THE USE OF ACTIVE OPTICAL SENSORS TO MANAGE N FERTILIZATION OF SORGHUM IN KANSAS

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ABSTRACT

Research in the Central Plains region has shown grain sorghum (*Sorghum bicolor* L. Moench) to be more tolerant of water-stress than corn (*Zea mays* L.). As a consequence sorghum is commonly grown in the region in rotation with winter wheat (*Triticum aestivum* L.) and soybeans (*Glycine max*) in areas and soils where corn does not perform well due to regular drought stress. Sorghum yields vary widely from year to year, making traditional pre-plant, yield goal based, N recommendations a challenge. The objective of this study was to develop sensor based mid-season N recommendations utilizing two active, optical sensors (GreenSeeker, NTEK Industries and Crop Circle, Holland Scientific). Eight field experiments were conducted across Kansas in 2006 and 2007. Specific treatments used consisted of factorial combinations of pre-plant and side-dress N rates to supply a total of 0-150 lbs N ac^{-1}. Pre-plant N treatments were applied immediately prior to planting at all locations. Side-dress N treatments were applied 30-40 days after planting. Grain yields ranged from 10 to 170 bu ac^{-1}. Grain sorghum yields were responsive to N at only a few sites. Non-responsiveness of grain sorghum yields at the rest of the sites were mainly due to high levels (> 65 lbs N ac^{-1}) of soil profile residual NO_3^-, and water stress conditions during the growing season. The sensor based mid-season N recommendation system developed provides a much closer fit to observed N response than the traditional pre-plant N recommendation system.

INTRODUCTION

The majority of the sorghum today is grown under dryland or rain fed conditions, in places where precipitation and stored soil water is inadequate to reliably grow corn. Yields and N use efficiency vary from year to year, generally tracking annual variations in rainfall during the growing season. With this high variability in yield, and increasing costs of inputs such as fuel and fertilizer, it seems logical to try to develop more efficient fertilization practices for sorghum. Being able to delay the final fertilization decisions and investments until 30-40 days after planting, would allow growers to have a better feel for the stored water available and yield potential that year, and increase the return the grower might obtain from the investment in side-dressed N fertilizer. Thus, fertilizer rates could potentially be adjusted to meet the sorghum crop's need at that time. Active optical sensing systems have been shown to be useful in measuring crop biomass early in the growing season and using that measurement to predict final yield. Coupled with a well fertilized reference strip and an unfertilized check strip, to provide an estimate of the soil N supply to the crop, sensors could provide a more accurate N recommendation.

