REMOTE SENSING TECHNIQUES TO IDENTIFY N DEFICIENCY IN CORN

T.M. Blackmer, J.S. Schepers, and G.E. Varvel[1]

ABSTRACT

Nitrogen management remains a primary concern for corn production. Environmental consciousness has increased the need for diagnostic techniques to identify N deficiencies to guide corrective measures or to provide feedback on management practices. This study was designed to evaluate several techniques that measure reflectance from corn plants to detect N stress. The experiment was located in Central Nebraska and involved four hybrids and five N rates. Leaf reflectance, canopy reflectance, and aerial photographs were evaluated for their ability to diagnose N stress. Leaf reflectance of green light was inversely correlated with chlorophyll meter readings. Canopy reflectance varied in its ability to detect N stress depending upon the wavelength measured. Reflectance near 550 nm and 710 nm provided the most sensitive separation between different N treatments. Digital analysis of the negatives of aerial photographs, especially the red gray scale, provided good detection of N stressed treatments that resulted in lower yields. All three methods effectively identified N deficient portions of a field as long as a proper in-field reference was used.

INTRODUCTION

Increasing pressure to lower N fertilizer usage raises concerns about possible N deficiencies that can result in yield loss. One way to address these concerns is to monitor the resulting crop canopy during the growing season for signs of N stress. In some instances, this stress can be corrected or minimized by applying additional fertilizer N. Additional fertilizer can be applied after sidedress time through fertigation techniques in irrigated areas or by high clearance applicators in dryland conditions. Nitrogen deficiencies detected too late for correction during the current growing season could be valuable in identifying areas within a field that would benefit from different N management in future years. Current tests like leaf N at silking, and chlorophyll meter readings provide information that is only as representative as the plants sampled.

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Chlorophyll meters have shown that monitoring chlorophyll in a corn plant can be used to identify N stress (Schepers et al., 1992, Wood et al., 1992). These measurements have been extremely effective for identifying N stress, but they are fairly time consuming and site specific. Other methods which incorporate larger areas in their scope of measurement would be more desirable. Leaf reflectance measurements are affected by chlorophyll concentration (Thomas et al., 1977) and are affected by N stress (Al-Abbas et al., 1974, Blackmer et al., 1994). Canopy reflectance measurements have also been used to identify N deficiency of a corn canopy (Walburg et al., 1982). Canopy reflectance has the advantage of incorporating reflectance from more than a small portion of a corn leaf. Both the larger sampling size and reduced labor (by not sampling many individual leaves) make canopy reflectance measurements an appealing remote sensing diagnostic tool. Another remote sensing tool, aerial photography, has been shown to be effective in vegetation analysis (Benton et al., 1976) and computer methods have been developed to analyze photographic images of crop canopies (Thomas et al., 1988).

The purpose of this paper is to discuss several of these techniques that could be used to identify N stress in a corn canopy.

MATERIALS AND METHODS

This study was conducted in 1992 on N response trials for four irrigated corn hybrids at the Nebraska Management Systems Evaluation Area (MSEA) project near Shelton, Nebraska. Corn was planted in 8-row (36" spacing) by 50-ft long plots in a east-west direction and fertilized at planting with NH_4NO_3 at rates of 0, 45, 90, 135, and 180 lb N/A. Pioneer brand hybrids 3162, 3379, 3394, and 3417 were planted at ~27,000 seeds/A. The experimental design was a split plot randomized complete block with four replications. Whole plot treatments were hybrids and the split plot treatments were N treatments.

Leaf Measurements

In early August of 1992, N deficiencies were observed visually and detected with a SPAD 502 chlorophyll meter[2]. At this time, the ear leaf of ten representative plants from each plots were packed in a dark cooler and transported to the laboratory for reflectance measurements. Reflectance measurements were made from 400 to 700 nm in 10-nm band widths. Three measurements per leaf were taken mid-length and midway

[2]Mention of trade names or proprietary products does not indicate endorsement by USDA, and does not imply its approval to the exclusion of other products that may also be suitable.

between the midrib and leaf edge. Chlorophyll meter readings were taken from the same portion of the leaf.

