR position was higher than the check IR position. In 1996, extractable K from the IR starter position (197 lb K/acre) would be classified as high while the BR sampling would be medium (113 lb K/acre). Soil samples collected from either IR or BR positions would be assigned a soil test rating of M. However, stratification within the starter plot had reduced extractable K in the BR position from 142 to 107 lb/acre, which is approaching a L soil test rating.

Broadcasting 75 lb K_2O resulted in significant differences in extractable K with sampling position, but differences between starter plots and years were not detected (Table 2). Extractable K from the IR sampled position was greater than the extractable K from the BR positions (Table 3). Vertical stratification of K was occurring in the long-term no-tillage corn soil. Stratification was greater as the rate surface-applied fertilizer increased. The soil K test level from the IR position would be classified as H or M for the BR position. Soil test fertilizer recommendations would vary depending on the position sampled.

CONCLUSIONS

Vertical stratification of Mehlich-I-extractable P and K has occurred in a long-term no-tillage corn soil. The amount of stratification was dependent on the broadcast rates of P_2O_5 and K_2O as well as previous starter applications. The effect of P starters was not detected in samples collected seven years after starter termination. Extractable P tended to be higher in the BR sample position relative to the IR sample position while the reverse was true for extractable K. A sampling protocol other than a random sampling may affect the extracted levels of both nutrients, which may affect fertilizer recommendations.

LITERATURE CITED

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Table 1. Type III F-values from statistical analysis of Mehlich-I-extractable phosphorus and potassium from a long-term no-tillage soil in corn production.

		Extractable P				Extractable K			
		Broadcast P rates				Broadcast K rates			
Item	df	0	50	100	150	0	25	50	75
Year (Y)	1	22.7**	79.6**	0.8	2.9	29.6**	8.4*	6.4	1.2
Error a	4								
Starter (S)	1	19.3**	106.7**	25.5**	3.4	13.9**	1.1	7.7*	0.2
S*Y	1	10.5*	39.1***	0.0	1.5	1.8	0.2	4.3	0.3
Error b	8								
Position (P)	1	14.6**	45.5***	7.4*	9.4**	89.3***	49.0***	83.2***	116.5***
P*Y	1	18.6***	94.0***	7.5**	5.8*	0.0	11.1**	29.3***	3.2
S*P	1	17.2**	68.7***	0.2	15.3***	3.0	0.0	1.2	0.0
S*P*Y	1	23.1***	78.4***	5.0*	4.6*	1.1	1.0	6.1*	4.5*
Error c	16								

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability level, respectively.

Table 2. Mehlich-I-extractable phosphorus (P) and potassium (K) from a long-term corn experiment as affected by year, starter applications and sampling position.

	Broadcast P_2O_5 rates (lb/acre)				Broadcast K_2O rates (lb/acre)			
	0	50	100	150	0	25	50	75
YEAR	---lb extractable P---				---lb extractable K---			
1989	14 A[1]	33 A	62 A	94 A	130 A	147 A	156 A	181 A
1996	6 B	20 B	58 A	102 A	103 B	129 B	144 A	170 A
STARTER								
Starter	14 A	34 A	72 A	103 A	109 B	140 A	156 A	174 A
Check	7 B	19 B	49 B	93 A	123 A	136 B	143 B	177 A
POSITION								
In-Row	13 A	31 A	56 B	92 B	128 A	151 A	171 A	208 A
Between-Row	8 B	22 B	65 A	105 A	105 B	125 B	129 B	143 B

[1]Within a column of each P or K rate, means followed by the same letter are not significantly different at $\alpha = 0.05$.

Table 3. Effect of broadcast phosphorus and potassium rates, starter applications, year of sampling and sampling position on Mehlich-I-extractable phosphorus and potassium.

In-furrow	Sample		Broadcast P_2O_5 and K_2O rates			
treatment	Position	Year	0-0	50-25	100-50	150-75
			---------------------------------lb extractable P/acre-----------------------------------			
Starter	IR	1989	30 A*	68 A	74 AB	113 AB
	BR	1989	9 B	21 BC	65 BC	90 CD
Check	IR	1989	7 B	20 BC	43 D	72 D
	BR	1989	8 B	21 BC	51 CD	101 ABC
Starter	IR	1996	7 B	20 BC	63 BC	96 BC
	BR	1996	8 B	25 B	85 A	112 AB
Check	IR	1996	6 B	15 C	45 D	85 CD
	BR	1996	5 B	19 C	56 CD	116 A
			---------------------------------lb extractable K/acre-----------------------------------			
Starter	IR	1989	136 A	154 A	163 B	198 A
	BR	1989	115 A	144 A	152 BC	157 B
Check	IR	1989	146 A	155 A	166 B	219 A
	BR	1989	122 A	138 A	142 C	151 B
Starter	IR	1996	102 A	153 A	197 A	214 A
	BR	1996	86 A	110 A	113 D	127 B
Check	IR	1996	127 A	143 A	158 BC	201 A
	BR	1996	98 A	108 A	107 D	138 B

* Within a column for each K rate, means of each extractable nutrient followed by the same letter are not significantly different at $\alpha = 0.05$.