A Field Study of Soil Test Variability, Its Effect on Accuracy of Fertilizer Recommendations, and the Subsequent Effect of Variable Rate Fertilizer Application on Soil Test Values[1/]

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ABSTRACT

Three 2.5 acre blocks were selected for intensive soil sampling from within an approximate 90 acre field which had been partitioned into 35, 2.5 acre blocks by a farm supply dealer. The 2.5 acre blocks had previously been sampled on a central composite grid basis and a variable rate fertilizer spreader (VRS) programmed for fertilizing the field. Three other more intensive sampling techniques were used to sample the 3 blocks selected for more detailed studies. Results obtained showed that soil test values for pH were the least variable and soil test P values were the most variable. Soil test K variability was much greater than that for pH but much less than that for P. The more intensive sampling methods resulted in different soil test values than those obtained from the central composite samples. Samples taken at 10 ft intervals along a linear transect in two blocks showed that there would be great variation in soil test values across 60 ft VRS swaths. Based on the central composite samples, the P and K fertilizer recommendation would have been zero. This recommendation was less accurate for P than K, when compared to the within-block variability measured by more intensive sampling. Soil test values measured on samples taken before VRS fertilizer application, and again, 6 months later, showed increases in P levels and decreased variation among the P levels. Changes in soil test K values were difficult to interpret because of reduced values, even at high rates of K fertilizer application. As would be expected, higher fertilizer rates resulted in higher soil test values.

INTRODUCTION

Use of precision agriculture techniques in Kentucky during the past several years has generated interest in how to soil sample a field for use in programming computer-driven, on-the-go, variable rate fertilizer spreaders (VRS). The advantage achieved by VRS is related directly to variability of soil test (ST) values within a specific field and the accuracy of how they represent the field. Since variability of

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ST values commonly exists on a small scale, a very intensive sampling procedure (grids of one acre or less in size) would be required to accurately describe the nature and extent of such variability within a field. The cost of sampling and analysis on such a scale would be prohibitive to most commercial producers. For this reason, many fertilizer dealers offering VRS to customers recommend central composite sampling (6-8 cores taken around a circle of 60-80 ft radius, centered in each block) on a 2.5 acre grid (330x330 ft), and using this 2.5 acre unit as the basis for VRS within a field. Use of this procedure to vary fertilizer rates within a field is based on the assumption that variability of ST values within each 2.5 acre block is less than that for the field as a whole. And further, this assumes that ST values are fairly uniform across the swath width of the spreader (about 60 ft) and along the 330 ft pathway of the spreader as it is driven through each 2.5 acre block. Both these assumptions are questionable.

Wells (1) reported variation in ST phosphorus (STP) of nearly two-fold across and along 40 ft wide spreader swaths in a 3.4 acre field which was intensively sampled in Shelby Co., KY. Recommendations for phosphate fertilizer rates among the 162, 8 x 20 ft blocks sampled in that study varied from 0 to 110 lbs/A. If the entire 3.4 acre area had been fertilized with a uniform rate based on results from one composite sample taken randomly from within the 3.4 acres, the entire area would have received 80 lbs P_2O_5/A. Application of the uniform 80 lb rate to the 3.4 acres as compared to the rate which would have been required for each of the 162 areas sampled within the 3.4 acres, would have resulted in only 31% of the area receiving the correct rate. Additionally, 39% would have been underfertilized and 30% would have been overfertilized. Such variability within a 3.4 acre block would not likely be overcome by use of a VRS programmed with the capability to vary rates every 2.5 acres.

We conducted a similar study in Hardin Co., Kentucky, during 1997, in a 90 acre field which had been sampled in 35, 2.5 acre blocks for use in programming a VRS to change fertilizer rates on each 2.5 acre block. The study was designed to determine how well a central composite soil sample from a 2.5 acre grid represents that grid, and if such a sampling method improves accuracy of fertilizer recommendations. Additionally, we measured soil test levels within blocks of a field which had been soil tested on a grid, before fertilizer was applied and at harvest, 6 months later. The objective was to define soil test variability within blocks before and after VRS fertilization. This information should provide insight into the effectiveness of on-the-go-VRS fertilizer application in lowering soil test variability between individual blocks.

