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FACTSHEET ON SOIL FERTILITY AND NUTRIENT MANAGEMENT

In-Season Diagnostic Tests for Self-Learning and Monitoring Nitrogen on Corn

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Introduction

Nitrogen (N) is the most important nutrient limiting corn yield. Ironically in nature, plants are surrounded by thousands of pounds of atmospheric N gas, but this abundant form is present as inert N_2 molecules that are not directly available for plants. Plants have to absorb most of their nitrogen through the root system. Nitrogen is a major constituent of chlorophyll, proteins, ATP and DNA. As chlorophyll is responsible for the plant's green color, N deficiency symptoms are commonly associated with pale green to yellow coloration. Healthy plants contain about 3-4% N on a dry matter basis.

Soil N exists in three general forms. Organic N, ammonium N and nitrate N. Vast quantities of potentially available N is present in organic matter, either in living or dead plant and animal residues. This nitrogen is not directly available to plants. The plant-available N is in the inorganic NH_4^+ and NO_3^- forms. Nitrogen goes through many transformations in the soil as dictated by the N cycle, and a good understanding of these processes is helpful to N monitoring and management decisions. At any point in time, the soil N status is quite dynamic; as N gains or losses are based on which processes of the cycle are dominant. Microorganisms play a key role in the N cycle and their activity will be depended on soil temperature. Microorganisms actively slow down as temperatures fall below 50F.

N Diagnostic Tools

There are three basic tools for diagnosing N deficiency in corn: (a) Visual observations (b) Soil analysis and (c) Tissue analysis. Visual observation is a qualitative test based on the symptoms expressed in response to a N deficiency. The soil analysis and tissue analysis are quantitative tests that will compare the data to a previously established sufficiency range.

(a) Visual observations

Visual observations of known symptoms can be difficult to interpret in some situations. Symptoms due to two or three nutrient deficiencies may look similar or masked if they occur simultaneously. Stress situations such as drought, disease, herbicides, abnormal soil pH and soil compaction may produce symptoms somewhat similar to N deficiency. In some advanced growth stages like tasseling and silking, if visual symptoms begin to appear, the crop health and productivity may have been substantially reduced already and corrective actions may not be effective.

Early season corn

If the N deficiency occurs in the early vegetative phases (V1-V6), the stems and leaves will turn uniformly light green to yellow (Figure 1). The leaves do not show any striping pattern, as seen in other nutrient deficiency situations. The plants are stunted and undersized compared to adequately fertilized areas. In Figure 1, N deficient and adequate plots are located side by side and light green color is visible at this stage. This situation is also seen when early flooding occurs and N is lost due to denitrification.

Figure 1. N deficiency in early stages of corn showing pale green to yellowish coloration of leaves on the center compared to adequately fertilized dark green plants to the right. Size differences are also visible.

Mid-season corn

When N deficiencies develop in the mid-season, leaves on the lower part of the plant begin to develop yellowing symptoms starting from the leaf tip and progressing towards the stalk. Lower leaves will be affected first as N is mobile and will be reallocated to the upper leaves (Figure 2). The yellow color will turn brown followed by the death of lower leaves, leading to a condition known as firing (Figure 3).

Figure 2. Typical leaf symptoms of N deficiency starting from leaf tip and progressing down the mid rib in an elongated V shape pattern. The picture on right shows the progression of symptoms in the leaf.

Figure 3. The row to the right shows N deficiency with browning and death of lower leaves, a condition known as "firing." The row on left was adequately fertilized with N. (Photo: courtesy Dr. Brenda Tubana, LSU)

Nitrogen window plots as learning tools

Knowing the correct N deficiency symptoms can be very helpful, but farmers still need on-farm tools and plot demonstrations to improve their self-learning skills. A practical N management learning tool that beginners may want to consider is the establishment of "N Window Plots" or "N Reference Plots." These plots will receive a pre-determined N fertilizer rate about 25% higher than the standard N practice (This plot then is assumed to have a non-limiting supply of N). Ideally the window plot should match the width of the combine and the entire length of the field to harvest and collect yield data. The plot has to be located in a representative part of the field avoiding problem areas such as weeds, compacted soils, headlands and low spots. The N window plot and the rest of the field should receive identical treatments throughout the season, the only variable being the N rate applied. This N differential can be achieved at the sidedress time by changing the N rate. The plots need to be clearly marked with flags for easier monitoring.

During the season, visual observations can be made of N deficiency symptoms, such as leaf color, growth rate, foliar diseases, and firing in the N window plot and rest of the field. At harvest, if the yield data indicates that the N window plot and the rest of the field with the standard N practice is very similar, then the field has a high N mineralization potential and the N fertilizer rate need not be increased. This situation is likely to occur in fields with high organic matter and/or manure and legume histories. On the other hand, if the N window plot has a higher yield compared to rest of the field, then the field has less capacity for N mineralization and the N fertilizer rates could be economically increased. This is likely to occur in coarse textured soils with low organic matter or in continuous corn. Window plots could be valuable to users of newly rented land.

Nitrogen window plots provide valuable data where calibrated equipment such as chlorophyll meters or active canopy sensors are used for N monitoring. After a few years, these plots will provide valuable learning experiences unique to each field and enable farmers to further fine tune their N practices.

