Site-Specific Management Guidelines

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SSMG-12

# Assessing Crop Nitrogen Needs with Chlorophyll Meters


## Summary

One of the most difficult challenges facing farmers is to determine the appropriate fertilizer nitrogen (N) application rate. Regardless of source, most N in soil is eventually transformed to the nitrate ($NO_3$) form. To minimize $NO_3$ leaching, cropping systems and management practices must minimize excess $NO_3$ in the soil and the potential for percolation below the root zone. 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 $NO_3$ leaching.


## Introduction

Determining when to apply additional N fertilizer during the growing season 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. Further, delays of a few days to a week between collection of tissue samples and the completion of chemical analysis are frequently considered unacceptable. In addition, 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 (SPAD 502 chlorophyll meter, Minolta Corp, Ramsey, NJ) makes it possible to circumvent many of these problems. The speed of data collection and ease of operation associated with chlorophyll meters make them a useful N management tool.

Since most leaf N is contained in chlorophyll molecules, there is a close relationship between leaf N and leaf chlorophyll content. This strong positive relationship is the basis for predicting crop N status by measuring leaf relative chlorophyll content.

Chlorophyll as quantified by the SPAD 502 chlorophyll meter represents a unitless relative measurement of leaf chlorophyll content. Chlorophyll utilizes red light, and the chlorophyll meter's operation is based on the relationship between the amount of red light absorbed and the amount transmitted through the leaf. Basically, the more red light absorbed means more chlorophyll is present, which, in turn, indicates a greener plant. Red light is supplied by an internal light source in the meter. It is theoretically possible to convert the meter readings to a measure of specific chlorophyll content. However, this is not necessary for N management considerations.

Chlorophyll meters have their greatest sensitivity in the deficient to adequate range of N nutrition. As such, the meter cannot indicate how much excessive N is available to a crop. Its strengths lie in measuring a relative difference in crop N status and the ability to detect the onset of an N stress before it is humanly visible. Managing N availability for crops like corn and sorghum is relatively easy because a slight excess does not adversely affect yield or quality of the grain. Excess N availability to other crops like cotton, sugar beets, wheat, and barley can adversely affect plant health, yield, and value of the final product. Therefore, application of chlorophyll meter technology needs to be examined in terms of plant growth characteristics and N management goals.

The sampling strategy for making chlorophyll meter readings needs to be tailored for each crop and type of leaf. When collecting meter readings, growth stage, relative age of leaves sampled, and position within a leaf should be consistent within a study. Because of the small size of the detectors, the meter can also be used on fine bladed grasses (i.e., turf, wheat, rice). Sampling strategies with chlorophyll meters have been published for only a few crops. This guideline primarily focuses on corn and wheat production.

## 1. Nitrogen Recommendations for Corn on an "as Needed" Basis

### A. When and how to collect measurements

Corn's greatest need for N starts about 30 to 45 days after emergence. The efficiency of N utilization can be

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improved if the N is applied after the spring wet season and near the time of greatest uptake by the crop. Because of the complex behavior of N in soil, delayed application of fertilizer allows corn growers to compensate for the numerous weather-driven factors which affect availability of soil N. Applying fertilizer N as late sidedress or on an "as needed" basis rather than using a single pre-plant approach has both environmental and economic benefits.

The recommended chlorophyll meter sampling strategy for corn developed from research in Nebraska is to start when the plant is at the V6 growth stage (about 1 foot tall) and use the uppermost fully expanded leaf (visible collar) until the ear leaf can be identified and used. Within a leaf, we suggest sampling midway between the base and tip and midway between the midrib and margin (**Figure 1**). Other sampling positions on the plant or within a leaf may be appropriate for some applications, but it is important that the same selection criteria be used for all plants used in making comparisons. Care should be taken not to sample atypical plants within a population, young leaves with non-uniform color, diseased or damaged areas, or plants with extremes in spacing. We recommend obtaining an average of 30 readings from representative plants as described above. Electronics within the chlorophyll meter permit storage of 30 individual values, elimination of atypical values, and an averaging function.

