EVALUATION OF ACTIVE OPTICAL SENSORS FOR ASSESSMENT OF PLANT N IN IRRIGATED CORN

W. C. Bausch and A. D. Halvorson
USDA-ARS, Ft. Collins, CO
walter.bausch@ars.usda.gov (970) 492-7411

ABSTRACT

Nitrogen (N) fertilizer has received attention for a long time as a potential source of ground water pollution. Considerable research has been conducted to investigate use of remote sensing for assessing plant N status to improve N use efficiency. Most of these studies have used passive type sensors which require sunlight. Clouds hinder their performance. Active type sensors provide their own illumination which means they can be used to take measurements anytime of day under all possible sky conditions. This study compared two active sensor systems to a passive system and their response to various levels of leaf N content in irrigated corn (*Zea mays* L.). Results showed that the two active sensors responded differently to corn leaf N content. The active Holland Scientific Crop Circle[1] and the passive Exotech[1] data were somewhat similar. Additional research is required to fully understand the active sensor's behavior to plant N status to effectively utilize the sensor for in-season N management.

INTRODUCTION

Nitrogen fertilizer has received attention for a long time as a potential source of ground water pollution because of the mobility of the nitrate ion through the soil and because of the large amount of N fertilizer used. Significant savings in applied N have been reported by monitoring the crop's N status via remote sensing during the growing season and applying N as needed by the crop and where needed in the field (Scharf et al., 2002; Bausch and Delgado, 2003, 2005; and others). These results have been based on passive type systems which require the presence of sunlight. The occurrence of clouds is a hindrance to these systems.

A new generation of sensors referred to as active sensors that provide their own illumination are becoming commercially available. These sensors can be used to take measurements anytime of day under all possible sky conditions. Unfortunately, they have greatly reduced fields-of-view compared to the passive sensors because of power requirements. Consequently, research is required to understand the operational characteristics of these sensors and their deployment to obtain the information required to estimate plant N status for various crops. The objective of this paper was to compare two versions of active sensors to a passive system and their response to various levels of plant N imposed by applying different amounts of N to irrigated corn.

MATERIALS AND METHODS

Nitrogen fertility and tillage treatments were established in 1999 (Halvorson et al., 2006) on an irrigated Fort Collins clay loam soil at the Agricultural Research, Development, and Education Center, Colorado State University, north of Ft. Collins, CO. For the 2005 corn

[1] Brand names are provided for the benefit of the reader and do not imply endorsement by USDA-ARS.

growing season, Pioneer 38P03 (planophyle canopy) was planted on April 25 in north/south rows with a 30-in row spacing. Half of the N fertilizer was applied the day of planting as urea ammonium nitrate (32-0-0) and the remaining half was applied on June 9 [five leaf growth stage, V5 (Ritchie et al., 1986)] using a poly coated urea (45-0-0) with a 30-day release period.

The conventional-till corn plots were used in this study. They were arranged in a randomized complete block design replicated four times and had N applied at 0, 30, 60, 90, 120, and 220 lb N ac^{-1}. Data reported in this paper were acquired on July 21 (V16 growth stage) and August 11 (R2 growth stage) and consisted of tissue sampling for leaf N content, SPAD chlorophyll meter data, and canopy reflectance obtained with passive and active sensors. Two plants were removed from designated areas within each plot, separated into leaves and stems, oven dried at 50° C, ground, and analyzed; SPAD data were taken on corn plants from two adjacent rows as the observer walked through the plots; and canopy reflectance data were acquired with a high-clearance tractor traversing designated transects through the plot area.

