Sensor-based management of Nitrogen of irrigated durum wheat in Arizona
2013 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.

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 2012 in order to enhance the response of the crop to nitrogen fertilizer. Durum wheat of Kronos variety was planted on dry ground at a rate of 150 lb/A on December 12, 2012, 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. 2013.

Treatment ID	Pre-planting (12/12/2012)	Tillering (1/24/2013)	Stem elongation (3/1/2013)	Heading (4/1/2013)
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 13, 2013 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. 2013.

Results

The soil sampling at the time of planting showed an average concentration of 7.9 ppm of Phosphorous and 3.3 ppm of Nitrates. With these findings we expected to have a strong response to nitrogen fertilizer applications. Phosphorous levels were adequate for crop development, since it was uncertain if the crop would respond to P applications it was decided not to apply and avoid confounding responses to a mixed fertility management. Tables 2 and 3 present a compilation of crop yield and grain quality, as well as crop response parameters measured during the season.

Plots in figure 2 show the response of fertility treatments that received the maximum amount of nitrogen fertilizer (i.e. 325 lb-B/A) and therefore reported the highest yields in these trials. These N-rich treatments resulted in similar protein levels but with significant differences in yield. The dynamics of change in sensor readings suggest that sensor readings can be used to apply rates based on the crop response to light. Statistical analyses are being carried out and will be completed at the time of submitting the final report.

Table 2. Average values of yield and grain protein content. Maricopa, AZ. 2013.

Treatment ID	Yield (lb/A)	Grain protein (%)
1	3361	10.24
2	4298	11.53
3	4501	13.40
4	5126	13.56
5	4095	8.35
6	5416	9.37
7	5779	11.63
8	5663	13.06
9	4646	9.61
10	4632	10.95
11	4443	12.85
12	4879	13.39

Table 3. Average values of spectral sensors, biomass production, and Nitrates concentration in soil and plant. Maricopa, AZ. 2013.

	Normalized-Difference Vegetation Index (NDVI)				**Above ground biomass (g/m^2)**		
Treatment ID	**1/24/2013**	**3/1/2013**	**4/1/2013**	**4/10/2013**	**2/5/2013**	**3/1/2013**	**4/5/2013**
1	0.25	0.53	0.39	0.37	15.50	27.69	64.18
2	0.26	0.73	0.58	0.52	15.50	50.46	103.84
3	0.25	0.73	0.60	0.51	15.50	50.46	100.17
4	0.26	0.72	0.64	0.57	15.50	50.46	100.17
5	0.26	0.60	0.52	0.48	15.12	33.98	75.93
6	0.27	0.70	0.69	0.63	15.12	46.11	98.03
7	0.27	0.72	0.72	0.67	15.12	46.11	97.64
8	0.26	0.70	0.69	0.64	15.12	46.11	97.64
9	0.25	0.65	0.55	0.53	16.49	39.10	85.97
10	0.26	0.68	0.54	0.52	16.49	44.23	105.13
11	0.26	0.67	0.55	0.50	16.49	44.23	107.16
12	0.25	0.68	0.58	0.53	16.49	44.23	107.16

	Soil Nitrates concentration 8-in (ppm)					**Plant lower stem Nitrates concentration (ppm)**			
Treatment ID	**12/8/2012**	**1/24/2013**	**3/1/2013**	**3/30/2013**	**4/9/2013**	**1/24/2013**	**3/1/2013**	**3/30/2013**	**4/9/2013**
1	3.23	3.12	0.86	0.23		3.72	0.16	0.16	
2	3.23	3.12	4.93	3.21		3.72	8.81	8.31	
3	3.23	3.12	4.93	9.96	8.11	3.72	8.81	20.98	19.01
4	3.23	3.12	4.93	9.96	23.65	3.72	8.81	20.98	21.43
5	3.23	10.13	1.21	0.19		12.55	0.29	0.08	
6	3.23	10.13	6.01	0.84		12.55	7.83	4.34	
7	3.23	10.13	6.01	7.33	1.60	12.55	7.83	20.58	17.95
8	3.23	10.13	6.01	7.33	12.54	12.55	7.83	20.58	18.93
9	3.23	10.27	1.66	0.15		16.62	1.57	0.21	
10	3.23	10.27	3.72	0.35		16.62	5.60	5.91	
11	3.23	10.27	3.72	10.44	7.31	16.62	5.60	18.90	15.72
12	3.23	10.27	3.72	10.44	32.64	16.62	5.60	18.90	15.84

