NITROGEN MANAGEMENT FOR YIELD AND QUALITY OF SPRING WHEAT 2005

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INTRODUCTION: Nitrogen is a major component in proteins. Proper nitrogen management is especially important in wheat in order to assure that both yield and wheat quality are optimized. An error that leads to insufficient N supply at critical periods has the potential to reduce crop yield and always reduces protein content. Conversely, conditions that cause nitrogen to be in excess may cause yield reductions and lodging. At the very least the fertilizer investment is not being properly used when nitrogen is in excess. In general, management practices that do not optimize N reduce profitability, impact wheat quality, and may affect the environment.

Nitrogen management is complicated by the fact that it exists in numerous organic and mineral forms in the soil. Some of these forms can undergo rapid transformations during the growing season. Some of these forms are mobile and subject to loss. Cropping history, landscape position, weather, and many other factors impact the quantity, availability, and cycling characteristics of nitrogen.

When most wheat was produced using conventional tillage methods, much of the nitrogen cycling had taken place prior to seeding. In this instance, a pre-seeding nitrate-nitrogen soil sample provided a viable estimate of the N that would be available to that crop. The remaining need was estimated by using a predicted yield goal. This was normally applied prior to seeding, at seeding, or soon after emergence.

This method is less than ideal in that it is not possible to accurately predict yield. Yield varies with landscape position. This leads to areas of the field being over and under fertilized. In addition, weather that occurs after the yield goals have been set might lead to rethinking yield potential. Good weather would lead to increasing the goal while poor conditions might cause the producer to reduce the target. Good weather in Oklahoma and Kansas might make it more important for a producer in South Dakota to maintain his protein levels.

The primary focus of this segment of the nitrogen research is to evaluate nitrogen management options that enable the producer to manage nitrogen in a manner that allow him to respond to field, market, and weather differences with special emphasis on maintaining quality and optimizing N use efficiency.

Background

Fields in South Dakota are often quite variable in terms of soils, slope, aspect, and native fertility. This makes them ideal candidates for variable fertilizer rate application. Unfortunately variable fertilizer rate applications are presently restricted since comprehensive field mapping based on soil tests and/or previous-year yield variability is required. In addition, present field mapping techniques cannot predict availability of mobile nutrients such as nitrogen. Sawyer (1994) indicated that there are various factors which limit the application of map-based variable rate technology (VRT). These include 1) cost of implementation (sampling, mapping, equipment, and personnel), 2) lack of expected increase in crop yield and 3) lack of input savings. Sawyer (1994) further suggested that in order to effectively implement map-based VRT, within-field variation must be accurately identified and reliably interpreted.

Sawyer (1994) indicated that for most soil chemical properties, on-the-go sensing is still futuristic. Sensing soil based chemical properties for VRT would likely require soil disturbance, would slow the operating speed of the machine, and would not necessarily deal with mobile nutrients and those that undergo rapid transformations in the soil. The goal of using sensor based variable applications is to avoid traditional costs (such as soil sampling, chemical analysis, data management, and recommendations) and to instantaneously adjust the application rate based on sensor measurements of fertility as an applicator travels across the field (Sawyer, 1994). Work by Wood et al. (1992) found high correlation between field chlorophyll measurements and corn tissue N concentration at V10 (tassel begins to develop rapidly and the stalk is continuing rapid elongation) and midsilk growth stages using the SPAD-502 chlorophyll meter, Minolta Camera Co., Ltd., Japan. The chlorophyll meter which they used measures the difference in attenuation of transmitted light at wavelengths 430 and 750 nm. The 430 nm wavelength is a spectral transmittance peak for both chlorophyll a and b, while the 750 nm wavelength is in the NIR region where low transmittance occurs (Wood et al., 1992).

Near infrared diffuse reflectance spectrophotometry has been used to measure protein, moisture, fat and oil in agricultural products (Wetzel, 1983). Early work by Thomas and Oerther, (1972) noted that leaf reflectance at 550 and 675 nm could be used to estimate the N status of sweet peppers. Blackmer et al. (1994) found that measurement of light reflectance near 550 nm could be used to detect

N deficiencies in corn leaves. The NIR spectral region has also been used for predicting organic C and total N in soils (Dalal and Henry, 1986).

Elliott et al. (1987) found that the concentration of NO_3-N in basal stems of spring wheat could be used to define the N status during tillering and for predicting grain yield responses to applied N. Vaughan et al. (1990) indicated that stem and whole-plant NO_3-N concentrations were highly variable and had limited use for N recommendations. Their work suggested that total N in the whole plant or leaves collected between Feekes 5 and 7 could be used for establishing critical N levels. Similar work by Roth et al. (1989) noted that whole-plant total N (between Feekes 3 and 6) could be used to predict N fertilizer requirements in winter wheat. Wuest and Cassman (1992) found that late-season applied N has greater uptake efficiency and is more effective in increasing grain N levels than N applied at planting. Similar work by Boman et al. (1995) found significant increases in grain yield from topdress N applied at Feekes stage 6. Early-season N must be managed to optimize grain yield, but adding excess N at that time reduces overall partitioning efficiency (Wuest and Cassman, 1992). When viewed in total these studies indicate that enhanced nitrogen management can be attained if accurate rates of N can be applied later. The problem is being able to quickly analyze the plant N status.