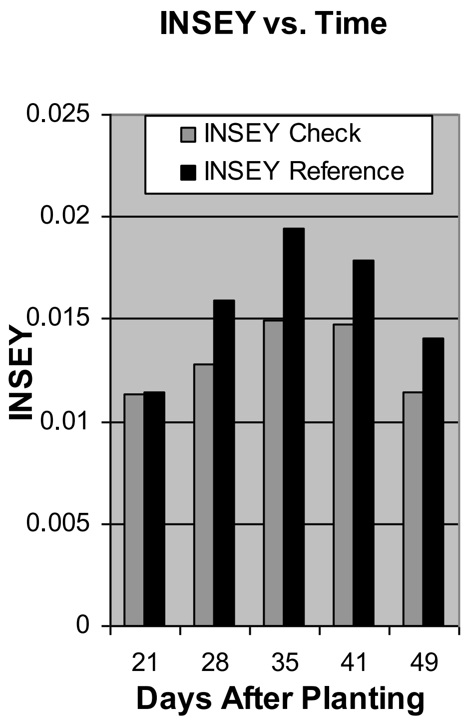
MATERIALS AND METHODS

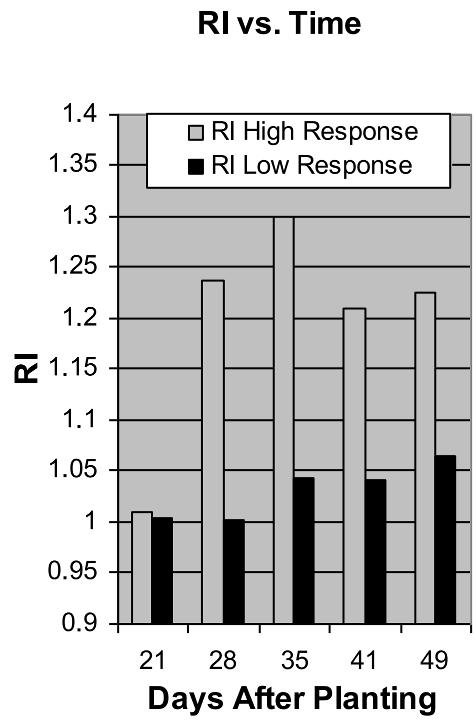
Field experiments were established in Kansas at the following sites: the North Central experiment station near Belleville in 2006, and the South Central Experiment Field near Partridge, the Agronomy North Farm in Manhattan and the West Central Experiment Station near Tribune in 2006 and 2007, to evaluate the effect of pre-plant, side-dress, and split N applications on the growth and development of sorghum, and to assess the potential of active optical sensing systems to predict yield potential and N needs. In 2006, a randomized complete block design was used with N rates ranging from 0-150 lbs/ac applied with timings of pre-plant, side-dress, and split applications. In 2007 a randomized complete block design was used with N rates ranging from 0-120 lbs/ac applied with timings of pre-plant, side-dress, and split applications. The sensors used for this study include the Crop Circle sensor (2007 only) and the GreenSeeker sensor. The Crop Circle sensor (ACS-210, Holland Scientific) simultaneously emits light in amber (590nm ±6nm) and NIR (880nm ±10nm) wavebands. The GreenSeeker (Hand-held unit Model 505, NTech Industries) emit light in red (660 ± 15nm) and NIR (770nm ± 15 nm) wavebands. Both of these sensors calculate NDVI by the following equation: (NIR-Visible) / (NIR+Visible). To collect these NDVI readings, sensors were positioned approximately 30 inches above the leaf canopy, and walked with the sensor head facing parallel to the row, and directly over the row. The middle two rows of each plot were sensed, and the NDVI values were averaged for the plot, as well as for each treatment. A response index (RI_{NDVI}) was calculated for each treatment by dividing the NDVI of the highest pre-plant N rate at GS-3 at each location by the NDVI of the other treatments. Similarly, a response index grain yield (RI_{GY}) was calculated by dividing the grain yield of the treatment receiving the highest pre-plant N-Rate by the grain yield of the other treatments. In-season estimate of yield (INSEY) was made by dividing NDVI measurements by the number of days from planting to sensing. Both sensors used in this study provided similar and well correlated readings. However only data collected with the GreenSeeker sensor is shown.

RESULTS AND DISCUSSION

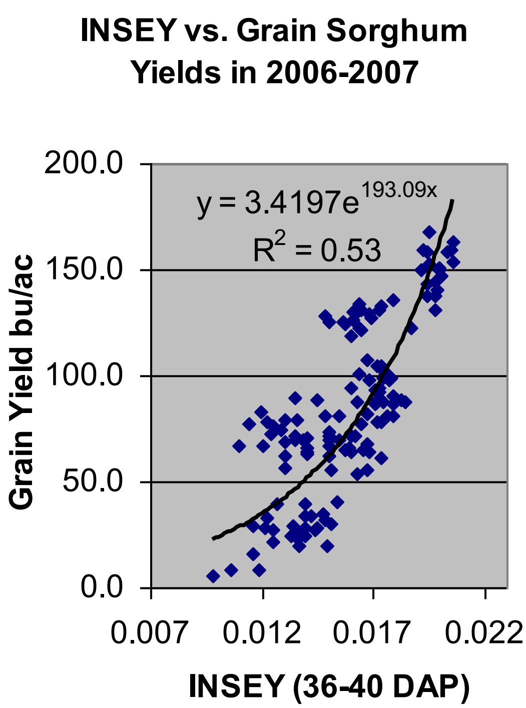
With sorghum, INSEY and RI_{NDVI} values maximized around 35-40 days after planting. This would suggest that the sensor probably has the most potential to differentiate between treatments at this GS-3 growth stage; therefore, the use of the active sensor systems to estimate mid-season N needs was focused on this time period (Figures 1 and 2). This period also corresponds to the end of the window of opportunity to side-dress sorghum with standard tractor and toolbar equipment. However, it would be desirable to be able to start side-dressing earlier, to lengthen the time available to farmers to complete this task. As can be seen in Figure 2, on highly responsive sites, the sensor is able to differentiate N response potential, a positive RI, around 28 days after planting. However, if the site is only marginally responsive, 35 days after planting may be the earliest one can make an accurate mid-season N recommendation.

