Assessing Crop Nitrogen Needs With Chlorophyll Meters

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Abstract

Tissue testing of corn leaves for nitrogen (N) concentration is not widely used because it is easier and perhaps more economical to apply sufficient fertilizer than to risk a yield reduction because of an N deficiency. Environmental concerns related to N fertilizer will require producers to improve N management practices to reduce the potential for nitrate leaching. Applying fertilizer N on an "As Needed" basis rather than using a "Lump Sum" approach has both environmental and economic implications. Corn leaf disk N concentrations and SPAD 502 chlorophyll meter readings from N rate studies were compared for a variety of hybrids at several locations. Data indicated that chlorophyll meter readings correlated well with leaf N concentrations for a given hybrid and location. Calibration of chlorophyll meters to determine crop N status by crop or region may not be practical considering the numerous variables affecting plant "greenness". Normalization procedures using an adequately fertilized area of each field could be used to standardize this tissue testing approach across hybrids, locations, and growth stages. The ultimate goal of this approach would be to allow consultants and producers to manage N on a "prescription basis" for each field.

Introduction

Support for tissue testing and the use of chlorophyll meters to quantify plant nitrogen (N) status is prompted by the need to improve N use efficiency and to protect ground water from contamination by nitrate. One of the most difficult challenges facing corn producers is to determine the appropriate fertilizer N application rate, especially considering the possibility for N losses by leaching and denitrification before the crop can utilize the fertilizer. The problem is basically one of synchronizing soil N availability (from all N sources) with crop N needs. This task is complicated because it is difficult to accurately predict climatic variables that influence crop growth, soil microbial activity, and nitrate leaching. Producers are inclined to compensate for a possible N deficiency by applying additional fertilizer to insure adequate N for the crop.

Knowing when to apply additional fertilizer during the growing season with a reasonable degree of confidence can be accomplished using conventional tissue testing procedures. However, few corn producers currently use tissue testing to evaluate crop N status because adequacy levels are not well established for most times during the growing season, except for at silking. Further, delays of a few days to a week between tissue sampling and completion of the chemical analysis are frequently considered unacceptable. Finally, differences in N sufficiency across hybrids and environments have not been adequately quantified. Problems associated with traditional tissue testing approaches may seem insurmountable, but the recent introduction of a commercially available hand-held chlorophyll meter may make it possible to circumvent many of these problems. The speed of data collection and ease of operation associated with chlorophyll meters makes them an ideal N management tool if their output can be correlated with crop N status.

The objectives of this research were to quantify the relationship between leaf N concentration and the SPAD 502 chlorophyll meter readings (Minolta Corp, Ramsey, NJ) for corn production. Specific goals were to evaluate the potential for calibration of chlorophyll meters across growth stages and plant cultivars for the purposes of evaluating crop N status and scheduling additional fertilizer application.

Materials and Methods

Existing N rate studies under irrigation and rainfed conditions were used to compare leaf N concentrations and SPAD 502 chlorophyll meter readings of corn. Leaf N concentration was determined using the leaf disk method (Lohry, 1989). One leaf disk (1-cm diameter) was collected from the uppermost expanded leaf before silking or the ear leaf after silking from each of approximately sixty randomly selected plants. Individual disks were taken midway between the sheath and leaf tip and midway between the midrib and edge of the leaf. These sampling guidelines where chosen to minimize data variability among leaves between plants and positions within a leaf. Leaf disks were dried, counted, and weighed prior to compositing for Kjeldahl digestion of the intact disks. Similarly, chlorophyll meter readings were taken from the same relative plant leaf and position on the leaf from 30 randomly selected plants. Chlorophyll meter readings from each plot were averaged for comparison with leaf N concentrations.

Results and Discussion

Leaf greenness quantified by the SPAD 502 chlorophyll meter represents a unitless relative measurement of leaf chlorophyll content. It is theoretically possible to convert the meter readings to a measure of specific chlorophyll content (reading/area) based on the area of the sensor. However, traditional wet chemical procedures used to determine leaf chlorophyll content are usually based on the mass of the tissue. Therefore, data expressed herein are given as direct chlorophyll meter readings.