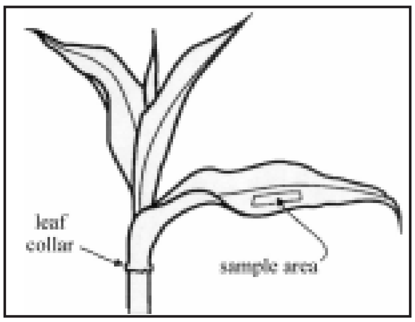


**Figure 1. Sample area for taking chlorophyll readings on small corn plants.**

### B. How to calculate

Interpreting chlorophyll meter data is not necessarily obvious because other factors besides N status can affect chlorophyll meter readings of leaves. Leaf chlorophyll content varies by type of crop, cultivars within a crop, growth stage, leaf position, soil type, and climatic variables. Water stress, plant diseases, other nutrient deficiencies, or other factors that cause plant stress also may affect leaf chlorophyll content. One way to minimize the effects of these complicating factors is to establish a small reference area in each field that has been adequately fertilized with N. In this approach, meter readings between the reference area in the field are compared with meter readings collected across the whole field. The meter readings recorded at sites across the whole field should be collected from the same crop cultivar, the same stage of growth, and from field areas with similar cropping history. In this approach we are trying to keep all factors the same except for N sufficiency. This calculation results in what has been termed N Sufficiency Index (NSI).

$$NSI = \frac{\text{(average meter reading from unknown area)}}{\text{(average meter reading from area with adequate N)}} \times 100\%$$

As with any type of measurement, repeated observations will show variation among readings. Variations found with traditional tissue tests for leaf N concentrations typically ranged from 3 to 6 percent. Therefore, it is probably not appropriate to consider fertilizer N additions until you are sure that a stress actually exists. Our experience with corn has shown that a NSI lower than 95 percent indicates an N deficiency that should be corrected or it may lead to a yield reduction. Recovery from this degree of N stress following fertigation or other means of N application should take less than a week.

### C. Nitrogen management plan based on calculation

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. Chlorophyll meters can accurately detect differences in leaf chlorophyll concentration of corn as early as the sixth leaf growth stage (about 1 foot tall). Readings taken from plants less than 1 foot tall are usually quite variable and probably not worth collecting. However, it is important not to allow these small plants to become severely stressed. If a corn plant experiences severe N stress before the sixth leaf growth stage, the size of the ear and number of kernels can be permanently affected and not corrected by later fertilizer applications. In practice, producers willing to consider a partial spoon-feeding approach to N management would apply 50 to 75 percent of the recommended N before planting or as an early sidedress treatment. A few areas of the field would serve as reference areas and would receive the full N recommendation rate or slightly more. Crop N status would be evaluated weekly. If the need for additional N is indicated (e.g., NSI is at or below 95 percent, or a trend indicates it soon will be), an additional 20 to 40 lb N per acre should be applied through fertigation or by high clearance applicator.

The positive feature of the tissue testing approach is that it permits producers to give a composite N credit for mineralization, legumes, and $NO_3$ 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 may be required to attain near maximum yields, but if an N stress develops, then it can be corrected via fertigation, spoke injection, or with other high clearance applicators.

## 2. Nitrogen Recommendations for Corn Using One-Time Sidedress

### A. When and how to collect measurements

Research in Pennsylvania has led to the development of a testing procedure that enables chlorophyll meter readings to be used as an indicator for fertilizer N sidedress requirements for corn. The procedure is applicable for corn crops that have received no fertilizer N before or at planting except for a normal amount of starter (i.e., about 100 pounds per acre of total starter fertilizer). Chlorophyll meter readings are taken from corn plant leaves shortly before the time suitable for N sidedressing. Readings can be taken as early as the sixth leaf growth stage, but the accuracy of the test is generally higher when sampling is done at the seventh or eighth leaf growth stage. Regardless of the leaf growth stage at sampling, meter readings are always done on the fifth leaf. The reading is done at a point on the leaf approximately one-half inch from the edge of the leaf and at a point three-fourths of the leaf length from the leaf base. These readings are compared to readings from a high N reference area. The result indicates whether the field requires N sidedressing and also provides an estimate of the amount of N needed. Research is continuing in an attempt to simplify the test and make it applicable to other conditions.

### B. How to calculate N recommendation

**Relative SPAD chlorophyll meter reading: Formula (1)**
Average field meter reading / average reference area meter reading = Relative SPAD reading

If the relative SPAD reading is $\geq 0.95$, the N recommendation is zero.

Otherwise continue the calculations below.

**Yield factor: Formula (2)**
Yield goal (bu/A) x 0.9 = Yield factor

**Manure factor: Formula (3)**
17 x Manure value[a] x Relative SPAD reading (1) = Manure factor

[a] Use 0.75 for manure value if no manure was applied to the field since the previous crop's harvest or use 3.50 if manure was applied since the previous crop's harvest.