Canopy Reflectance Measurements

Canopy radiation reflected over the 350 to 1050 nm range was measured in late August using a Spectron Engineering model SE-590 portable spectroradiometer with a 15-degree field of view optic. Plants were at the R5 (dent) growth stage when measurements were made. Sensors were mounted on a vertical pole and positioned 15 ft above the ground and directed parallel to the corn rows at a 40 degree angle from vertical. All measurements were made in triplicate on days without cloud cover. Measurements proceeded from N rates within hybrids to hybrids within blocks. The reference plot (plot with highest N rate) and the four other N rates within a hybrid for a given replication were randomly sampled within a 10 minute time period. Reflectance values reported from this study are expressed as a ratio of reflected radiation from treated plots to that from the highest N rate treatment within a hybrid (referred to as relative canopy reflectance).

Aerial Photographs

Aerial photographs using ASA 200 Kodak Gold were taken in late August in 1992. All negatives were digitized using a Nikon LS 3500 slide scanner and the software package Photostyler® by Aldus on a 486 Windows based personal computer. Each digitized image was analyzed using the Media Cybernetics Image Pro Plus® software package. The Nikon scanner provided a VGA image in 24-bit color (8 bits red, 8 bits green, and 8 bits blue), representing non-normalized RGB coordinates with integral values from 0-255. The intensity of each of these colors was converted into a gray-scale value. The average gray scale value of each color for each field plot was calculated by summing the product of the gray scale value and the percentage of pixels containing that value. The gray scale is a method used to measure differences in film exposure that resulted from differences in reflectance. The process of generating a gray scale is somewhat synonymous with creating a black and white image of the color photograph. For example, the red gray scale value is generated for only the red component of each colored pixel. Relative gray scale averages were calculated by dividing the average gray-scale value for each N rate by that of the highest N rate within each hybrid.

RESULTS AND DISCUSSION

All four hybrids were responsive to N fertilizer. Leaf reflectance around 550 nm was inversely correlated with chlorophyll meter readings (Fig. 1). The negative slope of the relationship means that more light at 550 nm was reflected by the leaves of more deficient treatments which had lower chlorophyll meter readings. Less light utilized by the leaf results in less photosynthetic activity, which results in lower plant dry matter production and lower grain yields. The high correlation between leaf reflectance and chlorophyll meter readings demonstrates the potential of reflectance measurements to identify N deficiencies. However, the convenience of reflectance measurements would be more useful if canopy reflectance could be measured as opposed to trying to measure individual leaves.