Deficient, sufficient, and excess N status of common agricultural crops, as determined by various tissue analysis, have been shown to be affected by growth stage, cultivar differences, water stress, nutrient stress (other than N), soil type, plant part sampled, and climatic variables, to name a few. Thus, the analytical relationship between crop N status and chlorophyll meter readings may also be complicated by a number of variables.

Calibration of the SPAD 502 chlorophyll meter for the purposes of estimating crop N status was studied across several of the above variables to learn how they may influence application of this technology. In general, corn leaf N concentration and leaf greenness are expected to increase as soil N availability increases. The influence of genetic differences between cultivars, stage of crop growth, and overfertilization on chlorophyll meter calibration was examined.

Effect of Crop Growth Stage

Calibration of the chlorophyll meters throughout the growing season presents a unique challenge in that a sampling strategy must be developed that is indicative of soil N availability, regardless of crop growth stage. For the past several decades, the ear leaf or an adjacent leaf have traditionally been analyzed for Kjeldahl N concentration to evaluate crop N status after silking (Dumenel, 1961; Melsted et al., 1969). Prior to silking, the uppermost expanded leaf (ie. youngest leaf with a fully exposed collar) was used for calibration. Younger leaves with unexposed collars showed considerably greater variation in chlorophyll meter readings along the length of the leaf (data not shown) and generally tended to have lower chlorophyll meter readings than the more mature leaves. Areas near the base of younger corn leaves usually have significantly lower readings than near the leaf tip until after the leaf collar is fully exposed. Once the leaf collar is exposed, variation in meter readings along the length of the leaf was minimized. Meter readings taken near the midrib tended to be slightly higher than near the leaf margin. This difference is attributed to a thicker leaf near the midrib than near the margin (data not shown).

Two selected hybrids from plots at Schuyler, Nebraska show that meter calibration varies with the stage of plant growth (Fig. 1). Further, the shapes of the calibration curves were different for each hybrid. Greater significance should be placed on the shape of the calibration curve with time than the absolute value of the meter readings because there are currently no procedures to standardize readings between dates. This fact may represent a limitation in the application of chlorophyll meter data.

Although comparison of chlorophyll meter readings between dates may be questionable, data collected on a given date should provide a relative comparison of crop response to fertilizer N rates. For example, chlorophyll meter readings at the 90 kg ha^{-1} N rate for both hybrids were similar to higher N rates early in the season. As the growing season progressed, meter readings for both hybrids showed the development of an apparent N stress at the 90 kg ha^{-1} N rate. Late in the growing season, care must be taken not to confuse lower chlorophyll meter readings with a natural yellowing of the leaves associated with senescence. Again, a relative comparison of chlorophyll meter readings across N rates on a given date should provide a reasonable index of crop N status aside from any minor changes in maturity induced by N rates.

<u>Cultivar Effects</u>

The large genetic diversity in a study at Shelton, Nebraska showed that all ten hybrids generally followed similar trends in terms of leaf disk N concentration and chlorophyll meter readings (Fig. 2). Significant differences in both chlorophyll meter readings and leaf N concentration existed at each of the three N rates. Some hybrids reached near maximum leaf N concentrations and chlorophyll meter readings at the 67 kg ha^{-1} N rate. Other hybrids required nearly 202 kg N ha^{-1} to attain maximum chlorophyll meter readings.

<u>Effect of Overfertilization</u>

Chlorophyll meter readings, as do corn yields, tend to reach a plateau when adequate N is available. Excessively high rates of N fertilizer may result in higher than normal N concentrations in crop tissue, but the amount of chlorophyll in leaves of excessively fertilized plants tends to be similar to plants receiving just enough N for optimum yield. This is demonstrated in a study sponsored in part by the Tennessee Valley Authority at Shelton, Nebraska. Both grain yield and chlorophyll meter readings reached a plateau at N rates beyond the 225 kg ha^{-1} N rate (Fig.3). In contrast, leaf disk N concentrations continued to increase to the 300 kg ha^{-1} N rate. In this case, the crop was not able to capitalize on the additional N uptake and did not produce additional grain above the 225 kg ha^{-1} N rate. Leaf greenness, as measured with the SPAD 502 chlorophyll meter, may provide a better estimate of potential yield than does leaf N concentration.

