Delineation of High Risk Field Areas for Variable Source N Fertilizer Applications to Optimize Crop N Use Efficiency

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Summary:

Research was conducted in 2007 and 2008 in Northeast Missouri to collect information related to spatial and temporal differences in soil water content and soil N availability across agricultural fields containing low-lying or depressional areas, to determine the spatial variability in crop response and plant N status due to application of different enhanced efficiency N fertilizer sources, and to develop and validate a computer program that would delineate the high risk N loss areas in a form that could be used for variable source N fertilizer application.

• In both years of this research, corn grain yields and plant N status increased significantly with an application of enhanced efficiency fertilizer sources (i.e. urea, polymer-coated urea (PCU), urea + urease inhibitor (UI) and urea + nitrification inhibitor (NI)) compared to the non-treated control depending on the landscape position. However, PCU was the only enhanced efficiency N source that had significantly higher average grain yields (20.4 bu/acre higher in 2007 and 50.0 bu/acre higher in 2008) compared to that of urea over all of the landscape positions.

• Maps of the grain yield differences between the enhanced efficiency N fertilizers and urea across the field indicate that in 2007 these enhanced efficiency fertilizers mainly outyielded urea in the low-lying areas of the field, probably due to differences in the fate of these fertilizers compared to urea under wetter soil conditions in the lower landscape positions of the field. These results confirm earlier research in the same field which observed consistently higher yields when PCU was applied compared to urea in low-lying areas.

• Higher than average rainfall in 2008 (approximately 35 inches during the growing season) and extended periods of saturated soils in the lower areas of the field, resulted in relatively higher yields in the upper landscape positions. Among the enhanced efficiency N fertilizers, PCU showed consistently higher yields compared to urea across all landscape positions.

• Maps of the net economic return for the enhanced efficiency fertilizers versus urea also show that strategic placement of these products in high risk areas of a field increased economic returns over a uniform application of urea or the enhanced efficiency fertilizers in claypan soils, especially in areas where there is variation in elevation and drainage.

• The relative performance of PCU, UI and NI in this research may be affected by the fact that all the fertilizers were immediately incorporated after application compared to surface application.

• Further testing and development of the variable source N fertilizer application strategy and an accompanying software tool are needed under different environmental conditions and on a farm field scale.
Materials and Methods

A field trial planted to corn was conducted in 2007 and 2008 at the University of Missouri Greenley Research Center in Northeastern Missouri. This field was previously mapped for elevation with a total station surveying instrument and apparent electrical conductivity (EC$_a$) using an EM-38 sensor. Relatively higher EC$_a$ indicates a relatively shallow depth to the claypan subsoil layer. The field was selected because it contained contrasting landscape positions, including low-lying areas, and differences in depth to the claypan layer.

The field was separated into 10 x 750 foot plots which passed through the low-lying and sideslope areas of the field. Nitrogen fertilizer treatments consisted of a non-treated control and 150 lb N/acre of urea, polymer-coated urea (ESN, Agrium, Inc.), urea + NBPT (N-(n-butyl) thiophosphoric triamide) urease inhibitor (UI) at 1 gal/ton (Agrotain, Agrotain International), and urea + nitrapyrin nitrification inhibitor (NI) at 1 qt/acre (N-Serve, Dow AgroSciences) were applied in the spring prior to planting of corn. All the N fertilizer treatments were incorporated using a field cultivator immediately after application. The experimental design was a randomized complete block with four replications.

In each plot, sampling points were set up every 30 feet across the field to allow for periodic collection of soil samples from the 0 to 6 and 6 to 12 inch depths during the growing season for determination of soil water content and soil inorganic N (ammonium and nitrate-N). Three subsamples were taken at each point and composited. All the sampling points were georeferenced using a differential GPS. Figure 1 shows the distribution of soil water content on June 4th, 2007 indicating the variation in soil water content that occurred across this field. In general, the low-lying areas had higher relative soil water content compared to that of the areas with higher elevation. Two additional soil samplings were taken during the 2007 growing season and two soil samplings were taken in June and July, 2008. The soil water content and soil inorganic N levels from the 2008 samplings are still being analyzed.

