UTILIZING THE GREENSEEKER TO EVALUATE SPRING WHEAT GROWTH AND YIELD

Shannon L. Osborne[1], Ron Gelderman[2], and Ann Weinkauf[2]
[1]USDA-ARS, North Central Agricultural Research Lab, Brookings, SD
[2]South Dakota State University, Brookings, SD
sosborne@ngirl.ars.usda.gov / (605) 693-5234

Abstract

There is currently little information on the use of existing sensor-based technologies for in-season application of nitrogen (N) to spring wheat (*Triticum aestivum* L.) in the northern Great Plains. Over the past decade researchers in the southern Great Plains have developed the Greenseeker as a tool for on-the-go N application to winter wheat. Field experiments were established in Brookings and Gettysburg, SD to evaluate the GreenSeeker Hand Held optical sensor (NTech Industries, Ukiah, CA) for measuring in-season N status on spring wheat. Five N rates were applied pre-plant as ammonium nitrate. Sensor readings and plant biomass samples were collected at Feekes 6 and Feekes 10 growth stages. The sensor measures reflectance in the red and near infrared (NIR) regions of the electromagnetic spectrum and calculates the normalized difference vegetation index (NDVI). The ability of the sensor readings to measure biomass, plant N uptake, and predict grain yield and protein for each sampling date was determined. In general, in-season plant biomass, plant N concentration, and grain yield increased with increasing N rate. Sensor readings (NDVI) collected at Feekes 6 and Feekes 10 showed a significant relationship with plant biomass, N uptake and grain yield, with readings collected at the later growth stage having higher correlation compared to the early sampling date. Initial results suggest that existing sensor-based variable nitrogen technology developed for winter wheat could be utilized in the northern Great Plains for estimating in-season N need for spring wheat, but additional testing is necessary.

Introduction

During the last 10-20 years there has been a rapid increase of research in the area of precision agriculture. Precision agriculture can be defined as assessing and understanding the spatial and temporal variability within a field and applying management decisions based on this variability. The variability within a field can lead to non-uniform yields and/or uneven yield potential, resulting in areas of the field that should be managed differently for economical and/or environmental reasons. Spatial variability within a field exists for a number of different reasons; including soil types, landscape positions, past management practices, or other factors (Kincheloe, 1994).

Previous management decisions frequently have been based on an average condition for a particular field or on the needs of the most limiting area. This management approach has resulted in some areas receiving more or less input than needed for optimum yield, which could contribute to increased environmental pollution due to over-fertilization, increased leaching, and runoff of nutrients. Precision agriculture has the potential to explain and overcome some of the spatial variability problems within fields. Tools now exist to help identify and manage different spatial zones according to the best management practice for each area, thereby decreasing the potential for environmental pollution.

One such technology is currently being marketed for topdress N fertilizer for winter wheat in the southern and central Great Plains. Additional research is needed to advance this technology to other production systems, such as spring wheat in the northern Great Plains. Early research found that reflectance measurements (NIR/red ratios) could be used to estimate leaf dry matter or leaf area in spring and winter wheat (Aase and Tanaka, 1984). Reflectance in the green region of the visible portion of the electromagnetic spectrum is a good indicator of N concentration in crops including corn (*Zea mays* L.), wheat, and bermudagrass (*Cynodon dactylon* (L) Pers.) (Blackmer et al., 1994, Walburg et al., 1982, Aase and Tanaka, 1984, and Blackmer et al., 1996).

Raun et al. (2001) demonstrated that in-season measurements of canopy reflectance explained 83 percent of the variability in measured winter wheat grain yield. In-season sensor readings (NDVI) collected every 1 m^2 area with a hand-held instrument, when used as a basis for variable rate applications of topdress N fertilizer in winter wheat, resulted in increased crop N use efficiency (Raun et al. 2002). Use of this in-season canopy measurement and variable rate application technology also has the potential of decreasing the environmental risks due to over-fertilization by applying N only where it is needed and/or at the locations most likely to respond to fertilizer N. Plant N use efficiency was increased by 15 % for fertilizer applied based on sensor readings compared to traditional methods. This research was conducted primarily in the southern Great Plains in winter wheat production systems; additional information is needed to expand this technology to other regions and production systems. The objective of our research was to evaluate this technology for predicting in-season N status and grain yield spring wheat in the northern Great Plains.