<u>Relative N Status</u>

Practical application of tissue testing to evaluate crop N status necessitates a universal strategy for data interpretation. The transitory nature of chlorophyll meter readings would preclude the development of a standard curve or sufficiency value which would cover a broad range of conditions. However, these variations would not prevent the development of techniques on a field by field basis as long as precautions concerning the variations were taken.

Adequately fertilized areas within a field could be used as a reference to normalize tissue testing data across locations, hybrids and growth stages. This internal calibration of each field would simplify interpretations and result in field specific recommendations. Relative crop N status can be calculated as follows:

$$\text{Relative N status} = \frac{\text{Data from an area under improved N management}}{\text{Data from an adequately fertilized area}}$$

With reference normalization the actual chlorophyll meter reading is not as important as the relative difference between the adequately fertilized reference and the rest of the field. Variations due to environmental factors are probably of limited importance because factors affecting chlorophyll meter readings would similarly influence the reference plants and those with less available N.

The fact that the chlorophyll meter readings tend to reach a plateau when adequate N is available indicates that over-fertilization of the reference area would have very little influence on this N management technique. This would allow addition of "insurance N" on the reference area, which is a very small part of the field, without influencing crop N status determinations for the whole field. If the relative differences calls of additional N, this would also allow the reference area to be treated with the rest of the field without having any affect on future N management decisions for that field.

As with any type of measurement, repeated observations will show variation between readings. We found that chlorophyll meter readings from replicated fertilizer N rate studies involving several hybrids typically showed 1 to 4% variability (ie. calculated as the coefficient of variation). Variation found for leaf N concentrations typically ranged from 3 to 6%. Therefore, it is probably not appropriate to consider fertilizer N additions until you are sure that a stress exists. A relative N deficiency approaching 5% is probably a realistic level to consider additional fertilization. Recovery from a small N stress following fertigation or other means of N application should take less than a week. We found that a 5% relative N deficiency at silking resulted in a 6% yield reduction if the deficiency was not corrected. Similarly, a 10% relative N deficiency that was not corrected caused a 12% reduction in yield. Under normal production systems, such N deficiencies would be corrected with fertigation or spoke injection and thus yield reductions are not likely to occur.

The success of tissue testing techniques for N management is based on early detection of an N stress and correction of this stress before it affects final yield. We found that chlorophyll meters could detect differences in leaf greenness as early as the V6 (sixth leaf) stage of growth. For example, in 1990 plants receiving 90 kg N ha^{-1} preplant N had the same meter readings as those receiving higher rates of preplant N (180 or 270 kg N ha^{-1}), compared to lower readings from check plots or those yet to be sidedressed. Within one week after sidedress N application, we found meter readings approached those of adequately fertilized plants and meter readings indicated full recovery from the N stress after two weeks.

It should be emphasized that chlorophyll meters have not been calibrated for the purpose of making specific fertilizer N recommendations. Soil testing procedures should be used to determine fertilizer N recommendations for an expected level of production. If one plans to apply N via fertigation or spoke injection, then the preplant or sidedress fertilizer N application should be reduced accordingly. In cases where the N contribution from either irrigation water or mineralization is expected to be significant, but not quantified, one should consider applying 50 to 100 kg N ha^{-1} less than the total recommended amount as a preplant or starter application and be prepared to fertigate or spoke inject if needed.

The positive feature of the tissue testing approach is that it permits producers to give a composite N credit for mineralization, legumes, and nitrate in irrigation water based on limited data, while minimizing the risk of developing an undetected N deficiency. The idea is to reduce early season N applications to the point where no additional N is required to attain near maximum yields, but if an N stress develops, then it can be corrected via fertigation or spoke injection. It is unlikely that even the most sophisticated N and water management practices can eliminate nitrate leaching and ground water contamination, but by combining tissue testing with improved water management and soil testing procedures it should be possible to protect ground water quality and increase fertilizer N use efficiency.