Chlorophyll meter as a supplement to visual observations

A chlorophyll meter is a tool that can be used to diagnose N deficiencies on corn. The test relies on adequately fertilized N window plots for its proper calibration. The chlorophyll meter (Minolta SPAD 502, cost about $1,500) is a small handheld device that instantly measures the greenness of plant leaves. The major advantage is that it is a non-destructive test and permits random, repeated measurements instantly throughout the growing season. A major drawback is that leaf greenness can vary between hybrids and due to other plant and environmental factors that are unrelated to N availability. This necessitates the establishment of high N window plots in the same field. Meter readings mean very little by themselves unless they are compared to the adequately fertilized window plots. Another consideration is that plants only produce as much chlorophyll as needed. At luxury consumption chlorophyll level reaches a plateau regardless of how much extra N is taken up. Therefore the chlorophyll meter is only effective at detecting N deficiency fields. Meter readings from the corn field and window plots are used to establish a N sufficiency index. Most universities recommend that the N sufficiency index should not be allowed to drop below the 90% value.

The meter readings have to be taken only after the plants have reached the six-leaf stage and be continued until the ear leaf at tassel stage. Using the meter early will permit additional N application if necessary using traditional side dress or high-clearance equipment. The late measurements will provide data for fine tuning N practices in future years. It should be emphasized that the chlorophyll meter be used as another tool to complement, but not replace other best practices such as soil nitrate testing.

(b) Soil analysis

Soil nitrate testing is an excellent diagnostic tool to determine the available nitrogen (N) status of the soil. Studies have shown that farmers could reduce their N fertilizer application rate on corn without risking yields if they used the pre-sidedress soil nitrate test (PSNT). Some prep work is necessary for PSNT. The test is ideally suited for fields with high N mineralization potential, e.g. fields with high organic matter, manure or legumes. Other fields that may have high nitrate levels are loam, clay loam and clay soils that have been heavily fertilized in previous years. The test measures both recently mineralized N from organic matter and residual nitrate N from previous year. No broadcast or incorporated pre-plant N fertilizer should be applied. A modest amount of starter N up to 40lb/A could be banded near the seed. Soil cores should be taken midway between the corn rows, avoiding the starter fertilizer band.

The greatest amount of mineralized N usually occurs once the soil has warmed up and about 3 to 4 weeks after corn emergence (V6 growth stage). At this stage, corn begins to take up N quite rapidly. The test will measure the nitrate concentration in parts per million (ppm) in the sample. The critical level is 25 ppm above which no N fertilizer is recommended. When the concentration is below 25 ppm, the N fertilizer recommendation is adjusted accordingly. As PSNT is primarily an index of mineralization, the best diagnostic value of the test is identifying N non-responsive sites, which is usually associated with animal manure or alfalfa rotation.

(c) Tissue analysis

The most widely used tissue diagnostic test in corn is the end of season cornstalk nitrate test (ECNT). It is one of the few diagnostic tools that could be used to determine if excess nitrogen was applied to corn.
The nitrate nitrogen concentration in the lower portion of the corn stalk just after the black layer formation is a good indicator of the nitrogen (N) status the crop experienced throughout the growing season. As corn approaches maturity, plants stressed for N will move nitrate from the lower cornstalk to the ear resulting in a low stalk nitrate concentration. When corn plants have more than sufficient N for maximum yield, nitrate N accumulates in the stalk. The ability of this test to distinguishing between sufficient and excess N situations makes it unique. Other infrequently used tissue tests such as the total N content in the ear leaf at silking or the corn grain N content at harvest are capable of showing some differences between N rates that were too low or adequate, but not between N rates that were in the adequate or excess range.

Based on research at Iowa, Pennsylvania and Michigan, stalk nitrate concentrations fall into 3 general categories: LOW (less than 700 ppm NO3-N) OPTIMAL (700 to 2000 ppm NO3-N), and EXCESS (greater than 2000 ppm NO3-N). The LOW range indicates high probability that greater availability of N would have resulted in higher yields. Visual signs of N deficiency usually are present in this range. The optimal range indicates N availability was within the range needed to maximize profits. The excess range indicates a high probability that N availability was greater than that required to maximize economic returns. Quite often the excess range is associated with over application of N fertilizer or animal manures. For most conditions prevailing in the Corn Belt, stalk N03 N concentrations between 700 to 2,000 ppm have been accepted as the critical optimal range. The advantage of the ESNT is that it does not require in field window plots for comparisons.

The time for stalk sampling is critical, 2-3 weeks after physiological maturity or black layers have formed on about 80% of the kernels. The portion sampled is the 8-inch segment of stalk between 6 and 14 inches above the soil. Corn producers should consider using the ECNT on a few fields each year. Those who find their fields test in the optimal range need not make any N fertilizer adjustments. Those who find they consistently exceed 2000 ppm are usually applying too much N and will find it profitable to reduce N rates. Familiarity with the test for a few years should help producers optimize N fertilizer rates. Those using animal manure should use the ECNT as most producers tend to underestimate the amount of N supplied by manure.

The test has a few limitations. When interpreting the results of the ECNT, consideration must be given to weather conditions that occurred during the growing season. Lower than desired concentrations are expected in years having unusually large amounts of in-season rainfall, such as 2011 in Michigan which results in unusually large leaching losses of N and loss of yield potential. In dry years, the nitrate levels tend to be higher than expected. Also, deficiencies of N early in the season may sometimes limit grain yield in ways that may not be directly indicated by the stalk test. Under normal conditions, however, the test values will reflect an overall assessment of N fertilizer practices during the growing season.

Despite the many scientific advances, however, we still do not have a perfect soil or tissue N test for monitoring the N status on corn. It is best to rely on multiple tests at the beginning to get a feel for the N mineralization and yield potentials of each farm field.