In a recent paper (Use of Spectral Radiance for Correcting In-Season Fertilizer Nitrogen Deficiencies in Winter Wheat by M.L. Stone, J.B. Solie, W.R. Raun, R.W. Whitney, S.L. Taylor and J.D. Ringer) the authors provide a possible solution. The commercialization of this technique is being sold as the Greenseeker.

Progress in 2005

Yield and percent grain protein from 2005 experiments at Gettysburg are shown in tables 1 and 2. Both sites have been in no-till for many years. The Holzwarth site soil test nitrogen (STN) was 8 lbs nitrate-nitrogen to 24 inches. The Cronin site STN was 30 lbs nitrate-nitrogen to 24 inches. Previous years crops were sunflowers at both sites. Using the SDSU soil test recommendations 120 lbs/a of seeding time N should produce 51 bu/a of wheat at the Holzwarth site. Similarly applying 80 lbs/acre as a surface broadcast would produce 44 bu/a.

Yield ranged from 45.8 to 60.4 bu/a (Holzwarth) and 43.4 to 56.4 (Cronin). Best yields were associated with earlier applications of N. Lack of rainfall after the 5 to 6 leaf stage limited the usefulness of these treatments. The surface application of the N at seeding did not perform as well as when this N was placed in the soil midway between the wheat rows. Mid-row banding capability has been around for many years but is just now becoming available in low-disturbance, no-till, air seeders.

Clearly, the yield for each site was above what would normally be expected for the amount of nitrogen in the system. This sometimes occurs when growing conditions are excellent and results in lower protein. Protein content increased when N was available later. This included treatments where N was applied at planting 5 inches to the side of the seed row. Tiller numbers for mid-row banded treatments were similar to when N was withheld and less than where N was surface applied. In other words, it was possible in 2005 to apply N in the soil at seeding without increasing tiller numbers above the no N treatments.

N Trt	Actual lbs N/Acre Pre-emerg.	actual lbs N/Acre 5-6 leaf	actual lbs N/Acre flag leaf	Yield bu/A	% Protein Harvest
5	60	0	0	53.3	13.3
4	0	60	0	45.8	13.0
8	60	60	0	57.4	14.1
6	60	0	60	55.1	14.1
7	60	30	30	58.2	14.7
9	120 (surface)	0	0	58.4	14.2
1	120 (1/2 in ground, 1/2 surface)	0	0	60.4	14.6
3	0	120	0	53.3	14.2
2	60	120	0	59.9	15.0
	LSD at p = 0.05			2.0	0.3

Table 1. Yield and protein at Holzwarth, 2005. Rows in yellow were tested for flour quality.

N Trt	Actual lbs N/Acre Pre-emerg.	actual lbs N/Acre 5-6 leaf	actual lbs N/Acre flag leaf	Yield bu/A	% Protein Harvest
5	40	0	0	47.4	13.3
4	0	40	0	43.4	13.4
8	40	40	0	52.8	14.4
6	40	0	40	53.3	14.4
7	40	20	20	53.4	14.7
9	80 (on surface)	0	0	53.4	13.9
1	80 (in ground)	0	0	54.7	14.0
3	0	80	0	48.5	13.9
2	80	40	0	56.4	15.1
	LSD at p = 0.05			3	0.9

Table 2. Yield and protein at Cronin’s, 2005. Rows in yellow were tested for flour quality.

The “best” treatment at both sites was the one that used a mid-row band at seeding for all N. This may not have been the case if the weather was either drier or wetter than occurred this year. If yields were lower, N would be unused. If yields were higher protein would have been limited.

The treatment that used a 1.5 rate of N split between mid-row and 6 leaf had highest protein and was in the highest yield group at both sites. This treatment would be an example of one that reflects the philosophy being developed by this project. A base N rate is used mid-row band at seeding or before 6-leaf stage. Sensors record plant N status later in the season. (It is hoped this can be done during a routine operation such as herbicide application or more remotely.) These data could be used to apply more N to increase protein if necessary. This may have been a viable option for the Cronin site this year.

Flour quality tests were completed on grain from treatments shown in yellow on Tables 1 and 2. Correlation between percent grain protein and flour protein, farinograph and alveograph-w is shown in Figure 1, 2 and 3 below, respectively. Quality data from other years is included in the data (Dakota Lakes, 2003 and 2004 and Aurora, 2005).

