Use of the Late-Spring Soil Nitrate Test in Iowa Corn Production

Nitrogen (N) fertilization is essential for profitable corn production. Nitrogen is a major input cost and can contribute to water quality impairment. Because application rate is related to economic net return level and nitrate-N concentration in drainage water, rate selection is important to improve overall N management. Also, required N rates can vary between years, therefore, in-season decision aid tools or tests can be helpful for guidance on application rate.

One tool that provides such information is soil nitrate sampling conducted in the late spring to assess the soil status for crop available N. This tool is called the Pre-sidedress Soil Nitrate Test (PSNT) in many areas of the United States, or the Late-Spring Soil Nitrate Test (LSNT) in Iowa where it is also implemented to assess the status of current-year fertilizer or manure application. In this publication the term LSNT will be used for the soil nitrate test. Sampling the soil for nitrate-N provides information on available N before the crop begins rapid N uptake and can enable site-specific assessment of available N and sidedress fertilization needs.

The soil nitrate-N (NO_3-N) concentration measured by the LSNT is an index of the soil's capacity to supply crop available N, not an amount of nitrate-N in the soil sampled. Therefore, as with phosphorus and potassium soil tests, there needs to be a correlation and calibration of test results with the expectation of relative crop yield and response to applied N rate in order to develop interpretations of LSNT results that are useful for making sidedress N application decisions. Figures 1-5 show correlation data for Iowa studies from 1986-2015 in which corn yield response is expressed relative (by percent or change) to yield with non-limiting N. Those studies have shown that the relationship between the LSNT and relative corn yield has been consistent across time.

Because the LSNT is an index, and soil nitrate-N concentrations vary with depth and across the season, sampling at times and soil depths other than established for the LSNT will not provide reliable results and the research-based LSNT interpretations cannot be used.

For example, once corn begins N uptake from the soil, soil nitrate-N concentrations decline, especially the rapid uptake period during mid-to-late vegetative growth. Therefore, low soil nitrate-N concentrations are expected

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as corn nears tasseling or silking (Figure 6). Conversely, sampling in the early spring before soils warm misses the period of rapid N mineralization and soil nitrate-N concentrations would be artificially low.

Soil sampling and testing

Time and depth of soil sampling

Soil samples are collected when corn plants are 6-12 inches tall (measured from the ground surface to the center of the whorl). This typically occurs from late May to early June, but varies depending on the spring season. If corn planting is significantly delayed, then collect soil samples in early June instead of later at the targeted plant height. T**he sample depth is 0-12 inches from the surface of the soil, the same depth used in the LSNT calibration research.** These are the sampling criteria of the LSNT calibration, both depth and timing. Depth of sample is critical as nitrate from injected manure or N fertilizer may be near the bottom of the one-foot sample depth.

Sampling areas

Selecting field areas for sample collection is one of the most challenging aspects of LSNT sampling, as it is for any other soil test. The LSNT has additional challenges due to sampling depth, number of cores, and cost as the LSNT is only useful for the current season. Each sample should represent a uniform field area, with a similar N fertilization history, that can be managed as a unit for N application.

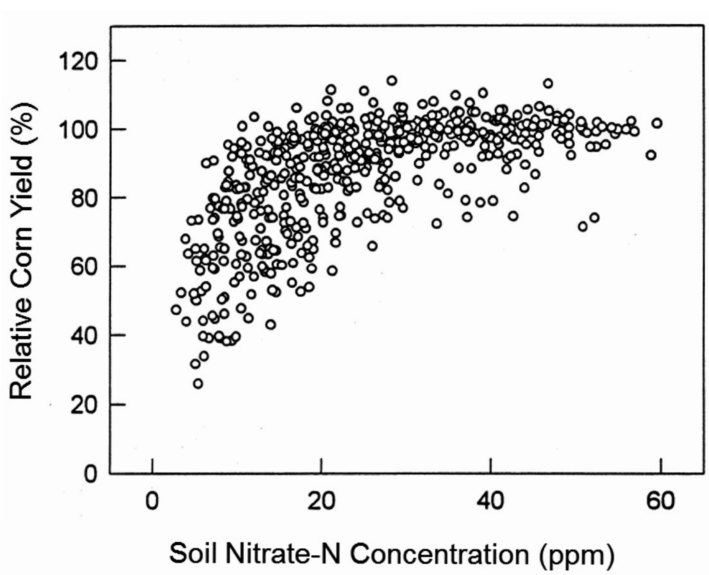

Figure 1. Relationship between the late spring soil nitrate test (LSNT) and relative corn yield across multiple trials (1987-1992) with at least six rates of fertilizer N applied early spring with corn following soybean and continuous corn (Yang, 1999).

