Use of the End-of-Season Corn Stalk Nitrate Test in Iowa Corn Production

Nitrogen (N) application is typically required for optimal corn yield and profitability. Rate selection is important, and can affect achieving both of those goals. There are in-season tests that can aid in N rate adjustment, such as soil nitrate testing and crop canopy sensing. An end-of-season test such as the corn stalk nitrate test (CSNT) cannot provide information for in-season rate adjustment, but instead provides information on N supply for the season that just ended. Research has shown that the concentration of nitrate in the lower corn stalk relates to N available to corn during the season.

Many producers associate a dark green plant throughout the entire growing season with an optimal rate of N fertilization. However, corn leaves on the lower part of the plant tend to lose their green color late in the season even when economically optimum N rates (EONR) were applied. Therefore, the end-of-season corn stalk test can help producers understand if there has been over-fertilization that reduces profitability and increases the chance of nitrate loss to water systems. Corn plants with optimal or inadequate N supply remove N from the lower stalks and leaves during the grain-filling period, and thus have low nitrate levels in the lower stalk. Corn plants that have more N available than needed to attain maximum yield for the specific growing conditions, however, accumulate nitrate in the lower stalk at the end of the season. The CSNT may be most helpful on manured fields where there is uncertainty in manure N supply and potential for too much N applied with manure and additional fertilizer. Corn following first year alfalfa is another situation where the CSNT can be helpful as the N supply from the prior alfalfa crop is typically adequate to meet the full corn N requirements.

Corn stalk sampling and testing

The corn stalk portion sampled is the eight-inch segment between six and 14 inches above the soil surface (see diagram on page 4). Leaf sheaths should be removed from the collected stalk segments. Research conducted in Iowa to develop the CSNT used a sampling time of 1-3 weeks after black layer formed on about 80 percent of the kernels of most ears. Research in Pennsylvania indicated test results would be similar for stalks collected at the one-fourth milk line growth stage (allows testing corn grown for silage) and 1-3 weeks after kernel black layer formation. Research in Connecticut with silage corn found that samples collected at the time of silage harvest and 24 hours after silage harvest (with no rain in the 24-hour period) provided the same test results (samples collected from the recommended stalk segment at each sampling). If silage harvest is already completed, then there would have to be areas where the cutter bar was raised to provide a 14 inch height of stalk to sample. When fields are combine-harvested for grain, samples could be collected during harvest for easier within-field access to non-harvested corn, or after combining (if within the suggested time period after black layer) as long as the required lower stalk height is intact and there has been no rain between harvest and sampling.

Plants severely damaged by disease or insects should not be sampled. The stalk segment to sample is critical as the concentration of nitrate-N decreases considerably with distance from the soil (that is, highest concentrations in the lower stalk), especially with moderate to high nitrate-N concentrations. Therefore, the eight-inch segment between six and 14 inches from the soil is the sample that has been used for the test correlation with yield response. Other

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segments or distances from the soil surface have not been correlated and interpretations would be different. Fifteen of the eight-inch segments should be collected to form a single sample for analysis. Areas differing in soil types or management histories should be sampled separately. Collecting one composite sample from each of several small areas (less than an acre) that seem to be representative of larger areas within a field is an effective strategy. To associate CSNT results with late spring soil nitrate (LSNT) results, corn stalk sampling locations could follow those used for the LSNT. However, access to sample locations within a field at plant maturity can be difficult when corn is full-sized.

Samples should be sent to a laboratory for analysis as soon as possible after collection. Samples should be placed in paper (not plastic) bags to enable some drying and minimize mold growth. The time normally required to ship samples to a laboratory is not a problem. Samples should be refrigerated (but not frozen) if stored for more than a day before shipping. Laboratories will dry the samples as soon as they are received. Splitting the stalk segments lengthwise into two halves can aid in drying and processing, and does not affect results. The samples should be ground and analyzed for nitrate-N concentrations. Concentrations are expressed as ppm (parts nitrate-N per million parts of dry material). Most soil testing laboratories can analyze samples.

