Summary

Wheat producers in the northern Great Plains market grain under a quality payment system that provides economic incentives for optimizing grain protein. Protein concentration in grain is greatly influenced by the level of nitrogen (N) fertility. However, there is significant spatial variation in N fertility in a field. Conventional uniform application ignores this variability and leads to over-fertilization in some areas and under-fertilization in others. Therefore, the question arises as to whether grain protein can be optimized on a site-specific basis by accounting for spatial variability of N fertility within individual fields.

Why Is Sensing Grain Protein Important?

Growers can use variable-rate application and global positioning system (GPS) technologies to account for spatial patterns of N fertility and may attempt to precisely optimize their crop’s protein level. However, few currently use variable-rate technology to optimize wheat protein due to the lack of an accurate, cost-effective method to resolve spatial patterns of N fertility in sufficient detail. Grid soil sampling and laboratory analysis are expensive, thus limiting feasibility in regions where gross economic return on wheat may be limited to $120 per acre.

Grain Quality Monitor

Milestone Technology, Inc. (Blackfoot, Idaho) is developing a grain quality monitor (GQM) that will continuously estimate the protein concentration of a grain from a combine-harvester (Figure 1). Continuous sensing of grain protein may provide the data to determine spatial variation of N fertility levels within a field and avoid expenditures associated with grid soil sampling and analysis. The speed and intensity of data collection along with ease of operation will improve the potential of this instrument for use as an N management tool.

Grain produced under adequate N fertility generally contains more protein and is darker in color than grain produced under conditions where N is limiting. The amount of light that is transmitted through grain is directly related to its darkness. This relationship between protein concentration and transmittance is the basis for measuring protein concentration by means of whole grain near infrared (NIR) transmittance. The GQM works similarly, except that it is a full-spectrum, microprocessor-based system. As such, its operating parameters enable it to produce measurements for protein and moisture in wheat that approximate laboratory measurements.

Accuracy tests

Laboratory tests of the GQM show that grain protein measurements were consistent with NIR laboratory analyses and that it could measure protein concentration in wheat to within 0.5 percent as grain travels through the auger (Figure 2). Its ability to interface with a flowing system of grain in an auger enables it to average over a much larger fraction of the grain than a system that would periodically sample and hold that sample of grain to measure protein.
Grain Protein Maps Reveal Soil Fertility Patterns

The concentration of protein in grain is related to the content of N in the soil. Figure 3 illustrates this relationship in a 250 acre field planted to spring wheat in 1997. Note that a map of soil N levels at the beginning of the growing season generally corresponds with a map of grain protein at harvest.

Measurements of grain protein concentration also provide a way to determine adequacy of N levels (see Figure 4). Research in Montana showed that spring wheat protein concentration below a critical level of 13.2 percent is usually associated with below maximum yields, indicating an N fertility deficiency. Proteins at 13.2 percent or higher are generally associated with maximum yields, indicating that N fertility is adequate.

Separating wheat that is N deficient vs. N adequate based on a critical protein level has practical application in precision N management. By mapping wheat protein levels across landscapes, field areas can be identified where the current N fertility program is either insufficient or adequate to obtain optimal yield and protein concentration. Such maps can be used to direct soil sampling, define management zones, and forecast fertilizer requirements, especially in semi-arid environments where water stress during grain-fill is common.
improving grain yield and protein concentration. A GIS and the following equation:

\[ \text{N deficit (lb/A)} = \left[ \text{target level (\%)} - \text{current level (\%)} \right] \times \text{N equivalent} \]  
\[ \text{Equation [2]} \]

are used to estimate the \( \text{N deficit} \), or additional \( \text{N} \) required for raising protein from a current level to a target level. Growers can consult with a soil fertility specialist in their region for a suitable value of the N equivalent, or lb N/A that is equivalent to a 1 percent change in protein concentration. Based on the inverse of slopes of protein-N response curves for dry conditions (see Figure 5), we have found that the N equivalent is between 11 to 16 lb of N/A for spring wheat. For practical purposes, we use 15 lb N/A as a reasonable approximation of the N equivalent when wheat is under water stress during grain fill, which is often the case in Montana. Therefore, if spring wheat is harvested at 12 percent protein it would mean an additional 30 lb N/A would have been needed for raising protein, to 14 percent at yield potential less than 56 bu/A.

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**Step 4: Deriving \( \text{N Management Zones} \)**

**Total N required** for a future crop is simply the sum of the \( \text{N removed} \) by the previous crop and the \( \text{N deficit} \) as calculated above. Using grain protein mapping to derive \( \text{N management zones} \) is illustrated in Figure 6. A 250 acre wheat field in Montana was divided into five arbitrary classes representing low, moderately low, moderate, moderately high, and high application rates. Class limits range from >-39 to ≤5 lb N/A for the low application rate, >5 to ≤30 lb N/A for the moderately low rate, >30 to ≤50 lb N/A for the moderate rate, >50 to ≤70 lb N/A for the moderately high rate, and >70 to ≤90 lb N/A for the high rate. To simplify this strategy, the upper limit in each class is used to represent the actual rate to be applied in a class. Thus the variable-rate treatment consists of 5 lb N/A applied to 83 acres (Management Zone 1), 30 lb N/A applied to 93 acres (Management Zone 2), 50 lb N/A applied to 45 acres (Management Zone 3), 70 lb N/A applied to 23 acres (Management Zone 4), and 90 lb N/A applied to 6 acres (Management Zone 5).

Finally, changes in moisture supply shift the protein-N response curve so that more \( \text{N} \) is needed to reach a certain protein level with increasing moisture (see Figure 5). This means that the \( \text{N} \) application rates will need to be adjusted upward or downward if the current year’s moisture conditions are greater or lower than that of the previous year. For instance, assume that the curve for the low moisture regime represents drought conditions in the year in which the yield and protein data were collected. Further, assume that the curve for the normal regime represents intermediate moisture conditions to be anticipated in the spring of the following year. To compensate for this increase in moisture supply, Figure 5 shows that the \( \text{N} \) application rate would need to be increased by 45 lb/A to maintain a protein level of 15 percent.

**Conclusion**

The approach taken in this project provides a method for identifying management zones for spring wheat. Currently, the procedure is applicable for dryland fields that are annually cropped to wheat. Research is continuing in an attempt to make it applicable to alternate wheat-fallow and other wheat cropping systems. Practical
implementation of this procedure requires that an appropriate sensor be made available to producers that can continuously read the protein concentration of grain from a combine harvester.

References

