Development and field testing of sensor-based algorithm for N fertilizer management of AZ durum wheat

2015 Final Report

Pedro Andrade-Sanchez, Principal Investigator
Michael J. Ottman, Cooperating Investigator

Summary

This project is focused on the use of commercially available precision agriculture technology and tested for its capacity to perform variable-rate application of Nitrogen fertilizer in irrigated durum wheat in Maricopa, AZ. The technology tested in this study includes active-light canopy reflectance and displacement sensors, as well as GPS-based rate controllers for application equipment. Multiple years of experimental data on sensor output and corresponding plant conditions are needed 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 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. During the 2015 season the tests included 4 combinations of N fertilizer amounts and application timing. Close monitoring of soil and plant (lower stem) Nitrates, as well as plant biomass was carried out during the early phases of crop development, followed by yield evaluations at maturity. Under the conditions tested during the 2015 season, only small differences in yield were observed as result of amount/timing application treatments. There was a trend of increasing yield by shifting higher amounts towards the flowering stages but these differences were not statistically significant. Protein content was slightly higher for treatments with larger amounts around tillering but these differences were not significant. The experiment in 2015 aimed at evaluating the potential gains of sensor-based management in soils with only moderate-low deficiency levels of N, a condition common in Arizona fields. The results showed that residual Nitrogen in the soil had a buffering effect that reduced the impact of N treatments on crop development and yield.

Introduction

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. Sensor-based management applies well to the irrigated farming systems in the semi-desert because their high productivity requires substantial amounts of production. 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 four borders corresponding to 3 acres of loamy-clay texture soil at the Maricopa Agricultural Center (Field 2, borders 51-55). This land had remained fallow for the last two years. Before planting, all plots received a blanket application of 100 lb/A of Triple Superphosphate (0-45-0) to avoid the possibility of having confounding effects due to P deficiency caused by previous crops. Durum wheat of Kronos variety was planted on dry ground at a rate of 167.3 lb/A on December 11, 2014, followed by next-day irrigation. The treatments were a combination of total amounts of nitrogen fertilizer and the application timing which resulted in similar cumulative amounts of 231 lb/A of applied nitrogen fertilizer for the whole season. Every combination was replicated six times to generate a total number of 24 experimental plots which were randomly allocated in six blocks. The harvestable area of each experimental plot was 4,000 ft^2 (strips of 200 x 20 ft). Figure 1 provides a visual description of treatments included in this study.