Approach

The experiments were located near Brookings, South Dakota during the 2003 and 2004 growing season while in 2005 the experiments were located near Gettysburg, SD. The experimental design was a randomized complete block design with four replications. The treatments consisted of five N rates (0, 34, 68, 102, and 136 kg N ha^{-1}) applied pre-plant as ammonium nitrate. Plots were 3 m X 3 m with 0.18 m row spacing. Sensor readings were collected at Feekes 6 and Feekes 10 growth stage (Large, 1954) with a GreenSeeker Model 505 Hand Held optical sensor (NTech Industries, Ukiah, CA). Sensor readings (NDVI) were collected at a height of approximately 1 meter. A 0.3 m by 0.6 m area was scanned at each growth stage and samples were taken for biomass production and N concentration. A separate 0.3 m X 0.6 m area was scanned at Feekes 6 and Feekes 10 that was left for grain yield estimation.

Biomass samples were dried in a forced-air oven at 60°C, and then weighed to obtain dry matter production. Samples were ground to pass a 2 mm sieve. Total N concentration was determined using dry combustion (Schepers et al., 1989). Nitrogen uptake was estimated by multiplying total N analysis and dry plant biomass. Grain yield was estimated by hand harvesting the 0.3 m by 0.6 m area scanned in-season at both growth stages. Grain yield was calculated and corrected to 130 g kg^{-1} moisture. Statistical analysis was performed on plant biomass, plant N concentration, plant N uptake and grain yield using the GLM procedure and correlation coefficients between sensor reading and plant measurements were calculated using the CORR procedure (SAS, 1988).

Summary

Spring wheat response to application of N was significant for all plant components measured and grain yield, increasing with increasing N applied (data not shown). The relationship between sensor reading and in-season plant components were better for 2003 and 2005 compared to 2004 regardless of sampling date (Table 1 and 2).

Table 1. Simple correlation coefficient for sensor readings with plant biomass (kg ha^{-1}), N concentration (g kg^{-1}) and N uptake (kg ha^{-1}) by variety, location and year, collected at Feekes 6 growth stage, Brookings and Gettysburg, SD 2003-2005

		2003	
Variety	Biomass	Plant N	N uptake
Ingot	0.59 **	0.62 **	0.64 **
Oxen	0.84 **	0.89 **	0.91 **
Walworth	0.72 **	0.74 **	0.73 **
Combined‡	0.72 **	0.70 **	0.73 **
		2004	
Variety	Biomass	Plant N	N uptake
Briggs	0.03	-0.24	-0.04
Ingot	0.33	-0.01	0.30
Oxen	0.62 **	0.11	0.61 **
Russ	-0.13	-0.23	-0.17
Walworth	0.34	-0.08	0.35
Combined	0.05	-0.13	0.02
		2005	
Location	Biomass	Plant N	N uptake
Forgey	0.27	0.53 *	0.46 *
Halzworth	0.59 *	0.59 *	0.67 **
Combined	0.48	0.39	0.55 *
All years	0.60 **	-0.51	0.39

‡, combined year correlation coefficient, **, * significant at the 0.01 and 0.05 probability level, respectively

In general correlation coefficients were higher for readings collected later in the growing season compared to the earlier sampling date (Table 1 and 2). One possible explanation could differences in ground cover at the time the readings were collected. Percent ground cover is limited at the early growth stage compared to later in the growing season, as illustrated by Figure 1. This difference could have contributed to the lack of correlation between the sensor readings at Feekes 6 and better correlations obtain later in the growing season (Feekes 10). Sensor readings collected during the 2004 growing season only resulted in significant correlation coefficients for Oxen at both sampling dates, readings collected later in the growing season having a higher correlation compared to the earlier sampling date (Table 1 and 2).