Care should be taken to avoid unusual spots such as old barnyards, feedlots or manure piles, field edges where applicators may have made skips or doubled applications, abnormal patches of growing weeds or plant residues, or areas where corn plants suggest abnormal conditions for plant growth or N availability.

Ideally, sampling would use grid sampling or zones, such as what is done for phosphorus, potassium, and soil pH. However, using the same sampling areas for those inputs may not be appropriate or affordable for soil nitrate sampling. The optimal number of sample areas per field should be expected to vary due to many factors, including environmental conditions that vary between years and affect field areas differently. When sampling a field for the first time, consider testing about five areas for the first 100 acres and two more areas for each additional 100 acres that have similar management. Information gathered in the first year can be used to help guide future sampling strategies that are appropriate for a particular field or sub-field area.

General guidance is to collect samples within several field areas that are up to 10 acres in size and uniform with respect to soil characteristics and management histories.

Number of cores per sample

As it is for any other soil test, the number of soil cores per sample is a challenging aspect of sampling for the LSNT. This is especially the case when manure or fertilizer has been injected or band applied as the nitrate formed from those applications will be concentrated in the application zone and sampling bias can be large. Therefore, test results can be quite variable. Research has shown that the LSNT can be used when a partial or full N rate is applied preplant in the spring, however, the test is more reliable when manure or fertilizer is broadcast. With banded manure or fertilizer there needs to be careful sampling and cautious interpretation of results. Even with a broadcast application, the LSNT variability is often higher with spring applied full N rates and the short period of time between application and sampling.

Collect soil cores at random from each sampling area, with each sample comprising of 16-24 cores. To reduce sampling bias with banded or injected manure or fertilizer, especially with spring applications, cores should be collected in a set pattern so soil is representatively collected from within and outside of N bands.

Collect soil samples in sets of eight cores that have various assigned positions relative to corn rows. Cores are collected randomly, but each time a core is collected, the position is selected relative to the two nearest corn rows.

1. **The first core is collected in a corn row.**
2. **The second is collected one-eighth of the distance between any two rows after moving to another part of the sampling area.**
3. **The third is collected one-quarter of the distance between any two corn rows after moving to another part of the sampling area.**

The process is continued until the eighth core is collected seven-eighths of the distance between any two corn rows. At least three sets (24 cores) should be collected.

Preparing, handling, and shipping soil samples

The soil from all cores must be crushed and thoroughly mixed before a subsample is removed for analysis. Soils that are extremely wet or muddy should not be sampled. It is difficult to mix wet soils and incorrect results will be obtained if water drips from the samples.

Moist soil samples should be protected from temperatures above 75°F and should be refrigerated or frozen if they cannot be analyzed within two days. Mailing usually poses no problem if the samples are without refrigeration for no more than two days. Assume soil testing laboratories will protect the samples as soon as they are received.

Soil samples expected to be without refrigeration for more than two days should be dried as soon as possible. Samples can be air-dried by spreading in a thin layer on paper, or by using a fan to accelerate drying. Samples can also be dried in an oven provided the temperature does not exceed 104°F.

