Sensor-based management of mid-season N fertilizer in durum wheat

2011 and 2012 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-level 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 - 2011
The approach taken for this project was to grow durum wheat in the 2011 season at the Maricopa Agricultural Center (MAC) in order to have the best possible level of control over the application of Nitrogen fertilizer. Critical elements for the success of this project were the timing, the amounts and the method of application. We used two fields at MAC of contrasting soil types: Field 124 (sandy) and Field 1 (loamy-clay). The wheat was planted on December 20,

2010 with conventional durum wheat seed of the Kronos variety at 150 lbs seed/acre. The treatments were a combination of three cumulative amounts that were split twice after the first in-plant application. These treatments were replicated four times to generate a total number of 36 experimental plots which were randomly allocated in each of the two fields. Each of the experimental plots measured 100 x 20 ft., these plots were reduced to 80 x 15 at the time of harvesting. Figure 1 represents the treatments selected by amount and timing of application of N fertilizer.

The actual applications of N fertilizer were carried out with a ground rig. We instrumented a two-behind sprayer with Raven flow and section control sensors. These sensors were connected to the 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 material was UAN-32 and this material was applied in top-dressing mode with no injury to the canopy. Figure 2 shows the tractor-sprayer setup used in this project to deliver the target application rates of N fertilizer.

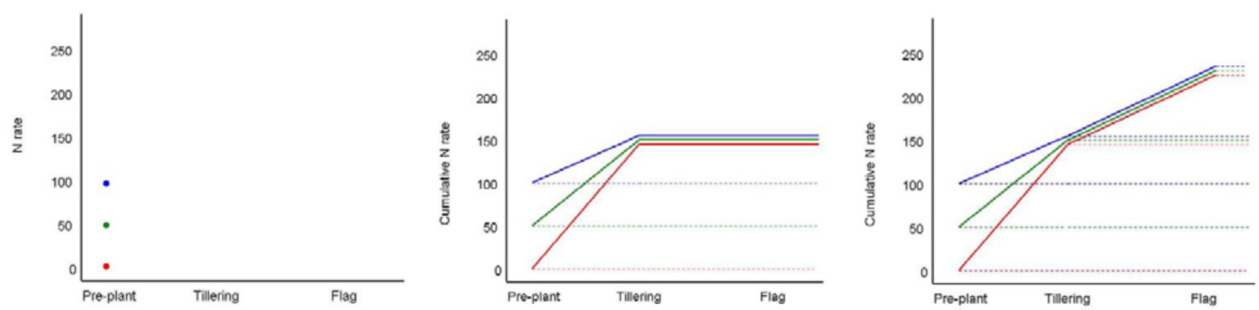


Figure 1. Graphical representation of treatments. Five levels of cumulative Nitrogen fertilizer (0, 50, 100, 150, and 250 lb N/Acre) with two splits at tillering and flag stage during the 2011 growing season.

Soil and plant samples were taken on each plot. These samples were collected following the guidelines recommended by Ottman M, “Fertilizing Small Grains in Arizona”, 2006 (http://cals.arizona.edu/pubs/crops/az1346.pdf) and were sent to the USDA-ARS laboratory for Nitrate Nitrogen quantification. These composite samples were collected before the timing of fertilizer applications which happened on February 11 and March 22, 2011 (Field 124); and on March 4 and April 4, 2011 (Field1). The in-season Nitrogen applications in Field 1 were off-set by one irrigation cycle with respect to Field 124 in order to increase the response to N applications and to explore the timing element of these treatments. These sampling dates are pictured in Figure 3 to show the distribution in time of these observations with respect to the stages of the crop. In addition to soil-plant sampling, on those same dates we deployed optical sensors to measure canopy light reflectance of the crop.

Figure 2. Ground system to apply liquid fertilizer in experimental plots in Maricopa AZ on March 4, 2011. System utilized electronic section and flow control to deliver accurate application rates.

