USING WHEAT CANOPY COLOR TO VARY NITROGEN APPLICATION RATE

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Background:

A technological improvement for the detection of N nutritional stress involves using spectral reflectance of red and near infrared light from the crop canopy, on-the-go, to determine the fertilization rate. A variable rate nitrogen application system, called the GreenSeeker system, has been developed by Oklahoma State University and is now commercially available. Liquid nitrogen is applied through a set of three stacked nozzles. Each set of nozzles has a remote sensor on the leading side of the tool bar to control nitrogen application rate, which is dependent on the normalized difference vegetative index (NDVI) of the crop canopy. The exciting feature of this technology is that the sensors and the applicator are coupled so that fertilization decisions are made in real time and based on the current condition of the crop. Using this technology it is possible to fertilize each 6 square feet independently at a top speed of approximately 15 mph. Years of research have gone into developing the algorithms that control the nitrogen applications. Field scale tests began in Oklahoma in 2002 on 17 fields in replicated strips. Compared to flat rate of nitrogen the variable rate application increased yields by 5 bu/ac and decreased overall nitrogen rates by 10 lb/ac. Complimentary research in Virginia using the same system over a two-year period has shown a yield increase of up to 8 bu/ac with a 15 lbs N/ac reduction in N fertilizer.

Methods:

A 20 foot plot sprayer manufactured by Ntech Industries, Inc. (Ukiah, CA) equipped with 8 red NDVI sensors each of which electronically control three stacked nozzles capable of delivering from 1 to 7 times a base rate of fertilizer was utilized for this study. Study sites were located in Caldwell, Trigg, and Woodford Counties, and plots ranged from 200 – 1600 feet in length depending on the location. In the first year of the study, four different N management strategies were employed. Two of the treatments involved variable rate N fertilization based on N prediction algorithms (equations) developed in Oklahoma and Virginia, while the other two treatments used uniform N applications. Treatments were: 1) a flat rate of 40 and 70 lbs N/acre split (Fig. 1) applied at Feekes 3 and 6, respectively, 2) a flat rate of 40 lbs N/acre at Feekes 3 followed by a variable rate (Oklahoma algorithm) applied at Feekes 6, 3) a variable rate applied at both Feekes 3 and Feekes 6 growth stages (Virginia algorithm), and 4) a flat rate of the average applied in treatment #3. A high N strip (120 lbs N/a) was also established at Feekes 3 for comparison purposes.

The Oklahoma algorithm's applied the highest rate of nitrogen to the lowest NDVI areas of the field and incremented downward to 0 lbs N/acre at the point where the canopy color was equal to the color of the high N strip (Fig. 2). For the Virginia algorithm, the Feekes 3 N application was based on tiller density. The areas with very thin stands (<50 tillers/sq ft) received 58 lbs N/a, areas where tiller density was between 50 and 100 tillers/sq ft received 31 lbs N/a, and the areas where tiller density was greater than 100 tillers/sq ft received 0 lbs N/a at this early application time. At the Feekes 6 stage, the Virginia algorithm calls for relatively low N applications where NDVI is low and increasing amounts of N up the average and then decreasing rates (Fig.3). The field average rate of N for the Virginia algorithm treatment was 33 lbs N/a at Feekes 3, and 38 lbs N/a at Feekes 6. These average rates were applied as a flat rate for the fourth treatment (Fig. 4).

In the second year of the study (2005), an additional algorithm was added that we called the Opposite algorithm. Like the Virginia algorithm, the new algorithm was based on tiller density at Feekes 3, but at Feekes 6, the highest N applications were made in the areas of the field with highest NDVI and lowest N applications in the areas with the lowest NDVI (Fig 5). In addition to the Opposite algorithm, all management algorithms were tested at two levels of N fertilization: low and slightly less than optimum. As in the previous year, treatments were also included that were uniform applications at the same rate as the variable treatments.

Whole plot yield was determined using a plot combine in Caldwell Co. Grain yield was determined at the other locations by using combines equipped with yield monitors. Whole plot yields were verified with a weigh wagon and grain monitor data was corrected when necessary.