Figure 1 shows the high clearance tractor with the various sensors. The passive sensing system used on the tractor consisted of three Exotech Model 100BX-T[1] four-band radiometers filtered in the blue, green, red, and near-infrared portions of the electromagnetic spectrum. One radiometer with a field-of-view (FOV) of 180° was positioned on the tractor ROPS to measure incoming solar irradiance while the other two radiometers (15° FOV) simultaneously measured canopy radiance from nadir and oblique views. The up-looking radiometer was automatically leveled. The nadir-view radiometer (on the boom pointed perpendicular to the crop surface, 0° view angle) was positioned 23.5 ft above ground for this study and viewed a 6.2-ft diameter spot on the ground; it was centered over the fifth row from the tractor's center. The oblique-view

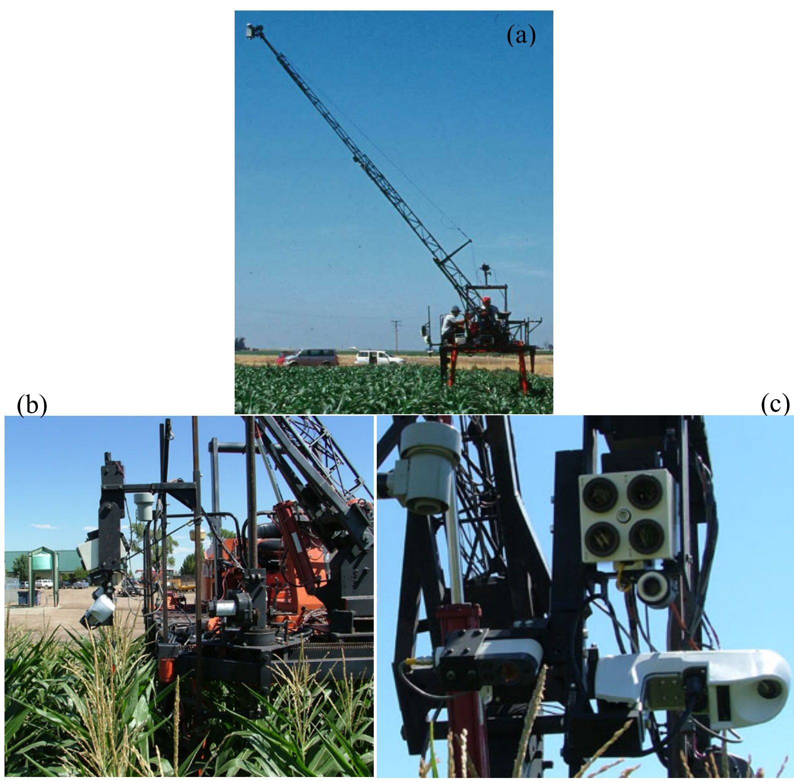

Figure 1. High clearance tractor instrumented for crop spectral measurements showing (a) extended boom with nadir-view radiometer, (b) front view of oblique-view radiometer and active sensors, and (c) side view of oblique-view radiometer and active sensors.

radiometer looked perpendicular to the corn rows; it was positioned 20° below the horizontal (70° view angle) and 2 ft above the canopy to view the same approximate area as the nadir-view radiometer. This view angle was automatically maintained with a gear motor and an inclinometer; its height was manually adjusted with another gear motor. Data from the Exotech radiometers were logged every second. The active sensors (NTech Industries GreenSeeker Model 506[1] and Holland Scientific Crop Circle ACS-210[1]) were mounted to the oblique-view Exotech radiometer platform and adjusted to view the adjacent corn row at a 45° view angle. This angle was automatically maintained via the Exotech platform. The sensor's illuminated area and its FOV was parallel to the corn stalks. Vertical positioning of the two active sensors placed the upper edge of the illuminated area near the top leaf of the corn plant. Distances between the sensor and the corn plants (stalks) were approximately 31 and 45 in from the top and bottom extremes of the illuminated area, respectively. Vertical position was maintained via manual adjustment of the Exotech radiometer platform. The active sensors were set at a 10 Hz sampling rate. The GreenSeeker Model 506 emits green and near-infrared light whereas the Crop Circle ACS-210 emits yellow and near-infrared light.

Both active sensors calculated the Normalized Difference Vegetation Index (NDVI). This index was designated as GNDVI for the GreenSeeker and YNDVI for the Crop Circle because the visible bands are green light and yellow light, respectively. The GNDVI was calculated for the Exotech radiometers. In addition to the NDVI, both sensors also output the visible (green for the GreenSeeker and yellow for the Crop Circle) and near infrared (nir) reflectance values. These data were used to calculate the N Reflectance Index (Bausch and Duke, 1996). The N Reflectance Index (NRI) requires a well fertilized reference area to normalize the nir/visible ratio. One of the 220 lb ac^{-1} N treatment plots was designated as the reference. This plot was also used as the reference for SPAD data to calculate the N Sufficiency Index (NSI). The NRI was also calculated for the Exotech data.