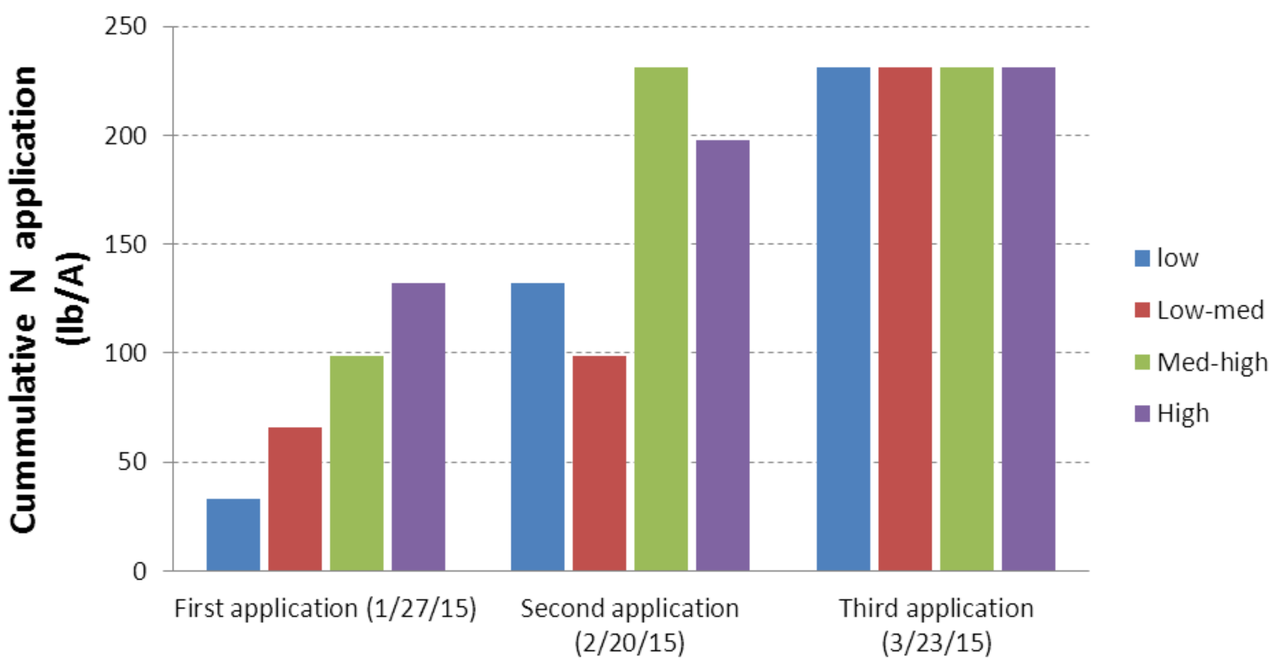


Figure 1. Graphical description of N application treatments. Maricopa, AZ 2015

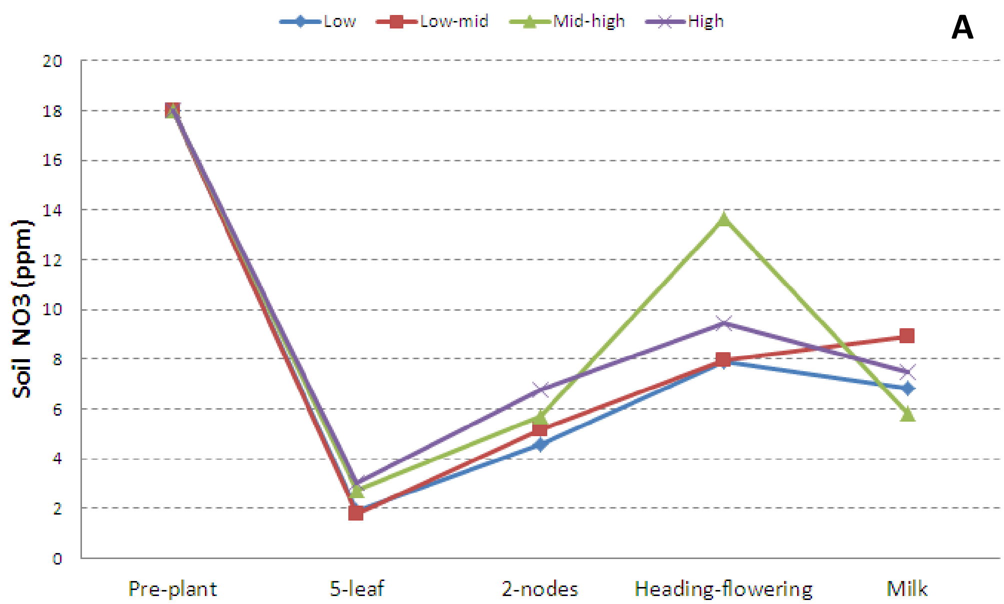
Nitrogen fertilizer applications were carried out using a ground rig with a rear boom with special nozzles for low-pressure, high-flow application. This rig was instrumented with Raven flow and section control sensors, along with GPS receiver and active-light "Green-Seeker" spectral sensors. These sensors 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 was UAN-32 which 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.

