NebGuide

University of Nebraska Lincoln

Published by University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources

G1632

Using a Chlorophyll Meter to Improve N Management

Charles A. Shapiro, Soil Scientist—Crop Nutrition; James S. Schepers, Soil Scientist, USDA-ARS
Dennis D. Francis, Soil Scientist, USDA-ARS; and John F. Shanahan, Agronomist, USDA-ARS

This NebGuide describes how to use a chlorophyll meter as a tool to improve nitrogen management by detecting nitrogen deficiency and determining the need for additional N fertilizer.

Fertilizer nitrogen (N) is increasingly recognized as the source of nitrate contamination in much of Nebraska's groundwater. Improving the efficiency of fertilizer N use reduces the amount of N that can potentially contaminate water resources. Effective N management is a major challenge for grain crop producers. Yet, factors like weather that affect its efficiency are beyond a producer's control. Fertilizer N is becoming more expensive, but deficiencies can result in substantial yield reductions and lost profits (a bushel of corn contains ~0.75 lb N). As a result, producers are inclined to manage fertilizer N to minimize the risk of deficiency, which can lead to excessive fertilizer applications and subsequent contamination of the environment.

Researchers have been developing ways to increase fertilizer N use efficiency. Using a soil test to adjust fertilizer N rates for residual nitrate works well under Nebraska conditions. However, the potential exists to fine-tune N management decisions during the growing season to react to changing weather and crop conditions.

The concept of using the crop to assess crop N status is not new. Research over the past decade indicates a close link between leaf chlorophyll content and leaf N content, which makes sense because the majority of leaf N is contained in chlorophyll molecules. The Minolta chlorophyll meter (model SPAD 502) enables users to quickly and easily measure potential photosynthetic activity, which is closely linked to leaf chlorophyll content, crop N status and leaf greenness. Essentially, the meter exposes a small portion of the leaf to abundant light and measures how much was not captured by chlorophyll in the photosynthetic process. The chlorophyll meter can be used to monitor crop N status and potentially increase N use efficiency.

Figure 1. A chlorophyll meter in use.

Figure 2. Close-up of chlorophyll meter.

The chlorophyll meter (*Figures 1* and *2*) has several advantages over other tissue testing methods. Samples don't need to be sent to a laboratory for analysis, saving time and money. The use of the chlorophyll meter (SPAD) is non-destructive and permits repeated measurements throughout the growing season. Plants produce as much chlorophyll as possible until something else becomes limiting. As such, luxury consumption of N does not increase leaf chlorophyll content. This causes SPAD meter readings to reach a plateau when N availability is adequate, regardless of how much extra N is taken up by the plant *(Figure 3)*. Using a chlorophyll meter to monitor leaf greenness throughout the growing season can signal the approach of a potential N deficiency early enough to correct it without reducing yields. This approach makes the SPAD meter especially useful where additional N can be applied through a sprinkler irrigation system (fertigation) or with a high-clearance sprayer. Fertigation via furrow irrigation is discouraged because the rate of water application can be highly variable. Fertigation in Nebraska must conform to state chemigation regulations, which require certification of the operator and inspection of the required safety equipment (see "Using Chemigation Safely and Effectively", 2nd Edition 2/2002 NDEQ and IANR).

In non-irrigated cropping systems, additional N fertilizer can be injected with a sidedress application if crops are not too tall or banded between rows using high-clearance equipment.

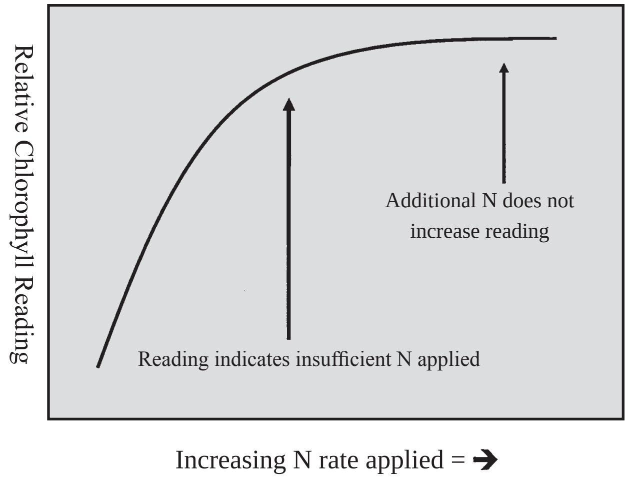

Figure 3. Relationship between applied nitrogen and chlorophyll readings. (Absolute chlorophyll numbers will vary, but relative numbers will be consistent.)