Results:

Unfortunately in 2004, the Caldwell and Trigg Co sites had severe disease pressure which dramatically reduced yield. At these two sites, N application treatment did not affect grain yield. Thankfully there was very little disease pressure at the Woodford Co site.

Average plot yield is listed in Table 1 for the Woodford Co site in 2004. The farmer practice was the highest yielding treatment, but it also received the highest rate of nitrogen fertilizer. Using the Oklahoma algorithm to vary the N rate saved 34 lbs N/a and produced yields statistically equal to the farmer practice treatment. By spatially varying the N rate, wheat yield was increased by about 3.5 bu/a when compared to a uniform application at the same N rate (trt 2 vs. trt 3).

For the 204-2005 cropping year, plant health at both locations was better than in the previous year. At the Woodford County location, the VA variable treatment received significantly less N fertilizer than the other treatments due to an applicator error, and therefore grain yield was significantly reduced compare to most of the other treatments (Table 2). At the low rate of N fertilization (target 51 lbs/a), grain yield for the Oklahoma and Opposite algorithms was significantly higher than the flat rate treatment. At the higher total application rate (target 105 lbs N/a), there were no significant yield differences between the algorithms. It was hard to achieve the target N application rate on the VRN treatments because the distribution of NDVI within each treatment was not known. Yield results from the Trigg County location at the low rate of N fertilization showed that the Oklahoma algorithm was significantly lower than the Virginia algorithm or the flat application rate. At the high rate of N fertilization, the Okalahoma algorithm produced significantly less grain than any of the other treatments.

Conclusions:

Results reported in this paper are for the two-year of the study, and might not be observed with different growing conditions in future years. The results, however, indicate the GreenSeeker technology can aid in N management decisions by giving farmers the confidence they need to decrease their overall N application. This technology also enables farmers to capitalize on within field N supply variability that may further improve nitrogen use efficiency. So far, none of the algorithms tested produced yields greater than the farmer practice. It appears that the main benefit of using NDVI based variable rate N applications is to improve N use efficiency by reducing total N application rate rather than increasing grain yield. Returns per acre were increased approximately 50% of the time when using the GreenSeeker system. Additional sites and algorithms will be evaluated in the 2005-2006 growing season.

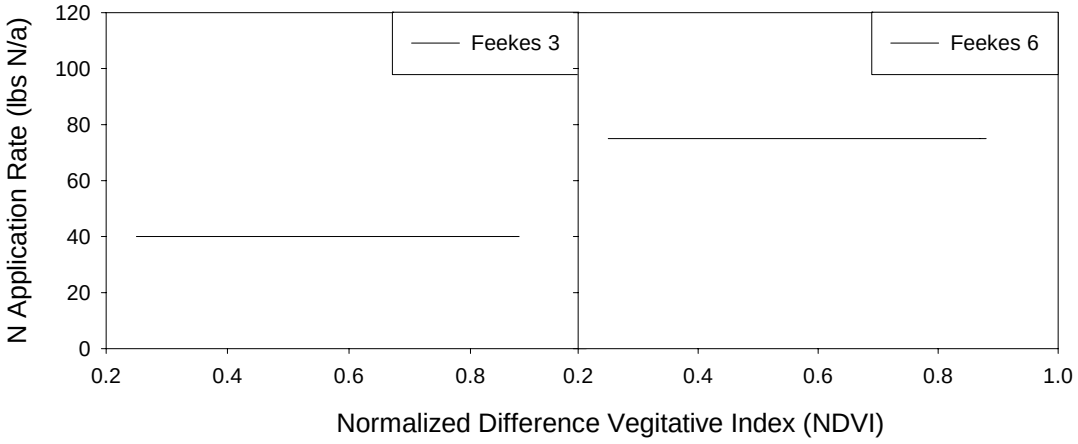

Figure 1. Nitrogen Application Rate At Feekes 3 And Feekes 6 For Farmer Practice (Treatment 1) For The Woodford Co Site.