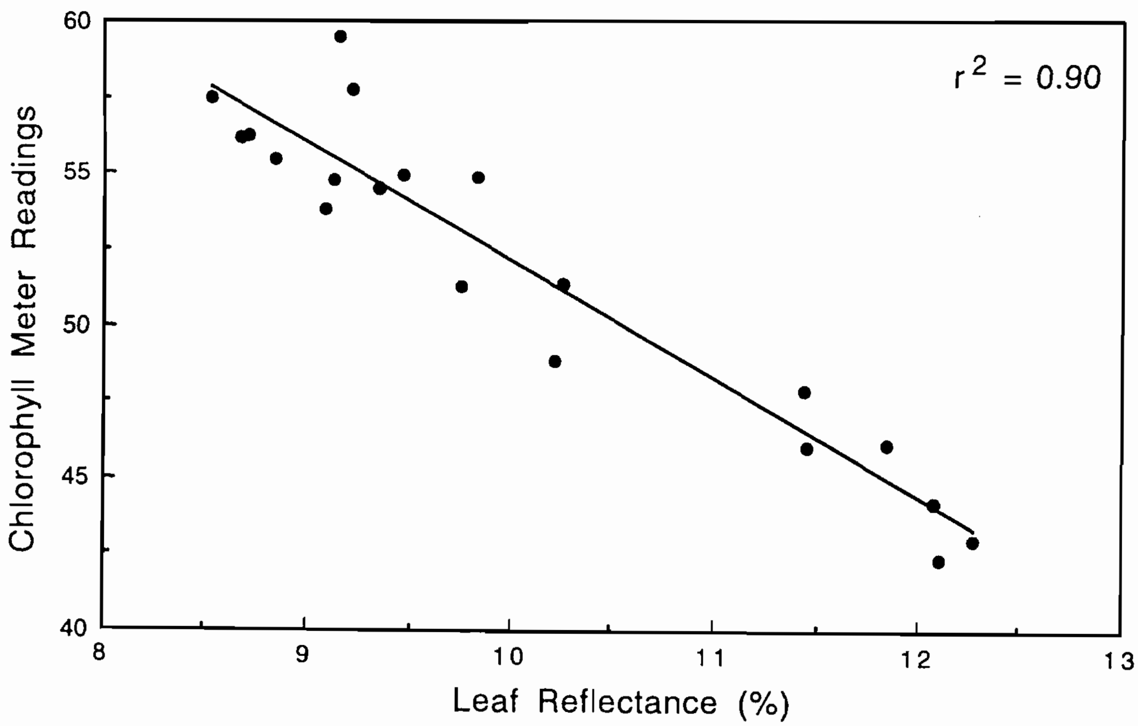

Figure 1. Leaf reflectance at 550 nm vs. chlorophyll meter readings for four hybrids and five N rates.

In order for canopy reflectance to quantify N deficiencies, the reflectance from upper leaves must be indicative of the N deficiency because they are what will be seen by a sensor located over the canopy. Figure 2 illustrates the relationship between chlorophyll meter readings and N rates as affected by leaf position. Upper leaves have the same relative capability of separating N status as the middle and lower leaves. This suggests that canopy reflectance dominated by upper leaves could be used to detect N stresses.

