FARM TEST OF CROP SENSING FOR SITE-SPECIFIC NITROGEN FERTILIZER APPLICATION IN WINTER WHEAT 2011

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WHAT WE LEARN FROM OUR EXPERIMENTS:

1. NDVI measurements shortly before the second N split reflect spatial differences in wheat growth and zones with high NDVI require less nitrogen than zones with lower NDVI.
2. In this year and in this field, calibration plots were not useful to convert NDVI measurement into a target N application rate.
3. Poor wheat growth in a particular zone with low soil quality could be overcome by higher N applications. For a substantial area, the same wheat yield could have been obtained with a slightly lower N rate.

INTRODUCTION

Wheat nitrogen fertilization and crop sensor experiments in previous years have clearly shown that induced nitrogen deficiency could be identified in the spring time by canopy reflectance measurements resulting in optical indices such as NDVI. In these experiments, spatial variation and representativity of sensor measurements and their relationship to grain yield were quantified in a farmer's field in Western Kentucky. A wide range of nitrogen fertilization rates caused obvious differences in NDVI and yield. Would these results be valid in a real-world situation when spatial variation in NDVI is smaller and would NDVI measured in early spring be a valid indicator for site-specific nitrogen application?

OBJECTIVE

The purpose of this year's experiment was to identify whether spatial NDVI differences found under a uniform application of nitrogen in the first split would support a decision for site-specific nitrogen fertilizer application during the second split. This investigation should answer the question whether site-specific nitrogen application provides an advantage to the farmer compared to a uniform application. In other words: How can NDVI measurements be converted into a relevant nitrogen recommendation, and what is the farmer's benefit compared to uniform N-application?

MATERIALS AND METHODS

As in previous years, the experiment was performed in the Hargis wheat field of the farmer Trevor Gilkey, Princeton (Hillview Farms). This year, two strips next to each other were investigated. Both strips were 2107 ft long and 90 ft wide and were treated identically until the second split of N was applied. One strip received a uniform N application at the second split, the other got the same total amount of N but with site-specific different rates. On February 17, 2011, the first split of N was applied [51 lbs N/acre (28-%-UAN)] uniformly across the two strips and the entire field. At this time, two plots – from here on called calibration plots – each 90 ft by 90 ft in size were established close to the two strips. One of the two calibration plots received no N fertilizer, the other received the full amount of 122 lbs N/acre at this time of the first split. The purpose of these two plots was to establish extreme differences between the maximum and minimum N supply. These differences were first intended to be used for optical scanner calibration. The full amount of N was expected to result in maximum NDVI, the zero-N plot in minimum NDVI. The high NDVI situation would need no further N, whereas the minimum NDVI should require the full rate of N to counteract N deficiency.

On March 29, the field was scanned with the GreenSeeker. Five sensors 7 ft apart on the sensor boom were run across the central 28 ft of both strips. Data were logged and an average NDVI derived at intervals of 16.3 ft along both strips, resulting in 129 NDVI values for each strip. The two calibration plots were scanned as well. The ranges of NDVI measurements within the 0-N- and Full-N-calibration plots overlapped and were very variable (Table 1). Moreover, the range of NDVI measurements in the experimental strip that had received 51 lbs N/acre at the first split was even larger than the ranges in the two calibration plots. Two conclusions were drawn from this behavior: 1) The NDVI from the calibration plots could not be used to convert field-scale NDVI into nitrogen application rates. 2) We assume that the reason for the differences in NDVI between the calibration plots and the two strips is a result of spatial soil variability.

Therefore, site-specific N-rate was based on the variation of NDVI across the variable rate strip with the restriction being imposed that the same exact total amount of nitrogen was applied in the uniform and the site-specific strip. The second N split was applied at a variable rate shown below in Figure 2.

TABLE 1. RESULTS OF NDVI MEASUREMENTS IN THE 0-N AND FULL-N CALIBRATION PLOTS AS COMPARED TO THE EXPERIMENTAL STRIP. NDVI MEASUREMENTS WERE TAKEN PRIOR TO THE SECOND N-SPLIT.

