Site-Specific Management Guidelines

D.S. Long, R.E. Engel and P. Reep

SSMG-24

Grain Protein Sensing to Identify Nitrogen Management Zones in Spring Wheat

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.

Figure 1. Grain quality monitor mounted to the outlet auger of a combine harvester.

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.

The Site-Specific Management Guidelines series is published by the Potash & Phosphate Institute (PPI) • Coordinated by South Dakota State University (SDSU) • Sponsored by the United Soybean Board (USB) and the Foundation for Agronomic Research (FAR). For more information, call (605) 692-6280. www.ppi-far.org/ssmg

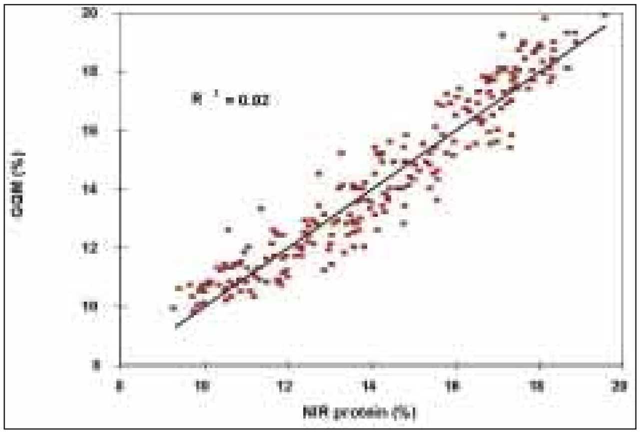

Figure 2. Relationship between spring wheat protein measured by Milestone GQM and measured by NIR transmittance.

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.

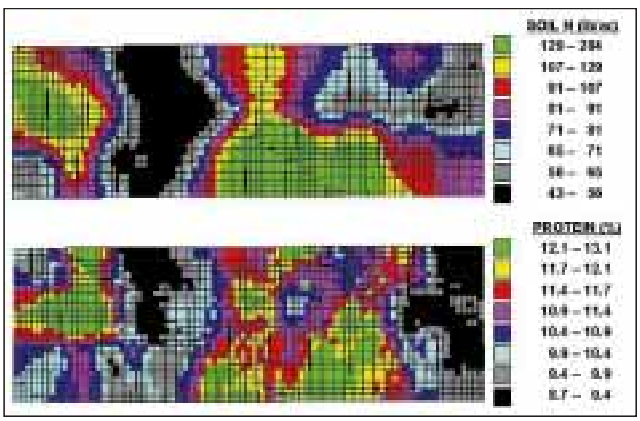

Figure 3. Visual comparison between maps of spring-levels of soil profile N and harvest-levels of grain protein.

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.

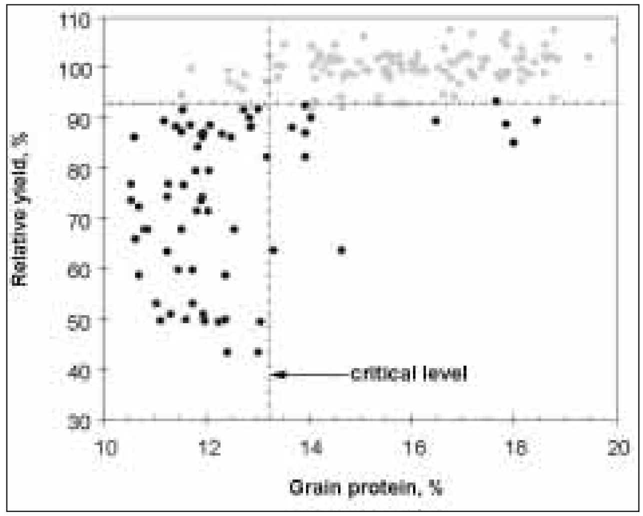

Figure 4. Relationship between relative yield and grain protein for spring wheat grown under a wide range of N and water regimes. Black dots indicate yield significantly (0.05 level) below maximum. Gray dots indicate yield was not reduced by N deficiency or excess.

Developing N Management Zones for Wheat

Step 1: Yield and Protein Mapping

Research conducted in Montana has led to the development of a procedure that enables site-specific grain yield and protein data to develop N management zones for spring wheat. GPS-based yield monitoring is used for acquiring the yield data. Until the GQM becomes available, the best method for obtaining protein data is by hand sampling from the combine's auger, followed by NIR analysis of the grain in a laboratory. Initially, the geostatistical interpolation procedure of kriging is used to estimate values of grain yield and protein for each cell of a regular-square estimation grid. This step allows yield and protein values to be registered and used as layers within a geographic information system (GIS).

Step 2: Estimating N-removed by the Crop

For parts of a field where N fertility is adequate, based on grain protein concentration, future N recommendations could use a maintenance approach, where N is applied at a rate equal to estimated crop removal. Maps of yield and protein can be mathematically combined in the GIS using the equation:

N removed in wheat (lb/A) =
yield (lb/A) x protein (%)/100 x 5.7 **Equation [1]**

to calculate **N-removed**. The factor 5.7 expresses the N concentration of the grain. Dividing this value into the protein-yield gives an estimate of the amount of N removed by the crop.

