REMOTE SENSING AS A TOOL FOR AGRICULTURE

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ABSTRACT

The tendency for nearly everything in our society to be bigger, better, faster, easier, cheaper, and safer than in the past has resulted in many challenges. Agriculture is not immune from these trends, and in some cases agriculture even leads the way. Incorporation of remote sensing into site-specific management activities is one area where technologies are being merged to develop a new array of products that are intended to help producers and consultants make better and more timely management decisions. Some of the new technologies involve a substitution of one type of measurement for another, while others involve scaling-up from individual plants or plot measurements to an entire field. Progressing from leaf N analyses in the laboratory to chlorophyll meter readings for select plants in a field to aerial photographs of an entire field represents a wide range in technologies. This research is attempting to bridge these technologies and better understand the strengths and limitations of each related to site-specific management.

INTRODUCTION

Considerable progress has been made in how we measure and assess crop N status. Each of these advancements comes with advantages and as well as some limitations. Being aware of these limitations or at least recognizing the need for caution when considering new technologies is becoming ever more critical as technologies are merged to generate impressive new products and types of information.

Introduction of the Minolta SPAD-502 chlorophyll meter has been promoted as a fast, easy, and convenient substitute for leaf N determinations that are made in a laboratory. This proposed substitution involves compromises and linkages that may not be obvious in that the correlation between the two types of data are usually very good. One advantage the chlorophyll meter holds over determining leaf N concentration is that data coming from the Minolta SPAD-502 meter is a measure of leaf photosynthetic activity which is closely related to yield. On the other hand, the typical management response to reduced photosynthetic activity is to add N fertilizer if it could be limiting. With this in mind, is it better to measure leaf N concentration or monitor crop N status using a chlorophyll meter? The

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answer depends on the intended use of the data and ultimately on how easy and cost effective it is to generate the information. Embedded within the answer are many considerations such as the spatial and temporal limitations on how the data were collected and how it will be applied.

All too often, field measurements of crop N status involve a few plants from which decisions are made to represent much larger areas. Not only are these point-in-time measurements, but they are influenced by interactions between the soil and climate. Perhaps these relationships are so complex that it is desirable to let the plant represent an integration of all pertinent processes. This strategy would seem to permit real-time monitoring of the crop to assess the dynamics of N in soil.

Spatial and temporal variability in soil represent major problems when attempting to manage N in such a way so as to minimize nitrate leaching and still not reduce yields to the point of reducing profitability. It follows that situations resulting from spatial variability in soils within a field could create opportunities for temporal solutions, especially since climate is the major driving factor in most biological systems. In fact, the temporal aspect of N mineralization and the patterns of crop growth result in positive feed-back situations that beckons for frequent assessment of crop N status and correction if a deficiency appears eminent.

Monitoring crop N status on a whole field basis is not practical using tissue sampling procedures or even chlorophyll meters. This is why other approaches for monitoring crop N status will be required if producers hope to assess the spatial and temporal variability in fields. This research was intended to determine the relationship between chlorophyll meter readings and corn yields, with the intention of better defining when and how remote sensing might be used to improve N management.

MATERIALS AND METHODS

Chlorophyll meter readings were taken with Minolta SPAD-502 meters on sprinkler-irrigated corn throughout the growing season at the Nebraska Management Systems Evaluation Area (MSEA) project near Shelton, Nebraska. Corn was fertilized at 0, 50, 100, 150, and 200 kg N/ha. The study involved both continuous corn and corn grown in rotation with soybean since 1991.

Chlorophyll meter readings for each sampling date during the growing season were normalized relative to the highest fertilizer N rate for that date. This permits evaluation of changes in crop N status during a growing season as influenced by fertilizer N treatment. Grain yield was also normalized relative to the highest N rate for a given year.