NDVI	Average	Maximum	Minimum
0-N Cal-Plot	0.76	0.81	0.62
Full-N Cal-Plot	0.81	0.85	0.74
Exper. Strip	0.77	0.84	0.54

RESULTS

The spatial changes of NDVI along the experimental strip are shown with the red dots in the bottom of Figure 1. In the upper part of Figure 1, the blue triangles describe the derived N application rate that is a mirror image of NDVI. The application rate reflects the fact that wherever high NDVI is observed, the need of the crop for additional N is less compared to zones where NDVI is relatively low indicating a situation of potential N deficit. In comparison, the straight purple line in Figure 1 denotes the constant rate applied in the uniform strip.

Next, we want to compare NDVI and yield measurements in both the uniform and the variable rate strips as shown in Figure 2. The NDVI measurements along both strips exhibit relatively similar behavior except for two zones. The first is from 0 to 60 feet distance of the transect and is a rather small zone where NDVI is much smaller in the variable rate strip than in the uniform strip. The second more pronounced zone is at the end of the transect, between 1700 and 1950 ft, where NDVI is much smaller in the variable rate than in the uniform strip. Severe topographic differences over short distances are the reason for low NDVI values in this zone of the variable rate strip. The land surface is very steeply sloped here, and the soil is extremely clayey even at the surface. This variation does not occur in the uniform transect.

Interestingly, between 50 and 350 ft, wheat yields are slightly higher in the uniform than in the variable rate strip despite the fact that NDVI and N application rates were the same. Between 700 and 1500 ft, the variable rate strip yields somewhat more although slightly less nitrogen had been applied as compared with the uniform strip (Figure 1). Presumably, the yield in the uniform strip in this part of the field could have been obtained with even slightly less nitrogen. From NDVI measurements and from past years' experience, low yields would have been expected in the low-NDVI area between 1700 and 2000 ft. In this zone, obviously, the increased N-rate counteracts this trend, and yields turn out to be similar to the uniform strip with fewer topographic differences and better soil quality area as compared to the variable rate strip.

The overall result: In both strips, the average yield is 84 Bu/acre. Hence, the same total amount of nitrogen is associated with the same average yield despite all spatial soil and NDVI differences.

Another very important observation is the fact that in the uniform strip, NDVI patterns do not reflect grain yield patterns although an association was expected. Throughout many years of NDVI and yield measurements on this farm, this was the first time that NDVI and yield did not agree. The extreme weather conditions certainly could have caused the results to turn out the way they did: A few days after measuring NDVI, extremely heavy rainfalls for several days caused serious flooding in depression zones of fields in this area. The last event of this intensity had been observed in the 1930's. Because of relatively flat topography in our field, flooding did not occur over larger areas. However, small local depressions collected excessive water through lateral flow from the surrounding area. This flooding certainly caused negative effects on crop growth that were obvious during harvest when zones that had few wheat plants or showed a few dead plants with symptoms of oxygen deficiency were seen. Presumably, extreme weather conditions between NDVI measurement and harvest destroyed their spatial relationship.

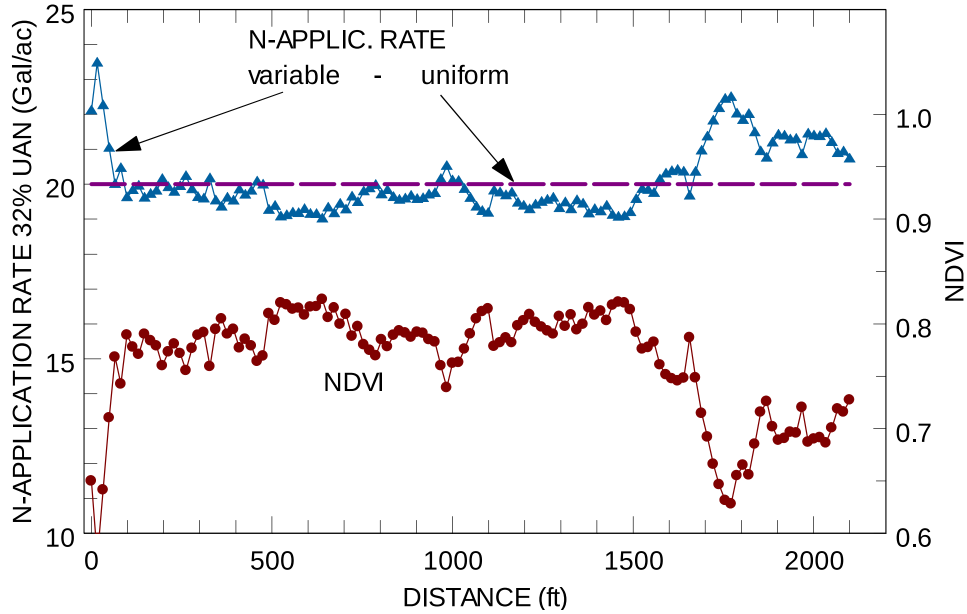

Figure 1. NDVI (red symbols) across the experimental strip, and resulting variable N fertilizer application rate (blue triangles). The purple dashed line denotes the amount of N applied in the uniform strip.

