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Profitability of Variable Rate Fertilization on a Kentucky Soil (a Theoretical Analysis)

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INTRODUCTION

Grid soil sampling and variable rate fertilizer applications are a part of the precision agriculture movement that has captured the interest of many farmers. Variable rate fertilization requires extra expense and effort plus the use of often unfamiliar technology. Global Positioning Systems (GPS) equipment and computer software are used to outline and grid the field into small manageable units or "cells" (usually 2.5 acres). Each grid cell is soil sampled and tested for pH and available nutrients. Fertilizer recommendations are made on each grid cell and the fertilizer is spread by each grid cell using a truck equipped with GPS and variable rate fertilizer spreaders.

In order for variable rate fertilization to be profitable, a field must have areas in it with a wide range of soil test levels(1). A field with only a small amount of soil test variability within it will not justify the expense for the use of variable rate technology (VRT). How wide does the variability need to be and does profitability change with distribution of the variability within the field? These questions were examined in this analysis.

The objective of this study was to look at different soil test variability patterns in fields and determine when VRT would be profitable. Hopefully, this will help producers make decisions about which fields or farms where VRT could be used to their advantage.

In this analysis, only phosphorus (P) and potassium (K) fertilization are considered and VRT is compared to aconventional field averaged soil test with single rate fertilization.

METHOD

The P and K response curves were used for a Belknap silt loam soil. This is a deep, somewhat poorly drained soil where both corn and soybeans have a high yield potential. The information concerning the yield response of corn and soybeans to added fertilizer at different phosphorus and potassium soil test levels was taken from work published by Dr. William Thom in the U.K. Agriculture Experiment Station Bulletin 720 in January 1985[2] . Average yield potentials of 150 bu/ac for corn and 50 bu/ac for soybeans were assumed when both P and K availability were not limiting. Grid cell size was set at 2.5 acres and was assumed that there was little or no soil test or yield variation within each grid. The soil test values used for the analysis, and other information used in the calculations, are found in Table 1.

Expected yields were calculated using the response curves listed in Table 1 and contained in Bulletin 720(2). Fertilizer recommendations were taken from AGR-1 "University of Kentucky Fertilizer Recommendation Guide". Soil tests P and K were determined by the Mehlich III extraction method used in the soil testing labs at Regulatory Services, University of Kentucky.

DISCUSSION

Response of Crops to Soil Test Levels

Crop response, and therefore, the profitability of the fertilization method is greatly affected by existing soil test levels. It should be understood that the expected yield response of crops to different soil test levels as set by the University of Kentucky, are the following:

Soil Test Level	Expected Yield Response to Added Fertilizer
Low	Yield response to added fertilizer is high and high amounts of fertilizers are recommended.
Medium	Yield response to added fertilizer is small or none and fertilizer is recommended at about maintenance rates.
High	No yield response is expected and no fertilizer is recommended.

These crop responses will help explain the results projected in this analysis.

Costs of Fertilizer Spreading, Sampling, and Technology

The costs of fertilizer spreading, soil sampling and technology will always be greater when VRT is used. Based on average charges in Kentucky in 1997, the costs used in this study was $8/ac per year for VRT vs. $3.70/ac per year for field average method (see Tables 2 & 3).

These costs will vary considerably depending on how often a field is sampled and the sampling and technology charges. In this study, costs were based on soil sampling every 4 years for the VRT method and every 2 years for the field average method. The cost of spreading fertilizer by the VRT method was always higher than that of the field average method. The fertilizer cost was directly related to the amount of fertilizer used.

The total amount of fertilizer recommended on the field differed between the two systems. More fertilizer was usually recommended by the VRT method (10 of the 18 situations - see Tables 2 & 3), but not always. This occurred when a field had both high and medium or high and low testing grid cells. More fertilizer was recommended for the field average method in 3 of the 18 situations and mainly occurred when a field had both low and medium testing grid cells. In the other 5 situations, there was less than $1/ac per year difference between the two methods.

Yield Comparisons

It was assumed that no factor other than fertility affected the yield. Such factors as drought, compaction, insect damage and disease, etc. could reduce the yields and limit the effect of fertility, but this cannot be predicted. It was also assumed that the 2.5 acre grid cells had uniform fertility and would produce maximum yields if fertilized according to recommendations.