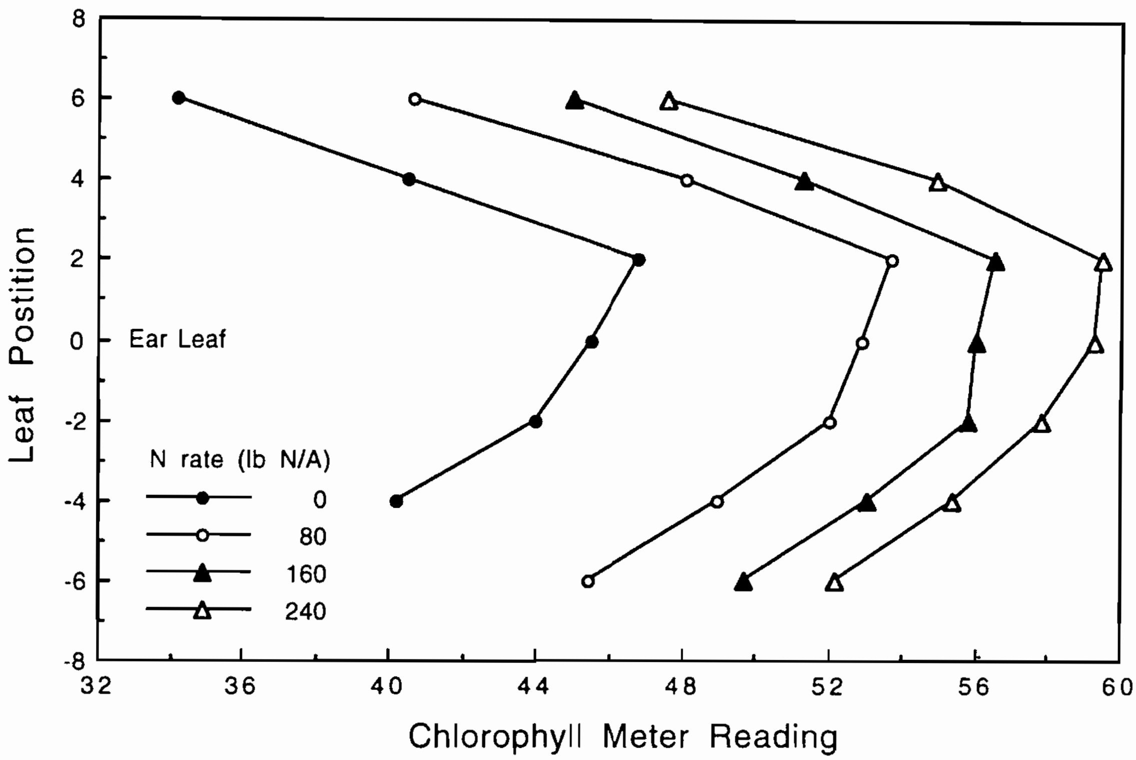

Figure 2. Chlorophyll meter readings as affected by N rate and leaf position.

Canopy reflection measurements were collected at the R5 growth stage. Peak sensitivity to N stress occurred around 550 and 710 nm for each hybrid (Figure 3). Because of reflectance differences among hybrids, within N rates, reflectance values were normalized by calculating a ratio with the highest N rate. Light reflectance around 550 nm was consistent with individual N deficient leaf reflectance measurements. The use of two separate wavelengths used as a ratio resulted in higher correlation than individual wavelengths. Ratios of reflectance involving both an wavelength interval of peak sensitivity to chlorophyll concentration and an interval not sensitive to pigmentation provide some degree of standardization against factors affecting reflectance other than pigmentation differences. In addition, a ratio calculated from two wavelengths measured simultaneously may be less sensitive to

