UTILIZING EXISTING SENSOR TECHNOLOGY TO DEVELOP A LATE-SEASON CRITICAL VALUE FOR SPRING WHEAT PROTEIN

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Abstract

A premium is paid to producers for spring wheat with a protein content greater than or equal to 14%. Obtaining that protein content can be problematic without proper nitrogen (N) fertilizer management. Sensor-based technologies have been used for predicting yield. The question is whether this technology can be used to determine the protein content in-season for spring wheat. Field studies were conducted in South Dakota in 2003 and 2005. Five N treatments (0, 34, 68, 102, 136 kg N ha^{-1}) were applied pre-plant. In 2003, three varieties (Ingot, Oxen, and Walworth) were tested in Brookings, South Dakota. In 2005, one variety (Briggs) was tested at two sites near Gettysburg, South Dakota. Sensor readings were taken at two separate growth stages (Feekes 6 and Feekes 10) using the GreenSeeker Hand Held optical sensor. The sensor measures the reflectance in the red and near infrared (NIR) region of the electromagnetic spectrum. Grain samples were collected at maturity and analyzed for protein content. The readings collected at both growth stages in 2003 and 2005 showed a significant relationship between grain yield, grain protein and N uptake. Using this information a critical normalized difference vegetation index (NDVI) value was determined using the Cate-Nelson procedure. The critical NDVI value needed to ensure optimum protein is 0.80586. If the NDVI value is below the critical value, N fertilizer could be applied foliar to obtain the protein content necessary to ensure the protein premium.

Introduction

The use and research of sensor based technologies has increased substantially over the past decade. Precision agriculture has grown dramatically and will continue to grow as the price of N increases. Precision agriculture and sensor based technologies allow for a more accurate application of fertilizer, applying only to areas in fields where needed. The technology is adventitious to producers because it leads to less variability across a field, producing more uniform yield potential. Fertilizer management in the past dealt with taking soil samples across a field and averaging those results and applying the same amount of fertilizer to every acre of the field. This new technology allows for a more precise application of fertilizer.

Protein premiums give producers an incentive to grow more spring wheat. Protein premiums vary from year to year but currently can add $0.10 per percent protein above 14% for each bushel of spring wheat. While protein content below 14% can result in a $0.20 discount per bushel. Proper in-season N management is critical to obtaining the necessary protein content.

Applying N near anthesis provides the greatest increase in grain protein content. This response decreases rapidly when N is applied before or after anthesis. In some cases applying N at anthesis has the potential to double the protein content of the wheat (Woolfolk et al., 2002).

The objective of the study was to utilize previously collected sensor data and determine a critical NDVI level that ensures 14% protein content.

Materials and Methods

The experiment was conducted in 2003 in Brookings, SD and in 2005 in Gettysburg, SD. In 2003 three varieties were tested (Ingot, Oxen, and Walworth) and in 2005 one variety was tested (Briggs) at two sites. The N treatments for both years were applied pre-plant as ammonium nitrate at five rates (0, 34, 68, 102, 136 kg N ha^{-1}) (Figure 1). The experimental design was a randomized complete block design with four replications.

Sensor readings were collected at growth stages Feekes 6 and Feekes 10 using a GreenSeeker Model 505 Hand Held optical sensor (NTech Industries, Ukiah, CA). A 0.3 m by 0.6 m was scanned at both growth stages another area was also scanned and left for yield (Figure 2). Grain yield was estimated by hand harvesting the area scanned (Figure 3). The yield was calculated and corrected for 130 g kg^{-1} moisture.

Statistical analysis was performed on grain yield, grain protein and N removal using the GLM procedure in SAS. NDVI and grain protein at the Feekes 10 growth stage were plotted against each other and the Cate-Nelson procedure was used to determine the critical NDVI value. This procedure was developed in the late 1960's as a simple and statistically sound way to determine class limits and critical levels. It is used most often in the area of soil testing to determine critical levels (Cate & Nelson, 1971).

Results and Discussion

Four varieties were tested in these experiments; these varieties are popular among producers across South Dakota. "Briggs" is a relatively new variety, with a higher-than-average test weight and average protein content. "Ingot" is a very early maturing variety with a very high test weight, medium to high protein content, and medium to high yield. "Oxen" is an early maturing variety with a medium test weight, protein content and very high yield. "Walworth" is an early maturing variety with medium protein content, low to medium test weight and a medium to high yield.

There was a significant response to applied N for grain yield, grain protein, N uptake for all varieties and all locations (Table 1). This significant relationship is the justification for pursuing the idea of a critical NDVI value for protein. The Cate-Nelson procedure was used to determine the critical NDVI value. The graph and calculations showed that the NDVI value that needs to be obtained is 0.80586 (Figure 4, Table 2). If a sensor reading is less than the critical value then N fertilizer needs to be applied in order to reach the premium level. If a sensor reading is greater than 0.80586 then no N fertilizer needs to be applied.