DESCRIPTION OF THE STUDY

Soils in the field were mostly Crider silt loam, selected because of their importance in cash grain production in Kentucky. Each of the 35, 2.5 acre blocks had been sampled on a central composite grid basis, whereby a composite sample, comprised of 8 cores (0-4 inch deep), was taken around a 60-80 ft radius from the center of each block. The soil test value of this composite sample was used to represent the entire 2.5 acre block for programming a VRS to vary rates on a block-by-block basis. We selected three of the 35 blocks (A, B, and C) for sampling on a more detailed basis in order to measure soil test variability within each of the three 2.5 acre blocks studied. In blocks B and C, we soil sampled every 10 ft along a linear transect through the center of each block. This resulted in 24 samples taken across the 240 ft width of each block. Additionally, we sampled a 300 x 300 ft area within block B, on a 60 x 60 ft grid basis, resulting in 25 samples taken from the grid intersects. In block A, we conducted a small plot fertility study which resulted in 44, 10 x 40 ft plots within a 110 x 160 ft area. Each of the 44 plots was soil sampled, providing a very detailed sampling within this small 110 x 160 ft area. All samples, taken from the 0-4 inch depth, were analyzed at UK's Soil Test Laboratory in Lexington, using the Mehlich-III soil test extractant.

Immediately before fertilizer was spread onto the field, we laid out a linear sampling transect across the center of 2 blocks (Blocks B and C). The width of the fertilizer spreader swath was 60 ft, so we sampled at 6 sites across each 60 ft swath of the spreader. The width of each 2.5 acre block sampled was 240 ft, so the spreader made 4 swaths across each block. Sample sites along the traverse were marked by wire flags and also by geographic positioning systems (GPS) technology. A soil sample consisting of 6, 0-4 inch depth cores was taken at each of the resulting 24 sample sites across each of the 2 blocks, just before fertilizer was applied (April 3, 1997), and again, immediately following corn harvest (September 17, 1997) at the exact same site the sample was taken before fertilization. Block B was selected because it had been programmed to receive a "low" rate of fertilizer (40 lbs P_2O_5, 30 lbs K_2O, 25 lbs Zn, and 50 lbs pelleted limestone per acre). Block C was selected because it had been programmed to receive a "high" rate of fertilizer (120 lbs P_2O_5, 90 lbs K_2O, 25 lbs Zn, and 100 lbs pelleted limestone per acre). These recommendations were made by the farm supply dealer. Based on UK's interpretation of STP and STK, results from the central composite sample taken by the farm supply dealer (168 STP and 483 STK for block B, and 88 STP and 309 STK for block C), no fertilizer would have been recommended for either block.

A detailed small plot study of the effect of P and K rates was conducted in a block (A) adjacent to block B, providing a more precise measure of the effect of 40 and 80 lbs/A each, of P and K on soil test values.

RESULTS

Scale of Sampling and Soil Test Variability

Table 1 summarizes ST variability on 4 scales: (1) a 90 acre field sampled in 2.5 acre blocks, (2) two, 2.5 acre blocks, B and C, each sampled 24 times along a 240 ft linear transect through the center of the block, (3) a 2.5 acre block, B, sampled on a 60 x 60 ft grid, and (4) a 110 x 160 ft area within block A divided into 44, 10 x 40 ft blocks for individual sampling. Ranges are given for ST values and % coefficient of variation (% CV; the higher the CV, the greater the variability). As shown, there was much less variability for pH than for STP and STK, regardless of sampling scale. Range of STP was very wide, and was only narrowed down to a two-fold difference by the very intensive sampling in block A. There was little difference in % CV for STP among the 35 blocks within the 90 acre field and the % CV of the more intensive sampling used in blocks B and C. Variability of STK was much less than for STP, regardless of sampling scale, although the very intensive sampling of block A reduced % CV for both STP and STK measurably, as compared to the 35, 2.5 acre blocks.

