USE OF A CROP CANOPY REFLECTANCE SENSOR FOR IN-SEASON N MANAGEMENT OF CORN

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ABSTRACT

Over-application of nitrogen (N) fertilizer on corn has resulted in elevated levels of N in ground and surface waters. A major factor contributing to decreased N use efficiency and environmental contamination for traditional corn N management schemes is routine pre-season application of large doses of N before the crop can effectively utilize this N. Our long-term research goal is to reduce these over-applications by using remote sensing to direct fertilizer only to areas needing N at times when the crop can most efficiently utilize the N. We have assembled a prototype high-clearance tractor configured with red (red and NIR bands) and green (green and NIR bands) versions of the active GreenSeeker® sensors, drop nozzles with electronic valves, and variable rate controller that is intended to deliver in-season variable rates of liquid N fertilizer based on crop needs. Various small plot and on farm strip trials were conducted in 2003 to evaluate the various components of the high-clearance applicator and the response of corn grain yields to varying rates of N applied at different growth stages and across landscape spatial variability. Preliminary results indicated that the green version of the active sensor is more sensitive than the red version in detecting variation in canopy N status during the window we propose to apply N. Yield responses to N application were observed to vary across the landscape, and N responsiveness was more highly associated with variation in canopy reflectance assessed by the sensor than spatial variation in soil properties such as soil color. The objectives of our future research activities are to verify recommendations on canopy reflectance thresholds for triggering in-season N applications by field testing sensor/applicator systems at a scale appropriate to farmers.

INTRODUCTION

Over-application of N fertilizer on corn has resulted in elevated levels of N in ground and surface waters. A major factor contributing to decreased N use efficiency and environmental contamination for traditional N management schemes is the routine pre-season application of large doses of N, well before the time when the crop can effectively utilize this N. Previous work by Blackmer and Schepers (1995) and Varvel et al. (1997) using the Minolta SPAD 502 chlorophyll meter to monitor crop chlorophyll or N status and applying fertilizer N as needed, demonstrated 1) that the chlorophyll meter could be used as a research tool to maintain an adequate N supply for corn by fertilizing as needed and 2) that yields could be maintained with reduced N rates relative to a single preplant application of N. Our findings show that it is realistic for producers to move away from the uniform early season approach to N management and toward a more reactive approach involving crop evaluation and in-season N application to coincide better with crop N uptake. Our long-term research goal is to reduce N over-applications on corn by using remote sensing to assess crop N status and to direct fertilizer only to areas needing N at times when the crop can most efficiently utilize the N (Fig. 1), and thereby improve water quality through reduced N leaching and runoff. Before we can recommend the crop-based strategy for in-season N management to farmers, we need to validate and refine the recommendations with further research. Specifically, the research objectives for this project are:

1. Build and test a prototype high clearance in-season N applicator configured with on-the-go active sensors, controller, and nozzle/valve system to deliver variable rates of liquid N fertilizer
2. Develop algorithms for triggering N applications based on crop-based in-season canopy reflectance along with soil-based spatial data

MATERIALS AND METHODS

A flexible system is envisioned for N management that will enable producers to make intelligent (economical and environmentally sound) decisions for corn production using a variety of inputs depending on the situation. At the broadest scale, producers could use some type of remote sensing (satellite or aircraft) imagery to examine broad areas that would allow delineation of individual field images into management zones. The resulting management zone prescription map would serve as input to a variable-rate controller. Alternatively an on-the-go canopy sensor could serve as input into the variable rate controller. Finally, variable N applications could be made by integrating both crop-based sensor readings with soil-based data layers such soil color, electrical conductivity, etc., preprocessed to incorporate crop growth stage into a sensor adjustment map (SAM).

