Sensor-based management of Nitrogen of irrigated durum wheat in Arizona
2014 Final Report

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Summary

Nitrogen use efficiency (NUE) in irrigated high-input wheat production is an area of concern due to N losses associated with fertility, irrigation, and tillage management. Restricted use of N fertilizer may improve NUE but yield potential would be compromised. An improved management option will make use of new sensing technology capable of detecting in-field variation of plant size and nutritional status and enable site-specific management of fertility inputs. Field-ready hardware can provide for automatic variable-rate dispensing of fertilizers, but a computer algorithm needs to be developed in order to provide instructions to the rate controller. Commercial-grade technology is being tested in Maricopa as part of this study and includes active-light canopy reflectance and displacement sensors, as well as GPS-based rate controllers for application equipment. Experimental data on sensor output and corresponding plant conditions are being used to develop an algorithm specific to the conditions and yield goals of Central Arizona. Application equipment and experimental testing of N rates by time of application and amount have been tested for three consecutive years since 2011 in Maricopa AZ with consistent results indicating the feasibility of using active sensors in ground application systems to control the timing and delivery of N fertilizer to optimize production of durum.

Introduction

The irrigated farming systems in the semi-desert are highly productive and require substantial amounts of production inputs to sustain this productivity level. For durum wheat production in Arizona, Nitrogen fertilizer is an essential component of fertility management. It is needed to ensure the crop will reach adequate protein levels in the grain. On the other hand, Nitrogen use efficiency (NUE) in wheat production can be an area of concern since wheat, as the case of most cereals, tends to have low NUE due to N released from the plant tissue and other losses associated with fertility, irrigation, and tillage management. Nitrogen fertilizer is an energy-intensive, expensive material that should be carefully managed to ensure high productivity within economical limits and with the minimum environmental footprint possible. This project targeted the use of new technology in sensing crop needs and dispensing prescribed rates of N fertilizer. There are three basic components of this technological package: a) improved application technology, which is commercially available and includes GPS, in-cab multi-function computer displays and electronic variable-rate controllers; b) crop biomass/vigor monitoring sensors such as active-light spectral sensors; and c) the mathematical algorithms that determine the rate to use according to the crop condition and location in the field.

Experimental Work

This experiment was established in 3 acres of loamy-clay texture soil at the Maricopa Agricultural Center. This land was sown with Sudan grass in the summer months of 2013 in order to enhance the response of the crop to nitrogen fertilizer. Before planting, all plots received a blanket application of 90 lb/A of Triple Superphosphate (0-45-0) to avoid possibility of having confounding effects due to P deficiency caused by the growth of Sudan grass. Durum wheat of Kronos variety was planted on dry ground at a rate of 158 lb/A on December 18, 2013, followed by next-day irrigation. The treatments were a combination of total amounts of nitrogen fertilizer and the application timing which created total cumulative amounts of 0, 100, 150, 250, and 325 lb/A of applied nitrogen fertilizer. Every combination was replicated three times to generate a total number of 36 experimental plots which were randomly allocated in three blocks. The harvestable area of each experimental plot was 2,000 ft^2 (strips of 100 x 20 ft). Table 1 contains a compilation of treatments in this study.

Table 1. Experimental fertility treatments showing nominal values of nitrogen fertilizer rates (lb-N/A) arranged by time of application. Maricopa, AZ. 2014.

Treatment ID	Pre-planting (12/18/2013)	Tillering (2/3/2014)	Stem elongation (2/28/2014)	Heading (3/19/2014)
1	0	0	0	0
2	0	150	0	0
3	0	150	100	0
4	0	150	100	75
5	50	0	0	0
6	50	100	0	0
7	50	100	100	0
8	50	100	100	75
9	100	0	0	0
10	100	50	0	0
11	100	50	100	0
12	100	50	100	75

Nitrogen fertilizer applications were carried out using a ground rig with a rear boom with special nozzles for low-pressure, high-flow application. This rig was instrumented with Raven flow and section control sensors, along with GPS receiver and active-light "Green-Seeker" spectral sensors. These sensors were connected to a Trimble FMX on-board computer with variable-rate unlock to handle the application function and control the flow to keep constant application rates as demanded by the experimental design. The liquid fertilizer used in this study was UAN-32 and this material was applied in top-dressing mode with no injury to the crop canopy. Figure 2 shows the sprayer setup used in this project to deliver the target application rates of nitrogen fertilizer.

The crop nutritional status was monitored with soil and tissue samples taken prior to each fertilizer application to determine Nitrates content. Tissue samples were collected according to guidelines recommended by the University of Arizona (Ottman M. 2006. Fertilizing Small Grains in Arizona. http://cals.arizona.edu/pubs/crops/az1346.pdf) to determine stored nitrogen available for plant growth. Soil samples were taken down to 8 inches deep in consideration to the maximum concentration of root mass. Above ground biomass per unit area was determined at the same time of sample collection. Flood irrigation management was done according to conventional practices in the area. The crop was harvested on May 21, 2014 using a grain combine with a 20 ft. header and instrumented with a GPS-based yield monitor. Grain samples were taken for quality analysis using percent protein at 12% moisture content.