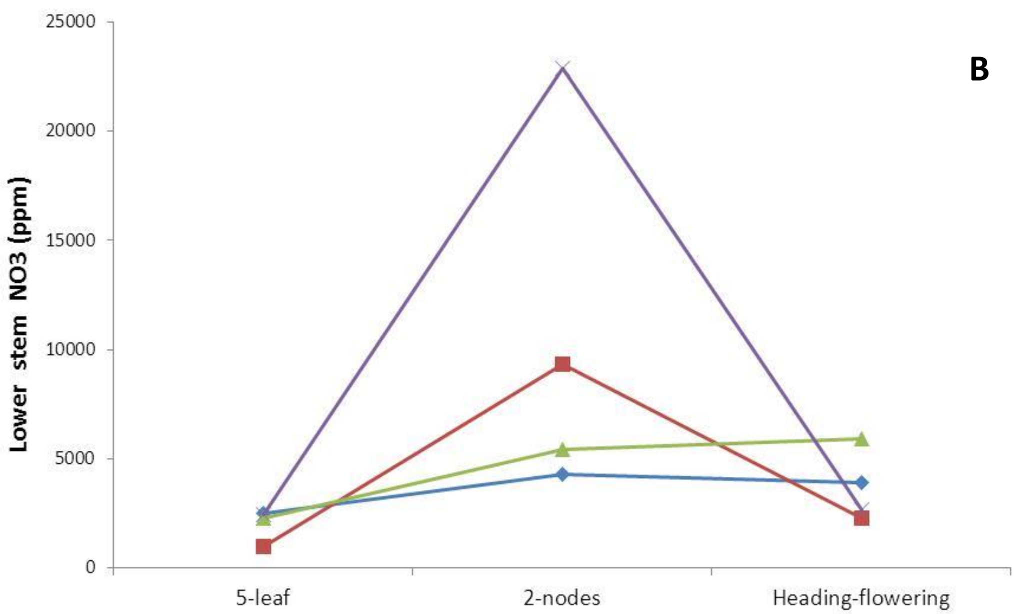
Soil and plant tissue (lower stem) Nitrates were monitored to assess the crop nutritional status. Samples were taken prior to each fertilizer application. Tissue samples were collected according to guidelines recommended by the University of Arizona (Ottman M. 2006. Fertilizing Small Grains in Arizona. 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 by harvesting an area of 15x40 inches. Flood irrigation management followed conventional practices in the area. The crop was harvested on May 15, 2015 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.

Figure 2. Ground rig during field deployment of application equipment. Maricopa, AZ. 2015.

Results and Discussion

The approach of using a field after an extended period of fallow showed that significant amounts of Nitrates were present at the start of the growing season therefore reducing the sensitivity of this experiment to N applications. Phosphorous levels were adequate for crop development given the pre-plant application of P fertilizer. With the fertility management treatments there was only a slight response in crop growth, yield and quality parameters as seen in the graphs of Figure 3.





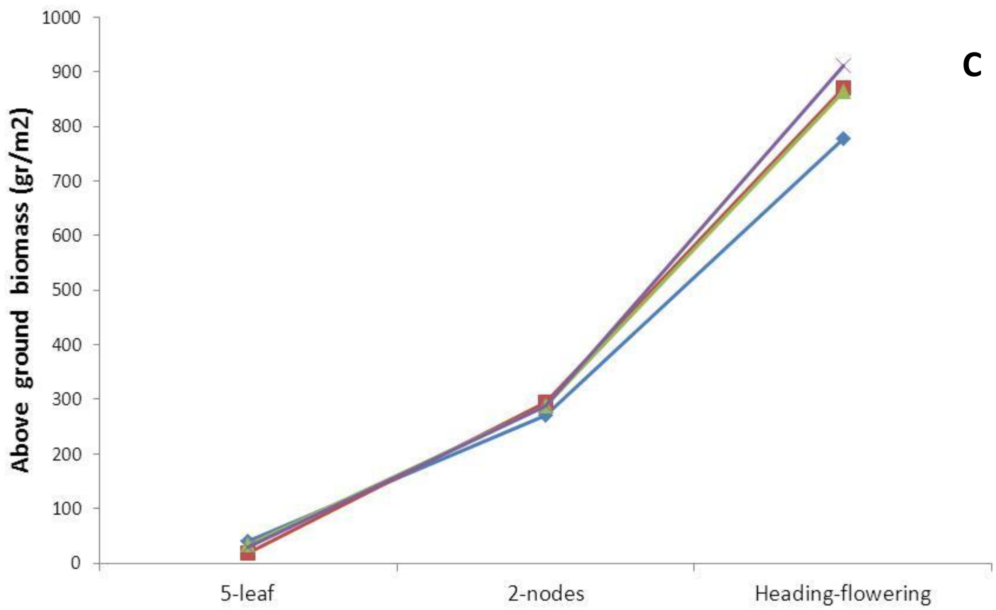


Figure 3. Indicators of crop development and nutritional status as defined by soil Nitrates (A), lower stem Nitrates (B) and above ground biomass (C). Maricopa, AZ. 2015

