UK COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY—COLLEGE OF AGRICULTURE

# Comparison and Use of Chlorophyll Meters on Wheat (Reflectance vs. Transmittance/Absorbance)

*Lloyd Murdock, Dottie Call, and John James*

Efficient use of nitrogen (N) fertilizer is important for economical wheat production and also for ground and surface water quality. Insufficient or excessive N levels reduce profit and yield. Intensive management studies on winter wheat have shown that split spring topdressings of fertilizer N improve N efficiency. The first topdressing N rate at spring green-up (Feekes 3) is best determined by tiller density. The second application at Feekes 5 to 6 growth stage is more subjective but probably more important. Tissue tests and chlorophyll meters can be used to help make the decision.

Chlorophyll meters are faster than tissue testing for N. Samples can be taken often and repeated if results are questionable. The meters are used to measure leaf greenness, which is positively related to leaf chlorophyll content. Research indicates a close correlation between leaf chlorophyll content and leaf N content because much of the leaf N is contained in the chlorophyll.

There are at least two types of handheld chlorophyll meters available to measure chlorophyll content of wheat. One type (SPAD 502) uses thumb pressure to close a chamber and measure light transmittance/absorbance (T/A) to determine chlorophyll content. Another type (Field Scout CM 1000®) measures reflectance (R). Ambient and reflected light is used to calculate the relative chlorophyll index with this R chlorophyll meter.

The T/A chlorophyll meter has been on the market for a number of years and has been studied using a number of crops. A recommended method for its use with wheat and an interpretation of the chlorophyll meter readings can be found in the University of Kentucky Cooperative Extension publication AGR-170, *Using a Chlorophyll Meter to Make Nitrogen Recommendations on Wheat.* That publication interprets the research results on wheat for a prospective user. It can also be found on the Web at www.ca.uky.edu/agc/pubs/agr/agr170/agr170.pdf.

The more recent R chlorophyll meter offers the advantages of increased speed and reduced effort to make each reading and also a canopy measurement rather than a single leaf measurement. How does the R chlorophyll meter compare to the T/A meter, and can it be used to make N recommendations or diagnose an N deficiency problem?

To help answer this question, a three-year study was initiated to compare the two meters. The first year of the three-year study is not reported because the R chlorophyll meter was found to be faulty. After repair of the meter, the wheat was in the soft dough stage. Although readings were taken and correlations with the T/A chlorophyll meter, yield, and N rates were excellent, they are not reported due to the late growth stage.

## Method

The three-year trial was initiated on a Pembroke soil in the fall of 2000 at the University of Kentucky Research Center in Princeton, Kentucky. Soft red winter wheat was planted in mid-October, and intensive wheat management practices were used for high yields. Nitrogen treatments were applied at the rates of 0, 30, 60, 90, 120, and 150 pounds of N/acre just after green-up (Feekes 3) in mid-February.

The experimental design was a randomized block with four replications. The chlorophyll meter readings were taken at early and late Feekes 6 growth stage. For the SPAD 502 (T/A) meter, readings were taken on the first fully expanded leaf from the top of the plant and about halfway between the tip and the base of the leaf. Nine readings were taken within each plot and averaged for the final reading. The readings for the CM 1000 meter were taken 3 to 5 feet from the canopy at either 45° or 90° angles of the meter in relation to the wheat canopy surface. Nine readings per plot were taken in the same areas that the T/A meter readings were taken. R meter readings were taken between 10 a.m. and 2 p.m. with the sun to the back of the reader without shading the ambient light receiver. The laser guide lights were used to aim the meter at target row sections.

## Advantages and Disadvantages of the T/A and R Chlorophyll Meters

The T/A meter has been proven to give excellent results. Sunlight conditions in the field do not affect its reading, so measurements can be taken in different weather conditions. However, it measures only one spot of one leaf on each measurement, so many measurements must be taken to get a reliable average. The use of the meter is time consuming and laborious since a specific leaf on a small wheat plant must be located and placed in the meter with each measurement.

The R meter is easy and fast to use and gives reliable readings. Chlorophyll measurements are made in a standing or walking position by the pull of the trigger. Measurements are made in a circular area, approximately 13 to 35 square inches (at 3 to 5 feet from the canopy) including many plants and leaves. A disadvantage for the R meter is that it is dependent on ambient sunlight. Therefore, its use is limited by the sun angle and heavy overcast conditions. The best time to use the R meter is with good sunshine from 10 a.m. until 2 p.m. Low angles of the sun greatly change light intensity and light quality. The angle at which the readings are taken in relation to the wheat canopy also affects readings.