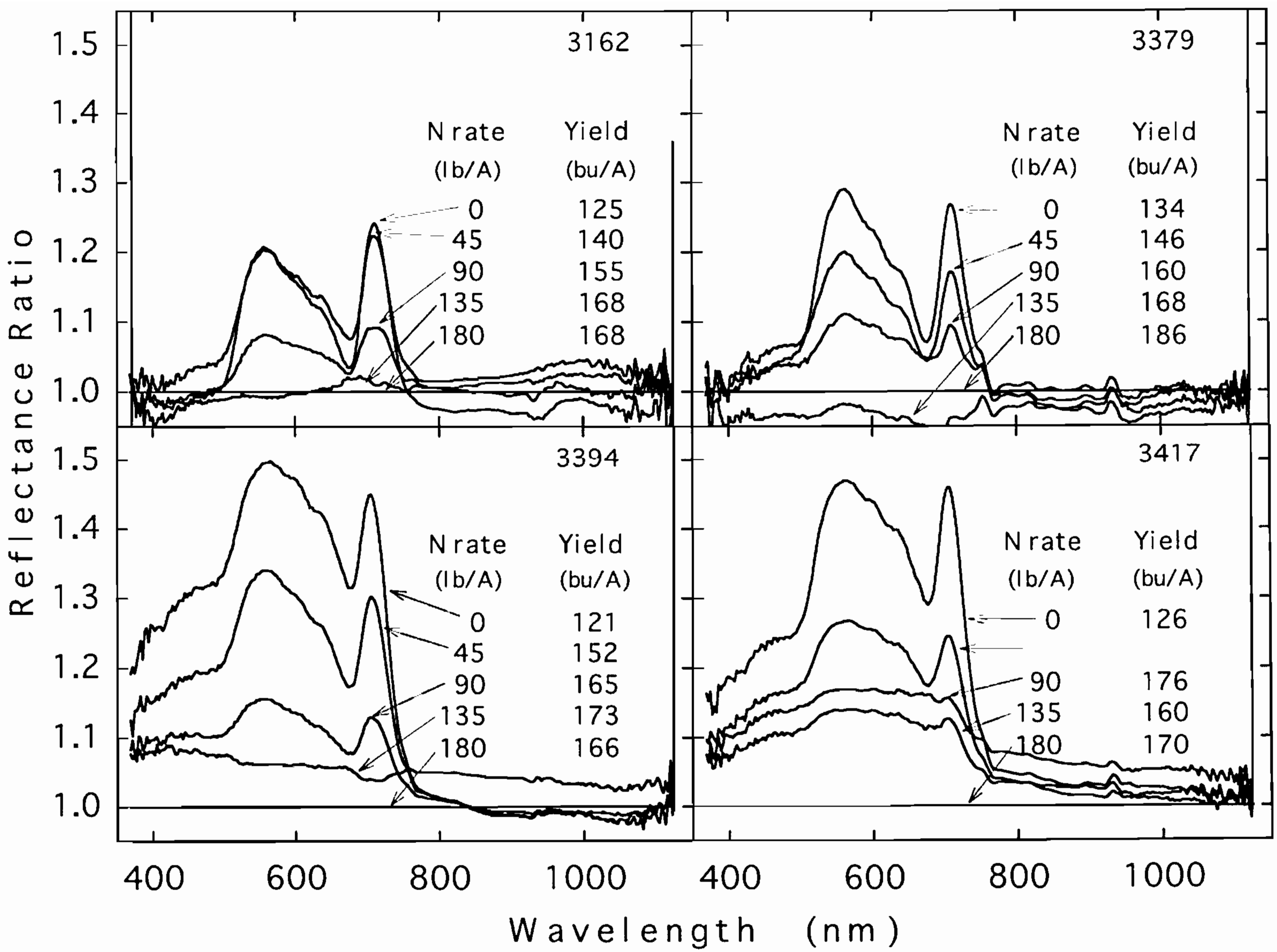

Figure 3. Relative canopy reflectance and grain yield for four Pioneer brand hybrids and five N rates.

fluctuations in incoming light (clouds or solar angle) than a individual measurement. This becomes important when comparing measurements taken from different portions of a field. Regression data for reflectance from individual hybrids at various wavelengths as well as for specific combinations are reported in Table 1. These data are helpful in identifying key wavelengths to monitor N deficiencies in a corn field.

Table 1. Correlations between grain yields and canopy reflectance ratios at various wavelengths at the R5 growth stage for corn.

	Wavelengths (nm)						
	Individual				Combination ratio†		
Hybrid‡	450	550	650	710	(830/660)	(575/850)	(710/850)
	r^2						
3162	0.05	0.71	0.63	0.77	0.70	0.82	0.72
3379	0.28	0.85	0.71	0.80	0.78	0.93	0.85
3394	0.85	0.94	0.93	0.96	0.95	0.96	0.96
3417	0.56	0.77	0.70	0.81	0.72	0.81	0.80
Combined	0.24	0.66	0.45	0.68	0.60	0.86	0.68

† Combination ratios are labeled as the mean of each wavelength interval. The actual intervals are (760-900 nm)/(630-690 nm), (550-600 nm)/(800-900 nm), and 710 nm/(800-900 nm).

‡ Pioneer brand hybrids.

An aerial photograph can monitor reflectance for an entire field at one time because differences in reflectance will result in differences in exposure on the film. Use of a filter on the camera restricts light to a desired wavelength, thus mapping differences in reflectance at the most sensitive wavelength. Another approach is to obtain a color photograph which can be broken down into components representing the three primary colors (red, blue, green) which are indicative of different portions of the visible spectrum. Differences in exposure, caused by differences reflectance, can be reported as a gray scale for each color. The results from color photographs taken at the R5 growth stage, showed that the gray scale for the red color provided the best predictor of grain yield response (Fig. 4).

