

END-OF-SEASON CORN STALK NITRATE-NITROGEN TEST FOR POST-HARVEST EVALUATION



Abstract

Sufficient supply of nitrogen (N) plays a key role in corn productivity and profitability. Excess nitrogen application wastes farmers' money, increases the risk of groundwater and surface water contamination, and contributes to greenhouse gas emissions. Evaluating N management is important for farmers to fine tune N management practices to achieve optimum corn yield and environmental sustainability. The end-of-season corn stalk nitrate-nitrogen test and corn yield are well correlated, which provides the basis for post-harvest evaluation of N sufficiency level.

Basis for Corn Stalk Nitrate-Nitrogen Test (CSNT)

Research has shown that the end-of-season corn stalk nitrate-nitrogen test (CSNT) is a reliable method to evaluate whether nitrogen (N) was adequate for optimum yield (Binford et al. 1990; Binford et al. 1992; Blackmer and Mallarino 2000; Ketterings et al. 2013). Under normal conditions, NO_3^- moves from the lower stalks and leaves to the corn ears during the grain-filling period. When excess N is available in soil during the growing season, NO_3^- accumulates in the lower portion of mature corn stalks. Therefore, CSNT can be a valuable post-harvest evaluation tool to assess N management practices. Future N management strategies, including N form, rate, and timing, can be adjusted based on two to three years of CSNT results.

CSNT measures nitrate-nitrogen (NO_3^- -N) concentration in the 6–14 inch, above-ground portion of corn stalks at the end of the growing season. CSNT results are typically categorized into four N sufficiency levels for corn growth: deficient (< 250 ppm), marginal (250–750 ppm), optimal (750–2,000 ppm), or excessive (> 2,000 ppm) (Binford et al. 1990). One study conducted for irrigated corn suggested that the deficient category

should be < 708 ppm (Isla et al. 2015), which is much higher than the original threshold established by Binford et al. (1990). The study further suggested that the optimal category should be 1,100–1,700 ppm under sprinkler-irrigated conditions, which is within the range established by Binford et al. (1990). Currently, CSNT is not broadly used by farmers in the state of Washington (WA).

Why Is CSNT Valuable?

Sufficient supply of N plays a key role in corn productivity and profitability. Excess N application wastes farmers' money, increases the risk of groundwater and surface water contamination, and contributes to greenhouse gas emissions. CSNT is an accurate post-harvest evaluation tool for identifying excess N availability.

Soil N tests, such as the pre-plant soil nitrate test (PPNT) and the pre-sidedress soil nitrate test (PSNT), are widely used to identify N sufficiency level in soils and to guide N fertilization. These soil tests are performed during the early growing season. Although these tests provide valuable guidance for estimating N availability on average, predicting N availability using a single soil test for any individual field is difficult, because N availability is influenced by many factors. For example, during the span of a growing season, N availability is influenced by rainfall patterns, air temperature, soil health, irrigation and other management practices, and manure and fertilizer application history. In-season, field-specific N applications based on PSNT should take into consideration these factors. Research is needed to develop N recommendations for in-season N applications based on PSNT for irrigated, long-term manured corn fields on WA dairy farms. The Illinois soil nitrogen test (ISNT) estimates the amount of readily mineralizable soil organic N in soils. The ISNT might be a useful test for estimating N availability for corn production in long-term manured fields and under irrigated conditions, which are typical for corn production systems on WA dairy farms. Research is needed to confirm the regional utility of ISNT for guiding N management for long-term manured corn fields on WA dairy farms. Proximal (such as

GreenSeeker crop sensing system by Trimble) and remote sensing images (such as satellite imagery and aerial imagery taken by cameras mounted on drones or aircrafts) can be used to identify N deficiencies later in the growing season (Tao et al. 2018).

At the scale of an individual field and within the context of particular soil and climatic conditions, CSNT estimates N uptake and evaluates the amount of N available to the plant during the growing season. Compared with PSNT and ISNT, the results of CSNT arrive too late to adjust N applications for the current crop; CSNT is a valuable tool for evaluating the performance of current N management practices and applying that information to future cropping seasons. By comparing CSNT results with established sufficiency levels, the high or low CSNT values are revealed. In turn, the farmer can make changes in N management that will benefit future crop production by evaluating long-term, end-of-season CSNT results. With time, N management changes can be fine-tuned, resulting in better N-use efficiency, greater economic returns, and less potential for negative environmental effects from excess N applications.