Current research is investigating what effects the N stress component has on final yield in corn production. This includes areas such as how long can corn be stressed before yields are reduced, are there critical growth stages where N stress must be avoided, and the practicality of removing late season N stress. These questions will have to be answered before chlorophyll meter techniques can be fully integrated into production practices, but early results appear very promising.

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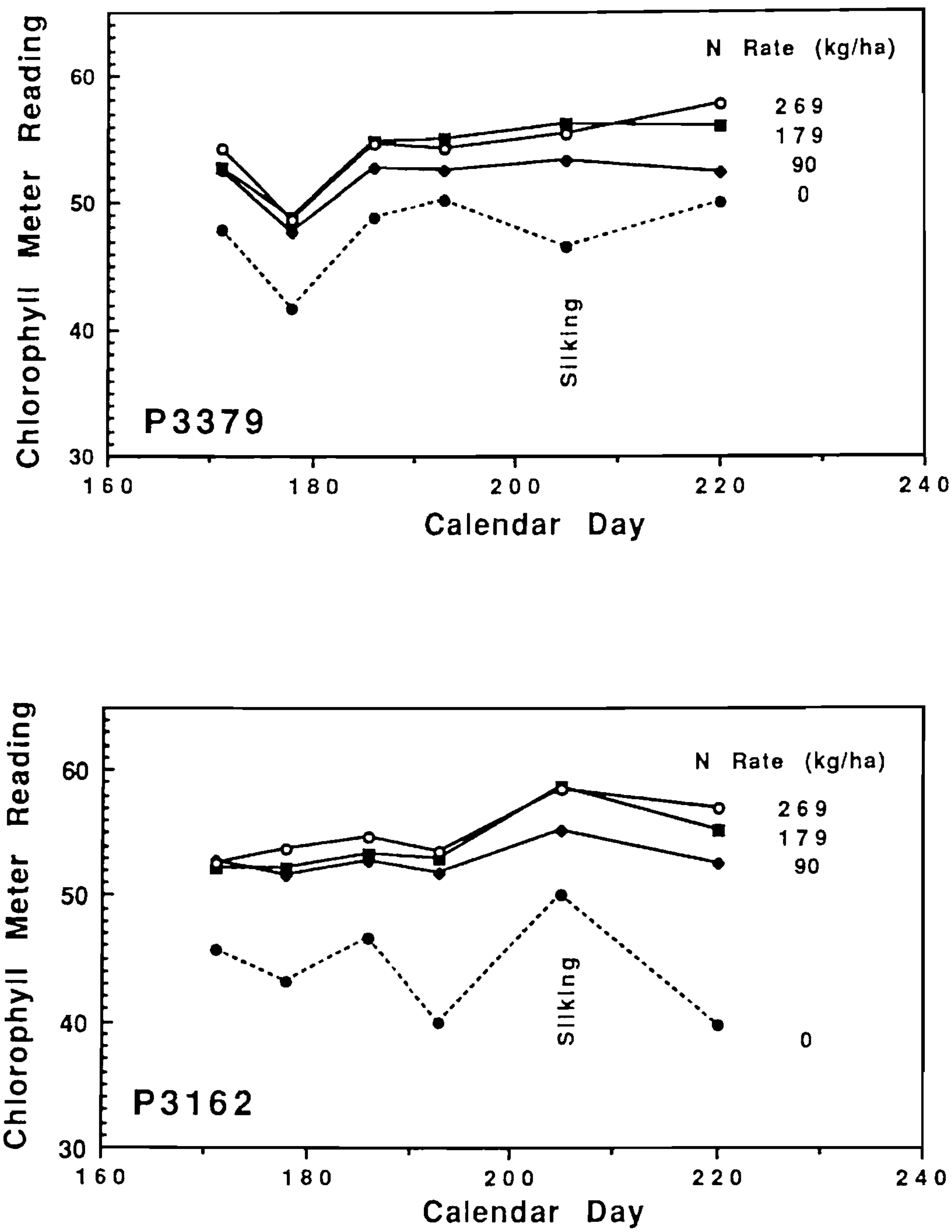

Figure 1. Seasonal variation in chlorophyll meter readings for two maize hybrids at four fertilizer N rates.