RESULTS AND DISCUSSION

All data from the four replications of each N treatment were averaged (three for the high N treatment) for graphing and analysis. Figure 2 depicts plant response in terms of leaf N content to the various N treatments at the V16 and R2 corn growth stages. A good range of leaf N was available for this study. Relationships between leaf N content and various surrogates (chlorophyll meter and vegetation indices) for the two corn growth stages are shown in figures 3 and 4. Axis scales were kept the same for all graphs for comparison purposes. The Exotech data are presented in terms of oblique view data at the V16 growth stage, whereas at R2, nadir view

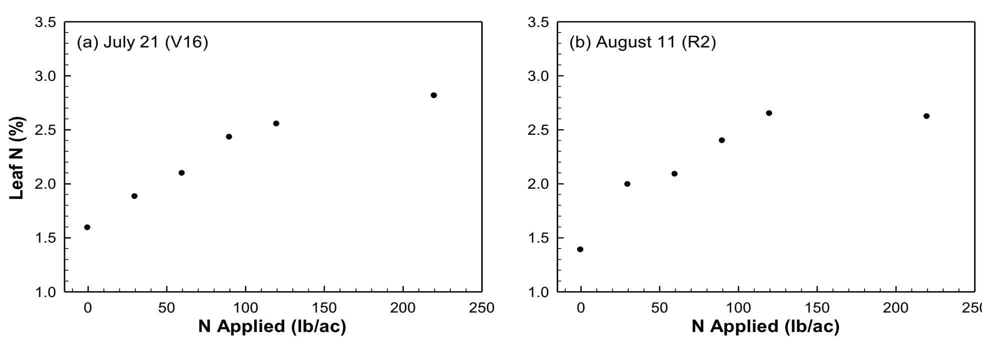

Figure 2. Plant response to applied N at two corn growth stages.

data were used. This was done because oblique view data minimize soil background influences; however, after tasseling, the tassel overwhelms the oblique view Exotech data. The most notable difference among the graphs is the GreenSeeker data at the V16 growth stage. Both the GNDVI and the NRI show a negative correlation for the 0 to 120 lb ac^{-1} N treatments instead of a positive correlation as indicated by the Exotech and Crop Circle data. At the R2 growth stage, the relationships have positive correlations. The Exotech and Crop Circle NDVI have similar slopes (visual) and range from low to high leaf N for both growth stages. Between the two vegetation indices, the NRI provides more response to leaf N than the NDVI. However, if the NDVI was also normalized to the reference area, the response may be similar.

CONCLUSION

Based on this limited data set, the two active sensors respond differently to irrigated corn leaf N content, however, the active Crop Circle and the passive Exotech data are somewhat similar. To effectively utilize either active sensor for in-season N management, additional research is required to fully understand the sensor's behavior to the particular crop of interest.

REFERENCES

Bausch, W.C. and J.A. Delgado. 2005. Impact of residual soil nitrate on in-season nitrogen applications to irrigated corn based on remotely sensed assessments of crop nitrogen status. Precision Agric. 6:509-519.

Bausch, W.C. and J.A. Delgado. 2003. Ground-based sensing of plant nitrogen status in irrigated corn to improve nitrogen management. In: *Digital Imaging and Spectral Techniques: Applications to Precision Agriculture and Crop Physiology*, edited by T. VanToai, D. Major, M. McDonald, J. Schepers, and L. Tarpley, (ASA Special Publication 66, ASA, CSSA, SSSA, Madison, WI, USA), p. 145-157.

Bausch W.C. and H.R. Duke. 1996. Remote sensing of plant nitrogen status in corn. Trans. ASAE. 39:1869-1875.

Halvorson, A.D., A.R. Mosier, C.A. Reule, and W.C. Bausch. 2006. Nitrogen and tillage effects on irrigated continuous corn yields. Agron. J. 98:63-71.