Tests commonly used by millers as predictor of flour quality include farinograph and alveograph. Farinograph testing describes how flour handles as dough in a mixer. The parameter of interest here is tolerance or stability. Bread, pizza or bagel flour farinograph stability should be > 18 minutes. An alveograph mixes the dough and then spreads it into a flat disc that is secured. The instrument then blows a bubble in the dough and measures inflation pressure. W-values represent total energy required to blow a bubble in the dough. Millers using SD HRW prefer W-values > 400.

Flour protein was correlated to grain protein for both Russ and Briggs (Figure 1). Farinograph and alveograph-W were correlated with grain protein for Russ but not Briggs (Figure 2 and 3).

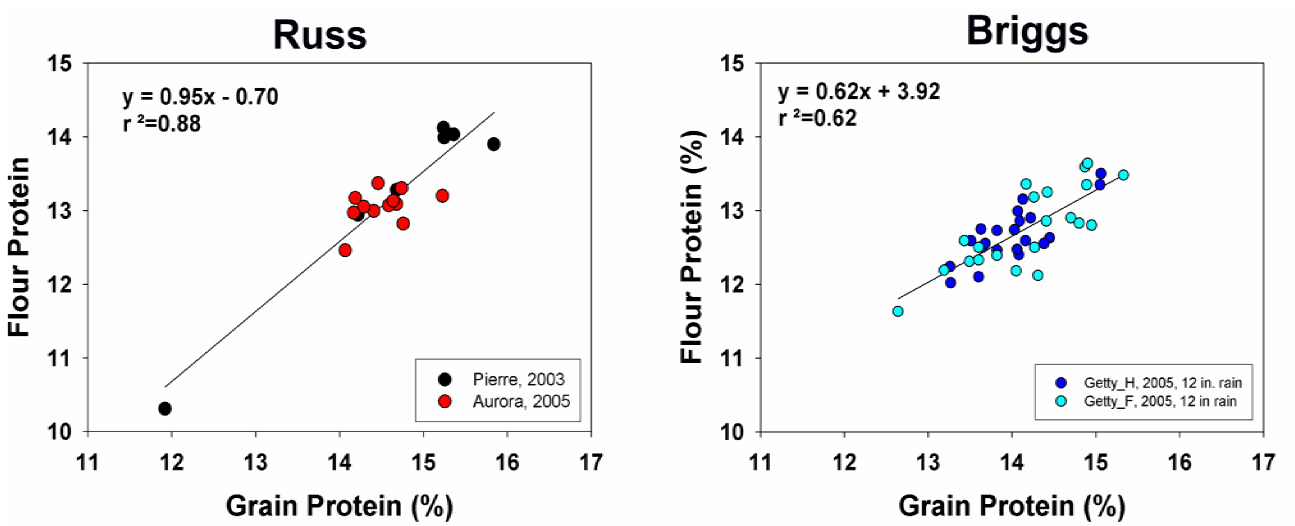

Figure 1. Percent flour protein as a function of percent grain protein for Russ and Briggs.

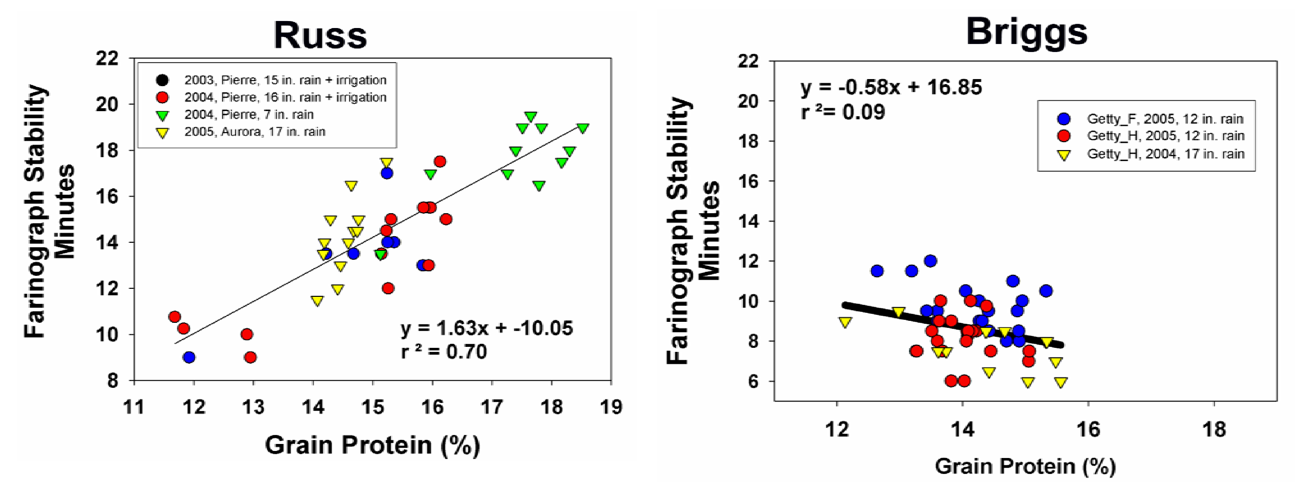

Figure 2. Farinograph stability as function of percent grain protein for Russ and Briggs.

