Agronomy Facts 53

The Early Season Chlorophyll Meter Test for Corn

SUMMARY

The chlorophyll meter is a portable, handheld device that instantaneously measures the greenness (or chlorophyll content) of a plant in the field.

Nitrogen (N) is closely associated with leaf chlorophyll; thus, chlorophyll-meter readings of corn leaves provide information about the N status of the corn plants.

The early season chlorophyll meter test consists of taking meter readings of corn leaves when plants are between the six- and eight-leaf stages (when plants are about 10 to 20 inches tall), which allows time to sidedress if necessary.

Meter readings taken from plants in a field will indicate if N is adequate for optimum yield with no additional N. If additional N is needed, the meter reading and other field information can be used to develop an improved sidedress N recommendation.

Currently, two methods exist for using the chlorophyll meter in corn. The preferred method is to establish a high-N reference plot that has been adequately fertilized with N fertilizer early in the season in each field to be tested. Readings are taken from this reference area and the rest of the field. Additional N is required for optimum corn yield if the average meter reading of the field is less than 95 percent of the high-N reference value.

An alternate method that is valid on fields with a history of manure since previous crop and/or first year after forage legume (alfalfa, alfalfa/grass, clover) does not require the establishment of a high-N reference plot. In this method, readings are taken at the six-leaf stage, and if the readings are very high, no sidedress N is recommended. If the readings are very low, a sidedress N recommendation can be made using the meter reading and other field information. For fields where the readings fall between very high and very low, a second reading is taken a week later to determine if and how much sidedress N is needed.

Advantages of the early season chlorophyll meter test:

- Chlorophyll meter readings are quick, easy, and provide instantaneous values.
- No samples need to be collected, processed, and sent to a laboratory for analysis.
- Cost of sampling involves only labor costs.
- Nitrogen recommendations are accurate (comparable to the presidedress soil nitrate test).

Disadvantages of the early season chlorophyll meter test:

- Initial expense is high (the meter costs about $1,500).
- Early season corn leaf chlorophyll levels are affected by hybrid characteristics and environmental stresses; therefore, for best results, establish high-N reference plots.
- This test is not applicable to fields that have received a preplant or an at-plant N fertilizer application beyond about 15 pounds per acre of starter N.

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NITROGEN AND CORN PRODUCTION

The nitrogen (N) requirement for optimum corn production can be met in a number of ways. Soils supply N by organic matter decay. In Pennsylvania, manure and N added to the soil by legumes like alfalfa are important sources of N. Also, N can be supplied in fertilizers. In most situations, the corn crop's total N requirement is supplied by a combination of these sources. When the only sources of N are the soil and fertilizer, N fertilizer recommendations have been estimated based on realistic expected crop yield. However, estimating the contributions of manure and legume N is complicated because of the variability of factors such as forage stand composition; timing, method, and rate of manure applications; and just the very dynamic nature of N behavior. Therefore, making economically and environmentally sound N recommendations is difficult on many farms in Pennsylvania.

NITROGEN CONTAMINATION AND THE ENVIRONMENT

Nitrogen from agricultural operations has been identified as a significant source of nitrate contamination not only in Pennsylvania's surface water and groundwater in agricultural areas but also in other areas of the Northeast, such as the Chesapeake Bay. Good N management, including efficient fertilizer N use, can minimize the amount of nitrate N that is excessive for crop growth and available for possible contamination of water resources. Since N deficiencies can lead to significant yield reductions, growers may be reluctant to risk applying fertilizer N rates that may be too low. Pennsylvania farmers need a reliable method of determining economically sound and environmentally safe N fertilizer rates.

CORN NITROGEN NEEDS AND SOIL TESTING

The complex behavior of N in the soil has several important implications for managing N for optimum corn production and determining availability of soil N. Corn has the greatest need for N starting about 30 to 45 days after emergence, which is after the period of greatest change in soil N availability in the spring. The efficiency of N use can be improved if the N is applied after the spring wet season and near the time of greatest need by the crop. Sidedressing N in June when the corn is 10 to 20 inches tall has become a common practice for Pennsylvania corn growers. Since corn has the greatest need for N several weeks after emergence, an N test at that point can more accurately reflect the actual availability of soil N for the corn crop.