Corn Stalk Sampling Procedure

Sample Collection and Handling

Collect 8-inch corn stalk segments by cutting plants at 6 and 14 inches above ground (Figure 1). Remove leaves and leaf sheaths (Figure 2). Place samples in paper (not plastic) bags to enable some drying and to avoid molding. Mail samples to the laboratory as soon as possible after sampling. If immediate testing is not available, store samples at room temperature or refrigerate for no more than 8 days. Avoid freezing.

Collect a composite sample of 15 randomly selected plants for every 15 acres or less. Areas with different soil types or with different management, for example, different crop rotation, tillage, or irrigation practices, should also be sampled separately.

Another method to determine sampling locations is the guided sampling method using remote sensing images taken at tassling stage. Overlay the remote sensing image with the digital soil map of a field and select one sampling location within each dominant soil type (more information on soil surveys and methods provided in the Further Reading section). Figure 3 illustrates boundaries of predominant soil types. Within each soil type take a composite sample consisting of 15 randomly selected plants in a representative location. A representative location is determined based on NDVI or NDRE indices. Import the georeferenced sampling locations to handheld GPS for navigation within the field while sampling. Avoid sampling in locations with unique conditions, such as drain tile lines, areas where manure was previously stockpiled, or sites where corn stalks show significant damage from disease or insects.



Figure 1. Collect an 8-inch portion of the corn stalk between 6 and 14 inches above the ground (Photo by Haiying Tao).



Figure 2. Remove leaves and leaf sheaths (Photo by Haiying Tao).

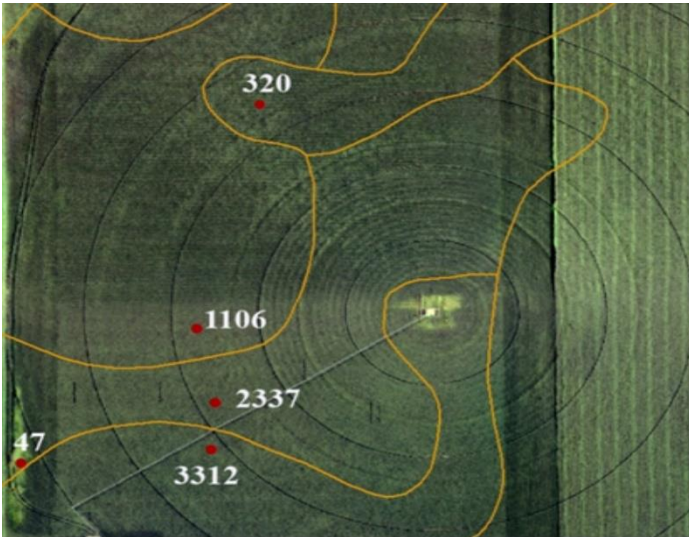


Figure 3. Yellow polygons represent soil type boundaries; numbers illustrate end-of-season corn stalk nitrate concentrations in ppm.

Sample Timing

Stalk samples can be collected when approximately 80% of the kernels of most ears reach black layer until harvest. The best time for sampling is between one and three weeks after black layer development. Collecting samples within five days after harvest will not significantly affect CSNT results unless rainfall, irrigation, or field management activities have occurred during this time period.

When corn is harvested for silage, collect stalk samples any time from one week before harvest to one day after harvest, or when the corn reaches approximately a quarter to one half of the milk line.

Interpretation of the CSNT Results

CSNT results are typically categorized into the following four sufficiency levels (Figure 4):

Deficient (< 250 ppm)

When CSNT measures NO_3^- -N below 250 ppm, the possibility is high that corn yield has been affected by N deficiency. The effects of N deficiency are easily observed by two methods. First, the corn plant's lower leaves will turn yellow and die prematurely. Second, based on remote sensing imagery, the visual sign of N deficiency is a yellow to light green canopy at tasseling stage. For example, in Figure 3, the canopy color is a much lighter green in the area where CSNT equals 47 ppm, compared to the darker green areas with higher CSNT values. Future increases in N application rates should be considered when corn becomes yellow or light green before drying down.

