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Liquid Flow Control Requirements for Crop Canopy Sensor-Based N Management in Corn: A Project SENSE Case Study

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Abstract. *While on-farm adoption of crop canopy sensors for directing in-season nitrogen (N) application has been slow, research focused on these systems has been significant for decades. Much emphasis has been placed on developing and testing algorithms based on sensor output to predict N needs, but little information has been published regarding liquid flow control requirements on equipment used in conjunction with these sensing systems. Addition of a sensor-based system to a standard spray rate controller with fixed orifice nozzles has certain limitations in terms of the range of achievable rates; however, little data has been published to confirm this. The goal of this study was to provide an analysis of liquid N rate control requirements from 13 field sites that received split-N application during the 2015 cropping season in coordination with Project SENSE in Nebraska. As-applied data from the Ag Leader Integra™ monitor coupled with the OptRx® sensor system were analyzed to estimate turndown ratios and rate changes that were required across all field sites. Results indicated that target rates across 121 acres ranged from 13 L ha^{-1} to 130 L ha^{-1} of 32% liquid UAN with a mean of 30.7 L ha^{-1}. The minimum rate was fixed at 13 L ha^{-1}; 95% of the data fell between this value and 46.4 L ha^{-1} which suggested that a turndown ratio not less than 4:1 would be necessary for a system to successfully achieve these rates. It should be noted that lowering the minimum rate would likely have resulted in lower target rates being recorded. These data support previous statements that typical fixed orifice nozzles would not likely allow for a full range of target rates to be achieved.*

Keywords. *Variable-rate application, precision agriculture, control system, response analysis*

Introduction

Crop canopy sensors for in-season nitrogen (N) management have been commercially available for several years. While significant research has been devoted to these systems in maize production in Nebraska, adoption of these systems has been very slow across the state. As research continues to develop, development of application control systems that can match target rate demands during field operations is critical to ensure that the proper rates are being applied. To date, little information has been published regarding control system needs during sensor-based liquid N application; however multiple extension documents have stated a need for systems beyond standard fixed-orifice nozzles and spray rate controllers (Scharf & Lory (2006); Taylor & Fulton (2010); Grisso et al., 2011). Bennur and Taylor (2010) evaluated controller response performance for two different advanced liquid control systems (a pulse width modulated (PWM) nozzle valve and fast close valve with variable-orifice nozzles) and found response times ranged between 0.5 s and 2.1 s under simulated conditions. The goal of this study was to quantify liquid N applicator operating envelope needs for target rate ranges and changes in target rates via post-analysis of the as-applied data from the 2015 growing season. The specific objective was to determine fixed orifice nozzles using a standard spray rate controller would have been sufficient to achieve the target rates.

Materials and Methods

As-applied data from an Ag Leader Integra™ monitor (Fig. 1) coupled with the OptRx® sensor system were analyzed to estimate turndown ratios and rate changes that were required across all field sites and rate change requirements observed during field applications. A total of 13 Nebraska field sites that received split-N application (32% UAN solution) during the 2015 cropping season were analyzed. Target rate N (L ha^{-1}) ranges were summarized to provide minimum to maximum desired rates recorded by the monitor (minimum and maximum application rates were fixed at 13 L $ha^{-1}$and 130 L ha^{-1}, respectively). Control system response requirements (L min^{-1} s^{-1}) were calculated as the change in target rates (L ha^{-1} s^{-1}) multiplied by the applicator speed (m s^{-1}).

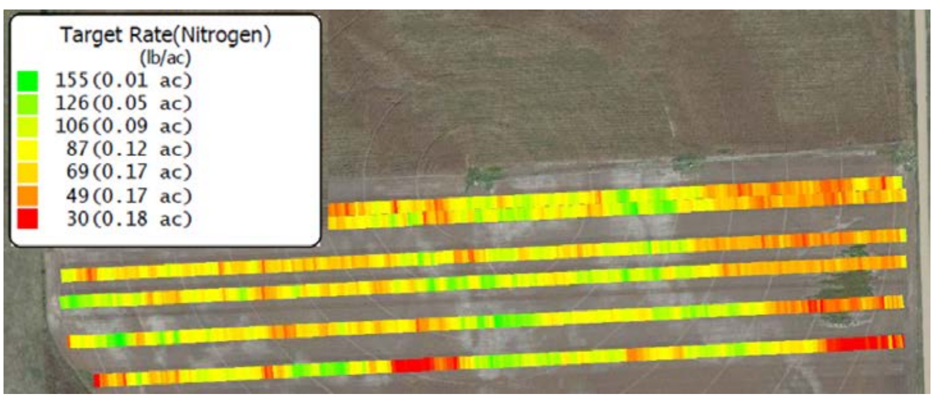

Figure 1. As-applied file coverage from Ag Leader Integra monitor showing N target rate (lb/ac) from field application.