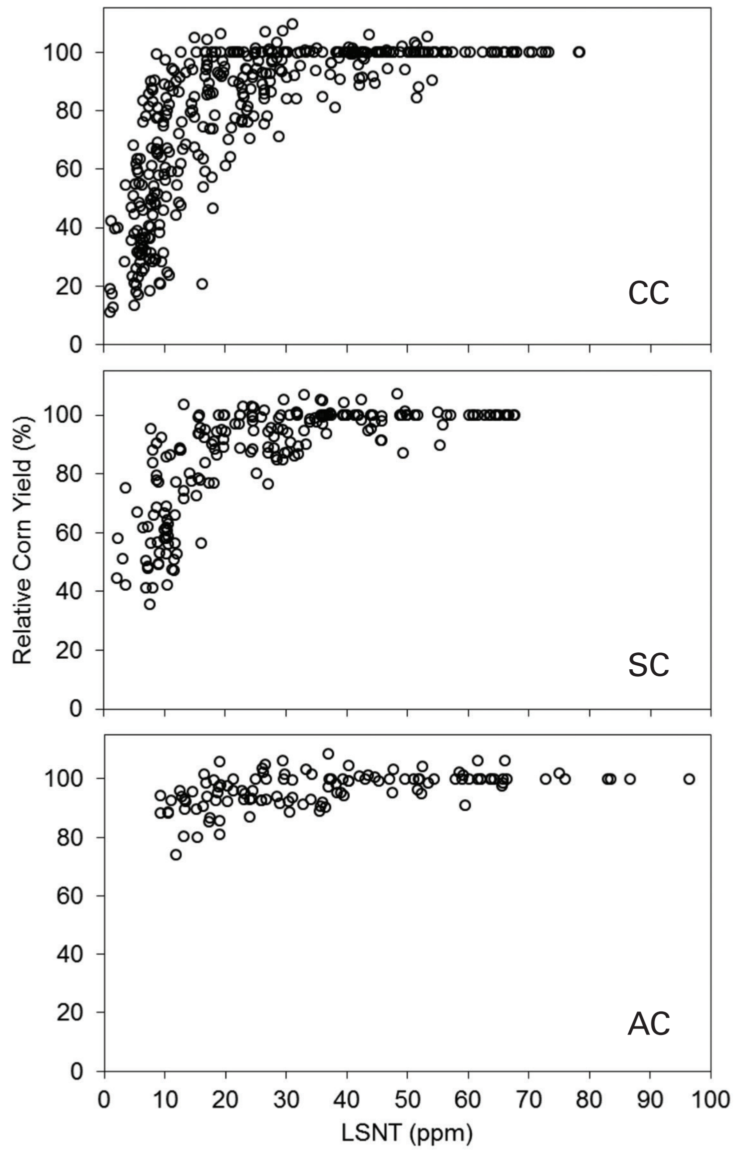

Figure 2. Relationship between the late spring soil nitrate test (LSNT) and relative corn yield at two sites in Iowa across ten years (1994-2004), with four N rates broadcast-incorporated as urea in the spring preplant, and with corn following corn (CC), corn following soybean (SC), and corn following one or two years of alfalfa (AC) (Ortiz, 2006).

Soil analysis

The LSNT is based on the concentration of nitrate-N in the soil sample. Most soil testing laboratories can perform this analysis. Nitrate-N concentrations can also be determined on the farm by using commercially available kits. However, following sound laboratory procedures will ensure reliable results.

All test results should be evaluated carefully due to the possibility of incorrect results from individual samples. Errors can occur during collection, handling, and analysis of samples, with the largest error typically from sample collection. The impact of such errors can be reduced by careful soil sampling and sample handling, evaluating trends and results from multiple sites, and using caution when making N rate decisions from results that deviate from trends or prior experience.

Test result interpretation

Every calibrated soil test has a critical test value, above which there is little expectation of response to applied nutrients. For the LSNT, that value is 25 ppm nitrate-N. This means that if a test result is more than the critical value, there is adequate plant available N in the soil system and no N application is needed. If a test result is below the critical value, then N application is needed. For the LSNT, as there can be variation in soil nitrate with recent high rainfall amounts, the critical value can be reduced by 3-5 ppm if rainfall is more than 20 percent above normal between April 1 and the time of soil sampling (critical concentration adjusted to 20-22 ppm). Reasons for this downward adjustment are to account for nitrate that may move below the soil sample depth shortly before sampling but is still in the crop rooting zone and weather effects on organic N mineralization.

Making a nitrogen rate decision

There are two steps in interpretation of LSNT results and N rate decisions.