Step 3: Estimating N Deficit in the Crop

In parts of a field where N fertility is deficient, a 'build approach' to N management would be recommended for improving grain yield and protein concentration. A GIS and the following equation:

N deficit (lb/A) = [target level (%) – current level (%)] x N equivalent **Equation [2]**

are used to estimate the **N deficit**, or additional 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.

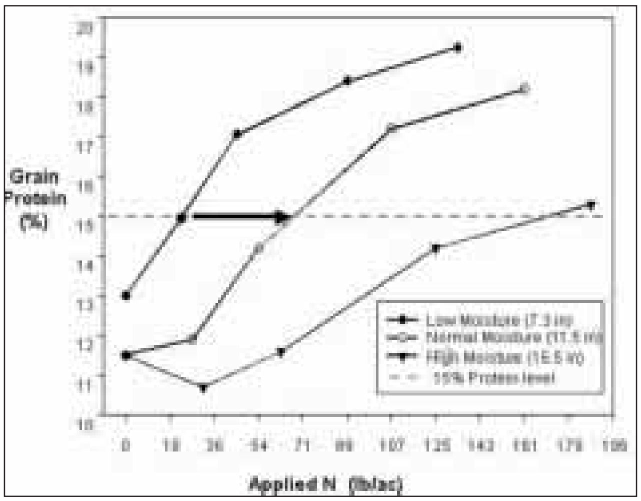

Figure 5. Relationship between grain protein and applied N for spring wheat grown under low, normal, and high moisture regimes. Arrow denotes that applied N would need to be increased by 45 lb/A to maintain a 15 percent protein level in a following crop if moisture supply for this crop increased from low to normal levels.

Step 4: Deriving N Management Zones

Total N required for a future crop is simply the sum of the **N removed** by the previous crop and the **N deficit** as calculated above. Using grain protein mapping to derive 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 N is needed to reach a certain protein level with increasing moisture (see **Figure 5**). This means that the 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 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

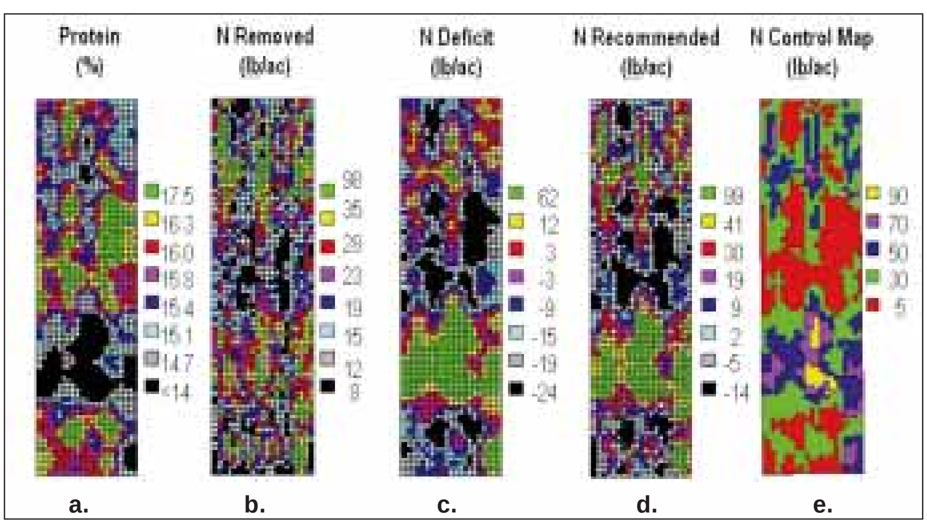

Figure 6. Maps of grain protein (a), N removed (b), N deficit (c), and total N recommended (d) to be used in deriving an N control map (e) for variable-rate application.

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

Goos, R.J., D.G. Westfall, A.E. Ludwick, and J.E. Goris. 1982. Grain protein concentration as an indicator of N sufficiency for winter wheat. Agronomy Journal 74:103-133.

Engel, R.E., D.S. Long, and G.R. Carlson. 1997. On-the-go grain protein sensing is near. Does it have a future in precision nitrogen management for wheat? Better crops with plant food. 81(4):20-23.

Long, D.S., R.E. Engel, and G.R. Carlson. 1997. Maximizing grain protein and profits in Montana's Golden Triangle. Precision Farming Supplement to GPS World Magazine, August, p. 24.

This Site-Specific Management Guideline was prepared by:

Dr. Dan Long
Assistant Professor of Site Specific Management
Northern Agricultural Research Center
Montana State University
Star Route 36, Box 43
Havre, MT 59501
Phone: (406) 265-6115
E-mail: dlong@montana.edu

Dr. Richard E. Engel
Associate Professor of Soil Fertility/Plant Nutrition
Land Resources and Environmental Science Department
Montana State University
PO Box 173120
Bozeman, MT 59717-3120
Phone: (406) 994-5295
E-mail: engel@montana.edu

Mr. Paul Reep
CEO
Milestone Technology
971 W 250 S
Blackfoot, ID 83221
Phone: (208) 528-8110
E-mail: miletk@ida.net

Ref. # 99094 / Item # 10-1024