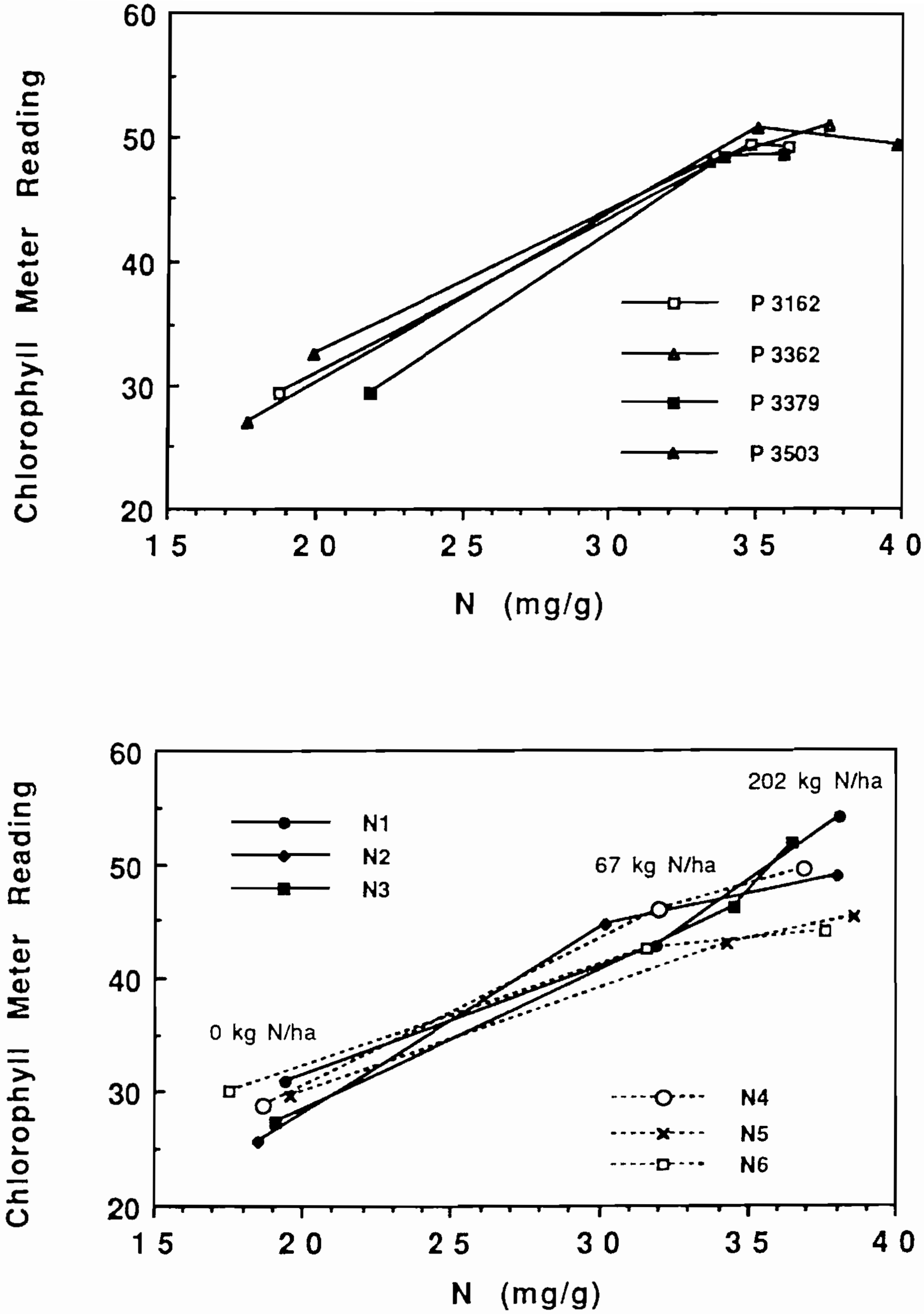

Figure 2. Comparison of leaf disk N concentrations and chlorophyll meter readings of ten irrigated corn hybrids grown at three fertilizer N rates.