The first step is to evaluate results relative to the critical level. If test results are above the critical level, no sidedress N application is suggested. If below, the second step is to estimate the fertilizer application rate by subtracting the test result from the critical level and multiplying by eight. This gives the fertilizer rate in lb N/acre.

Example: If a test result is 15 ppm, then 25 ppm – 15 ppm = 10 ppm multiplied by eight results in an application suggestion of 80 lb N/acre.

Nitrogen rate determination from LSNT results depends on the factor times the difference in results from the critical value. That factor can vary. Historically, a factor of 8 lb N/acre per ppm LSNT below the critical value has been suggested for Iowa. Additional research, where the change in LSNT ppm was calculated from various N fertilizer rates in the spring, indicated a median value of 6.2 and a mean of 7.6 (standard deviation of 3.8) in one study, and a mean of 6.4 across multiple corn rotations in another study. Therefore, the approach of a factor times the test differential should be considered general guidance. Generally, the smaller the LSNT value the greater the N application needed. Other states do not use the factor approach and instead break test results into a few deficient categories, with suggested rates for each category, like the guidance for use of the LSNT on manured soils and corn following alfalfa in Iowa.

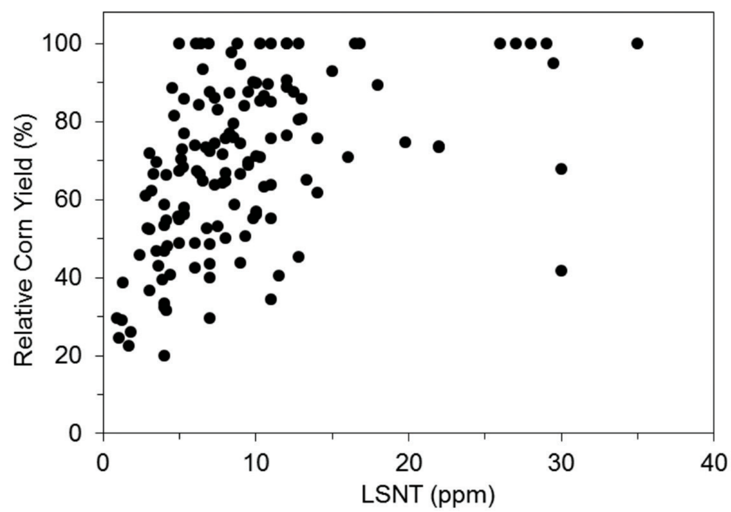

Figure 3. Relationship between the late spring soil nitrate test (LSNT) with no N applied and relative corn yield across field trials in multiple years (1999-2015) with corn following soybean and continuous corn (J. Sawyer, 2015).

Manured fields and first- and second-year corn after alfalfa

Soils that have received recent applications of animal manures, or have corn following alfalfa, tend to mineralize more plant available N after the time of LSNT sampling than do other soils. Therefore, the LSNT critical values are not correct, and these situations are treated as a separate category when making N rate decisions from the LSNT (Table 1).

When using Table 1, follow these steps:

1. **Decide whether the top half of the table or the lower half of the table best describes current prices for grain and fertilizer.**
2. **Decide whether the "excess rainfall" column or the "normal rainfall" column of the table best describes weather conditions before sampling.**
3. **Use results of the LSNT to select the appropriate N rate. Interpolation between listed rates can be made.**

Table 1. Nitrogen fertilizer rates for manured soils[a] and corn after alfalfa based on the late-spring soil nitrate test (LSNT).

		Nitrogen application rate			
		Manured soils		Corn after alfalfa	
Relative grain and fertilizer prices	LSNT	Excess[b] rainfall	Normal rainfall	Excess[b] rainfall	Normal rainfall
	ppm	- - - - - - - - - - lb N/acre - - - - - - - - - -			
Unfavorable	0-10	90	90	90	90
(1 bu buys 7 lb N)	11-15	30	60	0	60
(0.14 N:corn price ratio)	16-20	0	0[c]	0	0[c]
	> 20	0	0	0	0
Favorable	0-10	90	120	90	90
(1 bu buys 15 lb N)	11-15	60	90	60	60
(0.07 N:corn price ratio)	16-20	30	60	0	30
	21-25	0	30	0	0[c]
	> 25	0	0	0	0

[a] A field should be considered manured if animal manures were applied with a reasonable degree of uniformity since harvest of the previous crop or in 2 of the past 4 years.