Sub-plots of 28 ft in row length were established in each 750 foot long plot in order to assess the interactive effects of N treatment and landscape position on grain yield and plant N status. This resulted in approximately 23 to 27 subplots in each main plot. In order to assess the relative N status of the corn plants, chlorophyll meter readings were taken using a SPAD 502 Chlorophyll meter (Minolta Corp.) on 10 ear leaf subsamples on July, 30 2007 and August, 12 and 13, 2008. Ear leaf samples were collected on the same day for determination of tissue N concentration. Corn grain was harvested from the 28 foot row length between the sampling points on Sept. 19, 2007 and Oct. 6, 2008 using a two-row plot combine.

Relative yield performance of the enhanced efficiency N fertilizers (i.e., PCU, UI and NI) was assessed by taking the yield differences between the individual enhanced efficiency fertilizer and urea for each adjacent sub-plot in each replication. The relative economic benefit of the enhanced efficiency N fertilizer was assessed by calculating the increase or decrease in value of using the enhanced efficiency fertilizer compared to use of urea minus the additional cost of the enhanced efficiency fertilizer compared to urea. The calculations were based on a corn price of $4/bushel and an extra cost of $0.10/lb N for PCU, $0.05/lb N for UI and $0.06/lb N for NI.
The difference in cost of application for these enhanced efficiency fertilizers compared to that of urea were not included in the calculation.

**Results**

The differences in timing and amount of rainfall in 2007 and 2008 (Fig. 1A & B) had a large impact on crop growth and yields (Table 1). In 2007, heavy spring rain delayed treatment application and planting but cumulative rainfall during the growing season was only 11.9 inches (Fig. 1A). In contrast, the 2008 growing season was characterized by heavy rainfall throughout the season which delayed planting and resulted in standing water in the low-lying area of the field for extended periods (Fig. 1B). Poor seed germination in several low-lying subplots in 2008 led to poor or non-existent plant stands in those sub-plots (data not shown). Cumulative rainfall during the 2008 growing season was 35.0 inches, approximately three times greater than 2007.

Table 1 shows the average grain yields, chlorophyll meter readings and ear leaf tissue N across each plot for 2007 and 2008. The 2008 ear leaf tissue N concentrations are being analyzed. Based on this analysis, all N fertilizer applications increased grain yields over the non-treated control in 2007 and 2008. Grain yields with the excessive rainfall in 2008 were also generally lower than those of 2007. In comparing the performance of the enhanced efficiency N fertilizers, polymer-coated urea (PCU) had significantly higher grain yields compared to urea. It is important to note that the relative performance of the enhanced efficiency fertilizers may have been affected by the fact that in this research all the N treatments were immediately incorporated after application. For example, UI has been found to be effective in reducing ammonia volatilization of surface-applied urea. Therefore, incorporation of the urea may lower the relative effectiveness of the UI in reducing N loss.

The chlorophyll meter readings and the ear leaf tissue N concentration, which are relative measures of the N status of the plant, were significantly higher when N fertilizer was applied. However, the PCU treatment was the only enhanced N fertilizer treatment which had a consistently significantly higher average chlorophyll meter reading compared to urea in 2007 and 2008. Both the chlorophyll meter readings and ear leaf tissue N were good indicators of grain yield in 2007 (Fig. 2A) and 2008 (Fig. 2B) (ear leaf and yield data not shown) suggesting a large yield response to N availability in this field as influenced by landscape position and weather conditions.