Soil testing has been effectively used for years to determine the availability of phosphorus (P) and potassium (K) in agricultural soils and fertilizer recommendations for these nutrients. Unfortunately, due to the complex behavior of N in the soil, development of a reliable soil test for N availability has been more difficult. A major difficulty in managing N is that while manure and fertilizer are often applied far in advance of N uptake, N availability can be affected by numerous factors throughout the growing season. A soil test conducted during the growing season, such as the presidedress soil nitrate test (PSNT), can help growers adjust fertilizer N rates to meet the demands of the crop. (For additional information on PSNT, refer to *Agronomy Facts 17: Presidedress Soil Nitrate Test for Corn*.)

USING A CHLOROPHYLL METER TO ASSESS CORN NITROGEN STATUS

A small, portable chlorophyll meter (Minolta SPAD-502; retail cost is about $1,500) was developed that instantaneously measures the greenness of a plant leaf, which is directly related to the chlorophyll content of the leaf. Since most leaf N is contained in chlorophyll molecules, there is a close relationship between leaf N and leaf chlorophyll content. Therefore, chlorophyll meter readings of corn leaves can be an indicator of the N status of corn plants and the need for additional N for optimum yields. A chlorophyll meter test has many advantages. Taking chlorophyll meter readings of corn plants is easy and rapid. The readings are taken in the field, so no samples need to be collected, processed, and sent to a laboratory for analysis. Results are available immediately in the field.

Other factors besides N status can affect the chlorophyll meter readings of corn leaves. Leaf color may vary by hybrid. Soil and air temperatures, planting date, leaf stage, and leaf position may affect leaf greenness. Plant diseases, other nutrient deficiencies, or any other factor that causes plant stress may also affect plant color. One way to minimize the effect of these complicating factors is to establish a small reference area in each field to be tested that has been adequately fertilized with N fertilizer (see the "High-Nitrogen Reference Method" section below). Chlorophyll meter readings in the field can then be compared to readings from this reference area.

Research in Pennsylvania has led to the development of a testing procedure that uses chlorophyll meter readings as an accurate indicator for N sidedress requirements for corn. The procedure is applicable to corn crops that have received no fertilizer N before or at planting except for a rate of starter that applies no more than 15 pounds of N per acre. Chlorophyll meter readings are taken from corn plant leaves shortly before the time suitable for N sidedressing. These readings are good for predicting whether a response to additional side dress N is expected. If the test indicates that the crop needs additional N, the meter reading and other field information can be used to develop an improved N sidedress N recommendation.

THE EARLY SEASON CHLOROPHYLL METER TEST FOR CORN

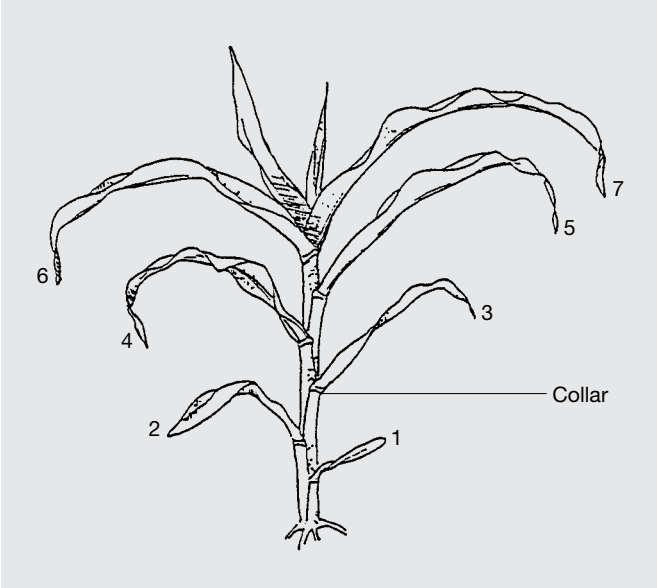
There are two methods for using the chlorophyll meter to improve N management for corn. One method involves establishing a high-N reference area early in the season in each field to be tested. When the test is run, chlorophyll meter readings are taken from this high-N reference area and from the rest of the field. The relative readings are then used to interpret the test results. The second method does not require a high-N reference area, but it is limited to fields with a recent history of manure or forage legumes and may require taking

chlorophyll meter readings at two different times in some fields. Detailed procedures for these two methods are given later in this fact sheet. Regardless of the test method used, you must be able to determine the growth stage of the corn so that readings are taken at the correct time and you must know how to operate the chlorophyll meter. These skills will be discussed first.