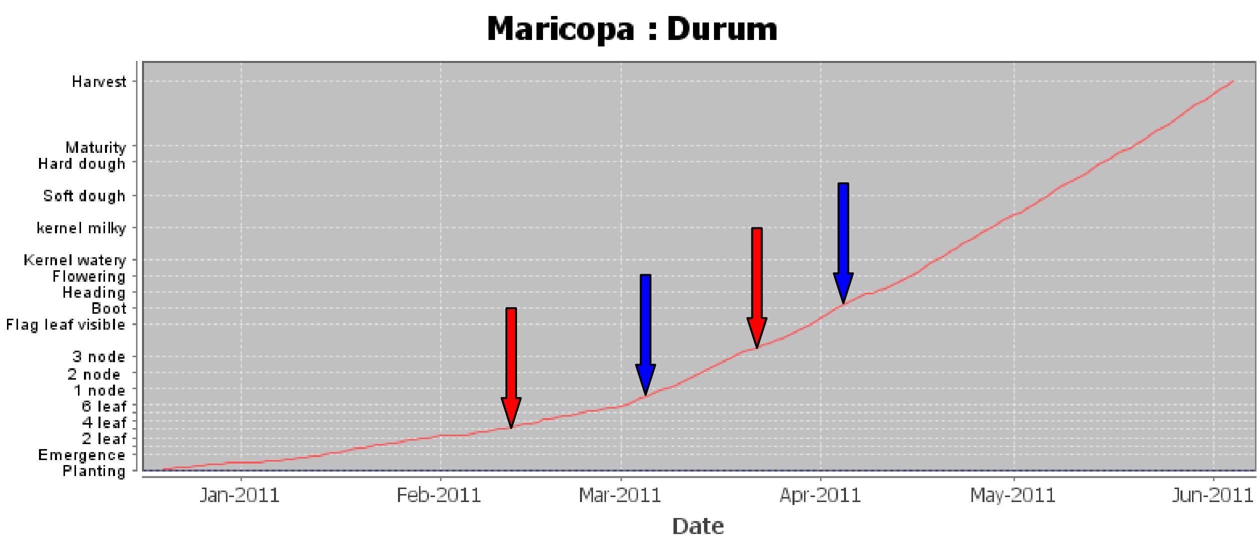


Figure 3. Distribution of times of in-season N applications and sampling dates in Field 1 (blue) and Field 124 (red) at the Maricopa Agricultural Center during the 2011 growing season in Maricopa AZ.

Harvest of all plots in these two experimental fields was carried out in June 3-5, 2011 with a 20' wide header Case-IH combine instrumented with a yield monitor system sponsored by the AGRPC in 2010. At the time of harvesting, we collected one grain sample per plot for quality determination in the laboratory.

Results – 2011

The ground rig for variable-rate application of liquid fertilizer was successfully built and tested on time for the in-season applications of Nitrogen fertilizer. This system used tractor auto-steer to guide the vehicle in the field and the display was programmed to deliver the specified amounts of liquid material with the integration of rate controllers and stream-bars as substitutes of spraying nozzles. As-applied maps were generated to have an electronic record of the work done and confirm the application rates. The two splits were carried out according to the proposed protocol.

Preliminary observations in the early part of the season showed some level of differentiation between plots of different pre-plant N application and their corresponding values of spectral response obtained as the Normalized Difference Vegetation Index. In particular, the plots that received some amount of pre-plant N showed an increase in lower stem Nitrates concentration. Figure 4 shows this response observed at the time of the first split in early February when the crop was reaching the first-node stage