To develop and test a flexible N management system, we have assembled a prototype high-clearance tractor intended to operate as an in-season N applicator (Fig. 2). Key components of this applicator consist of 1) on-the go active crop canopy sensors, 2) drop nozzles with electronic valves, delivering liquid N fertilizer, 4) Raven sprayer control System 5), commercial Field Point controller system connected via serial port to PC running commercial Lab View measurement and control software . Prescription map and active sensor modules have been written in Lab view, which are available to deliver variable applications of N fertilizer based on prescription map (i.e. management zone map), active sensor readings, or a combination of both. The red and green versions of the GreenSeeker® active sensor manufactured by Ntech Industries, Inc. were tested and evaluated. These sensors operate by using LED’s to generate their own source of modulated light in the red and NIR bands (red version) or green and NIR bands (green version) and determining with a detector the percent of modulated light reflected back from the crop canopy. Reflectance in the respective bands is used to compute the red version of the normalized difference vegetation index (NDVI) and green version of this same index (gNDVI), which should provide a measure of variability in canopy nitrogen status. Various small plot and on farm strip trials were conducted in 2003 to evaluate various components of the high-clearance applicator and response of corn grain yields to varying rates of N applied at different growth stages and across landscape spatial variability. One of the studies conducted involved four N rates applied on two dates (V-10 and V-14 growth stages) and replicated nine times across the landscape (west to east) and) to evaluate N response across landscape variability (Fig. 5). A bare soil aerial photograph was acquired, digitized, and inputted into the GIS to provide information regarding spatial variability in soil color. A soil electrical conductivity survey was also collected with an EM-38 sensor, and inputted into the GIS, providing another soil-based data layer for predicting grain yield response to N application across the landscape.

RESULTS

Output from the red and green version of the GreenSeeker® sensor (expressed as NDVI and GNDVI) acquired for the V-14 growth stage across small plots receiving different levels of N supply is depicted in Fig 3. These data show that the green version of the sensor is more sensitive in detecting variation in canopy greenness associated with N treatments than the read version (more variation in GNDVI vs. NDVI from plot to plot). Additionally, the variability in sensor readings was highly associated with variation in chlorophyll meter readings from the same plots (Fig. 4). Our results agree with those of Gitelson et al. (1996) and Shanahan et al. (2003), who found that the green band is more sensitive than the red band in detecting variation in canopy vigor or greenness, and would be more useful for assessing canopy N stress and applying N fertilizer.

Shown in Fig 6.is a late season aerial image, N treatment plot layout and grain yield response to N application by location for early (V-10) and late season (V-14) applications of N across a variable landscape. Yield responses to N application were much greater in the eastern vs. western portion of the field for both N application dates. The late season image further illustrates this, showing much greater variation in canopy color associated with N treatments for the eastern vs. the western portion of the field. Assessments of the associations (data not shown) between yield responses to N application for both dates and soil/crop variables indicate that the canopy reflectance, expressed as gNDVI, was a better predictor of N response than the soil variables (soil color and electrical conductivity).

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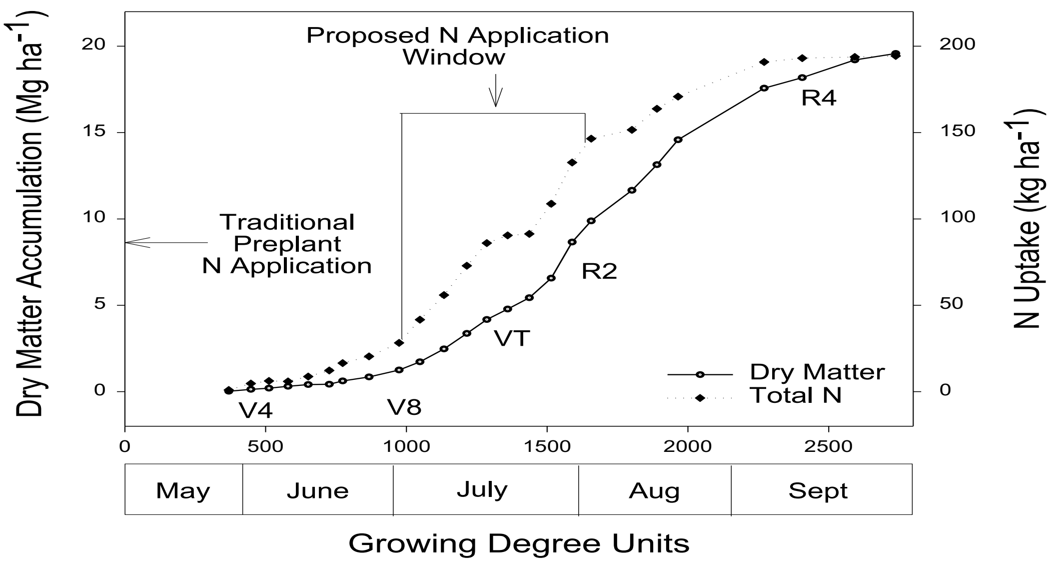