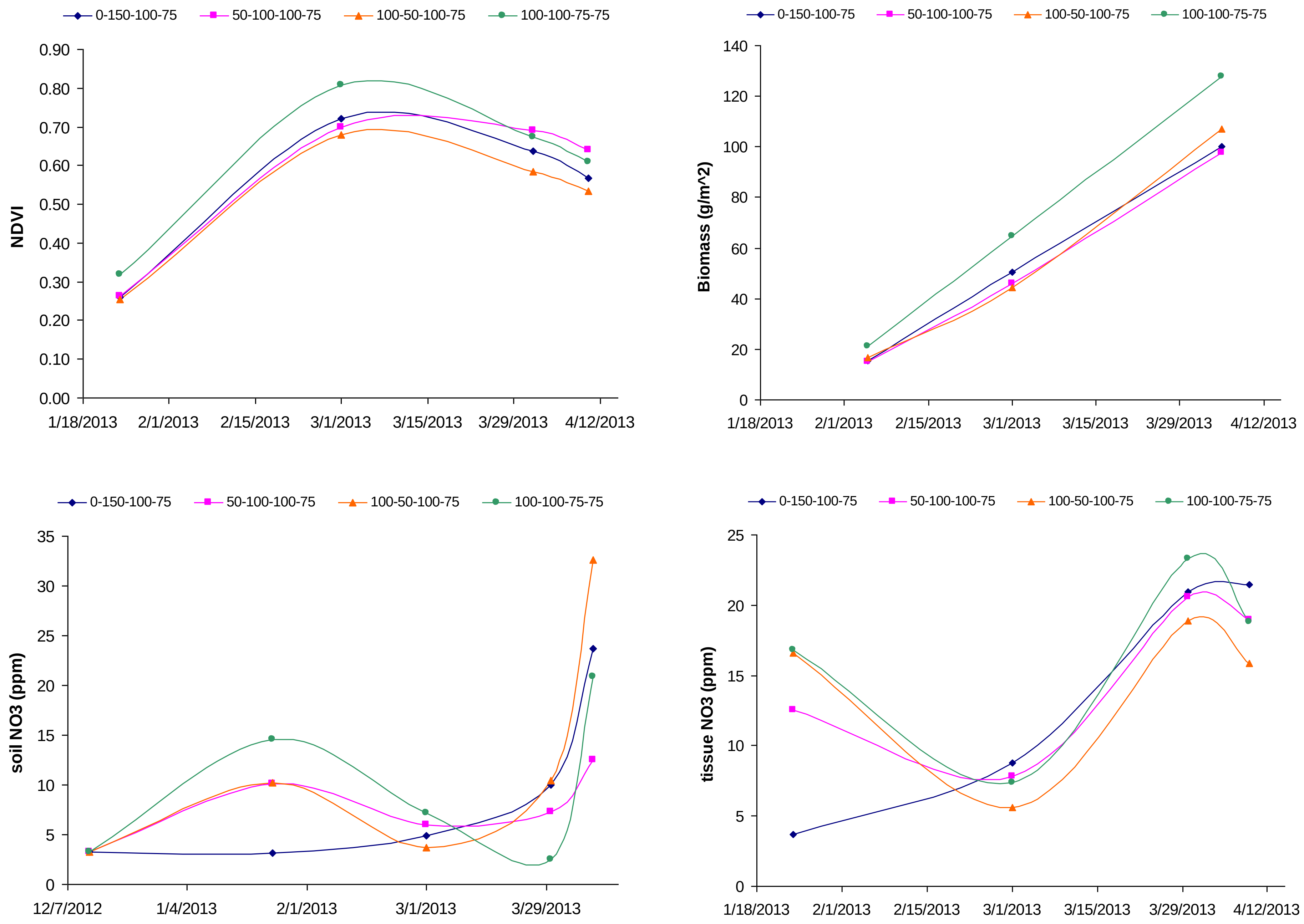

Figure 2. Dynamics of crop vegetation growth and nitrogen use. Maricopa, AZ. 2013.