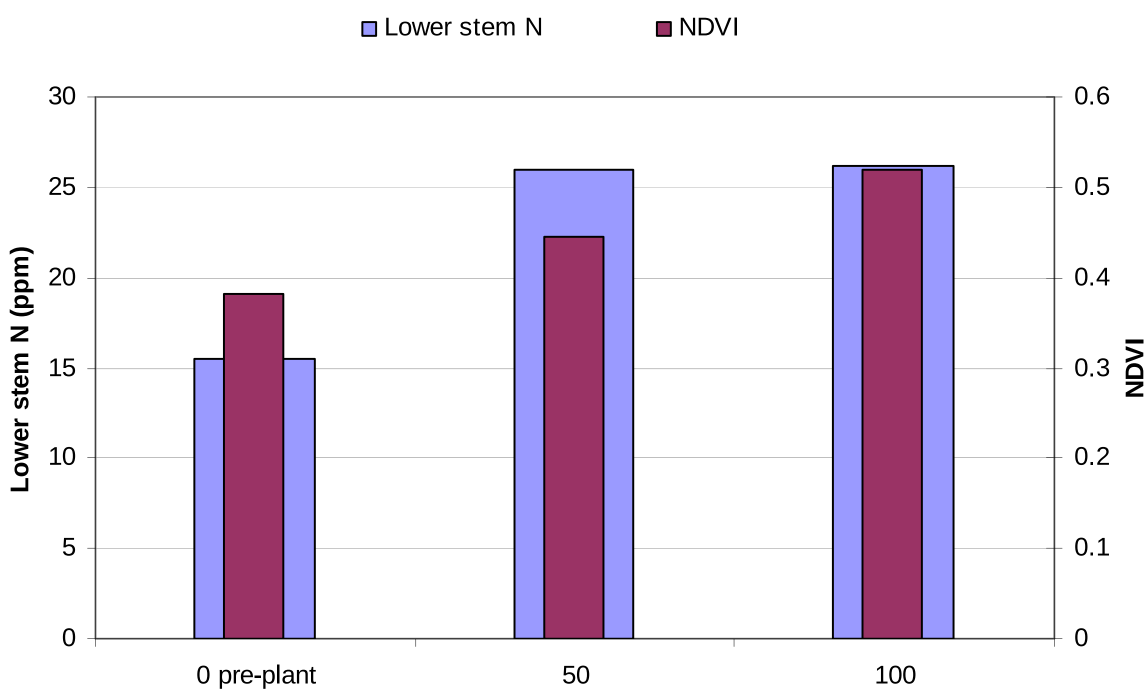


Figure 4. Spectral response and lower-stem Nitrates concentration of plots treated with different levels of pre-plant Nitrogen Fertilizer. Maricopa Ag Center. February 12, 2011.

In the later part of the growing season the differentiation between plots was reduced significantly. By the time of harvest the response to the application of Nitrogen did not follow the expected pattern where yield is a function of the amounts of input. As seen in Table 1, the relationship between the cumulative amounts of applied Nitrogen and yield (both in terms of quantity and quality) was not significant. Some factors that could be associated with these results were the relatively high amounts of Nitrates already in the soil at the time of planting, and the high concentrations of Nitrogen in the irrigation water. This experiment will be repeated in 2012 with no extra cost to AZGRPC. The field selected for the upcoming season was planted with sudan grass for depletion of soil Nitrates.

Table 1. Results of in-season spectral measurements and yield components. Maricopa Ag Center, 2011

Treatment	NDVI_3-8	CLR_3-8	NDVI_4-4	CLR_4-4	NDVI_4-4_hand	CLR_4-4_hand	yield_lb/a	protein_%
0-0-0	0.69	2.16	0.69	2.05	0.71	2.44	6081	12.51
0-150-0	0.75	2.53	0.78	2.73	0.69	2.31	5787	10.39
0-150-50	0.75	2.53	0.78	2.73	0.69	2.31	5787	10.39
100-0-0	0.73	2.44	0.78	2.65	0.76	2.84	5787	12.97
100-50-0	0.70	2.22	0.74	2.33	0.71	2.35	5312	10.52
100-50-50	0.72	2.31	0.74	2.37	0.79	2.97	5873	11.55
50-0-0	0.69	2.12	0.72	2.24	0.75	2.69	6279	12.42
50-100-0	0.73	2.33	0.72	2.25	0.68	2.21	6210	11.41
50-100-50	0.73	2.35	0.76	2.57	0.69	2.41	5632	11.20

Experimental Work - 2012

There were few differences to the methodology of this experiment in 2012. We repeated the same fertility treatments of 2011, but only Field 1 (loamy-clay texture) was used. Also, the sensor-based data collection was enhanced with a mobile platform to allow continuous data acquisition. In the summer of 2011 we planted Sudan grass to remove the Nitrogen in the soil and improve the N response of the crop. Procedures for fertilizer application, sensor instrumentation, soil/plant sampling, and harvest were followed according to the protocol of the previous year. Ground preparation and Irrigation management followed the common practice in the area.

Results – 2012

During the growing season we followed the crop as there were changes in canopy color and plant size. Figure 5 shows the changes in plant size from February 6 to March 22 in a field transect in border 2 as recorded by the sonar sensor installed in the moving platform. Similarly, the map in Figure 6 shows the differences in color as captured by the optical sensors and reported as canopy reflectance with the Normalized-Difference Vegetation Index (NDVI). Yield response to Nitrogen treatments was highly significant. Figure 7 summarizes these findings