Figure 1. Ground rig during field deployment of application equipment. Maricopa, AZ. 2014.

Results

The field treatment with a summer crop like Sudan grass was a very effective strategy to remove residual Nitrogen in the soil and make the experiment very sensitive to N applications. Phosphorous levels were adequate for crop development given the pre-plant application of P fertilizer. With the fertility management implied in this experiment we achieved a very strong response in yield and quality parameters as seen in Table 2 and Figure 2. These data show that crop response is a function of both time of application and amounts applied. These findings suggest there is a significant gain in N use efficiency by applying the bulk of N fertilizer during in-season events starting when the crop has reached the tillering stage and until flowering.

The spectral response of the crop measured with the Normalized-difference vegetation Index (NDVI) provided a good characterization of the crop condition in terms of plant biomass and fertility levels. The tabulated values in Table 3 compile the dynamic changes in spectral response as well as plant/soil fertility values. Figure 3 confirms that the crop response to Nitrogen fertilizer is captured with the use of spectral sensors.

Table 2. Average and standard deviation values of yield and grain quality parameters. Maricopa, AZ. 2014.

Treatment	Average values			Standard deviation		
ID	Yield (lb/A)	Protein (%)	HVAC (%)	Yield	Protein	HVAC
1	494	11.36	74.3	263	1.17	16.5
2	4581	9.28	27.3	743	0.36	11.5
3	5951	11.26	83.7	748	0.78	3.8
4	6186	12.63	94.3	380	0.12	4.7
5	2280	8.12	16.3	365	0.34	8.1
6	4494	8.68	24.0	460	0.14	9.2
7	5383	10.08	60.0	381	0.60	11.4
8	5939	11.62	84.7	309	0.44	4.7
9	3674	8.10	8.7	110	0.25	3.2
10	4436	8.72	25.0	148	0.76	17.3
11	5692	10.38	68.7	501	0.51	3.5
12	5597	12.27	88.7	590	0.59	7.0

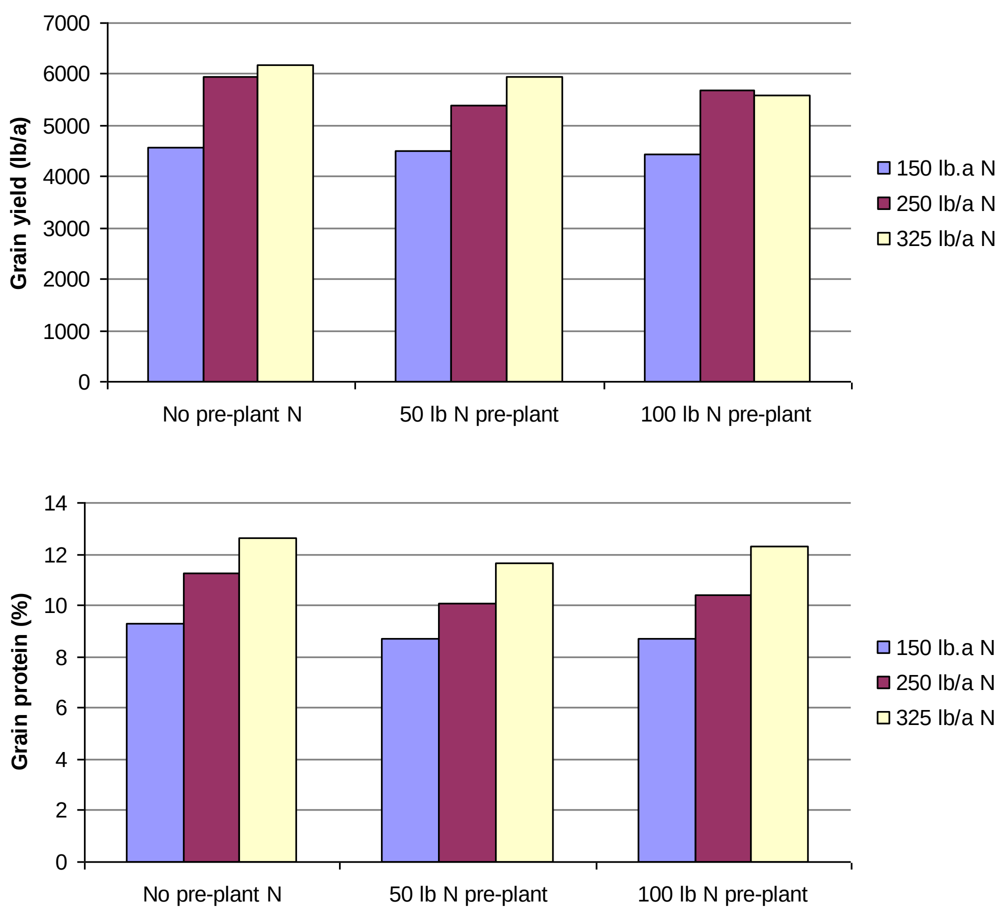

Figure 2. Average values of yield and grain protein for treatments with in-season applications of Nitrogen fertilizer. Maricopa, AZ. 2014

Table 3. Average values of spectral sensors, biomass production, and Nitrates concentration in soil and plant. Maricopa, AZ. 2014.