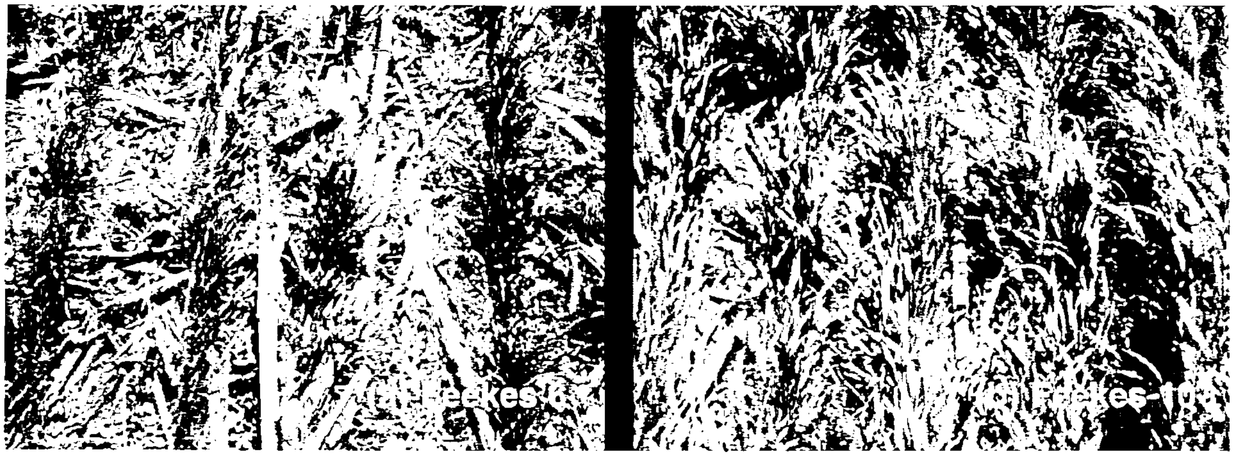

Figure 1. Photos collected prior to sensor readings for the Feekes 6 (a) and Feekes 10 (b) sampling dates for Gettysburg 2005.

Table 2. Simple correlation coefficient for sensor readings with plant biomass (kg ha^{-1}), N concentration (g kg^{-1}) and N uptake (kg ha^{-1}) by variety, location and year, collected at Feekes 10 growth stage, Brookings and Gettysburg, SD 2003-2005.

	--------2003--------		
Variety	Biomass	Plant N	N uptake
Ingot	0.65 **	0.71 **	0.71 **
Oxen	0.76 **	0.79 **	0.83 **
Walworth	0.65 **	0.72 **	0.72 **
Combined‡	0.60 **	0.65 **	0.68 **
	--------2004--------		
Variety	Biomass	Plant N	N uptake
Briggs	0.10	0.21	0.19
Ingot	0.34	0.12	0.36
Oxen	0.63 **	0.04	0.59 **
Russ	0.08	0.68 **	0.43
Walworth	0.15	0.11	0.23
Combined	0.59 **	0.04	0.61
	--------2005--------		
Location	Biomass	Plant N	N uptake
Forgey	0.81 **	0.51 *	0.85 **
Halzworth	0.91 **	0.66 **	0.85 **
Combined	0.86 **	0.50 *	0.83 **
All years	0.63 **	0.14	0.68**

‡, combined year correlation coefficient, **, * significant at the 0.01 and 0.05 probability level, respectively

There were similar relationships for the sensor readings and grain yield, with the 2003 and 2005 season having higher correlations compared to the 2004 readings, and the Feekes 10 readings having higher correlations for all years regardless of variety or location (Table 3-4). The highest correlations were obtained during the 2005 growing season (Feekes 10), with correlation coefficients greater then 0.80 for grain yield and grain N uptake (Table 4). This was a marked improvement over correlations for the earlier growth stage averaging around 0.50.

Table 3. Simple correlation coefficient for sensor readings with grain yield (kg ha^{-1}), grain N concentration (g kg^{-1}) and N uptake (kg ha^{-1}) by variety, location and year, collected at Feekes 6 growth stage, Brookings and Gettysburg, SD 2003-2005.

	---------------------	2003	---------------------
Variety	Grain Yield	Grain N	N uptake
Ingot	0.40	0.31	0.48
Oxen	0.43	0.42	0.50
Walworth	0.72 **	0.11	0.58 *
Combined‡	0.40	0.29	0.44
	---------------------	2004	---------------------
Variety	Grain Yield	Grain N	N uptake
Briggs	0.50	0.31	0.54
Ingot	0.24	0.55	0.07
Oxen	0.83 **	0.51	0.74 **
Russ	0.12	0.05	0.09
Walworth	0.66 **	0.22	0.61 **
Combined	0.19	0.15	0.19
	---------------------	2005	---------------------
Location	Grain Yield	Grain N	N uptake
Forgey	0.43	0.14	0.39
Halzworth	0.52	0.33	0.53
Combined	0.48	0.16	0.44
All years	0.46	0.22	0.39

‡, combined year correlation coefficient, **, * significant at the 0.01 and 0.05 probability level, respectively

Table 4. Simple correlation coefficient for sensor readings with grain yield (kg ha^{-1}), grain N concentration (g kg^{-1}) and N uptake (kg ha^{-1}) by variety, location and year, collected at Feekes 10 growth stage, Brookings and Gettysburg, SD 2003-2005.