Ritchie, S.W., J.J. Hanaway, and G.O. Benson. 1986. How a corn plant develops. Iowa State Extension Service Special Report 48. Iowa State University, Ames, IA.

Scharf, P.C., W.L. Wiebold, and J.A. Lory. 2002. Corn yield response to nitrogen fertilizer timing and deficiency level. Agron. J. 94:435-441.

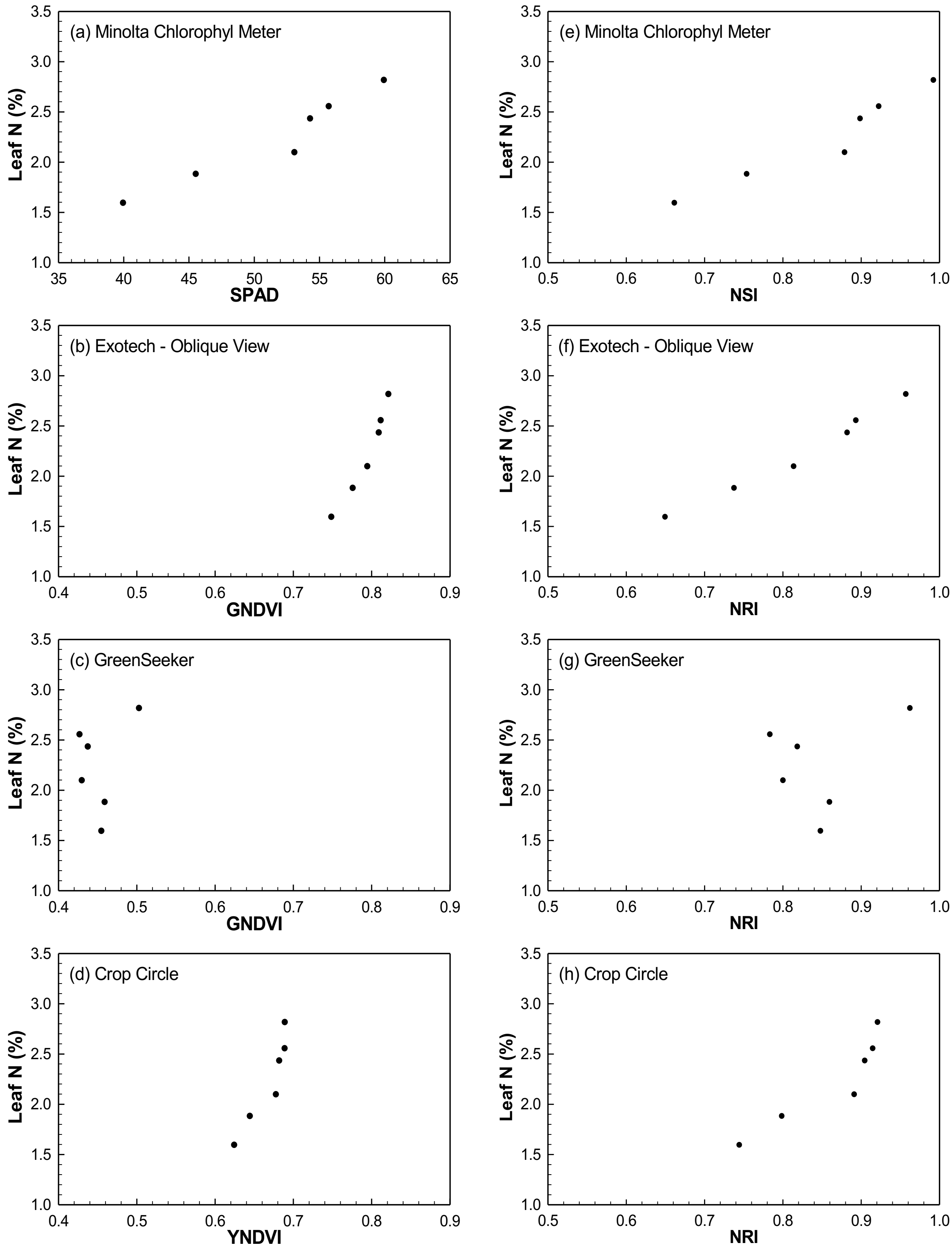

Figure 3. Relationships between leaf N and various surrogates at the V16 corn growth stage.