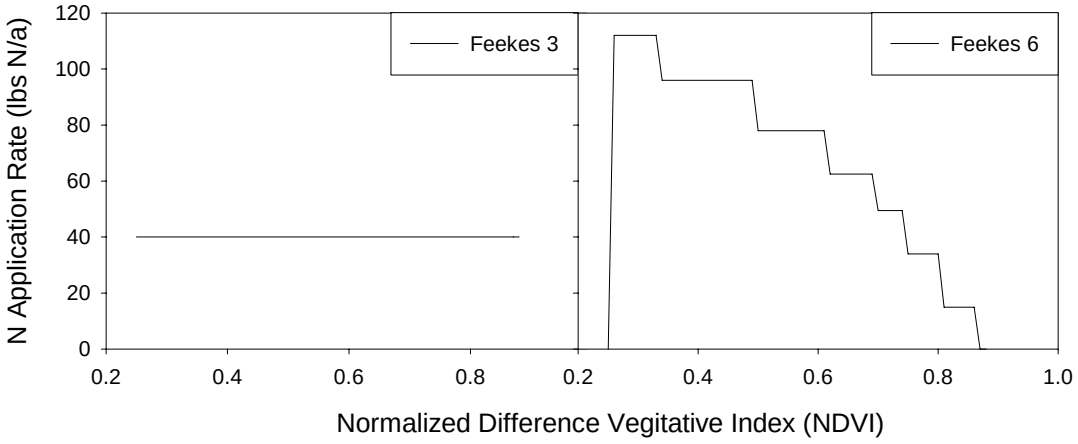

Figure 2. Nitrogen Application Rate At Feekes 3 And Feekes 6 For The Oklahoma Algorithm For The Woodford Co Site (Treatment 2).

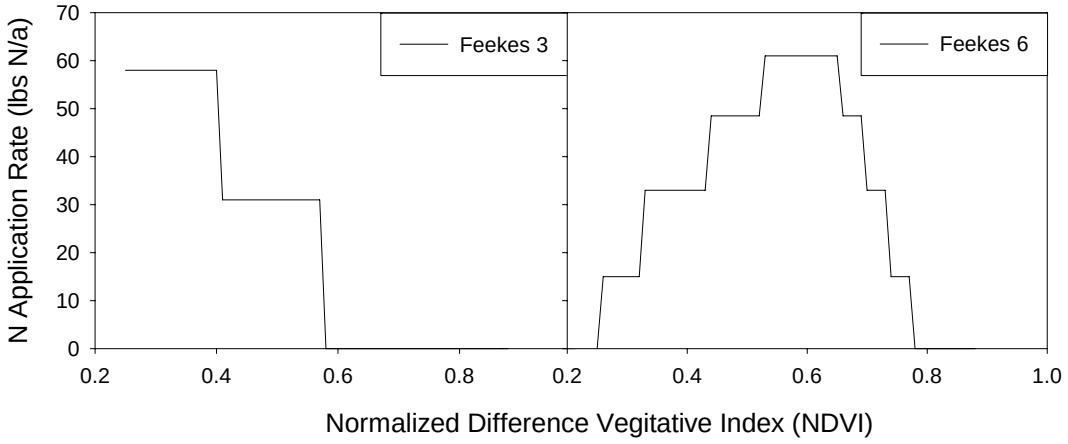

Figure 3. Nitrogen Application Rate At Feekes 3 And Feekes 6 For The Virginia Algorithm For The Woodford Co Site (Treatment 3).