Test result interpretation

As with any test, there needs to be correlation of test results with the expectation of relative crop yield and response to applied N in order to develop interpretations of results that are useful for evaluation of N management. Figure 1 shows that CSNT concentrations generally increase linearly as N rate increases after some minimal amount of N is applied.

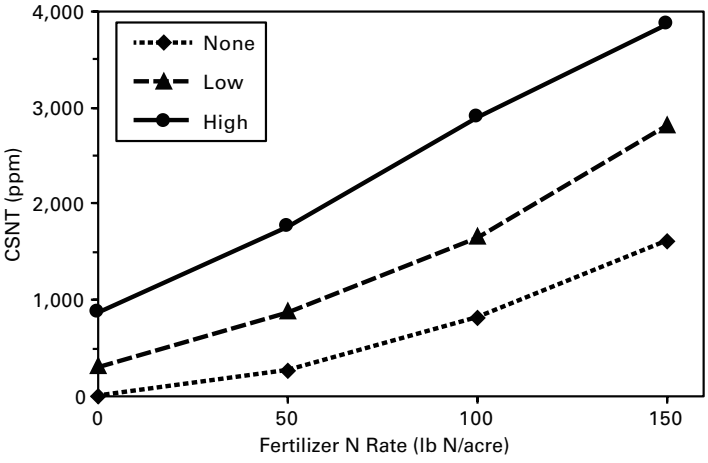

Figure 1. Effect of fertilizer N rate on the corn stalk nitrate test (CSNT) with no manure or in addition to poultry manure at two relative application rates, across multiple on-farm field trials in 2004-2006 (Ruiz Diaz et al., 2011).

This concentration response to applied N rate (manure, fertilizer, or combination) means there needs to be a clearly defined concentration or range that can be identified as a critical level or sufficiency zone. Continuously increasing concentration with increasing available N supply cannot be defined into a useable test.

Figures 2-4 show correlation data for Iowa studies in which corn yield response is expressed relative (by percent or bushel change) to maximum yield response. That is, yield reduced due to insufficient N will have a relative yield less than 100 percent or a yield increase from N application. Figure 2 is the correlation research presented in the original Iowa State University Extension and Outreach publication for the CSNT, "Cornstalk Testing to Evaluate Nitrogen Management"(PM 1584), with Figures 3 and 4 providing more recent Iowa research.

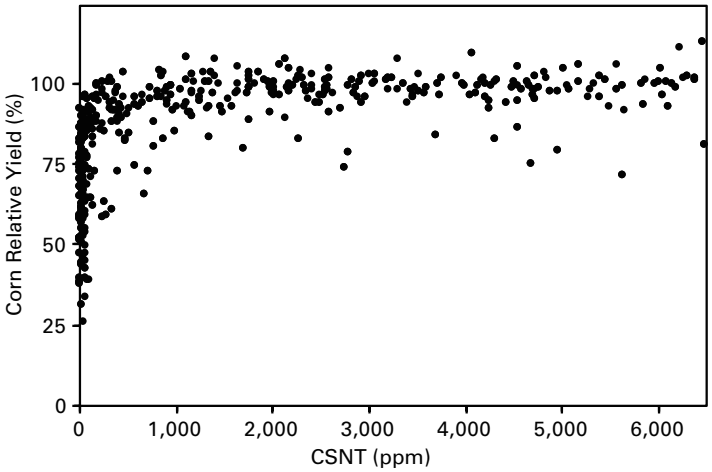

Figure 2. Relationship between the corn stalk nitrate test (CSNT) and relative corn yield (from PM 1584, Rev. 1996).