Table 2 summarizes the effect of sampling method on the average ST values for the 3 blocks studied. As shown, each method gave different answers, differing more for STP than for STK or pH.

Variability Across 60 ft Wide Spreader Swaths

Table 3 summarizes ST values measured within four, 60 ft wide swaths across blocks B and C. As shown, there was much variability across each swath width, more for STP than for STK or pH. The STP values varied about two-fold across the swath.

Accuracy of VRS Fertilizer Rates as Compared to a Uniform Rate

The question of concern in use of VRS fertilizer application is whether it is more effective in matching rate of recommended fertilizer applications to variations of ST levels to blocks within a field as compared to a single recommended rate for the entire field. Table 4 summarizes the accuracy of one uniform recommendation, as related to ST variability measured among the 35, 2.5 acre blocks for the 90 acre field and within 3 of the 2.5 acre blocks studied. Recommended rates of phosphate and potash are those made by the University of Kentucky (UK), on a crop sufficiency basis. As shown in table 4, all average levels of STP and STK, regardless of sampling scale, exceeded those needed to increase yields, and the UK recommendation was that no phosphate or potash was needed. On the basis of the zero fertilizer recommendation, accuracy of the recommendation is summarized in table 4 in terms of amount of area which would have been correctly or incorrectly treated. For treating the whole 90 acre field uniformly, based on the average soil test values of the 35 central composite samples, the recommended rate of no fertilizer would have been correct for phosphorus on 66% of the field, and on 74% of the field for potassium.

Effect of VRS on Soil Test Variability

Average values for STP and STK are shown in table 5 for the 24 samples taken from each of the 2 blocks. Results are summarized in terms of ranges and variability, both before and after fertilization, in table 6. For STP, there was a wide range of soil test levels measured within each block. One on-the-go pre-programmed rate of fertilizer, even if uniformly applied to each of the 2.5 acre blocks tested, could not have leveled out this degree of variability. As shown (table 6) in soil test ranges measured after fertilization, it did not. It did, however, lower the variability somewhat for STP, more in block C which received 120 lbs P_2O_5/A than in block B which received only 40 lbs P_2O_5/A.

There was also about a 2x range in STK. Although there was little change in variability, either at the 90 or 30 lb rate of K_2O/A, levels of STK dropped by about 20% between April and September. A drop of this magnitude, especially with addition of potash, cannot be accounted for by crop uptake alone. While the reason for this is unknown, we speculate that it was related to the effect of droughty soil conditions on the equilibrium levels of exchangeable and non-exchangeable soil K. Studies of some Kentucky soils have previously shown that drying soil can lower STK under certain conditions of clay mineralogy and levels of exchangeable K.

Effect of a High or Low Fertilizer Rate on Soil Test Values Across the Swath

Changes in soil test values across a 60 ft VRS swath width are shown in table 7 for a low rate of fertilization, and in table 8 for a high rate of fertilization. Values shown for each swath are averages of 6 soil samples taken across the 60 ft swath width. Soil pH dropped slightly, even with 50 or 100 lbs pelleted lime per acre. The "low" rate of fertilizer raised STP levels slightly, while the "high" rate of fertilizer raised STP substantially. As previously noted, STK levels dropped significantly, regardless of amount of K_2O applied.

Rate Effect of Phosphate and Potash on Soil Test Values

Table 9 summarizes the effect of rates on changes in soil test values. The 0, 40, and 80 lb/A P_2O_5 and the 80 lb/A K_2O rate effects were measured in a small plot rate study in another block (A), located adjacent to block B. The small drop in STP with no P_2O_5 was probably due to crop uptake effects, where no-till corn yields were in the 100-150 bu/A range. Additions of P_2O_5 raised average STP levels, increasingly more at each additional rate. Average levels of STK, as previously mentioned, dropped significantly, regardless of rate of K_2O applied. Crop uptake would not account for all of the drop in STK, which we speculate was mostly due to very dry soil conditions during July-September, causing the potassium to become temporarily unavailable.