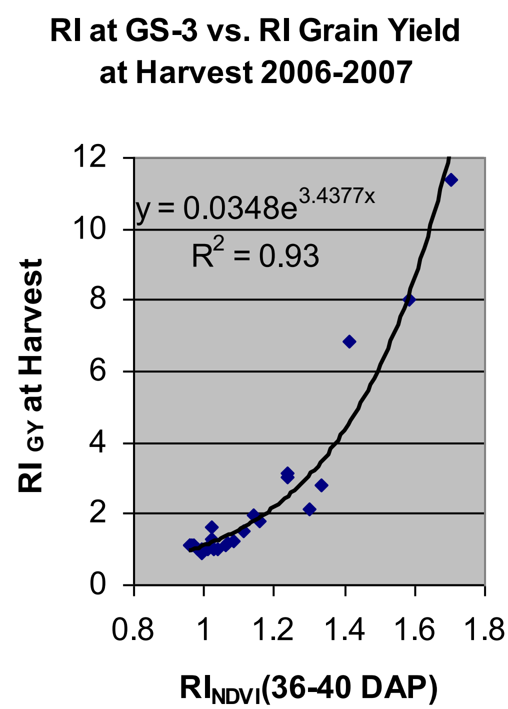
The sensor did a fair job of estimating yield potential, while RI_{NDVI} was strongly correlated with RI_{GY} during the 2006 and 2007 growing seasons at 35-40 days after planting (Figures 3 and 4). This would suggest that the sensor may be able to predict both yield potential and nitrogen responsiveness at GS-3. By being able to predict yield and nitrogen responsiveness, active sensors have a good potential to estimate mid-season N needs at 35-40 days after planting.





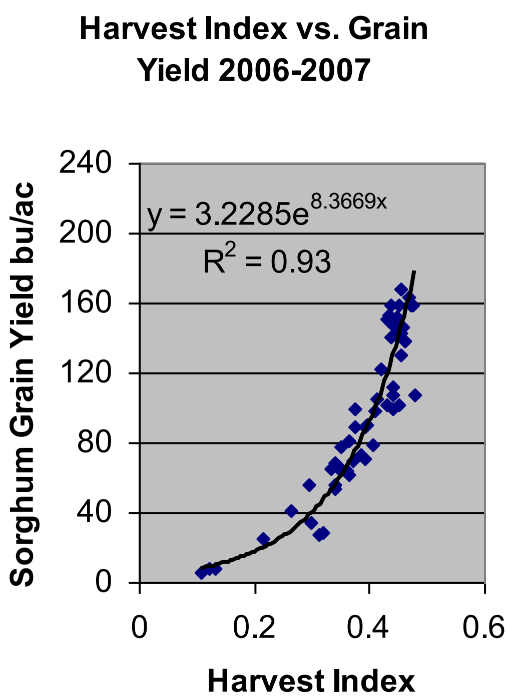
Figures 1 and 2. INSEY and Response Index$_{NDVI}$ (RI) over time.