Conclusions

Sensor based technologies and the critical NDVI value for protein has the potential to be very beneficial to spring wheat producers. It will allow for a more accurate application of fertilizer while reducing input costs and increasing protein and quality. This technology will also help the environment in terms of reducing fertilizer runoff and leaching into watershed and sensitive areas because the fertilizer is being applied when it can be best utilized by the plant and when weather conditions are favorable for N uptake. This technology will also allow for a more uniform yield and protein content across a field because a producer will only apply fertilizer to areas that need it.

Future Research

Research will be conducted over the next two growing seasons (2006-2007) at five locations in north central South Dakota to determine the validity of the critical NDVI value (Figure 5). The plots are designed to test the critical NDVI value (0.80586). Ammonium nitrate will be applied pre-plant at several different rates, sensor readings will be taken to determine if the plots need a foliar N application. If the sensor reading is below 0.80586 then foliar N will be applied to half of the plot and the other half will be left as a check. Sensor readings will be taken at boot, heading, flowering, and post-flowering. This information will help to improve the current critical value. Preliminary results, following the 2006 growing season, show that applying N at anthesis to the plots having a sensor reading below the critical value increased protein content to 14% or higher (Figure 6).

References

Cate R.B. and L.A. Nelson. 1971. A simple statistical procedure for partitioning soil test correlation data into two classes. Soil. Sci. Soc. Amer. Proc. 35:658-660.

Woolfolk, C.W. et. al. 2002. Influence of late-season foliar nitrogen application on yield and grain nitrogen in winter wheat. Agron. J. 94: 429-434.

Table 1: Yield response to applied nitrogen.

N Rate kg N ha^{-1}	Grain Yield kg ha^{-1}	Grain Protein %	N Removal kg ha^{-1}
0	3449	14.8	82
34	3903	14.9	92
68	4466	15.6	110
102	4254	16.2	109
136	4471	16.6	118
Pr > F	0.0013	0.0001	0.0001

Table 2: Calculations used in the Cate-Nelson procedure.

NDVI	Mean One	CSS One	Mean Two	CSS Two	R-Square
0.80168	0.80273	108.31	15.41	547.37	0.9224
0.80301	0.80326	108.51	15.44	546.83	0.9209
0.80352	0.80352	119.11	15.39	537.74	0.9277
0.80352	0.80352	119.85	15.39	537.26	0.9288
0.80441	0.80381	126.26	15.35	531.35	0.9310
0.80586	0.80432	127.04	15.34	530.62	0.9312
0.81012	0.80548	143.28	15.25	513.79	0.9286
0.81030	0.80628	143.60	15.29	513.61	0.9292
0.81077	0.80692	143.60	15.31	513.61	0.9292
0.81231	0.80760	143.67	15.34	513.59	0.9295

Figure 1: Variation among the plots with different N treatments

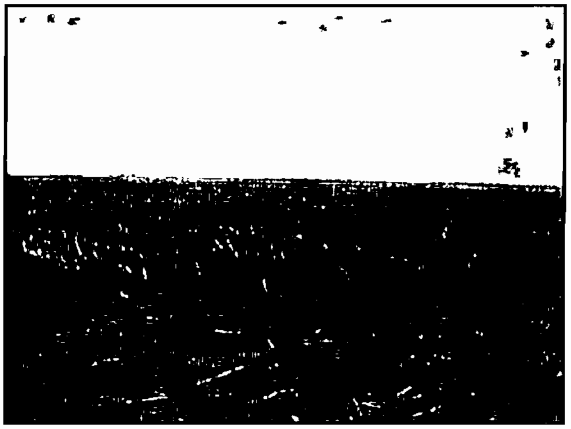


Figure 2: The Greenseeker collecting sensor readings

Figure 3: Hand harvesting of wheat

Figure 4: Critical value for sensor readings collected at Feekes 10, 2003 and 2005.