Figure 1. Corn N uptake versus accumulated growing degree units. Response curve derived from unpublished data from a study with six corn hybrids grown over two growing seasons at Shelton, NE in replicated plots. Crop dry matter and N accumulation were determined on a weekly basis throughout the entire growing season. Calendar dates and important phenological dates are depicted. Timing of N application for traditional versus proposed crop-based management scheme is also shown on the figure.

Figure 2. Pictured upper left is the high clearance N applicator illustrating key components, including the active GreenSeeker® crop canopy sensor mounted on front. Both the red and green versions of the active sensor manufactured by Ntech Industries, Inc. (http://www.ntechindustries.com/) were tested and evaluated. Shown in the upper right image is the liquid N fertilizer delivery system, consisting of two-drop nozzles/valves placed at alternating rows of corn. Depending on the configuration of valves turned on/off, the system can deliver a multiple of four (i.e., (0, 45, 90, 135 kg N/ha) rates of liquid N fertilizer on-the-go as directed by the controller system interfaced to the active sensor or with a prescription map.

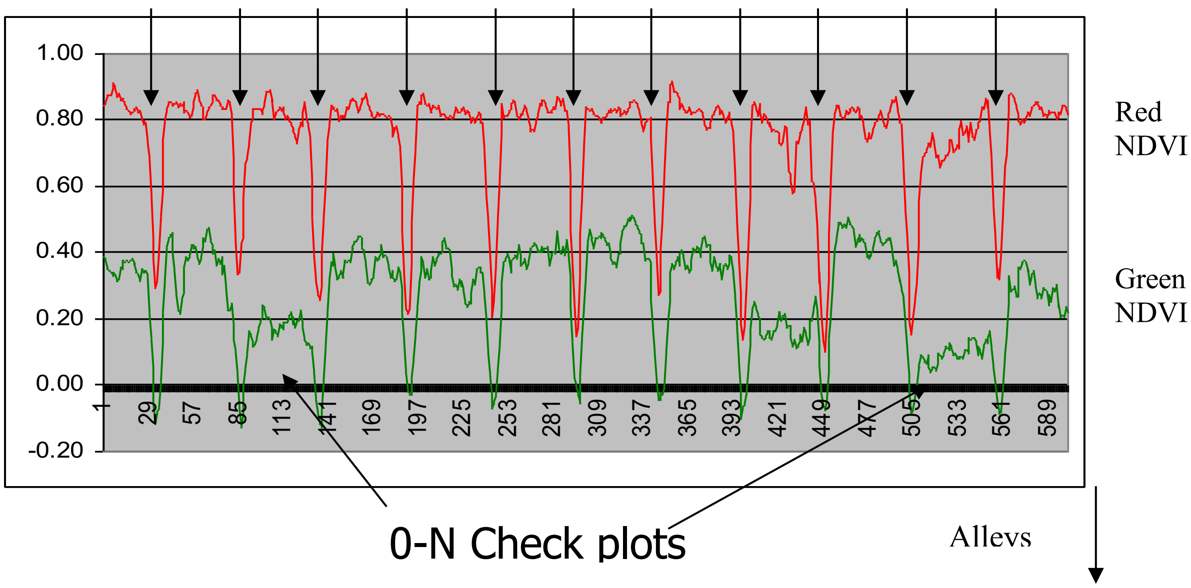

Figure 3. Sensor output from the red and green version of GreenSeeker®, expressed as NDVI and GNDVI, across small plots receiving different levels of N supply for the V-14 growth stage.