SUMMARY

Results of intensive soil sampling studies conducted on three 2.5 acre blocks in a 90 acre field indicated that the 2.5 acre sampling units were too large to account for the variability in STP and STK found within the three blocks studied. The UK soil test recommendation based on a central composite sample would have resulted in substantial under-fertilization of two of the three blocks for phosphorus, but was considerably more accurate for potassium.

The variability of STP and STK found within the two 2.5 acre blocks studied was high prior to fertilization, and an application of on-the-go rates of P_2O_5 and K_2O by a VRS did not overcome variability in STP or STK values in the two blocks. Athough the degree of variability in STP dropped sharply when a "high" rate of phosphate was added, the variability of STK was largely unchanged. Average values for STP were increased with increasing rates of phosphate application. Values for STK dropped significantly, regardless of rate.

REFERENCE

1. Wells, K.L. 1996. Variation in Soil Test Phosphorus and Corn Yields within a 3.4 Acre Field. In, Proc. 1996 Sou. Soil Fert. Conf. Memphis, TN. Oct. 15-16, 1996. Samuel Roberts Noble Foundation, Ardmore, OK

Table 1. Variability In Soil Test Values

	Range in S.T. Values			%Coefficient of Variation		
	pH	P[1]	K[1]	pH	P	K
Block A (44 small plots)	5.4-5.9	37-77	281-507	2.7	17.0	13.5
Block B 60x60 grid (25 sites)	5.5-6.3	42-221	267-725	0.6	60.2	25.4
Block B traverse (24 sites)	5.3-5.9	41-140	261-501	2.8	27.2	19.3
Block C traverse (24 sites)	5.5-6.5	29-212	272-533	4.1	62.3	17.3
90 Acre Field (35 blocks, 2.5 ac. ea.)	5.4-6.7	15-138	153-478	5.1	57.0	28.0

[1] lbs/A

Table 2. Effect of Sampling Method on Average Soil Test Values[u] Within 2.5 Acre Blocks

Sampling Method	Block A			Block B			Block C		
	pH	STP	STK	pH	STP	STK	pH	STP	STK
Central grid composite[y]	5.9	102	362	6.2	168	463	5.9	88	309
Linear traverse[x]	--	--	--	5.75	76	384	5.9	71	353
60 x 60 grid[w]	--	--	--	5.85	97	445	--	--	--
10 x 40 grid[v]	5.7	54	385	--	--	--	--	--	--

[u] STP and STK are lbs/A

[y] one sample per 2.5 ac, comprised of 8 cores taken along a 60 ft radius from center of block.

[x] Av of 24 samples per 2.5 ac, each sample comprised of 6 cores taken across the center of each block.

[w] Av of 25 samples taken on a 60 x 60 ft grid (300 x 300 ft) within a 2.5 ac block, each sample comprised of 6 cores taken at each intersect.

[v] Av of 44 samples taken from individual 10 x 40 blocks within a 110 x 400 ft area within a 2.5 ac block, each sample comprised of 6 cores taken linearly along the long axis in the center of each block.

Table 3. Variability of Soil Test Values Across Four Separate 60-Ft Wide Spreader Swaths [1]

Block	Swath 1 range	Swath 1 Av.	Swath 2 range	Swath 2 Av.	Swath 3 range	Swath 3 Av.	Swath 4 range	Swath 4 Av.
			pH					
B	5.8-5.9	5.9	5.7-5.8	5.8	5.4-5.9	5.7	5.3-5.8	5.6
C	5.8-6.6	6.2	5.8-6.1	5.9	5.6-5.9	5.8	5.6-5.8	5.7
			Phosphorus [2]					
B	41-59	51	53-90	72	70-140	86	70-122	94
C	99-212	123	45-129	84	29-43	33	35-59	45
			Potassium [2]					
B	284-375	320	261-418	334	368-476	427	388-501	454
C	341-533	420	319-407	368	272-316	292	309-334	332

[1] Av. of 6 composite samples taken across each 60-ft swath
[2] lbs/A

Table 4. Precision of Recommended Fertilizer Application: Comparison of Application Rates Based on a Single Composite Soil Sample Per Sampling Unit As Related to Soil Test Variability Measured Within the Field or 2.5 Acre Blocks.

