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# Sensor Based Nitrogen Management Reduced Nitrogen and Maintained Yield

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## Abstract

Nitrogen fertilizer needs vary from year to year and field to field leaving small grain producer's continuously seeking new techniques to improve their fertilizer use efficiency and reduce input costs. This study evaluated the use of the Sensor Based Nitrogen Rate Calculator (SBNRC) on large-scale producer fields to generate N recommendations for winter wheat production in Oklahoma. The SBNRC used Normalized Difference Vegetative Index (NDVI) measured with GreenSeeker sensors and N-Rich strips to predict yield potential and recommend a corresponding N rate. Fifteen on-farm trials were initiated in producers' winter wheat fields in the fall of 2008 and 2009. Each trial consisted of three treatments: 0 lb N/acre topdress rate (Check); uniform topdress N rate applied at the same rate as that applied by the producer over the rest of the field (Farmer Practice); and the SBNRC uniform rate generated from GreenSeeker sensor readings. Treatments were arranged in a randomized complete block design with three replications at each site. When averaged over all locations, the SBNRC recommendation used 20.2 fewer lbs N/acre than the Farmer Practice treatment, while maintaining final grain yield and protein levels.

## Introduction

Nitrogen needs of winter wheat vary across fields and growing seasons. The over- or under-application of N may be economically and environmentally detrimental leading to N leaching or reduced yields and grain quality (1). Variability in N requirement is often associated with soil type and environmental factors which affect N availability. Traditional methods of N fertilizer application do not account for variability among fields or for the changing N needs in different years (3).

When N is applied as a flat rate across all fields and growing seasons, the result is poor nitrogen use efficiency (NUE) (2). A 30-year study conducted at Oklahoma State University observed that when winter wheat was fertilized for maximum yield, the applied N rate was correct only 30% of the time. Applied N rates were 20 lb N/acre below what was required for maximum crop yield 37% of the time; while 33% of the time 20 to 80 lb N/acre were applied in excess of maximum yield (2).

Most small grain producers strive to produce the highest yields possible with the fewest inputs. Nitrogen fertilizer expense is one of the highest input costs for small grain producers, accounting for approximately 15 to 25% of total operating costs (1). To keep N fertilizer costs at a minimum without reducing yield, it is essential to account for N variability from year to year. The N-Rich strip and GreenSeeker sensor are tools that can help producers reduce input costs and increase N use efficiency (NUE) by capturing the variability of N for that season and field and providing a recommendation of the appropriate amount of N fertilizer. The GreenSeeker sensor and N-Rich strip can be used to estimate yield potential and N uptake using optical reflectance measurements from a growing crop to estimate N requirements and recommend a site-specific N rate tailored for an individual field and season (6,8).

The N-Rich strip is a high N rate strip-applied in the field prior to or soon after planting so that N is non-limiting in the strip. This allows a comparison to be made throughout the growing season between the N-Rich strip and the rest of the field (Fig. 1). In winter wheat production the GreenSeeker sensor is then used in early February or March (Feekes 5) to generate a measurement of total biomass, reported as NDVI readings, from the N-Rich strip and an area outside of the N-Rich strip representative of the rest of the field. The GreenSeeker sensor utilizes spectral radiance measurements in red (671 nm) and near infrared (780 nm) wavelengths (9). After sensing, the NDVI readings are entered into an online Sensor Based N-Rate Calculator (SBNRC) along with planting date, location, and the day prior to sensing with the GreenSeeker for producers in Oklahoma or cumulative growing degree days greater than 0 for producers outside of Oklahoma. The SBNRC outputs Response Index (RI), which is an estimate of the response to added N fertilizer. For example, a response index of 1.2 implies a 20% increase in yield is possible with additional N fertilizer. The RI is calculated by dividing the NDVI of the N-Rich strip by the NDVI of the adjoining area. The SBNRC will generate two yield potential values, YPO and YPN. The yield potential of the field if no additional N is applied is represented by YPO, while YPN represents the predicted yield potential if the recommended N rate is applied. The recommended N fertilizer rate is calculated by estimating the difference in N uptake from the N-Rich strip and the area outside of the N-Rich strip (5,7). The algorithm used in the SBNRC is expressed as:

Fig. 1. N-Rich strip in winter wheat, prior to stem elongation, indicating a response to fertilizer nitrogen.