One benefit of fertigation is that the applied N is rapidly taken up by the crop to correct the N deficiency. In a non-irrigated system, N application to dry topsoil may not be utilized until the next rain occurs, which may be too late for the plants to fully recover and produce optimal grain yields. Early N stress detection capabilities of the SPAD meter promises to improve fertilizer N efficiency and decrease risks associated with reduced preplant fertilizer applications. Using the SPAD meter for in-season N management should be coupled with traditional preseason soil testing procedures for best results.

Many factors affect chlorophyll meter readings. Variety or hybrid differences can greatly affect meter readings in that some adequately fertilized corn and sorghum hybrids are darker green than others. The stage of growth can affect leaf greenness, as can recent environmental conditions such as temperature, moisture stress and sunlight. Plant diseases, nutrient deficiencies and nearly any other kind of plant stress can affect the plant's ability to produce chlorophyll, thus affecting leaf greenness. Because the chlorophyll meter is affected by so many things, it is not possible to say that a given meter reading indicates sufficient N. Meter readings mean very little by themselves and must be calibrated for each field, soil, hybrid and environment to make use of the readings. The best way to calibrate the meter is to create a new set of adequately fertilized reference strips in each field every year.

Field Use of the Chlorophyll Meter

1. Establishing Reference Strips. It is crucial that the chlorophyll meter be calibrated for each field, previous crop, hybrid, fertilizer and/or manure application and differing soil types. Several adequately fertilized reference strips, identical to the rest of the field except that they receive sufficient levels of N fertilizer, should be established in each field. The amount of N applied to these strips should be adequate to ensure that plants in the reference strip do not exhibit an N deficiency. Research suggests that the entire field be fertilized with one-half to three-fourths of the total amount of fertilizer N recommended by standard soil test procedures. Less may be appropriate for sandy soils. Reference strips then should be established by applying additional N fertilizer so the total amount applied to the strips

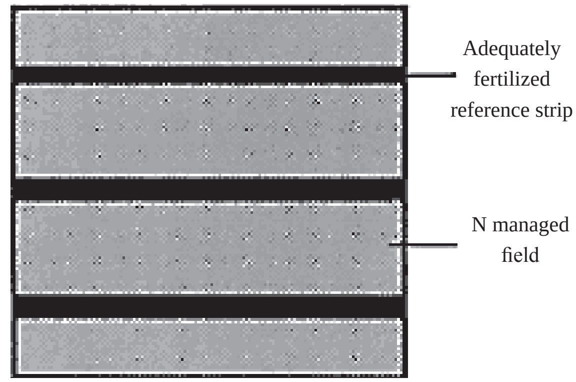

Figure 4a. Field planted with reference strips.

Figure 4b. Aerial photograph of reference strips under a center pivot.

is equal to or slightly higher than the N rate suggested by the University of Nebraska–Lincoln Extension. A large excess of N applied to the reference strips is not recommended and may reduce yields. Several reference strips should be established in each field to accurately represent conditions in that field (*Figure 4a* and *b*). By comparing the average chlorophyll meter readings from the reference strips to those from the rest of the field, N sufficiency and the need for additional N supplied through fertigation can be determined. Aerial photographs of bare soil or vegetation are especially useful to identify spatial patterns where differences in crop performance are likely. Reference N strips should be placed on parts of the field typical of the various soil conditions in the field.

In the aerial photograph *(Figure 4b)* pale green areas are clearly visible. These areas will show a low relative SPAD reading. It is the green areas that are similar to the reference areas (strips with yellow rectangles) in color where the SPAD meter may be able to distinguish between adequate and non-adequate nitrogen status.