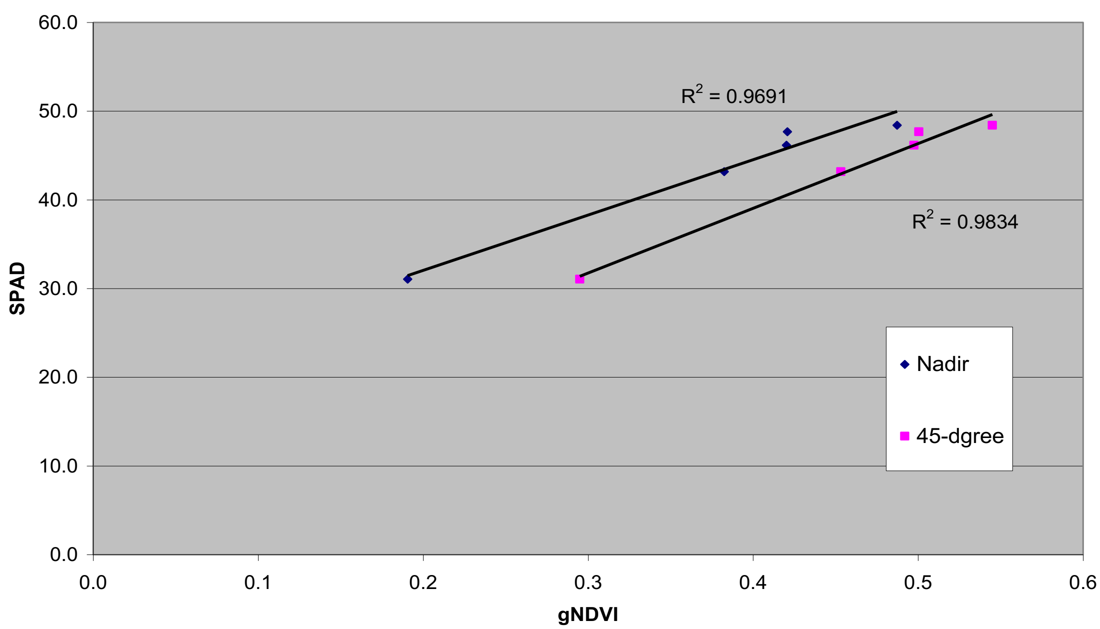

Figure 4. Association between GreenSeeker® sensor readings (gNDVI) for two sensor positions (nadir and 45 degree angle) and SPAD chlorophyll meter readings across small plots receiving different levels of N supply for the V-14 growth stage.