**Table 1.** Correlation of different chlorophyll meter readings with increasing nitrogen fertilizer rates at early and late Feekes 6 growth stage of wheat.

| | Correlation Coefficient ($R^2$) | | | | | |
|---|---|---|---|---|---|---|
| | 2002 | | | 2003 | | |
| Growth Stage | SPAD[1] | CM (45°)[2] | CM (90°)[3] | SPAD[1] | CM (45°)[2] | CM (90°)[3] |
| Early 6 | 0.88 | 0.71 | 0.85 | 0.91 | 0.93 | 0.94 |
| Late 6 | 0.85 | 0.84 | 0.85 | 0.96 | 0.90 | 0.93 |

[1] T/A chlorophyll meter.
[2] R chlorophyll meter at 45° angle to wheat canopy.
[3] R chlorophyll meter at 90° angle to wheat canopy.

**Table 2.** Correlation of SPAD (T/A) meter readings with CM 1000 (R) meter readings at two different meter angles.

| | | Correlation Coefficients ($R^2$)[1] | | | |
|---|---|---|---|---|---|
| | | 2002 | | 2003 | |
| Meter | Growth Stage | CM (45°) | CM (90°) | CM (45°) | CM (90°) |
| SPAD | Early 6 | 0.84 | 0.82 | 0.84 | 0.89 |
| SPAD | Late 6 | 0.69 | 0.82 | 0.95 | 0.95 |

[1] Correlated over seven different nitrogen rates.

**Table 3.** Correlation of SPAD (T/A) and CM 1000®) chlorophyll meter readings at Feekes 6 with final wheat yields.

| Correlation Coefficients ($R^2$) | | | | | |
|---|---|---|---|---|---|
| 2002 | | | 2003 | | |
| SPAD | CM (45°) | CM (90°) | SPAD | CM (45°) | CM (90°) |
| 0.92 | 0.92 | 0.93 | 0.88 | 0.93 | 0.95 |

## Comparison of Readings

When the T/A meter was compared to the R meter over a wide range of nitrogen treatments on wheat at Feekes 6 growth stage, both meters responded similarly. The numerical readings are much higher for the R meter than the T/A meter. However, the relative readings are very similar. As the nitrogen rates (0, 30, 60, 90, 120, and 150 pounds/acre) increased, leaf greenness increased, and the correlation with both the T/A meter and the R meter was excellent (Table 1). The R meter had a lower correlation in 2002 when used at a 45° angle to the wheat canopy. In general, the correlations were almost identical when the R meter was used between 10 a.m. and 2 p.m.

When the readings of the T/A meter were correlated with those of the R meter, the correlations were good (Table 2). This again indicates that the meters could be used interchangeably for a reliable estimate of relative chlorophyll content and N status of wheat in the field at Feekes 6 growth stage.

## Comparison of T/A and R Chlorophyll Meter Readings to Wheat Yield

The efficacy of the chlorophyll meters is supported by the correlation of the chlorophyll readings taken at Feekes 6 on the different N treatments to wheat yield (Table 3). The correlations are very good for both meters. The R-type meter actually resulted in slightly higher correlations than the T/A meter. This lends strong support for its use as a N recommendation tool. The harvested yields for the wheat with adequate N were between 100 and 110 bu/acre each year.