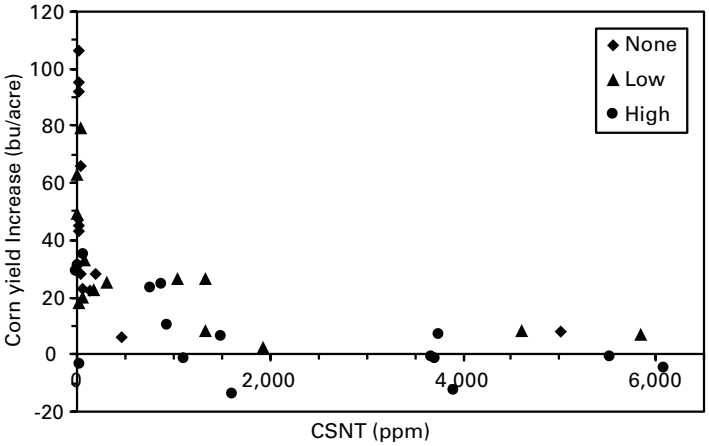

Figure 3. Relationship between the corn stalk nitrate test (CSNT) and corn yield increase to N fertilizer across multiple on-farm field trials in 2000-2003, with and without liquid swine manure relative application rate (Woli et al., 2013).

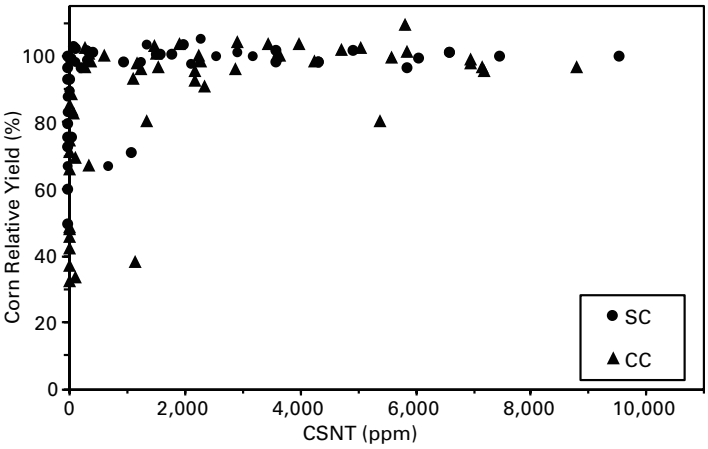

Figure 4. Relationship between the corn stalk nitrate test (CSNT) and relative corn yield across trials in 1999-2002 with corn following soybean (SC) and continuous corn (CC) (J. Sawyer, 2002).

As typically found, there is an almost vertical increase in relative yield or yield response up to a maximum versus CSNT concentration, and then a wide range in concentrations at maximum relative yield or with no yield increase. That sharp change in concentration (small concentration range) from low relative yield to 100 percent relative yield makes it difficult to quantitatively determine a critical level using response models. It is clear there is a large scatter of relative yield at low stalk nitrate concentrations. These results mean it is not possible to clearly define a single critical value. However, the data in Figures 4-6 indicate a break at 2,000 ppm, where above that concentration there is more than needed plant available N in the soil. Therefore, the 2,000 ppm level or greater can be used as an indicator of **High** CSNT concentrations. The original research studying the stalk nitrate test indicated an optimal range from 250-1,800 ppm. Using that criteria, and results of additional recent research in Iowa and other Midwestern states, an approximate **Sufficient** test category is suggested from 250-2,000 ppm nitrate-N in the lower corn stalk. Concentrations less than 250 ppm are considered a **Low** test category, but may or may not indicate deficient N depending on specific conditions. For example, in years with high yield and active grain fill late in the season where CSNT concentrations can be near zero, N supply would not necessarily be deficient. In years with drought conditions and poor ear development, concentrations can be in the **High** category (greater than 2,000 ppm) because drought limits yield; not because applied N would have been more than needed in a normal year. Also, in some instances with high CSNT concentrations there are no clear reasons for low relative yields. Based on data presented in Figures 5 and 6, the fewest errors occurred for CSNT values less than 250 and greater than 2,000 ppm (too little N or too much N). For the 250-2,000 ppm **Sufficient** category, and using an acceptable N rate range of ±30 lb N/acre around the EONR, there were about equal number of occurrences when the N rate was below or above the ±30 lb N/acre range. Therefore, CSNT tests should be conducted over several years to help understand variation that may be due to season or plant factors rather than N supply.