Sample Unit	Phosphorus STP	Recomm. lbs P_2O_5	% of Area Fertilized: correct	over	under	Potassium STK	Recomm. lbs K_2O/A	% of Area Fertilized: correct	over	under
90 acre field [1]	99	0	66	0	34	378	0	74	0	26
Block A [2]	102	0	36	0	64	362	0	95	0	5
Block B [2]	168	0	71	0	29	463	0	83	0	17
Block C [2]	88	0	42	0	58	309	0	83	0	17

[1] Composite value based on the Av of 35, 2.5 ac. blocks in the field
[2] One central grid composite sample per block

Table 5. Average Soil Test Values of 24 Samples Taken From Each Block Before and After VRS Application of Fertilizer.

	STP		STK		Standard Deviation STP		Standard Deviation STK	
Block	Before	After	Before	After	Before	After	Before	After
B	76	79	384	290	24	21	74	53
C	71	104	353	289	44	40	61	57

Table 6. Range and Variability of Soil Test Values of 24 Samples Taken From Each Block Before and After VRS Application of Fertilizer

	Range in STP[1]		STP Variability[2]		Range in STK[1]		STK Variability[2]	
Block	Before	After	Before	After	Before	After	Before	After
B	41-140	51-113	32	27	261-501	201-411	19	18
C	29-212	54-225	62	39	272-533	228-461	17	20

[1] lbs/A of soil test phosphorus (STP) and soil test potassium (STK).
[2] % coefficient of variation (the higher the number, the greater the variability).

Table 7. Soil Test Values Before and After VRS Application of a "Low"[1] Rate of Fertilizer.

	Block B					
	pH		STP (lbs/A)		STK (lbs/A)	
Swath[2]	Before	After	Before	After	Before	After
1	5.9	5.8	51	60	320	248
2	5.3	5.7	72	74	334	254
3	5.7	5.7	86	89	427	329
4	5.6	5.5	94	93	454	327
Av	5.75	5.68	76	79	384	290

[1] VRS programmed to apply 40 lbs P_2O_5, 30 lbs K_2O, 25 lbs Zn, and 50 lbs pelleted limestone per acre.
[2] Values shown are the average of 6 separate soil samples taken across a 60-ft spreader swath

Table 8. Soil Test Values Before and After VRS Application of a "High"[1/] Rate of Fertilizer.

	Block C					
	pH		STP (lbs/A)		STK (lbs/A)	
Swath[2/]	Before	After	Before	After	Before	After
1	6.2	5.9	123	151	420	339
2	6.0	5.7	84	102	368	256
3	5.8	5.5	33	75	292	266
4	5.7	5.5	45	86	332	295
Av	5.9	5.7	71	104	353	289

1/ VRS programmed to apply 120 lbs P_2O_5, 90 lbs K_2O, 25 lbs Zn, and 100 lbs pelleted limestone per acre.

2/ Values shown are the average of 6 separate soil samples taken across a 60-ft spreader swath

Table 9. Rate Effects of Phosphate and Potash on Soil Test Values

	STP (lbs/A)		
lbs P_2O_5/A	Before	After	% Change
0[1/]	57	53	-7
40[2/]	70	72	+3
80[3/]	61	77	+26
120[4/]	71	104	+46

	STK (lbs/A)		
lbs K_2O/A	Before	After	% Change
0[1/]	409	297	-27
30[3/]	384	290	-24
40[2/]	400	329	-18
80[3/]	390	323	-17
120[4/]	353	289	-18

1/ 3/ Av. of 16 plots within a fertilizer rate study conducted in an adjacent block.

2/ Av. of 16 plots from a rate study conducted in an adjacent block and 24 sites sampled across block B.

4/ Av. of 24 sites sampled across block C.

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