RESULTS AND DISCUSSION

Normalization of chlorophyll meter data by sampling date within a cropping system and grain yield within a year facilitated evaluation across cropping systems (i.e., continuous corn and a corn/soybean rotation), years, and fertilizer N treatments. Normalization also helped characterize trends and identify unique situations that should be helpful when considering remote sensing as a N management tool. Data from 1991 are not presented because this was the first year of the study and as such the site was not responsive to the N fertilizer treatments. Crop damage caused by strong winds in July of 1993 and 1994 reduced yields by 30 to 35% compared to the average yield for 1992, 1995, and 1996 (11.38 Mg/ha with adequate N fertilizer). Wind damage in 1993 increased with fertilizer N rate and was generally more severe for corn following soybean than for monoculture corn. As such, crop response to N fertilizer was atypical in 1993. Wind damage in 1994 reduced plant populations in all plots to the point where no N response was observed (average yield for continuous corn across N rates was 7.83 Mg/ha in 1994 compared to 11.47 Mg/ha for 1992, 1995, and 1996).

Trends in crop N status expressed as relative chlorophyll meter readings illustrate the relative consistency of meter readings for a given N rate throughout the season (Figure 1). At some N rates and in some years, patterns of relative crop N status provided valuable in-sights into factors that influence yield. For example, early season N stresses (relative chlorophyll meter values <0.95) that became more severe during the season as in 1992 reduced yields more than would be expected based on the early season chlorophyll meter readings.

Growing conditions that promoted early season mineralization as in 1995 tended to minimize crop N stresses even during the rapid N uptake period prior to silking (Figure 1). The 1995 data suggest that as long as early season relative chlorophyll meter readings stay near 0.95 (50 kg N/ha) or higher (>100 kg/ha), then near maximum yields can be expected. A similar scenario developed in 1996 except it required 100 kg N/ha to maintain a relative chlorophyll meter value of ~0.95.

Moderate to severe early season N stresses can significantly reduce grain yields even though the crop may not demonstrate an N stress at silking (no N fertilizer in 1995). The situation in 1996 was similar except that little irrigation was required and thus little N was applied via the water (~30 mg/L nitrate-N). In this case, N was not available to reduce the stress (0 and 50 kg N/ha in 1996) and yields were reduced to a greater extent than the relative chlorophyll meter readings would suggest might be expected.

Although chlorophyll meters were not developed to predict relative grain yield, the availability of such data presents a temptation. Relative chlorophyll meter values and relative yields for the three years follow similar trends (Figure 2). In general, the greater the N stress (i.e., lower relative chlorophyll meter values), the lower the relative yield. Beyond that, it is not possible to make generalizations because of climatic conditions that influenced mineralization and the need for irrigation which supplied supplemental N to the crop. As such, it was not possible to identify an ideal stage of growth or time during the growing season to predict corn yields. However, if one considers only situations where relative chlorophyll values and relative yields were <0.95, then the data clearly show yield reductions are very likely to be greater than would be suggested based on relative chlorophyll meter values alone. This observation emphasizes the importance of adequate early-season N nutrition for corn production.

Moving beyond chlorophyll meters to remote sensing to monitor crop N status presents a challenge because the parameters involved are usually not a true measure of photosnythetic activity. Rather, the measurements are only related to something that is in turn related to yield. As one might expect, the combination of several loose linkages can be an unreliable relationship. On the other hand, sometimes parameters can be identified that effectively integrate several factors and thus result in valuable information that is other wise difficult to understand. For example, chlorophyll meter readings provide information about the photosnythetic activity of individual leaves but fail to integrate factors like the number of leaves per unit area. Canopy reflectance measurements can provide information about both crop N status and existing biomass, but the measurements may be confounded by other stresses or reflectance from the soil. This example also helps to illustrate why the reliability of some relationships may change as the crop matures.

Remote sensing is best viewed as a tool for management because the information that can be provided to producers and consultants is no better than the understanding that goes into the interpretation. Because biological systems are dynamic, they are essentially a moving target in terms of remote sensing. Therefore, our techniques to interpret remotely sensed images in agriculture need to be robust and have the potential to integrate the expertise of many disciplines and vocations.