Calibration of the CSNT to estimate a needed change in N rate for a future corn crop has not been possible. Research has shown high N rate variations that maximize economic yield over time, even for the same field, and data in Figures 5 and 6 show there is considerable scatter in stalk nitrate-N concentrations both below and above the economic

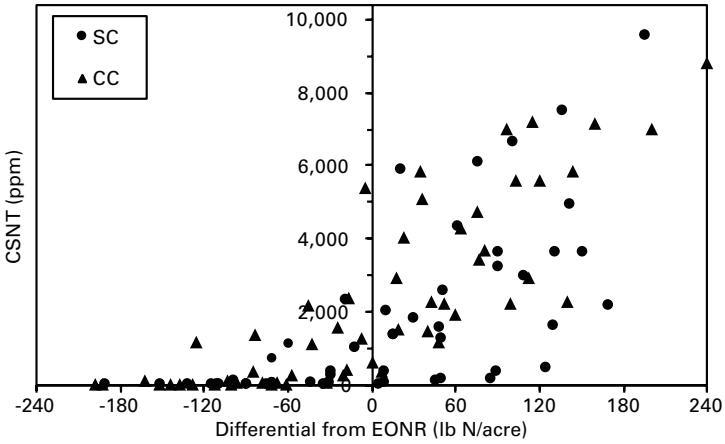

Figure 5. Relationship between the difference in fertilizer N rate from the economic optimum N rate (differential from EONR) and the corn stalk nitrate test (CSNT) across trials (1999-2002) with corn following soybean (SC) and continuous corn (CC) (J. Sawyer, 2002). Negative differential N rate values indicate deficient N and positive values more than needed available N.

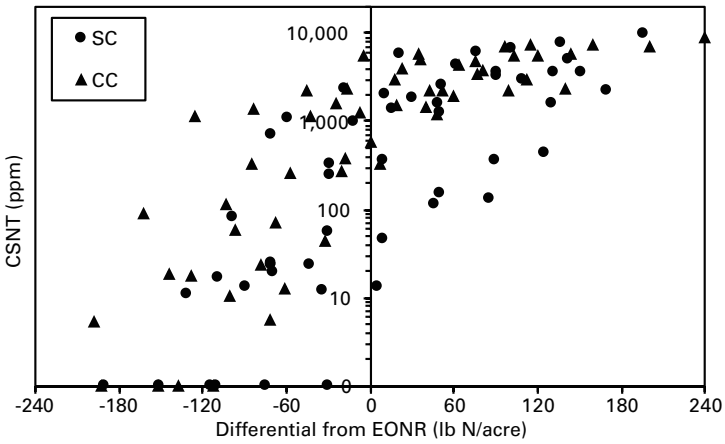

Figure 6. Relationship between the difference in fertilizer N rate from the economic optimum N rate (differential from EONR) and the corn stalk nitrate test (CSNT) across trials (1999-2002) with corn following soybean (SC) and continuous corn (CC) (J. Sawyer, 2002). Data from Figure 5 with the CSNT axis converted to log base 10 values in order to expand the scale for low CSNT concentrations.

optimum N rate (EONR). This means the test cannot be used to determine either how much more N should have been applied in a given year (left side of the graph), or how N was applied that was not needed (right side of the graph). Therefore, the CSNT is not a tool for determining specific rate adjustment. However, the test is most useful for determining when too much N is available on a consistent basis (greater than 2,000 ppm), and producers can try to determine the reasons why CSNT values are **High**. If results are **High** across multiple years, then rate reductions would be appropriate with minimal chance of yield loss. Similar types of considerations are useful for results in the **Low** test category. If results are **Low** over multiple years, then additional N would be appropriate or adjustment to N management practices that may be limiting N supply to the corn crop.