Farinograph and alveograph data are used to infer flour protein or gluten strength. Protein subunit composition is determined genetically while protein extractability and concentration are influenced by both genetics and environment such as weather or nitrogen fertilizers (Johansson, 2004). Lack of precipitation at Pierre, 2004 may have caused flour to have high gluten strength. Further work with varieties, environment and agronomic management are merited by this study to understand complex relationships between flour quality, gluten strength and fore-mentioned factors in South Dakota wheat.

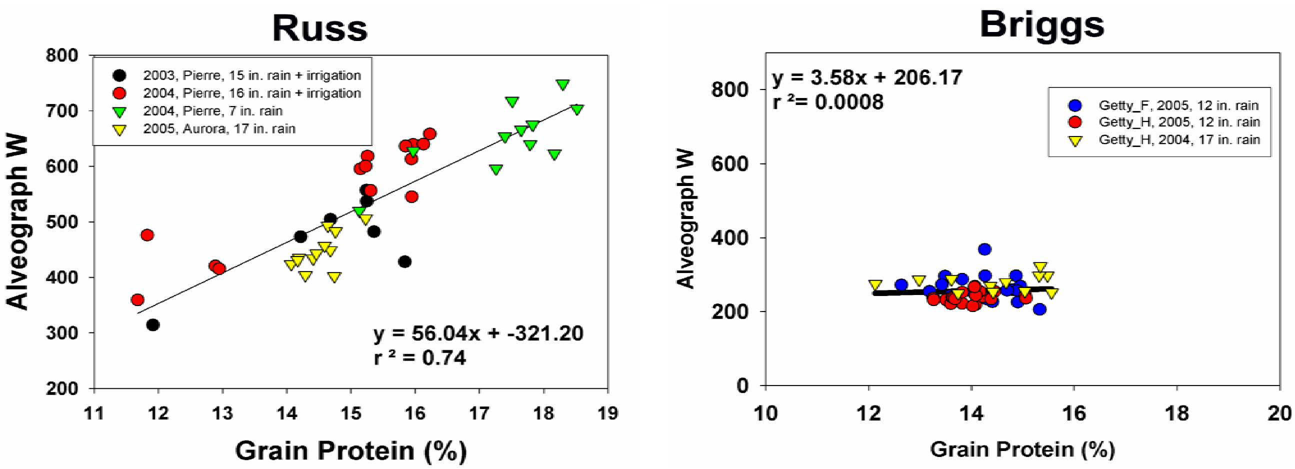

Figure 3. Alveograph-W as function of percent grain protein for Russ and Briggs.

In addition to yield and protein data, crop reflectance using a Greenseeker and a Cropscan unit were collected at both site at the 5-6 leaf stage and flag leaf stage. In-season biomass samples and grain samples will be analyzed for total percent nitrogen, carbon, ^{15}N and ^{13}C. From this data, carbon 13 discrimination will be determined. Carbon-13 discrimination can be used to determine impact of yield loss to nitrogen stress as well as yield loss to water stress.

Research by Clay (2006) in corn suggests that NDVI is correlated with nitrogen and water stress. A remote sensing model based on yield loss to nitrogen stress did a better job at accurately predict N requirements than models based on yield or yield plus water stress. In the research by Clay 2006, GNDVI was a better indicator of yield loss to nitrogen stress as compared to NDVI.

Conclusions and Future Work

Research to this point has indicated that some source of optical sensing can be valuable in determining whether and how much N is needed to maintain quality. That may be variety dependent in that all varieties may not respond to these additions in a way that produces better quality (protein but not quality).

Mid-row banding appears to delay the availability of the N to the plant. Poly-coated urea may do the same thing. Studies in 2006 will focus on evaluating these tools for their ability to improve the producer’s capability for managing quality.

Reference:

Clay, D. E., K. Kim, J. Chang, S. A. Clay and K. Dalsted. 2006. Characterizing Water and Nitrogen Stress in Corn Using Remote Sensing. Agronomy Journal 98:579-587.

Johansson, E., M. Preito-Linde, and G. Svensson. 2004. Influence of nitrogen application rate and timing on grain protein composition and gluten strength in Swedish wheat cultivars. J. Plant. Nutr. Soil Sci.. 167:345-350.