Time of Sampling

For both methods of using the chlorophyll meter it is critical to not take the readings before the six leaf stage of growth of the corn (when corn is usually 10 to 20 inches tall). The test can be taken at later leaf stages, but the interpretation must be adjusted for the actual leaf stage. Thus, to use these tests correctly, the growth stage of the corn must be accurately determined. Figure 1 shows a corn plant at the six-leaf stage. The first leaf on the corn plant is often rounded and small. Usually, each succeeding leaf will be wider and longer than the leaf below it. As each leaf becomes mature, a collar will form around the stalk of the plant at the base of the leaf. The collar will appear as a thin, lighter-colored line. Leaf six of the plant in Figure 1 is fully mature and collared. Leaf seven has not fully emerged and has no leaf collar. As plants mature (sometimes by the eight-leaf stage), the lower leaves may senesce (mature and die) and fall off, which makes it difficult to determine the leaf stage. The small oval leaf at the bottom is especially susceptible to senescence. Even if no small oval leaf is present it should be counted as the first leaf anyway.

Figure 1. Illustration of corn plant showing leaf number and collar region.



All the plants in the field often will not be at the same leaf stage. Use the following guide to estimate the leaf stage of the field:

6.00 almost all plants at the six-leaf stage

6.25 mostly six-leaf-stage plants with a significant number of seven-leaf-stage plants

6.50 about half six-leaf-stage plants and half seven-leaf-stage plants

6.75 mostly seven-leaf-stage plants but a significant number of six-leaf-stage plants

7.00 almost all plants at the seven-leaf stage

7.25 mostly seven-leaf-stage plants with a significant number of eight-leaf-stage plants

7.50 about half seven-leaf-stage plants and half eight-leaf-stage plants

7.75 mostly eight-leaf-stage plants but a significant number of seven-leaf-stage plants

8.00 almost all plants at the eight-leaf stage

Chlorophyll meter readings should not be done if the corn in the field being tested is not yet at the six-leaf stage or older. Plants younger than leaf stage six may still be overly affected by starter N and environmental stresses. Readings at the seven- and eight-leaf stages usually result in more accurate fertilizer recommendations than those done at the six-leaf stage. Depending on weather conditions, corn plants may mature one leaf stage in about three to six days. Readings can be done later than the eight-leaf stage, but plants may be getting too large to sidedress or leaf five may be beginning to senesce. Specific instruction for when to sample for the two methods will be given below in the procedure details. If there is doubt about the growth stage of the corn, it is much better to err on the late side rather than test too early.

TAKING CHLOROPHYLL METER READINGS OF CORN LEAVES

Regardless of which method is used for the test, chlorophyll meter readings are taken the same way. The manual provided with the chlorophyll meter gives detailed instructions for operating the meter. Below is a brief explanation of how to use the meter to take leaf readings for the early season chlorophyll meter test:

1. Internal calibration of the meter is necessary when the meter is switched on. To calibrate the meter, turn on the meter. “CAL” will appear in the window. With no sample in the sample slot, press the measuring head down. The meter will beep when the calibration is complete. The display will now show “N = 0” (N is the sample number). If the display flashes “CAL” and beeps, the calibration was not performed correctly (probably because the sample head was not closed completely). Repeat the procedure. If the meter beeps and “EU” appears at the top of the dis-

play, the top and bottom windows of the measuring head may be dirty. Wipe them clean and repeat the procedure.

2. Pick representative plants in the field for meter readings. Care should be taken to avoid any unusual or damaged plants or leaf parts when doing meter readings. Plants chosen should be relatively evenly spaced rather than separate from others or in a cluster.
3. Chlorophyll meter readings of corn leaves are affected by the part and position of the leaf on the plant that is sampled. Therefore, it is necessary to standardize which part of the corn plant is read with the chlorophyll meter. For this test, chlorophyll meter readings should always be done on leaf five (Figure 1) of the plants being tested. The reading is done at a point on the leaf approximately 0.5 inch from the edge of the leaf and three-quarters of the leaf length from the leaf base (Figure 2).
4. To take a leaf reading, place the leaf in the slot of the meter head. Use the center line on the measuring head to align the measuring head window and the spot on the leaf to be read. When the head is closed on the leaf, the meter will beep, a digital reading will appear on the display, and the reading will be stored in the meter. Sometimes the meter will beep and not give a reading. When this happens, try slightly changing the alignment before closing the head again.

Figure 2. A chlorophyll meter in use.