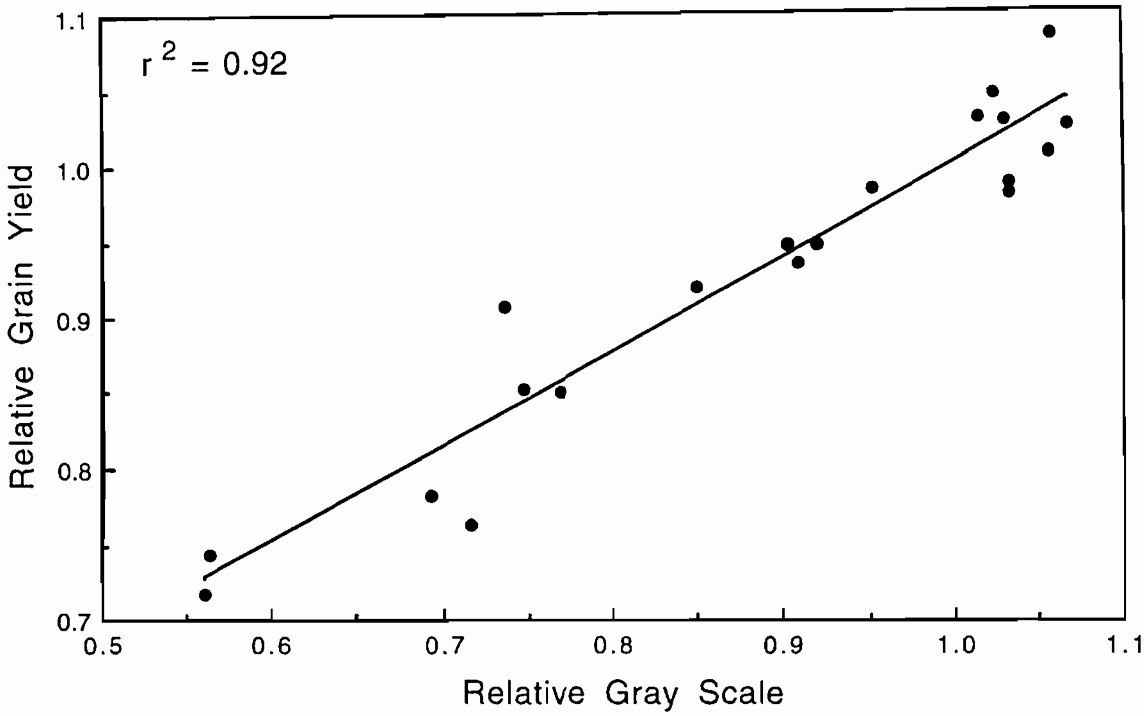

Figure 4. Relationship between relative red gray scale and relative grain yield for four hybrids and five N rates.

CONCLUSION

The three different types of reflectance measurements discussed in this paper were capable of detecting N stress that resulted in grain yield reduction. Reflectance at 550 nm and 710 nm provided the best quantification of N stress while other wavelengths varied in sensitivity. Relative red gray scale calculated from digitized negatives of aerial photographs was a good predictor of N stress that resulted in yield reduction. Remote sensing techniques require less labor to collect data and can represent more areas of a field than methods that require sampling individual plants.

REFERENCES

Al-Abbas, A.H., R. Barr, J.D. Hall, F.L. Crane and M.F. Baumagardner. 1974. Spectra of normal and nutrient-deficient maize leaves. Agron. J. 66:16-20.

Benton, A. R., Jr., R.H. Hass, J.W. Ronse, Jr., and R.W. Toler. 1976. Low-cost aerial photography for vegetation analysis. J. Applied Photo. Eng. 37:46-49.

Blackmer, T.M., J.S. Schepers, and G.E. Varvel. 1994. Light reflectance compared to other N stress measurements in corn leaves. (In press). Agron. J.

Schepers, J.S., D.D. Francis, M. F. Vigil, and F.E. Below. 1992. Comparisons of corn leaf nitrogen concentration and chlorophyll meter readings. Comm. Soil Plant Anal. 23:2173-2187.

Thomas, D.L., F.J.K. daSilva, and W.A. Cromer. 1988. Image processing technique for plant canopy cover evaluation. Trans. ASAE 31:428-434.

Thomas, J.R. and H.W. Gausman. 1977. Leaf reflectance vs. leaf chlorophyll and carotenoid concentration for eight crops. Agron. J. 69:799-802.

Walburg, G., M.E. Bauer, C.S.T. Daughtry, and T.L. Housley. 1982. Effects of nitrogen nutrition on the growth, yield, and reflectance characteristics of corn canopies. Agron. J. 74:677-683.

Wood, C.W., D.W. Reeves, R.R. Duffield, and K.L. Edmisten. 1992. Field chlorophyll measurements for evaluation of corn nitrogen status. J. Plant Nutr. 15:487-500.

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