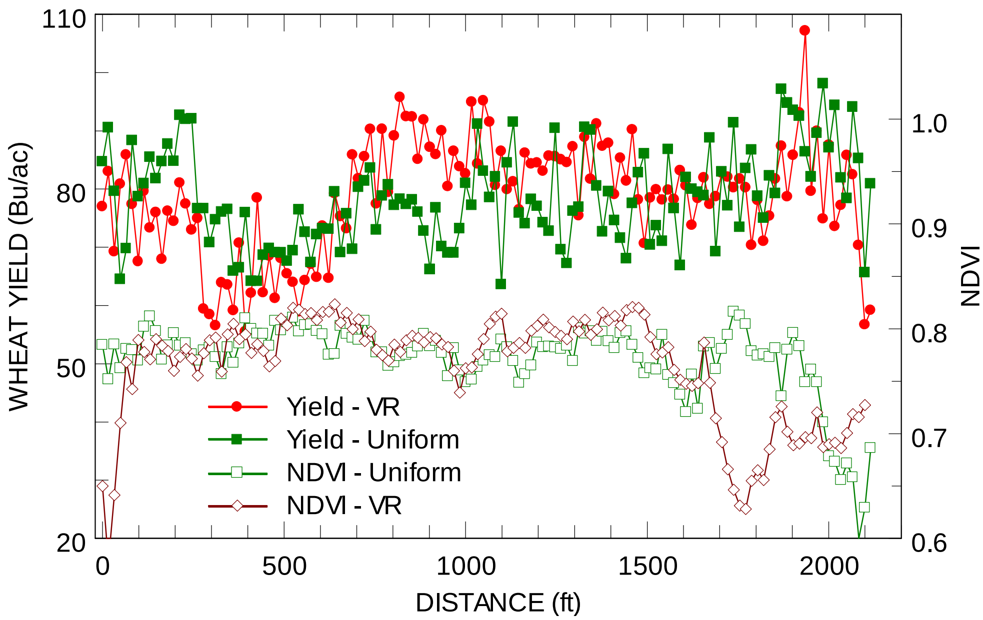

Figure 2. Wheat grain yield in the variable rate strip (red dots) and in the uniform strip (green dots). In the lower part, NDVI is shown for the uniform (open green symbols) and the variable N-rate (open red symbols).

WHAT IS NEXT?

Should a wheat field be scanned for NDVI in an extra pass before N application or should scanning and site-specific N application be accomplished at the same time?
It seems more logical to scan a field first, then spend time on the data analysis necessary for creating a map and only then applying the fertilizer. But this means an extra pass and more time. Is it worth the extra pass and time or can scanning and fertilization be accomplished at the same time?

DISSEMINATION OF PAST YEAR'S RESULTS:

Presentations:

Wendroth, O., C.J. Matocha, and L. Murdock. 2011. Additive State-Space Model for Decomposing Variation at Different Scales: Opportunities for Experiments in Variable Landscapes. Oral presentation, Annual Meeting, ASA-CSSA-SSSA, Oct. 16-19, 2011, San Antonio, Texas.

TV contribution on remote sensing-based optimization of nitrogen fertilizer application in "Growing Kentucky.

Wheat Field-Day, Princeton Kentucky, "How close is close enough?" Ole Wendroth, Lloyd Murdock, Greg Schwab, R. Jason Walton.

Publications:

Wendroth, O., K.C. Kersebaum, G. Schwab, and L. Murdock. 2011. Spatial relationships of soil properties, crop indices and N application pattern with wheat growth and yield in a field. In: Ahuja, L., and L. Ma (Eds.) Methods of Introducing System Models in Field Research, Volume 2 in the Advances in Agricultural System Modeling Series, ASA-SSSA-CSSA, Madison, WI. (in press).

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