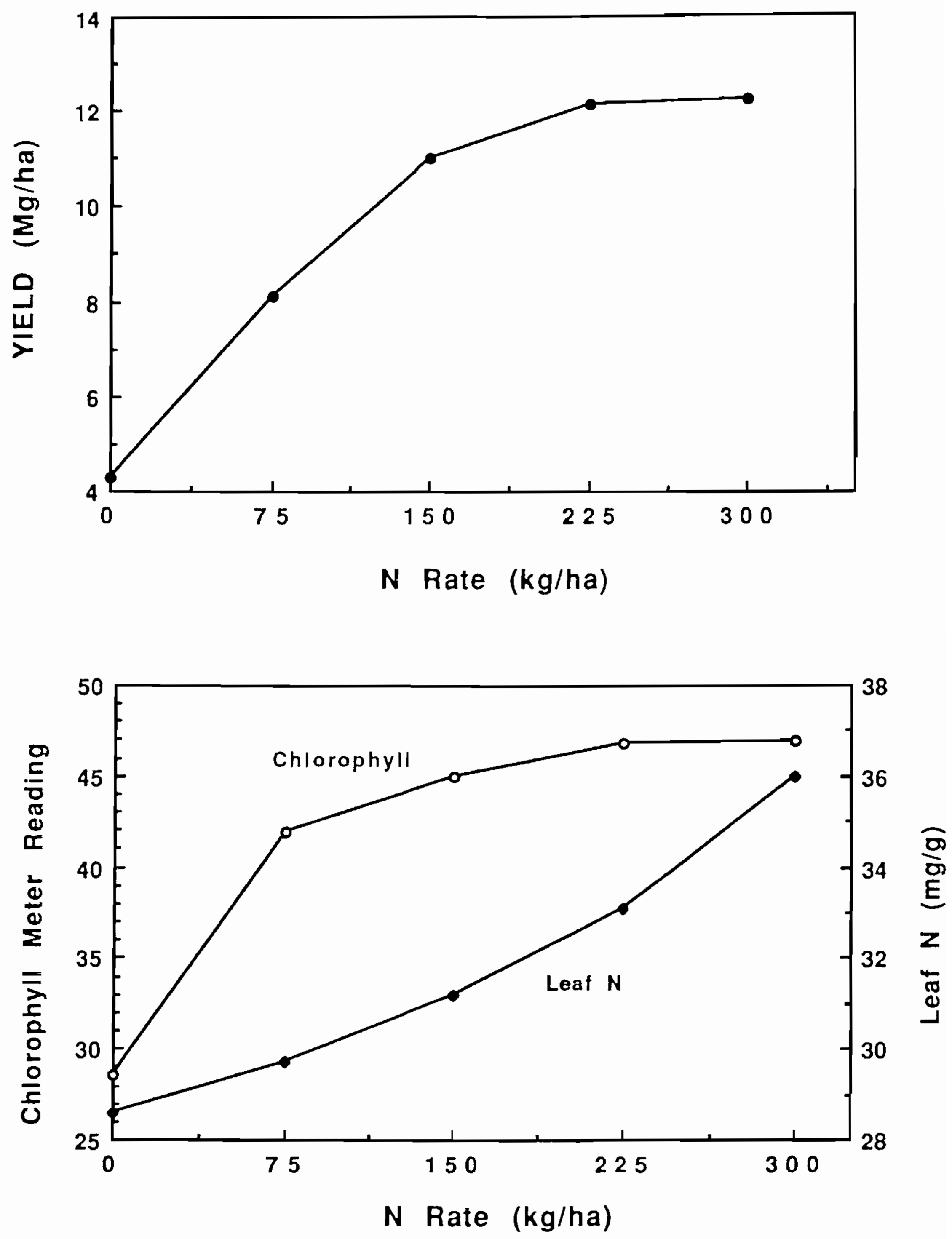

Figure 3. Effect of fertilizer N rate on leaf disk N concentrations and chlorophyll meter readings at anthesis and on final grain yield for irrigated corn at Shelton, NE.

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