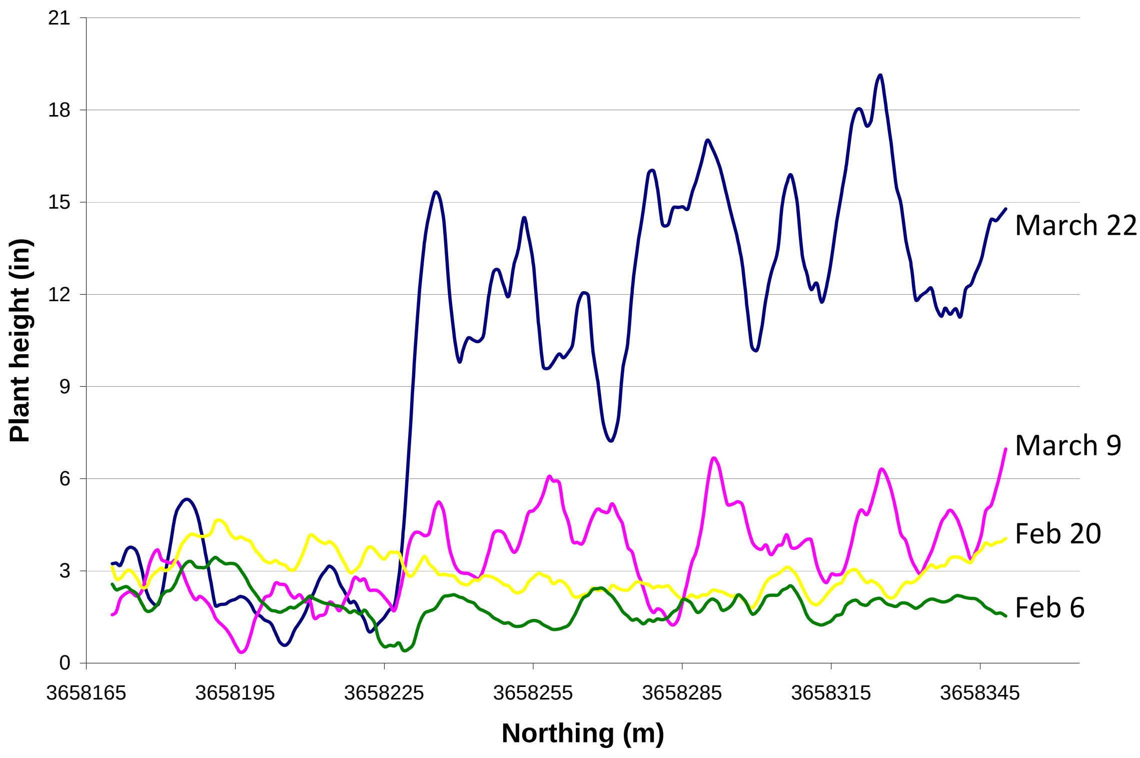
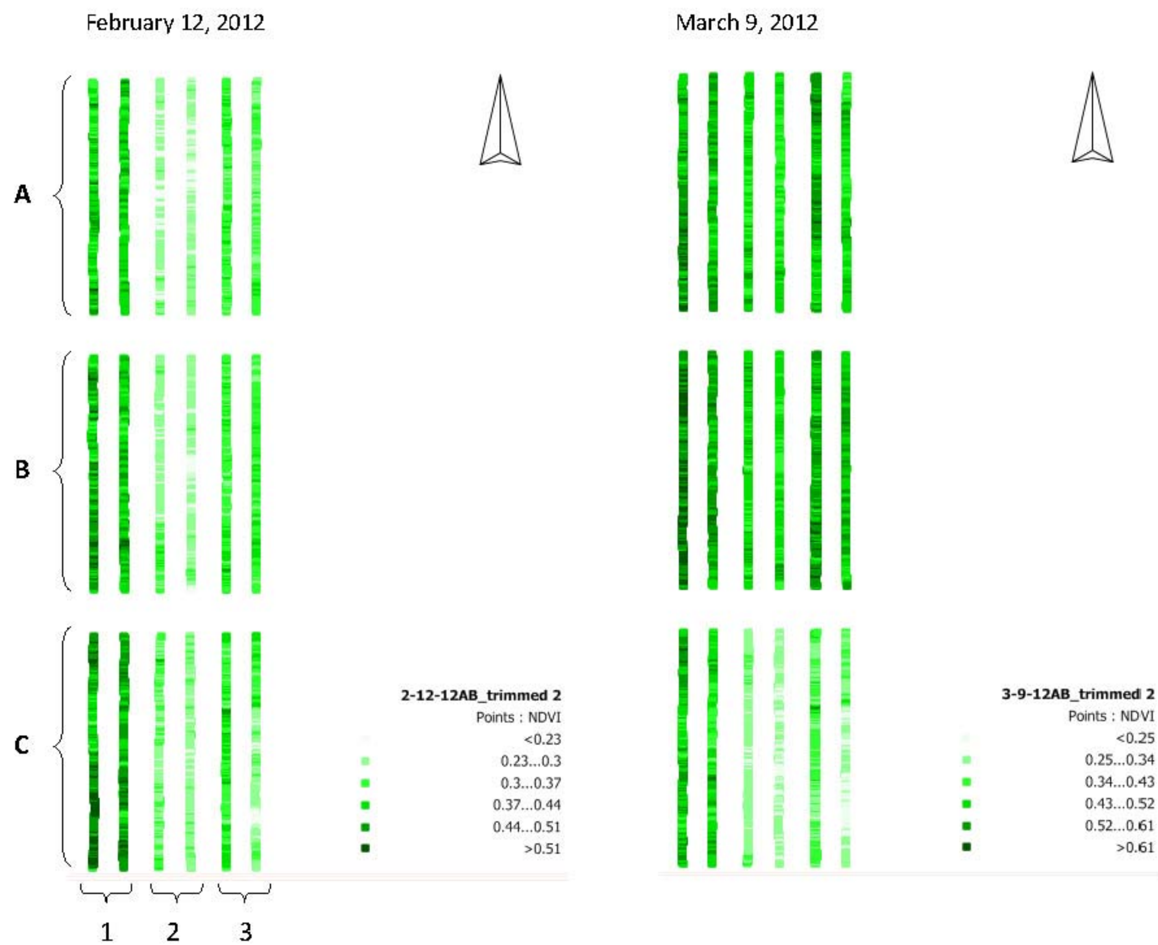