$$\text{N rate} = \{ (\text{YPO} * \text{RI}) - \text{YPO} \} * \%\ \text{grain N} * \text{NUE factor}$$

The N-Rich strip and GreenSeeker sensor have been tested extensively in small plot research trials, allowing for more accurate yield predictions and prescribed N rates based on these yield predictions. This method has been shown to increase/maintain wheat yields, reduce input costs, and/or decrease environmental contamination due to excessive N fertilization (5,8). This small scale research is extremely important in the development of the technology; however, producers are more apt to adopt new technology that has been tested on large scale farm trials (3). For this reason, a large scale study was conducted in winter wheat on producers' fields throughout Oklahoma to evaluate sensor based N management compared to individual producers' topdress N management.

## Implementation

In the fall of 2008 and 2009 8 and 7 experimental sites, respectively, were established throughout Oklahoma. Sowing and pre-plant fertilization was performed by each producer according to their typical production practices. Fields and locations were selected after emergence to ensure good stand establishment. Each trial consisted of 3 treatments arranged in a randomized complete block design, replicated 3 times. Plot size ranged from 60 ft × 400 ft to 30 ft × 200 ft depending on the size of field.

Fig. 2. High clearance applicator with a 30-ft boom used to make top-dress nitrogen fertilizer applications in winter wheat.

The check treatment received zero topdress N, the Farmer Practice treatment received the same N rate that the producer applied to the rest of that field, and SBNRC treatment received an N rate generated using the GreenSeeker sensor and the SBNRC. Three to four nitrogen-reference strips were applied on both sides of each experimental site.

The N-reference strips and an area outside of the strips that received only the preplant N rate were sensed at Feekes 5-6 using the GreenSeeker handheld sensor to generate the NDVI values necessary for the SBNRC. Planting date and yield goal, which was determined by averaging the yield for that field over the past 5 years, were also needed as inputs (4). The N rate generated by the SBNRC was used for the SBNRC treatment. Producers were asked for their topdress N rate prior to any sensing. A high clearance applicator with a 30-ft boom was used to apply treatments (Fig. 2).

Producer equipment was used to harvest each plot separately (Fig. 3). The combine unloaded the grain into a weigh wagon that weighed grain in 10 lb increments. A sub-sample of each plot was collected for grain N, protein, and moisture content. Statistical analysis was performed using Statistical Analysis Software PROC GLM and Duncan's multiple range test (alpha = 0.10) (release 9.1, SAS Institute Inc., Cary, NC).

Fig. 3. Winter wheat harvest where producer equipment was used to harvest grain and university equipment was used to record plot weight.

## Results and Implications

In the 2008-2009 growing season weather conditions had a substantial impact on production in Oklahoma. The winter was dry and mild, followed by rain showers during the spring which led to higher than normal yield potential for many producers throughout central and north-central Oklahoma. In 2009, the weather pattern resulted in above-average yields for southwest Oklahoma and below-average yields in the north-central portion of the state. Yield, N rate, and protein results from the 2009 and 2010 seasons are reported in Table 1.

Table 1. Winter wheat grain yield and protein as affected by N rate in Oklahoma, 2009 and 2010. The Check treatment has zero N topdress, Farmer Practice treatment has the farmer N rate, and the SBNRC treatment is the SBNRC recommended rate. Means within a row followed by the same letter are not different ($P < 0.10$).