[b] Rainfall should be considered excess if rainfall in May exceeded 5 inches.

[c] Addition of 30 lb N/acre may have no detectable effects on profits, but producers could reasonably elect to apply this rate.

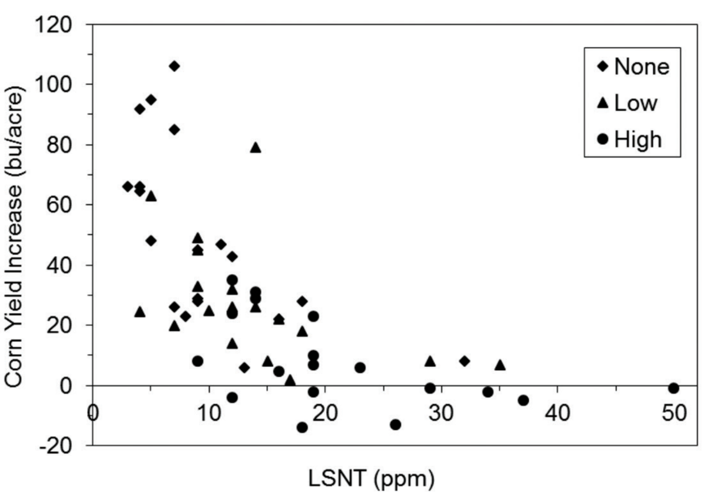

Figure 4. Relationship between the late spring soil nitrate test (LSNT) and corn yield increase to additional fertilizer N application across multiple trials (2000-2003), with and without liquid swine manure relative application rate. Each point represents a trial with the three manure rates (Woli et al., 2013).

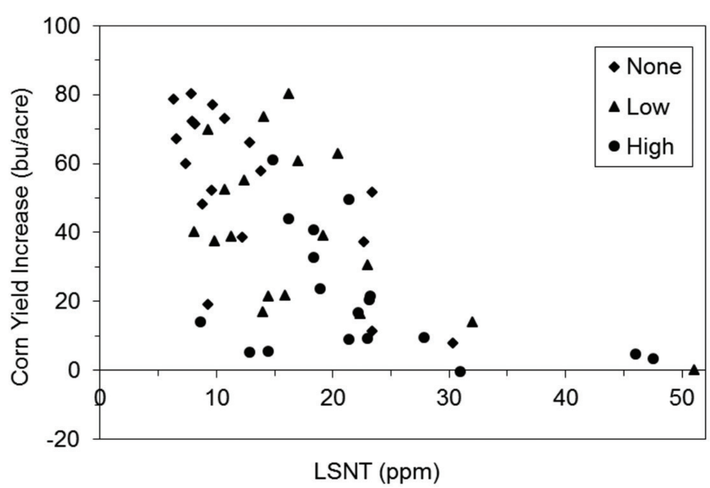

Figure 5. Relationship between the late spring soil nitrate test (LSNT) and corn yield increase to additional fertilizer N application across multiple trials (2004-2006), with and without poultry manure relative application rate. Each point represents a trial with the three manure rates (Ruiz Diaz et al., 2011).

Soil test reliability and precautions

The LSNT should be considered only as a tool for estimating crop N-availability in soils and a general guide for sidedress application. Like any tool, reliability will vary. In general, research has shown that the LSNT is most reliable at predicting a lack of corn response to additional N at values above 25 ppm. However, determining if N should be applied may be incorrect around 25 percent of the time. One aspect of late spring soil nitrate testing across the Corn Belt and other areas of the world has been the consistency in critical level, ranging between 20-25 ppm, and the interpretation of no application needed when above the critical level. Less consistency and reliability has occurred for interpretation of deficient test values and rate selection. When using the LSNT for the first time, experiment in small areas before using the LSNT to guide fertilization on large acreages. The LSNT is intended to improve profits from N fertilization when used across many sites and years. Because many factors that influence corn N needs at a specific site and year happen after fields are sampled, the LSNT should not be expected to be a perfect predictor of sidedress fertilization rate (Figure 7). This is why some states use set N rates within test interpretation categories rather than specific rates per LSNT value.