If the field consisted of high and medium soil testing grid cells, the yield reduction for using a field average soil test was very small when compared to the VRT method (Tables 2 & 3). When the field consisted of low and medium soil testing grid cells, the yield reductions for using the field average method were small for corn and almost non-existent for soybeans. The greatest yield reductions occurred when the field had both low and high testing grid cells. This is also where the VRT was most profitable.

Profitability of the VRT

It appears that the VRT will be most profitable where large differences in soil test levels exist in the same field. Veryspecifically, it must have both low and high soil testing grids. In fact, the high testing grids must represent 50% or more of the field with the rest testing low (Table 4). In such a case, the yield and profitability increases for the use of the VRT method are large (Tables 2 & 3).

The least profitable situation for VRT was where the field contained mainly high and medium soil testing grids. In this case, VRT would result in negative returns due to increased fertilizer, spreading and technology cost with very little increase in yield (Tables 2 & 3).

When the soil test levels for a field were mainly in the low and medium range, the profitability for the use of VRT was break-even for soybeans and marginally profitable for corn (Tables 2 & 3).

VRT is favored by the method of calculations

The analysis calculations probably result in a greater profitability for VRT using P and K than would actually be realized by a farmer because:

1. It was assumed that each 2.5 acre grid cell did not vary in soil test across the cell. This is usually not true. When there is variability within the cell, the fertility recommendation used for each cell may not be the best one for all the area in the cell.
2. It is assumed that the yields were limited by only soil fertility. In fields where yields will be limited by other soil types, drought, compaction, insects, disease, etc., the yields advantages shown in this study for the use of VRT may not be

realized, which would effect it's profitability.

3. The low P and low K testing grid cells were randomly assigned in the field and not assumed to occur together. Realistically, when one element tests low, the other will often be low also. When low P and low K occur in different grid cells, the yield response to VRT is greater because yields are increased over a larger percent of the field.

These three factors probably result in this study favoring the profitability of the VRT. Therefore, it is safe to assume that anytime the profitability of the field average method is favored it is solid and where situations result in a marginal profit for VRT this may also favor the field average method.

Different Soil Types may change profitability

Soils that result in a larger crop yield response than the Belknap soil would increase the profitability of VRT and soils which are less responsive to fertilizer would decrease the profitability of VRT and favor the field average method.

Identifying fields for use of VRT

There are soil test levels of P and K that will make it profitable to use the VRT and these have been previously discussed. However, in order to know if a field has that potential it must be grid sampled at least once to determine the variability that exists in the field. If the soil test variability within a grid cell is similar to the variability between the grid cells in the field, then the calculations that favor VRT become less reliable.

This study only covers P and K. The pH variability is also an important factor in some fields and reducing this variability by using VRT may be more important than applying P & K with VRT.

Comparing a yield map of a field with the soil test map of a field will probably help a producer more fully understand the potential profitability of VRT fertilization and identify areas that need to be sampled separately.

CONCLUSIONS

Using VRT as a fertilization tool for P and K may be profitable, but it will depend on the soil test levels in the field. The potential profitability is greatest when a field has grid cells that test both in the high and low soil test range with 50% or more of the grid cells testing high. VRT does not appear to be profitable when a field has mostly high and medium soil test levels of P and K.

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TABLE 1. Data Base for Calculations

Selected Soil Test Values and Fertilizer Recommendations			
----PHOSPHORUS (P) ----			
Soil Test Range	Soil Test Value (lb P/ac)	Fertilizer Recommendation (lb/a P_2O_5/ac)	
		Corn	Soybeans
Low	20	90	70
Medium	45	40	30
High	80	0	0
----POTASSIUM (K) ----			
Soil Test Range	Soil Test Value (lb K/ac)	Fertilizer Recommendation (lb/a K_2O/ac)	
		Corn	Soybeans
Low	100	110	70
Medium	240	40	40
High	350	0	0

Fertilizer Costs: P_2O_5 = $0.28/lb. K_2O = $0.12/lb.