5. Do not take readings on the leaf midrib or too close to the edge. Use your body to shield the meter from direct sunlight. Wet leaves may be read if beaded water is shaken or rubbed off before inserting the leaf in the meter.
6. Occasionally, you may get readings that are very different from others in the field or that do not seem correct to you. These can be deleted by pressing the "1 DATA DELETE" button (Figure 3), which will remove the last reading. A new reading can then be taken to replace the deleted reading. Be careful not to press the "ALL DATA CLEAR" button because this will remove all readings taken to that point. If you want to look over all your readings at any time, use the "DATA RECALL" button to scan the readings you have taken. Each time this button is pushed, the meter will cycle through the readings in the order they were taken. During the scan, you may use the delete button to remove a reading and then replace it by taking another reading.
7. The chlorophyll meter will store up to 30 readings. At any point, pressing the "AVERAGE" button will display the average of the readings taken so far. When you have completed the readings on a field, record the average reading and then press the "ALL DATA CLEAR" button to delete all the readings currently saved before you begin a new set of readings.

Figure 3. Picture of chlorophyll meter showing function buttons, display screen, and meter head.

Once the operator has become familiar with the meter operation and leaf stage identification, readings can be done very quickly. Since the meter will store up to 30 readings in memory and then calculate an average reading, at least 30 readings should be done. If a field is very variable, more readings may be necessary for an accurate field average or to determine if several different N rates would be appropriate for the field.

DETAILED PROCEDURES FOR THE TWO CHLOROPHYLL METER TEST METHODS

High-Nitrogen Reference Value Chlorophyll Meter Test Method

Because early season corn leaf chlorophyll levels depend on factors besides N fertility (e.g., hybrid characteristics, soil temperatures, cold stress), it is helpful to have a high-N reference where N is more than adequate for optimum production for each field tested. This area provides a standard for comparing the rest of the field to when the readings are taken. Having this high-N reference area improves the accuracy and reliability of this test. This is the preferred method for using the chlorophyll meter test.

Procedure

1. Fields to be tested should not have received fertilizer N beyond a normal amount of starter N—**no more than 15 lbs N/acre in the starter.** Violating this rule will often result in the test indicating that the crop has adequate N, but in reality it may not, resulting in a potentially significant yield reduction. Manure N applied before the crop is okay.
2. Establish a high-N reference area in each field to be tested.
   - The reference area should be in a representative part of the field where the corn will not be unusually stressed by factors like weed competition, soil compaction, or other negative impacts. Ideally, because different hybrids often have different leaf color, high-N reference areas should be established for each hybrid.
   - This area could consist of at least two small hand-fertilized sections about four rows wide by about 20 feet long, or it could be a longer strip that was machine fertilized.
   - Apply more than enough N to meet potential crop requirements for this area. Typically, at least 150 to 250 pounds of N per acre is applied. The actual rate and fertilizer material used is not critical. While sulfur (S) deficiency is rare, if there is a possibility of an S deficiency, then ammonium sulfate should not be used in the high-N reference area.
   - The fertilizer should be applied to the reference area no later than the spike stage so that plant leaves are not burned.
   - Mark this area (e.g., with a flag or stake) so that you can find it at the six-leaf stage when the corn may be over 20 inches tall.
3. Monitor the growth stage of the corn in the fields to be tested. Readings can be taken when the corn is at least at the six-leaf stage—no earlier. Sometimes, the high-N reference area of the field may be the best place to first check for the leaf stage since high-N plants retain their lower leaves longer than N-stressed plants. However, the growth stage for the bulk of the field should be at least at the six-leaf stage before taking any readings.
4. Take readings as described earlier with the chlorophyll meter from the fifth leaf of 30 plants in the high-N reference area, record the average, and clear all the data from the meter. Repeat, taking readings in the same way from the rest of the field.
5. Use the worksheet on the following page to determine if additional sidedress N is needed and, if so, how much to apply.

The calculated N fertilizer recommendation should be rounded to a number that is practical or convenient for the farmer. The N recommendation from this calculation can range from about 0 to more than 200 lbs N/A. Research has shown that when this calculated N rate is less than 30 lbs N/A, the probability is extremely low that the field will respond to N fertilizer. In other words, this formula can identify additional nonresponsive sites that had relative meter readings below the critical level of 0.95. However, in these cases other background factors may influence the N fertilizer recommendation. For example, if the calculated N fertilizer rate is 25 lbs N/A and the plant population is high, growing conditions look good, and the corn is to be harvested for silage, the final recommendation might be to sidedress with approximately 30 to 50 lbs N/A. In contrast, if the plant population is low, conditions are droughty, and the corn is to be harvested for grain, the better recommendation might be no additional N

CALCULATING AN N FERTILIZER RECOMMENDATION FOR THE HIGH-N REFERENCE AREA METHOD

RECOMMENDATION CALCULATIONS

Relative SPAD reading[a]

	Average field meter reading	÷	High-N reference value	=	Relative SPAD reading	**1**

If the relative SPAD reading is ≥ 0.95, the N recommendation is zero.
Otherwise, continue the calculations below.