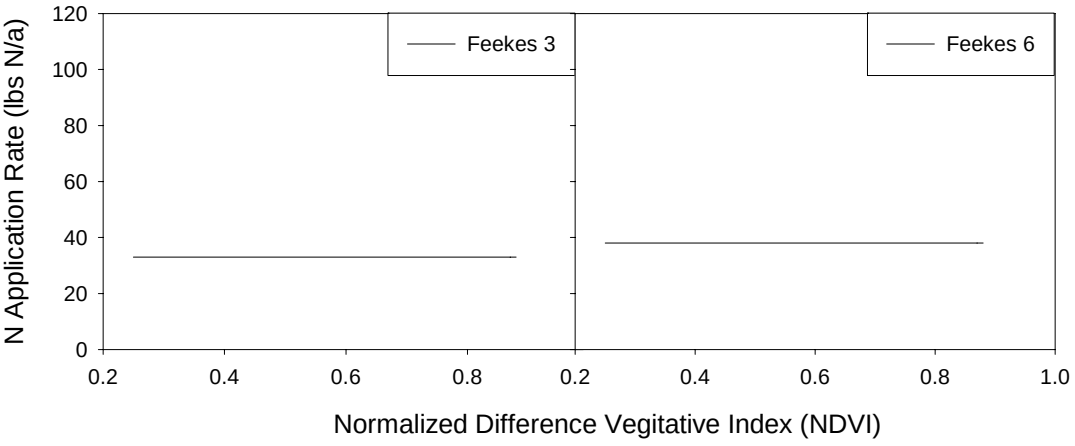

Figure 4. Nitrogen Application Rate At Feekes 3 And Feekes 6 For Flat Rate Of The Virginia Algorithm For The Woodford Co Site (Treatment 4).

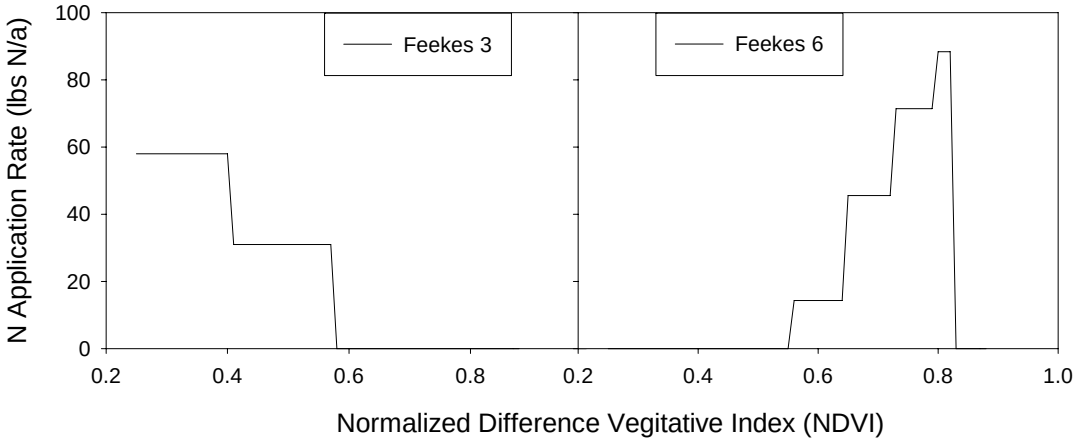

Figure 5. Nitrogen Application Rate At Feekes 3 And Feekes 6 For Flat Rate Of The Opposite Algorithm For The Woodford Co Site.

Table 1. Total N Application Rate Used For Each Treatment And Average Treatment Yield At The Woodford Co. Site In 2003-2004.

	Nitrogen (lbs/a)			Yield	Profit*
Treatment	Feekes 3	Feekes 6	Total	bu/a	$/a
Farmer Practice	40	75	115	64.3	152
VA Variable	33	39	72	58.6	148
VA Average Flat	33	38	71	54.9	138
OK Variable	40	41	81	61.7	155
			LSD (0.10)	3.3	
			C.V.	4.3	

*Profit is total return after N fertilization assuming wheat at $3.00/bu and N at $0.35/lb.

Table 2. Total N Application Rate Used For Each Treatment And Average Treatment Yield At The Woodford And Trigg County Sites In 2004-2005.

	Woodford Co			Trigg Co		
Algorithm	Total N	Grain Yield	Profit*	Total N	Grain Yield	Profit
	lbs/a	bu/a	$/a	lbs/a	bu/a	$/a
Low Rate						
VA VRN	37	70	197	62	74	200
Oklahoma VRN	55	81	224	62	63	167
Opposite VRN	54	81	224	62	70	188
Flat Rate	51	74	204	62	71	191
High Rate						
VA VRN	90	87	230	87	82	216
Oklahoma VRN	80	87	233	87	71	183
Opposite VRN	87	88	234	87	84	222
Flat Rate	105	87	224	87	84	222
Farmer Prac.	110	88	226	107	90	233
N Rich Strip	122	86	215	120	80	198
	$LSD_{(0.1)}$	7		$LSD_{(0.1)}$	8	

*Profit is total return after N fertilization assuming wheat at $3.00/bu and N at $0.35/lb.