2. How to sample. Weekly chlorophyll meter readings from each reference strip and adjacent bulk area of the field after the six-leaf growth stage of corn should be compared at a minimum of three locations. At each location, the average reading of 30 plants from the reference area and the adjacent bulk field should be compared. The Minolta SPAD 502 collects and stores up to 30 individual readings and calculates the average automatically. Care must be taken during collection. Individual readings vary up to 15 percent from plant to plant, but the goal is to collect 30 readings so that the average accurately represents leaf greenness for that crop. Avoid taking readings from plants that do not represent typical plant spacings (e.g., wide guess rows, doubles or planter skips). It may be helpful to systematically sample each row across the planter width to avoid problems caused by differences among rows such as plant population, compaction or variations in starter or other fertilizer application.

The same leaf on each plant and the same place on each leaf should be sampled. Readings taken from plants less than 1-ft tall are usually quite variable and not appropriate to sample. For plants between the six-leaf stage (about 1-ft tall) and tassel, sample the newest fully expanded leaf that has a leaf collar exposed (see *Figure 5*). After the tassel stage, sampling the ear leaf (the leaf attached to the primary ear shank) provides an accurate comparison. After selecting the leaf to be sampled, it is important to take the reading on about the same location on each leaf. It works well to collect the reading from a point one-half the distance from the leaf tip to the collar and halfway between the leaf margin or edge and the leaf midrib *(Figure 5)*. Chlorophyll meter readings are usually stable during the day unless plants are under water stress. As long as readings are collected from the reference strip and the adjacent bulk field at about the same time, the comparison is valid. It is best to avoid collecting readings when moisture is on the leaves (i.e., after a rain or sprinkler irrigation or in the early morning) or when plants are under drought stress as this can distort the readings. Meters should not be subjected to extreme temperature changes before making measurements.

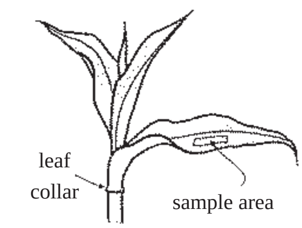

Figure 5. Sample area for taking chlorophyll readings.

3. Interpretation of chlorophyll meter readings. After recording average meter readings from the bulk field and reference area at several locations in each field, an N sufficiency index can be calculated as follows:

Sufficiency Index = (Average Bulk Reading/Average Reference Strip Reading) x 100%

For Worksheet 1 (on the next page): Four places in the field were sampled obtaining the following N sufficiency index values: 101, 98, 97 and 96 percent with an average of 98 percent. Research shows that a sufficiency index lower than 95 percent indicates an N deficiency that should be corrected or it may lead to a yield reduction. This recommended trigger point of additional fertilizer N includes a 3 to 4 percent uncertainty attributed to sampling variability. In Worksheet 2, the four readings average less than 95 percent, indicating the need for additional N. At least 20 lbs N/acre should be applied through the irrigation system to correct the N deficiency, particularly since the crop is rapidly taking up N during this period. This field should be checked again with the meter four to six days after the N application to make sure the deficiency has been corrected or that recovery is under way.

Since the readings vary depending on weather and growing conditions, readings collected from a single sampling date are not as useful as comparing trends in the sufficiency index through the growing season. Readings should be collected weekly from the six-leaf stage until about 20 days after silking. Nitrogen applications later than this do not increase yield.

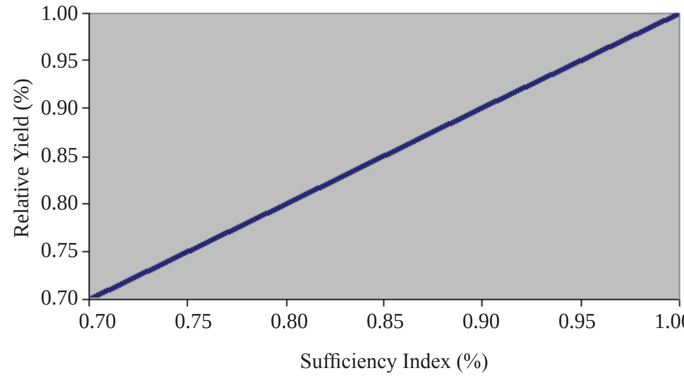

Figure 6. General relationship between the sufficiency index and relative yield.