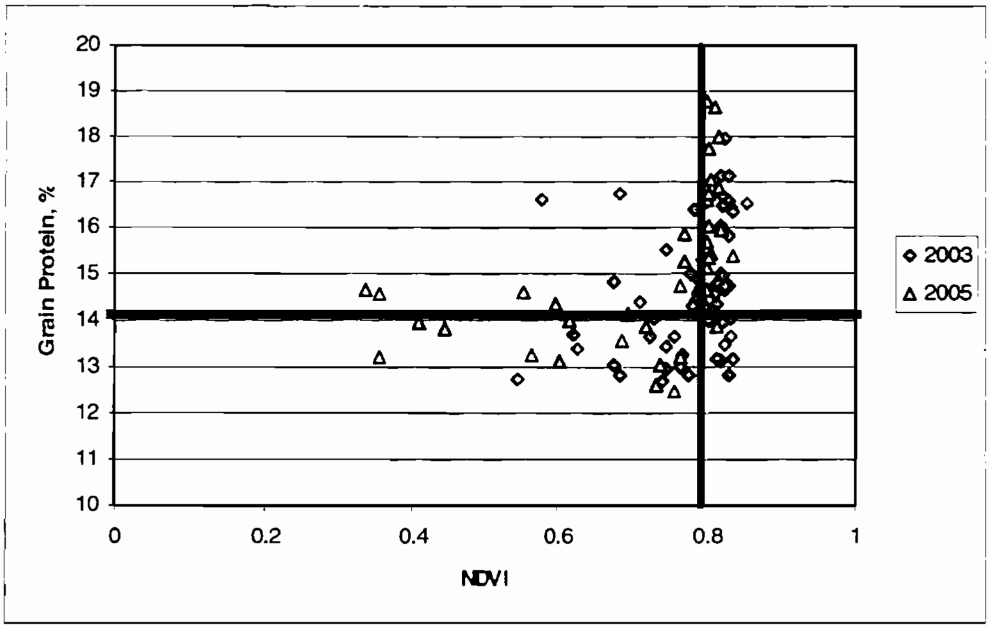


Figure 5: Future research locations, 2006-2007 growing season.

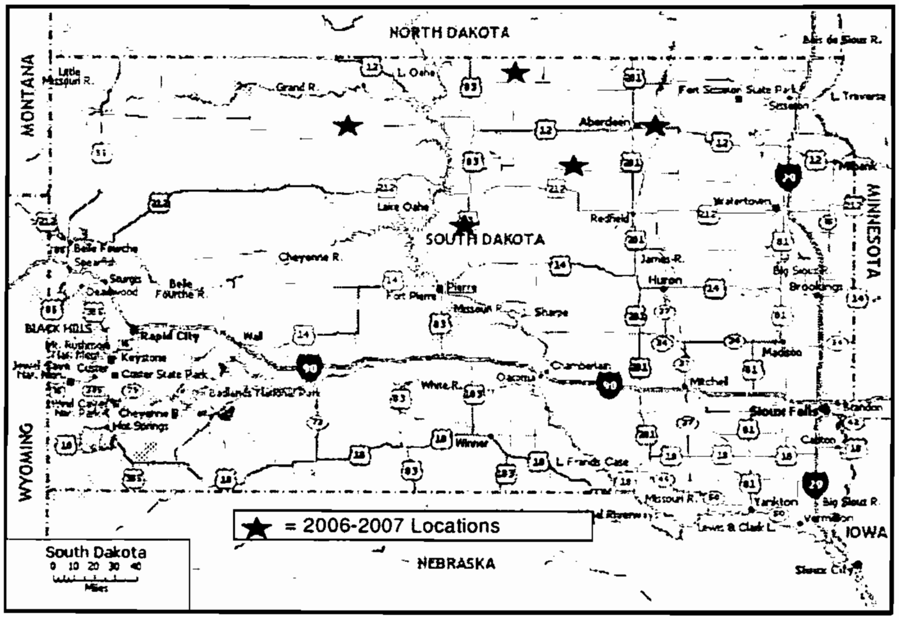
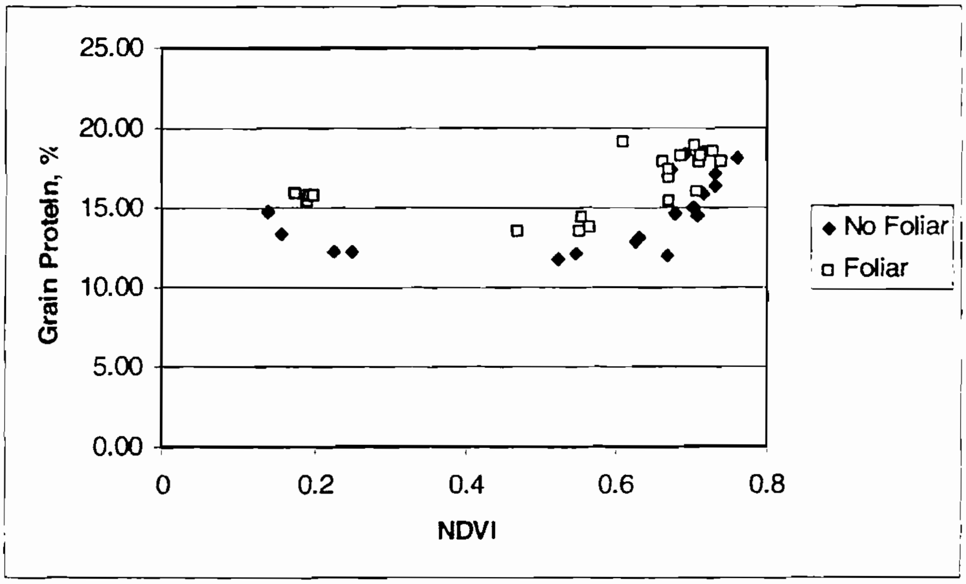


Figure 6: Comparison of foliar and no application of N at the Feekes 10 growth stage at Bath, SD.



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