Fig. 1. Relative chlorophyll meter readings during the growing season and relative yield for irrigated corn at several N fertilizer rates.

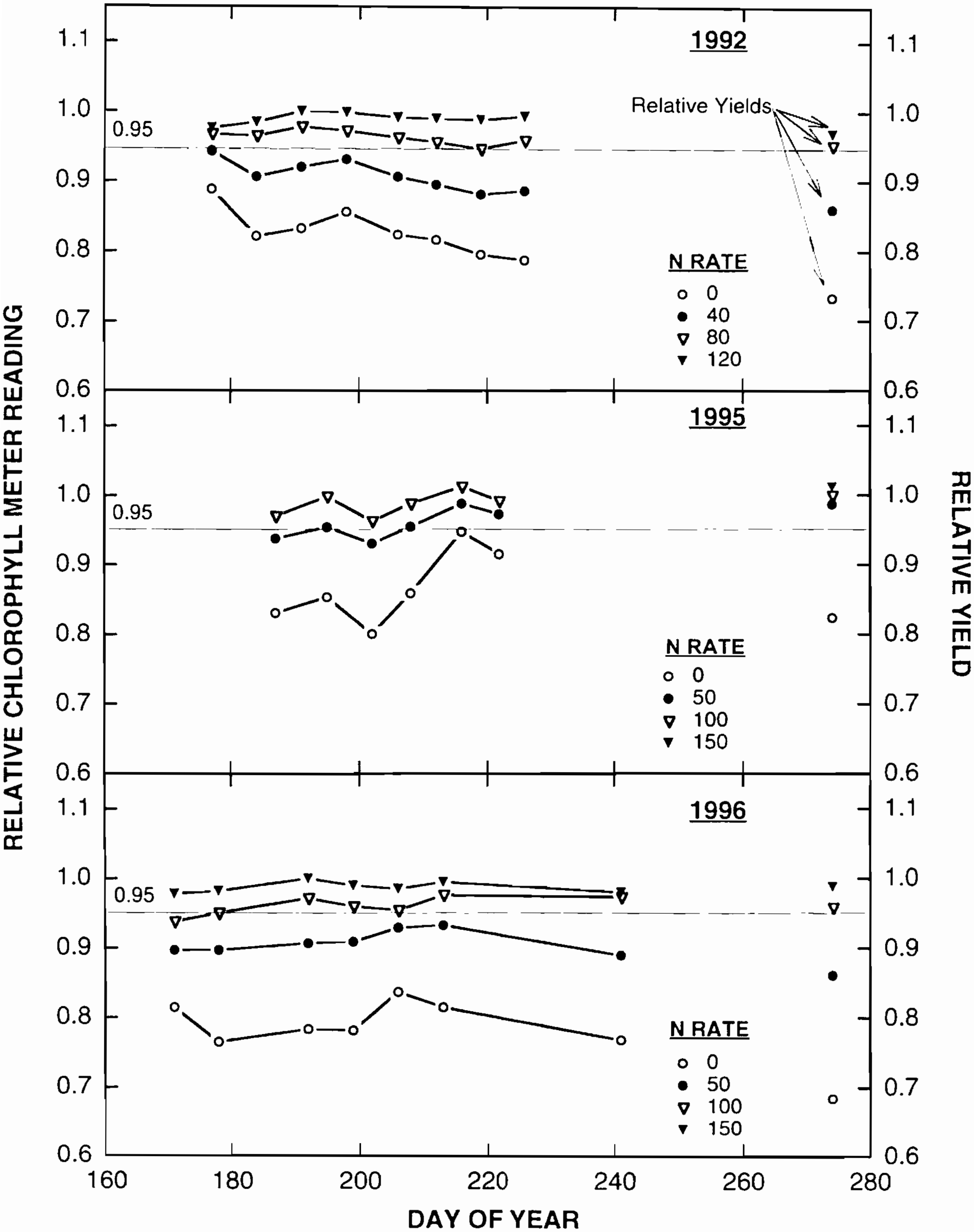
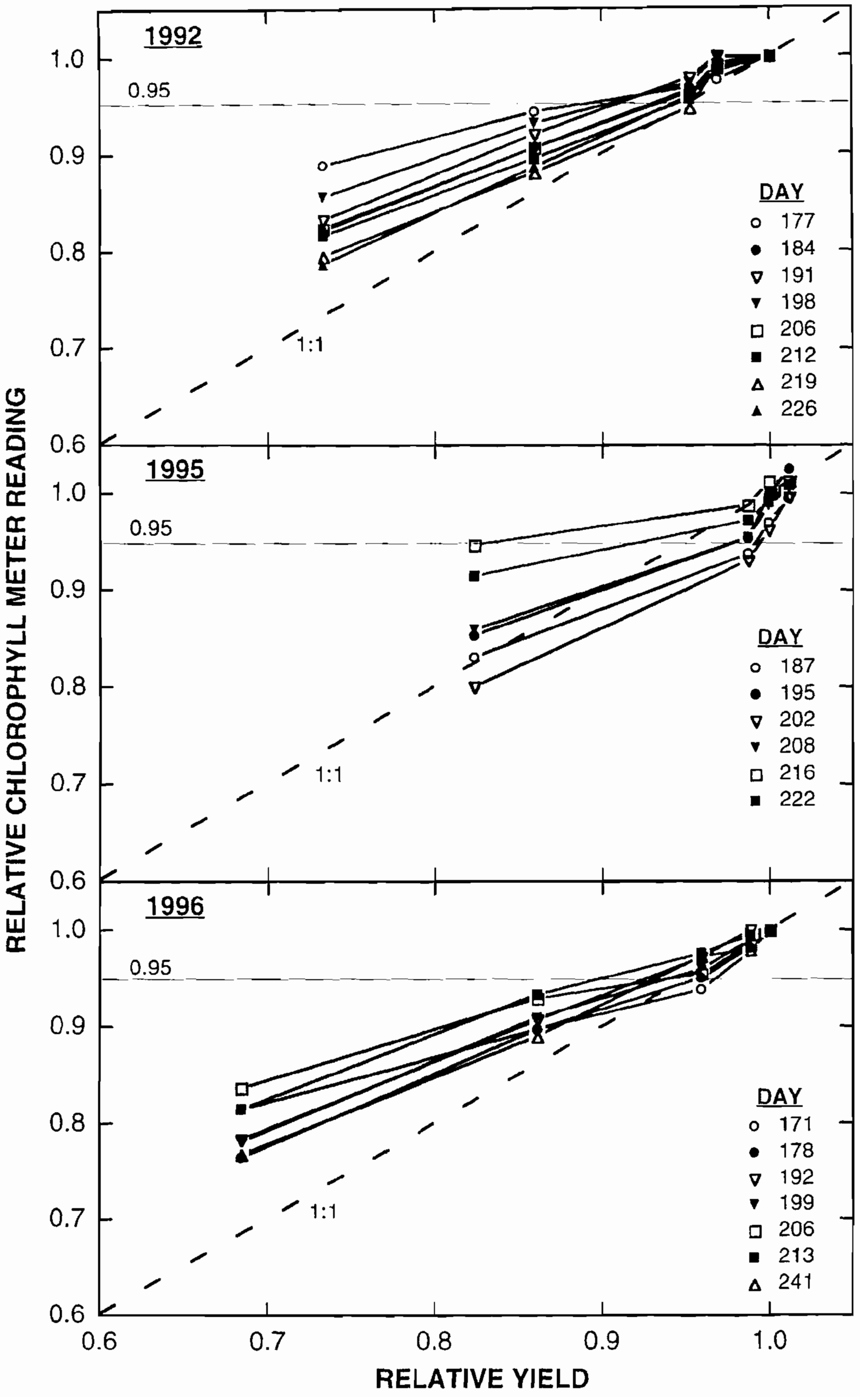


Fig. 2. Relative chlorophyll meter readings versus relative yield for irrigated continuous corn at several times during the growing season.



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