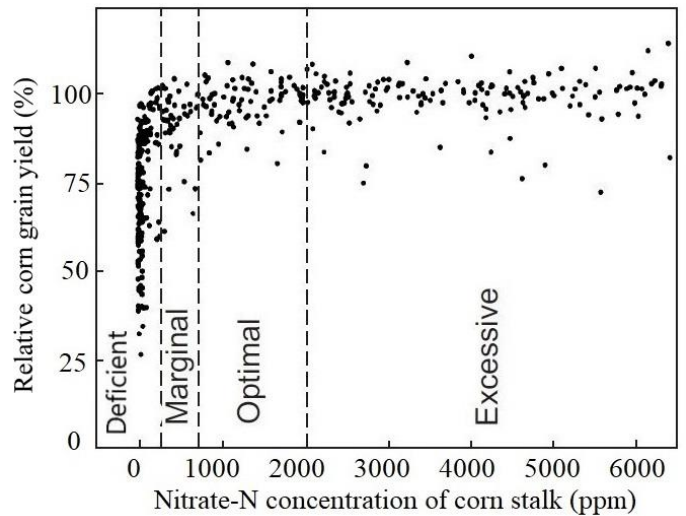


Figure 4. Relationship between corn stalk nitrate-nitrogen concentrations (CSNT) and relative yield (adopted from Sawyer and Mallarino, 2018). Relative yield = yield at the data point/maximum yield of the research site. Relative corn grain yield is shown as affected by the four CSNT N sufficiency levels: deficient, marginal, optimal, and excessive.

Marginal (250–750 ppm)

The marginal N sufficiency level represents NO_3^- -N concentrations at which economic return to N is maximized, although yield will be slightly lower than the maximum achievable. In other words, the N availability is very close to the optimum amount of N needed for maximum yield, but with additional N availability, a slightly greater yield response is possible. Growers should observe their cornfields closely to fine-tune N application rates that provide the greatest chance of optimizing yields in the following season's crop, while maintaining sufficient economic returns.

Optimal (750–2,000 ppm)

The possibility of increasing yields by increasing N application rates is low when CSNT values are within the optimal category range. The average yield increase is 5% as CSNT increases from 750 to 2,000 ppm. However, a large amount of N may be necessary to achieve this level of yield increase. In this case, site-specific judgment based on many years of CSNT values should be used before adjusting N rates.

Excessive (> 2,000 ppm)

When CSNT values exceed 2,000 ppm, N availability is substantially beyond what is needed to obtain maximum yield. In this case, reduction in N application rates should be considered and is strongly encouraged, especially when CSNT values are consistently in the excessive category for several years (two to three years). Consistent excessive CSNT suggests an excessive N supply for the corn field, which can lead to N loss to the environment. We recommend fine-tuning fertilization practices based on two to three years of CSNT data, because

CSNT values are affected by several factors that can vary from year to year. For example, CSNT could be high under drought conditions, which can cause reduced N remobilization from the lower portion of the corn stalk to the grain. Other stressed conditions, such as insect and disease pressure, could lead to fluctuation of the CSNT. This fluctuation is illustrated in Figure 4, which shows < 80% of maximum yield was achieved in some cases even though some of the CSNT values exceeded 2,000 ppm.

Other Considerations for CSNT Interpretation

Manured Cornfields

The within-field variability for CSNT values can be large in manured fields. Previous research has found that CSNT NO_3^- concentrations in the excessive category should be > 3,500 ppm for manured fields (Kyveryga et al. 2010; Isla et al. 2015). Conducting replicated strip trials to assess N response in fields under manure-based N management practices can help determine whether N rates should be adjusted. When land application of manure is the major method of manure disposal on dairy farms, fertilizer N should be reduced or eliminated first when CSNT results are in the excessive category. If CSNT is continuously high after eliminating fertilizer N applications, farmers may want to reduce manure application rates and relocate manure to fields where manure is applied less frequently.

Irrigated Corn Fields

The CSNT deficiency level in irrigated cornfields may be greater than in dryland cornfields. This difference may be because irrigated corn has higher yield potential and N demand or because different varieties are grown in irrigated versus dryland production systems. Isla et al. (2015) found deficiency levels of 708 ppm in sprinkler irrigated corn and 2,205 ppm in flood irrigated corn. The optimal category should be 1,100–1,700 ppm under sprinkler irrigated conditions, which is within the optimum level established for non-irrigated systems.

Drought Years in Non-Irrigated Areas

Drought conditions reduce the conversion of NO_3^- to protein in plants; therefore, NO_3^- can accumulate in corn plants. In addition, rainfall after a period of severe drought can result in a surge of NO_3^- uptake that may be poorly assimilated into protein

for days. These conditions make it difficult to evaluate N management based on a single-year CSNT and, thus, support the recommendation to collect CSNT samples for at least two to three years before adjusting N management.

Acknowledgement

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Further Reading

USDA-NRCS (United States Department of Agriculture, Natural Resources Conservation Service). 2019. [Web Soil Survey](#).

University of California Davis Soil Resource Lab. [Soil Survey](#).

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