Careful soil sampling is a must for achieving good test results. The LSNT requires a one-foot sample depth and many cores, which takes time. Reliability of the LSNT can be reduced by rainfall near the time of sampling. This is due to nitrate movement in the soil profile, or loss from mineralized or applied N. Rainfall immediately before sampling can cause underestimation of N supply, low LSNT values, and over-fertilization. Rainfall after sampling can cause nitrate loss, which would have been previously measured in the LSNT, and thus cause under-fertilization. Low reliability can also result from under-represented spatial variability when sampling does not reflect field variation in soil N availability.

The LSNT results can be variable and less reliable when anhydrous ammonia or manure are injected close to corn planting, even when suggested sampling methods for these conditions are followed. The LSNT may underestimate plant-available N when nitrification inhibitors are used, more than 150 lb N/acre is applied as anhydrous ammonia, or more than 150 lb N/acre is applied as injected manure, especially when these applications are made in the spring. This underestimation can occur because ammonium is still present at sampling, and the LSNT only measures nitrate.

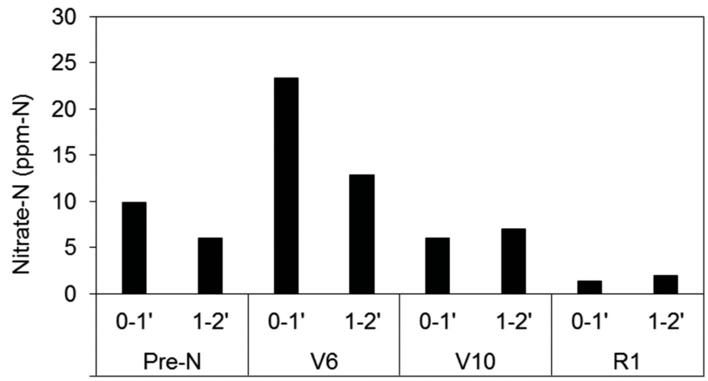

Figure 6. Soil nitrate-N concentrations through the springtime period. The trial was on a Clarion Loam near Ames, Iowa with corn following soybean. The N source was urea treated with urease and nitrification inhibitors, broadcast (not incorporated) at planting. The soil sample timing was 5 days before N application (Pre-N) and after N application at the V6, V10, and R1 (silking) corn growth stages. The V6 sampling would correspond to the late spring soil nitrate (LSNT) sample timing (0-1 foot depth). The soil nitrate-N concentrations for the second foot are provided for reference (J. Sawyer, 2015).

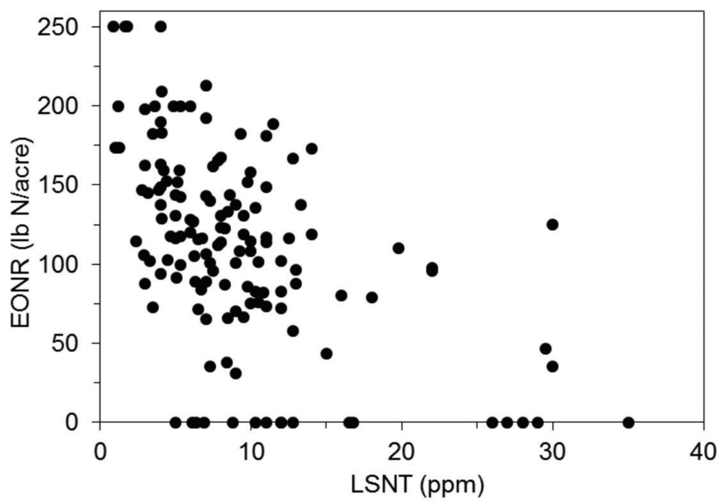

Figure 7. Relationship between the late spring soil nitrate test (LSNT) and the economic optimum N rate (EONR) across trials in multiple years with corn following soybean and continuous corn. Each point represents a trial presented in Figure 3 (J. Sawyer, 2015).

The LSNT is not suggested for use on sandy soils as mineralization is typically low and nitrate leaching below the sampling depth can easily occur with rainfall events.

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