**Leaf stage factor: Formula (4)**

19 x Leaf stage of crop[b] x Relative SPAD reading (1) = Leaf stage factor

[b] Leaf growth stage of the field and not of the high N reference plot.

**Reference plot factor: Formula (5)**

4 x Avg. reference area meter reading = Reference plot factor

**N Recommendation: Formula (6)**

280 + [Yield factor(2)] – [Manure factor (3)] – [Leaf stage factor (4)] – [Ref. plot factor (5)] = lb N/A[c]

[c] If the calculated N recommendation is less than 30 lb/A, a zero N application is suggested.

## 3. Nitrogen Recommendations for Winter Wheat

### A. When and how to collect measurements

Scientists at the University of Kentucky have developed a procedure for using chlorophyll meters as an alternative to tissue tests which are taken at Feekes 5 growth stage to make N recommendations on winter wheat. The Feekes 5 growth stage generally occurs from mid to late March in Kentucky and is the best stage for measuring chlorophyll and completing the last N fertilization. Several small reference areas are established in February by applying 150 lb/A of actual N to representative areas of the field.

Use the first fully expanded leaf from the top of the plant for each reading. A fully expanded leaf is one that has a collar surrounding the stem. After selecting the leaf to be sampled, take readings from a point half the distance between the leaf tip and the collar and halfway from the leaf margin to the mid-rib.

Precautions need to be taken to not collect chlorophyll meter readings when plants are under stress other than N. Poorly drained soil conditions, diseases, late winter freezes, and recent herbicide applications are the most common of these stresses.

### B. How to calculate N recommendation

After recording the average meter readings at Feekes 5 from the bulk of the field as well as from the reference areas, the N recommendation is calculated as follows:

$$N = 6 + (7 \times D)$$

where;

N = N (lb/A) needed at Feekes 5 for optimum growth.

D = Difference between average chlorophyll readings from the field and the reference areas where high levels of N were added in February.

Example:

Small reference areas or strips (high N added at Feekes 3) read an average of 52 at Feekes 5 growth stage.

Rest of field gives an average meter reading of 45.

52 – 45 = 7

6 + (7 x 7) = 55 lb N/A recommended.

## 4. Late-Season N Application in Irrigated Spring Wheat

Variable climatic conditions often result in N fertility levels in spring wheat that are short or in excess of optimum. This makes it difficult for irrigated spring wheat growers to determine if grain protein responses to late-season N will be realized. Montana State University recommends the use of chlorophyll meters as a method for assessing irrigated spring wheat N status late in the season to help in predicting the effectiveness of late-season applied N to increase grain protein.

### A. When and how to collect sample readings

Use of chlorophyll meters for diagnosis of the likelihood of protein response requires comparison to a well-fertilized reference area in the same field. SPAD meter readings are collected from the flag leaves at heading. Average meter readings are obtained for the well-fertilized reference area and for the unknown areas in question.

## B. How to calculate N recommendation

A relative or "normalized" SPAD meter level is calculated by dividing the average meter reading from the unknown area by the average meter reading from the reference area. Protein responses for irrigated spring wheat will be expected where relative SPAD levels are below 0.93 to 0.95 at heading (93 to 95 percent of the reference area). An additional 40 lb N/A should be added when relative levels are below these values.

Flag leaf analysis is reliable in predicting the likelihood of a grain protein response to late-season N application, but is not useful in predicting the magnitude of the response nor the final grain protein level.

## Summary

Chlorophyll meter techniques allow "fine-tuning" N management to field conditions for the whole field or for management zones established in the field to address spatial variability concerns. This reduces the risk of having yield-limiting N deficiencies and reduces the potential for over-fertilization and possible $NO_3$ contamination of ground and surface water. Farmers should recognize this as another tool that may complement, but does not replace, other aspects of sound N management.

Numerous researchers over the past several years have been trying to develop remotely sensed methods that provide information similar to SPAD meters. Currently, several systems are being tested which utilize sensors to measure crop N status "on-the-go". These sensors are coupled with variable rate fertilizer applicators to automatically correct crop N deficiencies on a site-specific basis. Potential uses of these techniques in the future also include remote sensing by satellite or airplane to schedule the need for additional fertilizer N. ■

## Reference Methods


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