Results and Discussion

Fig. 2 summarizes the range of target rates recorded by the monitor at 1 Hz during field applications; 16,945 data points were collected. Rates ranged from the minimum fixed rate (13 L ha^{-1}) to 122 L ha^{-1} with a mean of 30.7 L ha^{-1}. Analysis indicated that 95% of the data fell between the minimum fixed rate and 46.4 L ha^{-1} which suggested that a turndown ratio not less than 4:1 would be necessary for a system to successfully achieve these rates. Control system response requirements (L min^{-1} s^{-1}) are summarized in Fig. 3; rate changes averaged 0.004 L min^{-1} s^{-1}. Further analysis indicated that 95% of the data (i.e., mean plus or minus two standard deviations) ranged between -1.7 L min^{-1} s^{-1} and 1.7 L min^{-1} s^{-1}. This response analysis provides metrics that liquid control system design should consider when developing or evaluating system performance or capabilities.

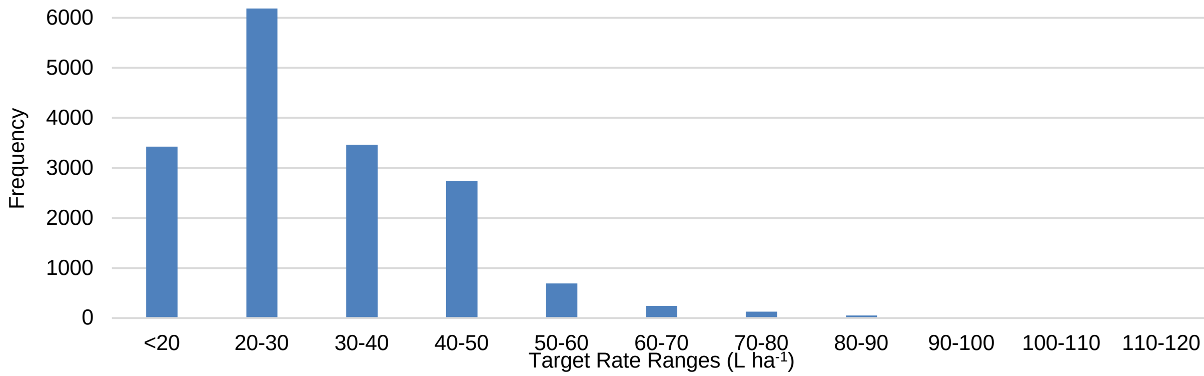

Figure 2. Histogram of target rate values (L ha^{-1}) observed during 2015 growing season applications.

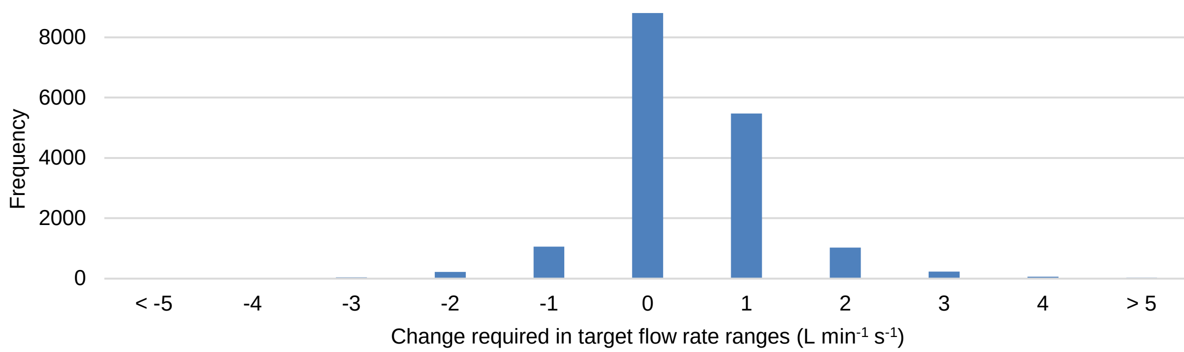

Figure 3. Histogram of required target flow rate changes (L min^{-1} s^{-1}) observed during 2015 growing season applications.

Conclusions

Based on the as-applied data collected, it was clear that the fixed orifice nozzle system utilized during the 2015 growing season was not adequate. Typical turndown ratios for a fixed orifice nozzle are on the order of 2:1 to 2.5:1. To cover 95% of the target rates observed in the 2015 as-applied data, a minimum turndown ratio of 4:1 would have been required. Thus, further technology would be required for this system to more fully cover rate ranges observed. Examples would include variable orifice nozzles, or PWM nozzle control valves to expand the system operating envelope, such systems would be recommended for future crop canopy sensor-based in-season N applications.

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