	---------------------	2003	---------------------
Variety	Grain Yield	Grain N	N uptake
Ingot	0.45 *	0.36	0.55 *
Oxen	0.37	0.35	0.42
Walworth	0.76 **	0.22	0.68 **
Combined‡	0.41	0.31	0.46
	---------------------	2004	---------------------
Variety	Grain Yield	Grain N	N uptake
Briggs	0.52 **	0.33	0.57 *
Ingot	0.35	0.54	0.19
Oxen	0.85 **	0.37	0.80 **
Russ	0.31	0.09	0.34
Walworth	0.49	0.14	0.48
Combined	0.60 **	0.31	0.57 **
	---------------------	2005	---------------------
Location	Grain Yield	Grain N	N uptake
Forgey	0.85 **	0.49	0.83 **
Halzworth	0.84 **	0.46	0.83 **
Combined	0.84 **	0.47	0.82 **
All years	0.67 **	0.07	0.67 **

‡, combined year correlation coefficient, **, * significant at the 0.01 and 0.05 probability level, respectively

Initial results on estimated grain yield reported here were not as promising as previous research in winter wheat production systems in the southern Great Plains, and suggest that additional testing is needed to properly evaluate this sensor for determining the impact on N use efficiency and its suitability in more northerly growing conditions. Future research will evaluate the sensor at different growth stages (Feekes 6, 10, and 10.5), and several different locations (Artas, Bath, Cresbard, Gettysburg) throughout South Dakota.

References

Aase, J.K., and D.L. Tanaka. 1984. Effects of tillage practices on soil and wheat spectral reflectance. Agronomy Journal 76:814-818.

Blackmer. T.M., J.S. Schepers, and G.E. Varvel. 1994. Light reflectance compared with other nitrogen stress measurement in corn leaves. Agronomy Journal 86:934-938.

Blackmer, T.M., J.S. Schepers, G.E. Varvel, and E.A. Walter-Shea. 1996. Nitrogen deficiency detection using reflected shortwave radiation from irrigated corn canopies. Agronomy Journal 88:1-5.

Kincheloe, S. 1994. Tools to aid management: The use of site specific management. Journal of Soil Water Conservation 49:43-45.

Large, E.C. 1954. Growth stages in cereals. Plant Pathology 3:128-129.

Raun, W.R., J.B. Solie, G.V. Johnson, M.L. Stone, E.V. Lukina, W.E. Thomason, and J.S. Schepers. 2001. In-season prediction of potential grain yield in winter wheat using canopy reflectance. Agronomy Journal 93:131-138.

Raun, W.R., J.B. Solie, G.V. Johnson, M.L. Stone, R.W. Mullen, K.W. Freeman, W.E. Thomason, and E.V. Lukina. 2002. Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. Agronomy Journal 94:815-820.

SAS Institute. 1988. SAS/STAT procedures. Release 6.03 ed. SAS Inst., Cary, NC.

Schepers, J.S., D.D. Francis, and M.T. Tompson. 1989. Simultaneous determination of total C, total N and 15N on soil and plant material. Communications in Soil Science and Plant Analysis 20:949-959.

Walburg, G., M.E. Bauer, C.S.T Daughtry, and T.L. Housley. 1982. Effects of nitrogen nutrition on the growth, yield, and reflectance characteristics of corn canopies. Agronomy Journal 74:677-683.

PROCEEDINGS OF THE

THIRTY-SIXTH NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 22

November 7-8, 2006
Holiday Inn Airport
Des Moines, IA

Program Chair:
Dale Leikam
Kansas State University
Manhattan, KS
(785) 532-6183
dleikam@ksu.edu

Published by:
Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
Web page: www.ppi-ppic.org

Cover photo provided by Dr. Harold F. Reetz, Jr., Monticello, Illinois.