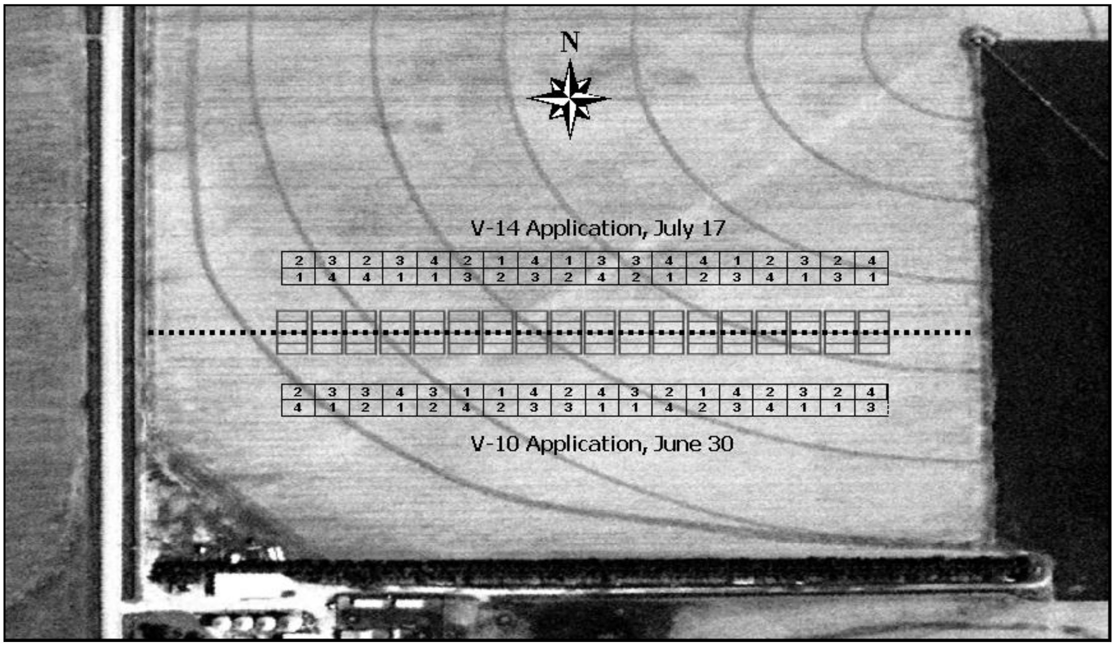

Figure 5. Depicted above is a study conducted under center pivot irrigation. Four N rates (0, 45, 90, and 134 kg N/ha), which correspond to treatments 1,2,3, and 4, respectively, were applied on two dates (V-10 and V-14 growth stages). The N rates treatments were replicated nine times across the landscape from west to east to evaluate N response across landscape variability.

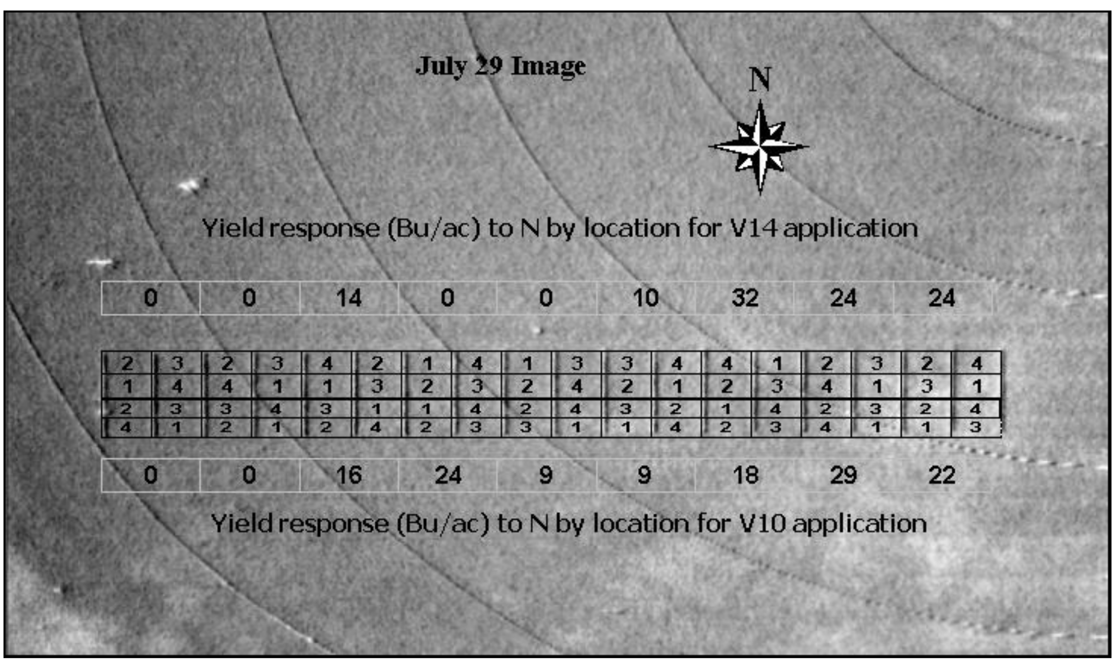

Figure 6. Depicted above is a late season aerial canopy image, N treatment plot layout shown if Fig. 5, and grain yield response to N application by location for early (V-10) and late season (V-14) application.