Figures 3 and 4. Relationships between INSEY at 36-40 days after planting and yield, and RI$_{GY}$ and RI$_{NDVI}$ at 36-40 days after planting.

By utilizing the relationships between sensor based INSEY at GS-3 and yield (Figure 3) and RI_{NDVI} at GS-3 and $RI_{Grain\ Yield}$ (Figure 4), one can calculate the delta yield, or anticipated increase in yield due to N fertilization, for a given field. Once delta yield is calculated, an N rate could be calculated by taking delta yield*lbs N/bu and dividing this by an efficiency factor. The efficiency factor would need to consider both the traditional NUE or uptake efficiency of the plant and the efficiency with which the plant utilizes the N once it has been taken up. An estimate of the physiological utilization coefficients was derived from the relationships between harvest index, grain yield, and total N uptake (Figures 4 and 5).



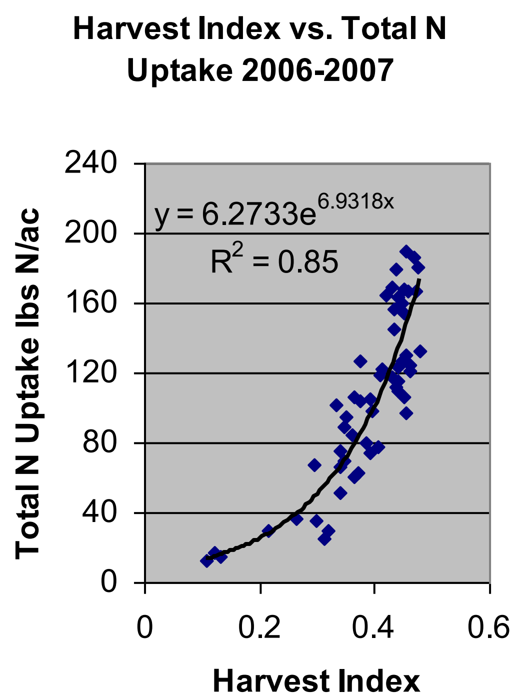


Figure 5 and 6. Relationships between Harvest Index (HI) and grain yield and HI and nitrogen uptake.

Using these relationships for grain yield, harvest index, and total N uptake, we can solve for harvest index at a given yield level using the trend line equation from Figure 5, and then solve for the amount of N uptake that would occur given the harvest index using the trend line equation from Figure 6. Solving for multiple yield levels, a series of coefficients can be developed for different expected yield which can then be inserted into the current N recommendation formula to adjust the N rates for physiological efficiencies (Table 1). These efficiency factors listed in table 1 are very preliminary, proposed , efficiency factors, based on a limited number of studies.

Since N moves to the plant primarily by mass flow, and water is the primary factor influencing yield in most years, having adequate water and N in the soil profile, means we can expect higher yields, than if either one of these were limiting. This would suggest that in the Central Plains, sorghum's ability to recover applied N should be lower at lower yield levels than at higher yield levels. Thus the pounds of N used per bushel of grain produced and the expected efficiency of N use would improve as yield increases.

Table 1. Expected yield, N uptake, lbs N/bu, and side-dress efficiency at a given HI.

Harvest Index	Expected Yield bu/ac	N uptake lbs/ac	lbs N/ bu grain	Expected Side-dress Efficiency
0.3	40	50	1.25	0.38
0.384	80	90	1.13	0.47
0.432	120	125	1.04	0.57
0.467	160	160	1.0	0.66
0.493	200	191	.96	0.72

Now that we have a yield prediction equation, can solve for delta yield by using RI, know the amount of N required per bushel increase at the yield level, and have a set of proposed efficiency factors, we can develop a sensor based mid-season N recommendation for sorghum (Figure 7).