Yield factor[b]

Expected yield (bu/A)	x	0.9	=	Yield factor	**2**

Manure factor[c] (Enter factor from list below box.)

17 x Manure since last harvest None = 0.75 Any = 3.5	x	**1** Relative SPAD reading	=	Manure factor	**3**

Leaf stage factor[d]

19 x Leaf stage of corn crop	x	**1** Relative SPAD reading	=	Leaf stage factor	**4**

Reference plot factor

4 x High N reference value			=	Reference plot factor	**5**

Recommendation

280+ [ ] **2** Yield factor − [ ] **3** Manure factor − [ ] **4** Leaf stage factor − [ ] **5** Reference plot factor = [ ] lbs N/A[e]

a. SPAD refers to the portable chlorophyll meter (Minolta SPAD-502).

b. Express in bushels per acre (bu/A). The yield should be a realistic goal. Increasing the yield goal will increase the N recommendation.

c. 0.75 for field where no manure was applied since the previous crop's harvest; 3.50 for field where any manure was applied since the previous crop's harvest.

d. Leaf stage of the field (not the high-N reference plot).

e. If the calculated recommendation is less than 30 lb/A, a zero recommendation is suggested.

even though the calculation called for 25 lbs N/A.

Two-Step Chlorophyll Meter Test Method (No High-N Reference Area)

Because it is sometimes difficult to anticipate where the chlorophyll meter test will be used and the extra effort required to establish a high-N reference area, an alternative procedure was developed that does not require a high-N reference area but may require multiple readings from a given field. This procedure has only been calibrated and verified for fields that have a recent history of manure applications and/or are being rotated from a forage legume crop.

Procedure

1. Fields to be tested should not have received fertilizer N beyond a normal amount of starter N—**no more than 15 lbs N/A in the starter**. Violating this rule will often result in the test indicating that the crop has adequate N, but in reality it may not, resulting in a potentially significant yield reduction. Manure N applied before the crop is okay.
2. Only use this test on fields that have received manure since the previous crop was harvested and/or that are in the first year of corn following a forage legume (alfalfa, alfalfa/grass, clover). **This procedure is valid only on these fields.**
3. Monitor the growth stage of the corn in the fields to be tested. When the corn is at least at the six-leaf stage—no earlier—readings can be taken.
4. Take readings as described earlier with the chlorophyll meter from the fifth leaf of 30 plants in the field and record the average.
5. Use Table 1 below to determine the recommendation based on this reading.
6. If the first reading is taken at the seven- to eight-leaf stage, skip Table 1 and go directly to Table 2 below for interpretations and recommendations.
7. If the reading at six-leaf stage is between 42.0 and 45.9, the recommendation in the table is to "Test Again." This means that a second set of meter readings should be taken approximately four to seven days later on that field, by which time the plants should be at the seven- to eight-leaf stage. Depending on weather conditions, fields usually advance one leaf stage in about three to six days. Use the same procedures as for the first reading. **Make sure you are still reading leaf five.** Use Table 2 to predict whether a field needs to be sidedressed based on this second set of readings.

METER CARE

- Do not leave the meter on the dashboard of your vehicle or lying in the sun.
- The meter is water resistant and can be used on wet plants, but it should not get excessively wet or be immersed in water. If the meter is dirty or wet, wipe it gently with a clean, soft cloth.
- Turn off the meter when it is not in use. Remove the batteries if the meter will not be used within two weeks.

Table 1. Interpretation of chlorophyll meter readings taken at the six-leaf-stage in fields with a recent history of manure or a forage legume without a high-N reference plot.

Average meter reading for the field	Less than 42.0	42.0–45.9	≥ 46.0
Nitrogen recommendation	Sidedress 80 lbs N/acre	Test again or sidedress 50 lbs N/acre	No sidedress N needed

Table 2. Interpretation of chlorophyll meter readings taken at the seven- to-eight-leaf stage in fields with a recent history of manure or a forage legume without a high-N reference plot.

Average meter reading for the field	Less than 43.0	≥ 43.0
Nitrogen recommendation	Sidedress 50 lbs N/acre	No sidedress N needed

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