Treatment	Crop canopy spectral response (NDVI)				Above-ground plant biomass (g/m^2)			
ID	Feb-19	Feb-26	Mar-19	Mar-28	Feb-19	Feb-26	Mar-19	Mar-28
1	0.18	0.17	0.17	0.17	4.6	14.5	33.9	
2	0.26	0.34	0.70	0.68	4.6	37.2	159.9	
3	0.27	0.37	0.75	0.74	4.6	34.7	176.5	
4	0.27	0.38	0.76	0.75	4.6	37.2	176.5	327.5
5	0.34	0.34	0.33	0.32	12.9	51.7	102.7	
6	0.39	0.47	0.69	0.66	12.9	51.0	211.8	
7	0.42	0.49	0.75	0.69	12.9	51.0	176.8	
8	0.40	0.46	0.76	0.70	12.9	51.0	176.8	309.1
9	0.44	0.50	0.64	0.60	12.2	46.4	154.9	
10	0.37	0.44	0.64	0.63	12.2	60.5	202.4	
11	0.44	0.51	0.77	0.75	12.2	60.5	217.2	
12	0.44	0.51	0.77	0.74	12.2	60.5	217.2	356.3

Treatment	Soil Nitrate concentration 8-in (ppm)				Plant stem Nitrate concentration (ppm			
ID	Feb-19	Feb-26	Mar-19	Mar-28	Feb-19	Feb-26	Mar-19	Mar-28
1	1.91	1.63	0.85		506	361	226	
2	1.91	23.92	4.11		506	9211	1772	
3	1.91	23.92	29.78		506	9211	4814	
4	1.91	23.92	29.78	33.33	506	9211	4814	13368
5	11.89	10.77	0.29		3144	4861	171	
6	11.89	13.72	3.86		3144	2547	664	
7	11.89	13.72	9.01		3144	2547	7093	
8	11.89	13.72	9.01	15.75	3144	2547	7093	11118
9	41.11	14.63	10.30		3632	5225	307	
10	41.11	10.27	0.88		3632	4468	918	
11	41.11	10.27	9.23		3632	4468	4586	
12	41.11	10.27	9.23	10.76	3632	4468	4586	9795

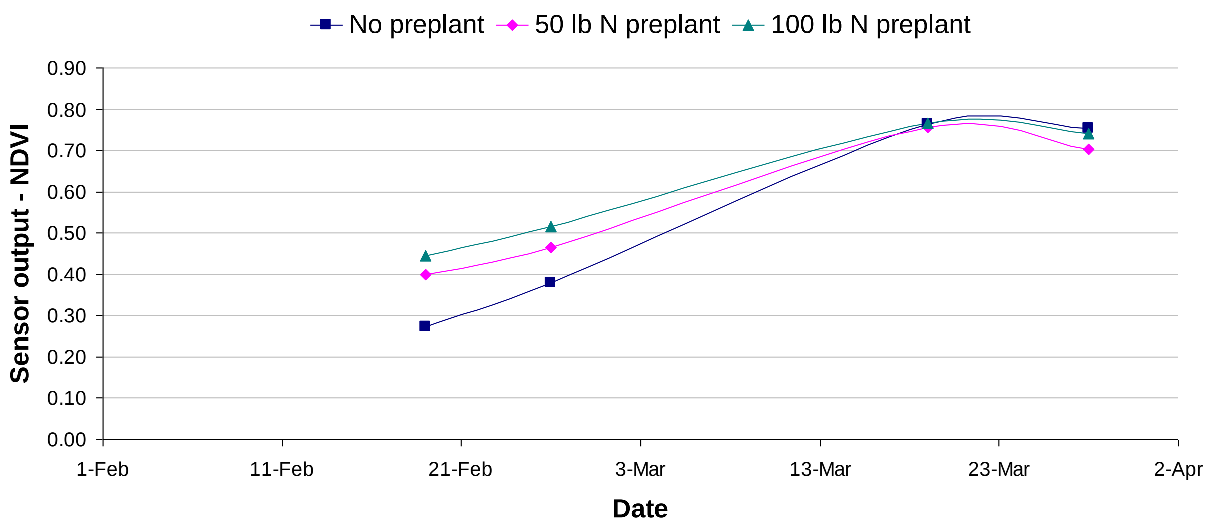

Figure 3. Average values of Normalized-difference Vegetation Index (NDVI) across the growing season for highest yielding treatments. Maricopa, AZ. 2014