Soil Sampling, Technical and Fertilizer Spreading Costs:
Variable Rate = $8/ac/yr (Grid soil sampling every 4th year)
Field Average = $3.70/ac/yr (Field sample every 2nd year)

Corn Price: $2.50/bu
Soybean Price: $6.00/bu
Grid Size: 2.5 acres

Yield Potential (average over years):
Corn - 150 bu/ac Soybeans - 50 bu/ac

Response Curves:

	K	P	
Corn	$\log(100-y) = 2-.02(x-65)$	$\log(100-y) = 2-.043(x-11)$	x = soil test values
Soybeans	$\log(100-y) = 2-.043(x-70)$	$y = [1-e^{-.102}(^{x-5.8})]$	y = relative yield

TABLE 2. Estimated Returns ($/A) to P-K Fertilizer Application Rates for Soybeans[1] From Variable Rate (VRT) Spreading as Compared to a Field Average (FA) Soil Test for Nine Soil Test Scenarios[2]

Soil Test Range of Field (VRT)[3]	Field Avg. Soil Test for P & K	$/A Spreading & Technology Cost of VRT Compared to FA	$/A Fertilizer Cost of VRT Compared to FA	Estimated Yield Bu/Ac Variable Rate	Estimated Yield Bu/Ac Field Avg.	$/A Returns of VRT Compared to FA
75% Hi; 25% Med	P 71; K 323	8.00	3.30	50	49.75	-9.80
50% Hi; 50% Med	P 63; K 295	4.30	3.00	50	49.5	-4.30
25% Hi; 75% Med	P 54; K 268	4.30	-2.10	50	50	-2.20
75% Lo; 25% Med	P 26; K 135	4.30	-.90	50	49.53	.59
50% Lo; 50% Med	P 32; K 170	4.30	-.30	50	49.31	.13
25% Lo; 75% Med	P 39; K 205	4.30	-.30	50	49.44	-.63
75% Lo; 25% Hi	P 35; K 163	4.30	3.80	50	48.69	-.23
50% Lo; 50% Hi	P 50; K 225	4.30	2.00	50	48.5	2.70
25% Lo; 75% Hi	P 65; K 288	4.30	4.60	50	46.84	10.04

[1] Yield based on P - K response curves for a Belknap silt loam soil (2).
[2] Soil test values from Mehlich III extractant.
[3] Soil test values (High, Medium, Low) can be found in Table 1.

TABLE 3. Estimated Returns ($/A) to P-K Fertilizer Application Rates for Corn[1] From Variable Rate (VRT) Spreading as Compared to a Field Average (FA) Soil Test for Nine Soil Test Scenarios[2]

Soil Test Range of Field (VRT)[3]	Field Avg. Soil Test for P & K	$/A Spreading & Technology Cost of VRT Compared to FA	$/A Fertilizer Cost of VRT Compared to FA	Estimated Yield Bu/Ac Variable Rate	Estimated Yield Bu/Ac Field Avg.	$/A Returns of VRT Compared to FA
75% Hi; 25% Med	P 71; K 323	4.30	7.70	150	149	-9.50
50% Hi; 50% Med	P 63; K 295	4.30	4.40	150	148	-3.70
25% Hi; 75% Med	P 54; K 268	4.30	0	150	149.25	-2.43
75% Lo; 25% Med	P 26; K 135	4.30	-1.60	150	147.56	3.39
50% Lo; 50% Med	P 32; K 170	4.30	-2.00	150	146.5	6.45
25% Lo; 75% Med	P 39; K 205	4.30	.40	150	147.5	1.55
75% Lo; 25% Hi	P 35; K 163	4.30	2.40	150	145.7	4.08
50% Lo; 50% Hi	P 50; K 225	4.30	4.80	150	139.5	17.15
25% Lo; 75% Hi	P 65; K 288	4.30	6.00	150	134.25	29.08

[1] Yield based on P - K response curves for a Belknap silt loam soil (2).
[2] Soil test values from Mehlich III extractant.
[3] Soil test values (High, Medium, Low) can be found in Table 1.

TABLE 4. Estimated Returns ($/A) for VRT as Compared to Field Average (FA) Method[1] for a Corn and Soybean Rotation[2]		
Soil Test Range of Field [3] (VRT)	**Field Avg. Soil Test for P and K**	**$/A Returns to VRT Compared to FA**
75% Hi; 25% Med	P 71; K 323	-9.65
50% Hi; 50% Med	P 63; K 295	-4.00
25% Hi; 75% Med	P 54; K 268	-2.32
75% Lo; 25% Med	P 26; K 135	1.99
50% Lo; 50% Med	P 32; K 170	3.29
25% Lo; 75% Med	P 39; K 205	.46
75% Lo; 25% Hi	P 35; K 163	1.93
50% Lo; 50% Hi	P 50; K 225	9.93
25% Lo; 75% Hi	P 65; K 288	19.56

[1] Yield based on P - K response curves for a Belknap silt loam soil (2).
[2] Soil test values from Mehlich III extractant.
[3] Soil test values (High, Medium, Low) can be found in Table 1.

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