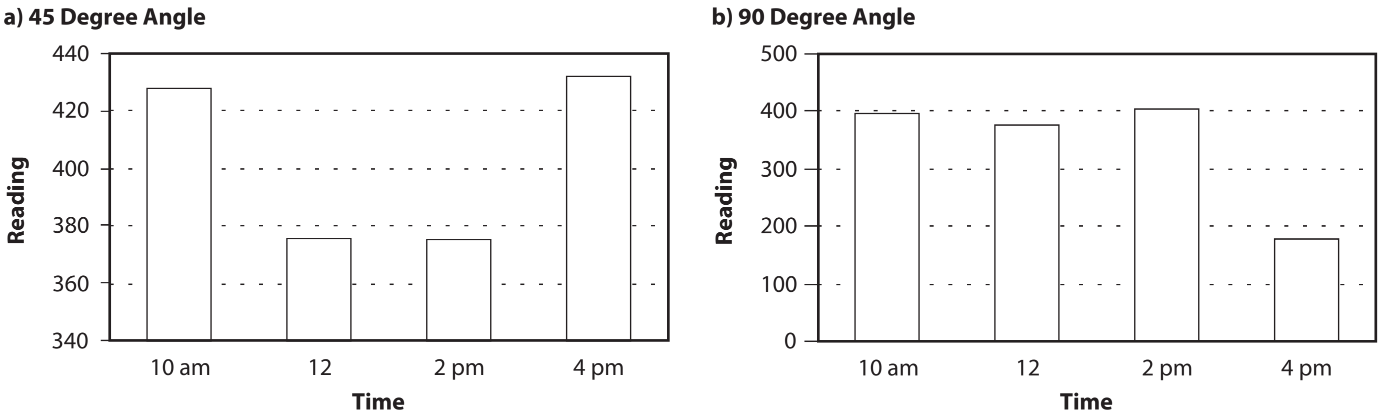
## Time of Day

The time of day, sunlight intensity, sun angle, and meter angle in relation to the wheat canopy affect the readings of the R-type meter (Figure 1). Using the R meter at a 45° angle to the wheat canopy resulted in fairly high readings between 10 a.m. and 4 p.m. (Figure 1a). When the angle of the sun is lower than 12 noon, there is more reflectance from the canopy at 45° when standing with the light at the reader's back. However, readings are still fairly high around noon.

Using the R meter at a 90° angle to the wheat canopy gives very consistent readings between 10 a.m. and 2 p.m. (Figure 1b). The readings drop greatly when the sun angle lowers. The reflected light from the canopy to the meter at this angle is very low and may be unreliable.

It should be remembered that both types of meters must be used with an enriched nitrogen area for maximum readings. The interpretation of the readings is in relation to this reference reading. If readings in the reference strip and in the rest of the field are made at a similar time, the smaller changes due to sun angle should not be a concern.

**Figure 1.** Effect of the time of day on CM 1000 readings at 45 and 90 degrees to the canopy surface.




## Interpreting Chlorophyll Meter Readings

### *N Recommendations*

The interpretation below is designed for chlorophyll readings of wheat at Feekes 5 or 6 growth stages and making N recommendations for N application at about the same time. It should also be remembered that this requires an N-enriched reference area. This area can be a strip or small block where a high rate of N was applied four to six weeks earlier to develop maximum chlorophyll concentrations in the leaves.

A more detailed explanation of the procedure can be found in the AGR-170 publication or on the Web site previously listed.

After recording the average meter readings from the field as well as reference areas, calculate an N recommendation as follows:

**Transmittance/Absorbance Meter (SPAD 502)**

N = 6 + (7 x D)
N = N (lb/acre) needed for optimal growth
D = Difference between average chlorophyll readings from the field and the N-enriched reference area.

**Reflectance Meter (CM 1000)**

N = 6 + (0.33 x D)
N = N (lb/acre) needed for optimal growth
D = Difference between average chlorophyll readings from the field and the N-enriched reference area.

When interpreting the recommendations from the readings, consider the weather conditions and expected response of the recommended nitrogen so that appropriate adjustments to the recommendations can be made.

### *Diagnosing N Distribution Problems*

The chlorophyll meters can be used in fields with uneven N distribution to help estimate the difference in the N distribution. Multiple measurements (20 or more) are made in the area with the greenest color (high N) and also in the lighter green area (low N) area. The difference in the two average readings are placed in the respective formula to get the estimate.

**Example (T/A Meter)**

Darker green area = 42.5 average reading
Lighter green area = 36.5 average reading
Difference (D) = 6.0
7 x D = lb of N/acre difference between areas
7 x 6 = 42 lb of N/acre difference between two areas

So, if 80 pounds of N/acre were applied to the entire field, we would estimate that the low-N area received about 60 pounds of N/acre, and the high-N area received about 100 pounds of N/acre. This is estimated by the fact that the field average N application was 80 pounds of N/acre, and there was about a 40 pound of N/acre difference between high-N strips and the low-N strips.

## Conclusions

The transmission/absorption-type of chlorophyll meter (SPAD 502) and the reflectance-type of chlorophyll meter (CM 1000) were compared for their use on wheat. Both meters performed well. When the chlorophyll readings were taken on wheat at Feekes 6 growth stage with different nitrogen rates, they resulted in these findings.

- Readings with both types of meters correlated very well with the amount of nitrogen available to the crop and the final yield. This lends strong support that either type of meter can be used to assess nitrogen status of the crop and to make nitrogen recommendations and diagnose nitrogen distribution problems.
- The reflectance-type meter is faster and easier to use and measures a larger area with each reading.
- The reflectance-type meter is affected by sunlight intensity and angle of the sun. Readings made between 10 a.m. and 2 p.m. with good sunlight are the most reliable.
- The reflectance-type meter is affected by the angle of the meter in relation to the canopy surface. Readings taken at 90° to the canopy surface are more consistent than measurements taken at 45° to the canopy surface when taken between 10 a.m. and 2 p.m. However, measurements taken at a 45° angle are less affected by sun angle and can be taken over more hours during the day.



Issued 11-2004