The spectral response of the crop measured with the Normalized-difference vegetation Index (NDVI) showed no differentiation between treatments and quickly approached saturation. This finding reinforces the value of an approach that incorporates additional pieces of information in order to characterize in-season growth and development of durum growing on soils ranging from mild to low deficiency levels of Nitrogen, and enable a variable-rate application strategy that will work under conditions of low nutritional stress.

Yield evaluation showed only a moderate response to the amount and timing application treatments. Figure 4 below shows that there was a trend of increasing yield by shifting higher amounts towards the flowering stages of plant development but these differences were not statistically significant. Protein content was slightly higher for treatments with larger amounts around tillering but the magnitude of these differences were not significant. Another parameter of grain quality, the Hard Vitreous Amber Color (HVAC) was flat with values in the top tier ranging from 95.0 to 96.2%.

The results from 2015 experiment suggest that the best setting for testing sensor-based strategies of N management in Arizona durum is to perform the experimental work at the field scale where within-field variations in crop management and soil properties provide a wide range of soil fertility conditions. This is the actual condition that new technology will be applied and ultimately tested upon.

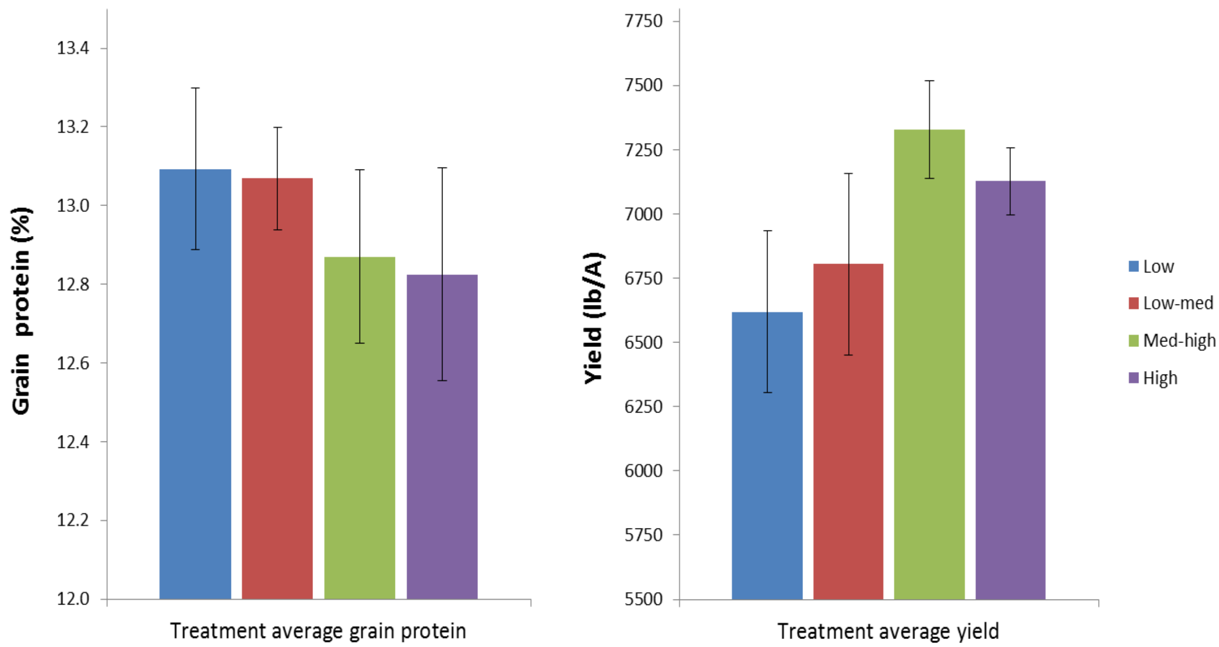


Figure 4. Yield response in grain quality (left) and production (right) to timing and amount of N fertilizer treatments. Maricopa, AZ. 2015