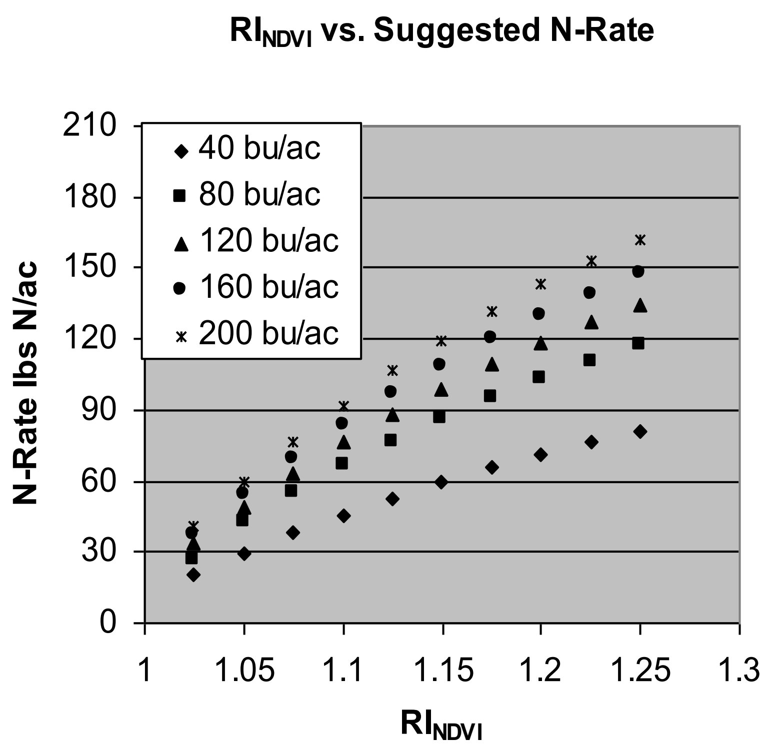


Figure 7. Proposed GreenSeeker Based Mid-Season N Recommendations.

Using this proposed sensor based mid-season N recommendation, we compared our recommendations to what we observed in our field experiments (Table 2). When our predicted yield was close to what was observed in the field, the sensor based recommendations were very close to observed N utilization. However, when the system was used on plots where a N starter fertilizer treatment was applied, the sensor underestimated N needs substantially. For this reason we feel it is important to not only have a reference strip in a field but also a check strip. If this is done, a producer could subtract off the amount of N used as starter from the check strip N-rate estimate the amount of N they need to apply. When the sensor overestimated yield potential, it seemed to overestimate N needs as well. Thus post-sensing conditions which may alter yield need to be considered.

Table 2. Sensor based mid-season yield predictions and N recommendations across sites and years, vs. observed yield and N response.

Location	Starter	Sensor Yield Potential bu/ac Ref. Strip	Observed Yield bu/ac	RI_{NDVI}	Observed N Response lbs/ac	Sensor Recommendation lbs/ac	difference
Belleville 2006	None	96	96	0.99	0	0	0
Manhattan 2006	None	160	160	1.02	33	33	0
Manhattan 2007	None	112	109	1.2	115	108	-7
Partridge 2006	None	64	32	1.3	55	107	52
Partridge 2007	None	64	70	1.01	23	16	-7
Tribune 2006	None	80	128	1.01	14	23	11
Tribune 2007	None	50	79	0.99	0	0	0

CONCLUSIONS

The use of optical sensors to estimate mid-season nitrogen needs in grain sorghum looks promising. This technology will likely require the use of a high N reference strip and a no N check strip for best results. The sensor technology seems to work best 35-45 days after planting; however, this only provides a narrow window of opportunity to fertilize the crop. Producers may want to apply a base level of N on sorghum at planting, especially in a soil testing low for N or in a high yield environment, to ensure optimum yield, especially if the producer is concerned about side-dressing N in a timely manner. However pre- or at planting N applications seem to reduce the accuracy of the mid-season N recommendations. For those not willing to soil test for N prior to planting, the use of sensor technology to estimate the soil N contribution would offer an alternative. The sensors would also offer a means of addressing in season N loss from leaching or denitrification. Whichever management decision the grower decides to make, the sensor technology can help aid the farmer in making better nitrogen fertility decisions in the future.