Figure 5. Plant-size response to Nitrogen fertility treatments in a field transect.



Border/Plot	Pre-plant rate (lb N/acre)	Feb-13 in-season rate (lb N/acre)
1 / A&B	100	50
1 / C	100	0
2 / A&B	0	150
2 / C	0	0
3 / A&B	50	100
3 / C	50	0

Figure 6. Changes in Normalized-Difference Vegetation Index (NDVI) obtained with spectral sensors. Accompanying table indicates physical allocation of Nitrogen treatments.

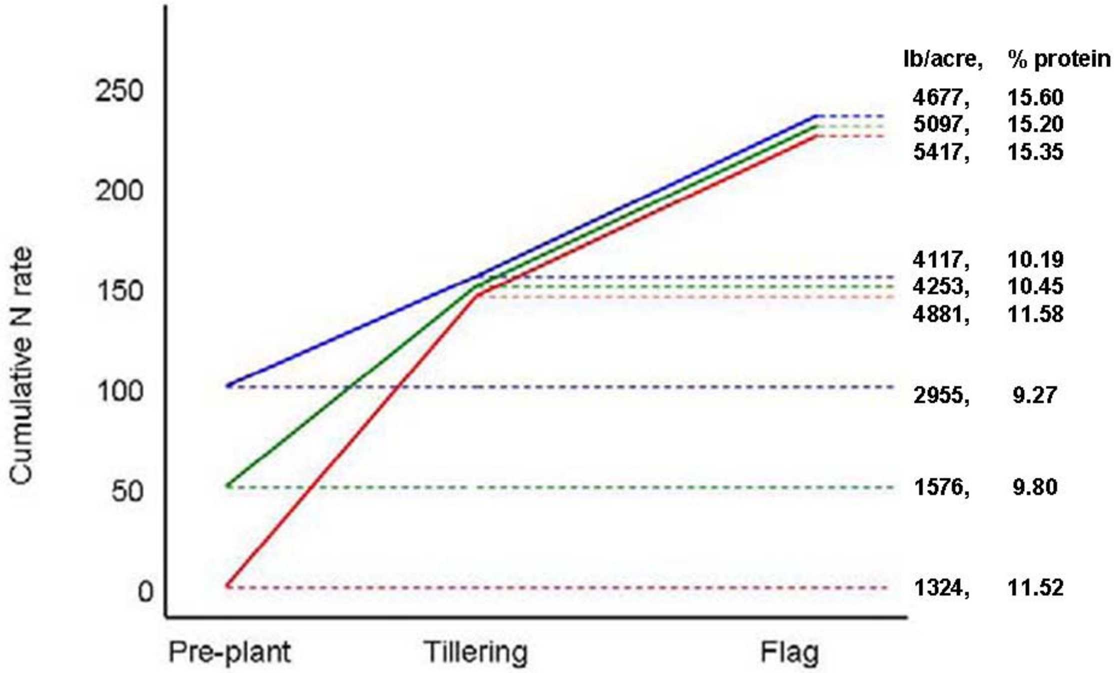


Figure 7. Effect of Nitrogen fertilizer treatments on yield (lb/ac) and grain quality as expressed by protein content.