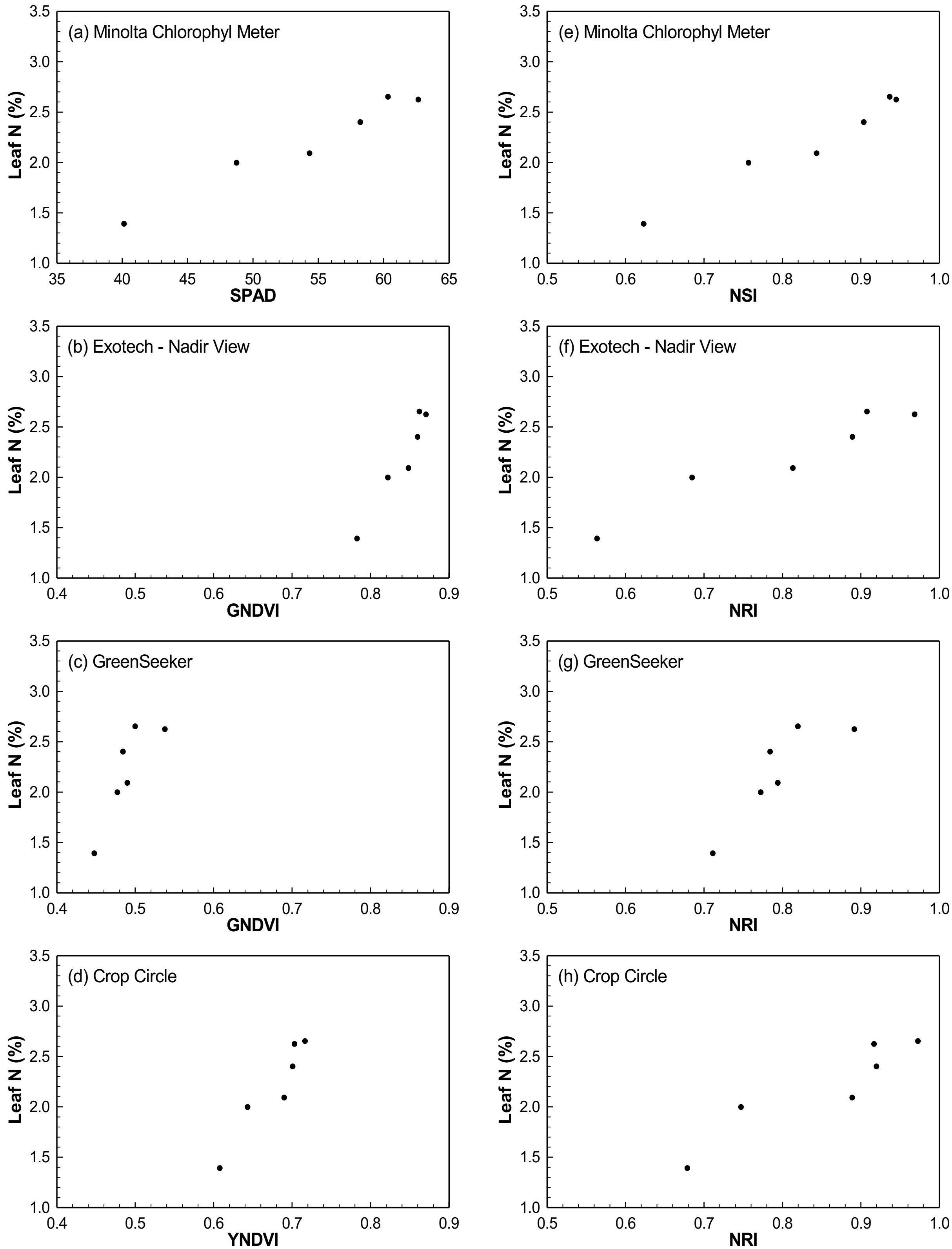

Figure 4. Relationships between leaf N and various surrogates at the R2 corn growth stage.