4. The chlorophyll meter as an N management tool. The chlorophyll meter enhances a producer's ability to make N management decisions but does not replace other aspects of good N management. Environmentally and economically sound N management must begin with a representative soil sample and a realistic value for expected yield. It is suggested that at least one-half to three-quarters of the total fertilizer N be applied to the entire field prior to the six-leaf stage to ensure the chlorophyll meter technique is effective. If a corn plant experiences moderate to severe N stress in the early growth stages, the size of the ear and number of kernels may be limited so additional N fertilizer applied later will not allow full recovery of grain yield. Readings that get to 90 percent may not recover. Figure 6 shows the yield reduction for relative readings that have not received additional N. Cornfields, which are routinely monitored, should never be allowed to drop below the 90 percent value.

Using the chlorophyll meter to schedule fertigation allows adjustments throughout the season based on the amount of N supplied by mineralization of organic matter and manure, by contaminated irrigation water, or when plant roots come in contact with additional N. When the need for additional N is indicated by the chlorophyll meter (e.g., N sufficiency index is at or below 95 percent, or a trend indicates it soon will be), an additional 20 to 40 pounds N per acre should be applied through fertigation. The decision on how and when to fertigate is affected by many factors, including stage of growth, developing trends in chlorophyll meter readings, equipment limitations and anticipated crop N needs for the rest of the growing season. Most N fertilizer should be applied before the tassel stage. N applied more than 20 days after silking probably will not affect grain yields. Generally chlorophyll meter readings will respond to show crop recovery within two to three days after fertigation depending on environmental conditions.

The chlorophyll meter technique allows fine-tuning N management to field conditions and reduces the risk of yield-limiting N deficiencies. Producers should recognize this as another tool that may complement, but does not replace, other aspects of sound N management. One soil scientist said it succinctly: "Use the chlorophyll meter to schedule your last 50 lbs N/acre, not your first." Other uses of SPAD meters are to verify spatial patterns observed in satellite and aircraft imagery and to compare chlorophyll levels between rows where cultural practices are suspected of affecting crop growth.

Worksheet 1

Field: North 80

Date: June 28

Stage: V14

	Average Bulk Field Reading	Average Reference Strip Reading	N Sufficiency Index
Location 1	54.5	54.1	100.7%
Location 2	56.8	58.0	97.9%
Location 3	49.6	51.3	96.7%
Location 4	57.2	59.5	96.1%
		Average	97.9%

Action: None required

Worksheet 2

Field: South 40

Date: July 10

Stage: silking

	Average Bulk Field Reading	Average Reference Strip Reading	N Sufficiency Index
Location 1	50.2	52.4	95.8%
Location 2	48.8	51.6	94.6%
Location 3	51.3	54.4	94.3%
Location 4	54.0	58.1	92.9%
		Average	94.4%

Action: Fertigate

Your Data

Field: ___________

Date: ___________

Stage: ___________

	Average Bulk Field Reading	Average Reference Strip Reading	N Sufficiency Index
Location 1	___________	___________	___________%
Location 2	___________	___________	___________%
Location 3	___________	___________	___________%
Location 4	___________	___________	___________%
		Average	___________%

Action: _____________

Note of caution: Sufficiency Index values should not be used to predict absolute yield because of climatic uncertainties. However, research indicates that relative SPAD readings are a good indication of relative yield.

Acknowledgment

The authors would like to acknowledge the work of Todd A. Peterson, Extension Cropping Systems Specialist, and Tracy M. Blackner, Graduate Research Assistant, who were contributors to the previous edition of this publication.

UNL Extension publications are available online at *http://extension.unl.edu/publications*.

Index: Soil Resource Management
Fertility

Issued Octtober 2006