| **2009** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **N rate, lb /acre** | | | **Yield Bu /acre** | | | **Protein, %** | | |
| **Site** | Control | Farmer Practice | SBNRC | Control | Farmer Practice | SBNRC | Control | Farmer Practice | SBNRC |
| 1 | 0 | 39.3 | 48.2 | 18.2 b | 23.5 ba | 26.0 a | 11.7 b | 11.9 ba | 12.1 a |
| 2 | 0 | 35.7 | 49.1 | 38.2 c | 52.9 b | 54.5 a | 12.9 a | 13.5 a | 13.7 a |
| 3 | 0 | 83.9 | 39.3 | 18.9 c | 39.4 a | 33.2 b | – | – | – |
| 4 | 0 | 59.8 | 24.1 | 43.0 b | 52.0 a | 44.4 b | 10.4 a | 11.7 a | 10.7 a |
| 5 | 0 | 59.8 | 7.1 | 58.7 a | 58.7 a | 60.7 a | 14.2 a | 14.4 a | 14.5 a |
| 6 | 0 | 59.8 | 38.4 | 55.2 c | 66.5 a | 61.8 b | 10.5 b | 11.7 a | 10.8 b |
| 7 | 0 | 33.0 | 58.9 | 23.7 c | 29.3 b | 36.9 a | 9.9 a | 10.1 a | 10.2 a |
| 8 | 0 | 27.7 | 58.9 | 30.6 c | 42.0 b | 47.8 a | 10.0 b | 10.3 b | 11.1 a |
| Avg | 0 | 49.9 | 40.5 | 35.8 | 45.5 | 45.7 | 11.4 | 11.9 | 11.9 |
| **2010** | | | | | | | | | |
| | **N rate, lb /acre** | | | **Yield Bu /acre** | | | **Protein, %** | | |
| **Site** | Control | Farmer Practice | SBNRC | Control | Farmer Practice | SBNRC | Control | Farmer Practice | SBNRC |
| 1 | 0 | 159.8 | 23.2 | 60.6 a | 62.6 a | 62.4 a | 13.2 b | 15.2 a | 13.1 ba |
| 2 | 0 | 59.8 | 49.1 | 29.5 b | 39.1 a | 39.9 a | 12.8 a | 12.5 a | 12.6 a |
| 3 | 0 | 59.8 | 72.3 | 21.1 b | 40.3 a | 42.0 a | 12.3 a | 12.2 a | 11.9 a |
| 4 | 0 | 50.0 | 33.9 | 87.5 a | 91.1 a | 91.4 a | 13.5 a | 13.6 a | 14.3 a |
| 5 | 0 | 40.2 | 48.2 | 62.8 b | 65.3 ba | 66.8 a | 10.8 b | 10.9 ba | 11.1 a |
| 6 | 0 | 50.0 | 11.6 | 46.8 a | 45.2 b | 46.5 a | 14.3 b | 15.0 a | 14.6 ba |
| 7 | 0 | 50.0 | 13.4 | 57.6 a | 58.8 a | 53.7 b | 12.0 a | 14.0 a | 12.9 a |
| Avg | 0 | 67.1 | 36.0 | 52.3 | 57.5 | 57.5 | 12.7 | 13.3 | 12.9 |
| Total | 0 | 58.5 | 38.2 | 44.0 | 51.5 | 51.6 | 12.0 | 12.6 | 12.4 |

Across all sites harvested in 2009 and 2010 the SBNRC treatment resulted in higher yields than the Check and Farmer Practice treatments. When looking at individual locations the SBNRC treatment reduced N 60% of the time and increased the N rate above the Farmer Practice treatment 40% of the time. Whether the N rate was increased or decreased was commonly controlled by a combination of two factors, producer's historical N management and weather conditions. Many producers have the opinion that the N-Rich Strip and GreenSeeker methodology always reduces N rates; however, in six of the fifteen locations the SBNRC recognized a greater need for N than the producer anticipated.

Yield of the SBNRC treatments were statistically lower than the Farmer Practice treatments at three locations and statistically higher at five of the fifteen locations. On average the SBNRC treatment produced similar yields to the Farmer Practice treatment but applied approximately 20 lb N/acre less than the Farmer Practice treatment. Although average yields were similar between these two treatments, the economic benefit associated with applying only the amount of N needed could be substantial depending on the cost of N and the price of grain.

Many producers question the SBNRC method's impact on grain quality as most assume with a reduction of applied N, grain protein will also be decreased. The two-year average grain protein concentration of the SBNRC was equal to the Farmer practice. The protein level of the Farmer Practice was significantly higher at one location while the SBNRC had a significantly higher protein level at one location. The protein levels of the Farmer Practice and SBNRC were not significantly different at the rest of the locations.

This research demonstrated that the use of sensor based technologies has the potential to produce maximum yields and increase NUE without a detrimental reduction in grain protein. Producers using the technology will be able to take advantage of those environments that are conducive to higher yields and reduce inputs in those years where yield is limited or the environment supplies adequate levels of N. Our results indicate that the use of N-Rich Strips, the GreenSeeker sensor and SBNRC does not always lead to increased yields or reduced N rates. Overall, however, we show that the SBNRC method typically outperforms current producer practices. The goal of this technique is not to reduce the overall use of nitrogenous fertilizers, but is focused on ensuring the correct N rate is applied in a specific environment to achieve maximum yield and improved NUE.

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