Corn Stalk Nitrate Test (CSNT) Interpretation Categories:

Low: < 250 ppm

Sufficient: 250-2,000 ppm

High: > 2,000 ppm

Test reliability and precautions

The concentration of nitrate-N in the lower corn stalk at the end of the season reflects all factors that influenced N availability and crop N needs during the growing season. A CSNT result within the **Sufficient** category indicates a high probability that N supply was adequate for the conditions during the growing season. Because many factors influence N availability, however, mainly after manure and fertilizers are applied, it is unrealistic for stalk nitrate concentrations to be in the **Sufficient** category in all fields in all years.

Many factors can influence test results, including drought, high rainfall, poor ear development, long end-of-season grain fill, hybrid used, and insect or disease damage. When interpreting test results, consideration must be given to these factors and conditions that occurred during the growing season, especially during grain development, that may affect poor grain production or fill (drought, poor kernel development) or provide for prolonged and exceptional grain fill (high N use efficiency by the plant). Typical suggested rates of fertilization can result in **Low** or **High** CSNT concentrations, but are not too low or too high N rates in most years.

Fertilization rates can be increased in future years for fields or areas that usually test in the **Low** category and rates decreased for fields or areas that usually test in the **High** category. The test does not directly indicate how much N rates should be increased or decreased, but continued use of the test for several years will provide a trend and thus allow adjustments that move concentrations more frequently into the **Sufficient** test category. The lower corn stalk test is most reliable at indicating situations when too much N was available, and thus best for helping reduce chances of over-application.

Collecting a good sample:

- Sample 1-3 weeks after black layer
- Collect 15 eight-inch stalk segments between six and 14 inches above the soil surface
- Randomly select stalks from about a one acre area that represents a larger area
- Separately sample different soil types and management areas
- Place stalks in paper bags, not plastic, for shipment to the lab
- Ship samples within one day or refrigerate until shipping

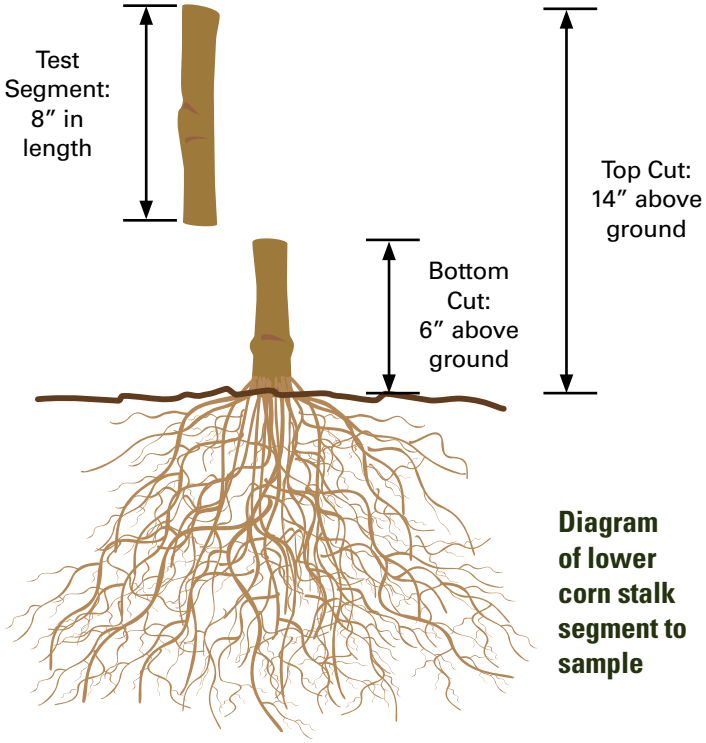

Diagram of lower corn stalk segment to sample

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