Significant variation in grain yield response to each N fertilizer treatment also occurred across the field in both 2007 and 2008 (data not shown). In 2007, the highest yields tended to occur in the lowest landscape positions of the field, but in 2008 because of the excessive saturation of the soil, higher yields occurred in the higher landscape positions. An approach we are using to determine the areas in the field which would have the greatest grain yield response to the enhanced efficiency fertilizers is to map the differences in yields between urea and the enhanced efficiency fertilizer. Figures 3 and 4 show the results of mapping the differences in yield between the PCU-, NI- and UI-treated plots and the urea-treated plots. Positive yield differences indicate the enhanced efficiency N fertilizer-treated area yield was greater than the urea-treated area. When this yield difference is zero or negative then urea was equivalent to or
greater than the enhanced efficiency fertilizer. Based on the yield differences and relative price difference between urea and enhanced efficiency fertilizers, we also mapped the net economic return from using these products compared to urea in 2007 (Fig. 3) and 2008 (Fig. 4).

The results of these analyses showed large differences in relative yield performance across the field which affected the relative economic return. For example, in 2007 the low-lying region in the field had greater yield response to the PCU fertilizer compared to urea (Fig. 3A). Based on an economic analysis, the increased value of using PCU versus urea minus its extra cost was highest in the low-lying area while urea was more cost-effective on the sideslope (Fig. 3B). In contrast, in 2008, the yield and economic benefits of using PCU was positive over the whole field and was highest in the upper positions of the field (Fig. 4A). For 2008, PCU showed the highest economic benefit of all the enhanced efficiency N fertilizer treatments with some locations in the field having over a $400/acre economic benefit by adding PCU compared to urea (Fig. 4A). Use of NI and UI also showed variation in yield and economic benefit compared to urea alone across the field in both years (Fig. 3B&C and 4B&C). As with the use of PCU in 2007, these products also had areas of the field where use of these products resulted in a negative economic return compared to using urea alone, possibly due to lower grain yields or the extra cost of using these products.

An initial effort at developing software to delineate the areas in the field that will respond to enhanced efficiency N fertilizers was undertaken, but further funding is required to continue development and conduct testing for commercial use. This software would be of utility to producers who wish to apply the enhanced efficiency N fertilizers to areas of a field where the potential yield and economic benefits would be optimal. Further testing of what we are calling a “variable source” fertilizer application approach to N fertilization with enhanced efficiency N fertilizers needs to be undertaken in larger production fields, in different soil types, and with use of commercially available multi-bin fertilizer spreaders since all of the research conducted so far has been done on a relatively limited field area in claypan soils in Missouri.

**Outreach and Training:**

1. A M.S. graduate student in soil science and undergraduate students majoring in environmental science have been involved in working on this project as part of their training.

2. The research results were presented to growers and agricultural professionals by the M.S. student at the 2007 and 2008 Greenley Center Field Day in Northeast Missouri and the 2008 meeting of the North Central Extension-Industry Soil Fertility Conference in Iowa. In addition, the research was presented in a poster session at the 2008 National Meeting of the American Society of Agronomy in Houston, Texas.
Table 1. Average grain yields, chlorophyll readings and earleaf tissue N across the field in 2007 and 2008 due to applications of different enhanced efficiency N fertilizers.
† Urea + urease inhibitor
§ Urea + nitrification inhibitor

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* LSD(0.05) = Least Significant Difference at p < 0.05
Figure 1. Daily and cumulative rainfall over the growing season at the Greenley Center in A) 2007 and B) 2008.
Figure 1. Map of soil water content distribution at the 0 to 6 and 6 to 12 inch depths in the experimental field on June 4, 2007. Lines represent the contour intervals with elevations above sea level given in meters.
Figure 2. Relationship between chlorophyll meter readings and grain yield for all treatments in A) 2007 and B) 2008.
Figure 3. Field maps showing spatial differences in corn grain yields and economic benefits with application of polymer-coated urea (PCU), nitrification inhibitor (NI) and urease inhibitor (UI) compared to urea in 2007. Note the differences in legend scales among maps for each N treatment. Numbers along contour lines are elevation in feet above sea level.
Figure 4. Field maps showing spatial differences in corn grain yields and economic benefits with application of polymer-coated urea (PCU), nitrification inhibitor (NI) and urease inhibitor (UI) compared to urea in 2008. Note the differences in legend scales among maps for each N treatment. Numbers along contour lines are elevation in feet above sea level.