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# Assessing and Managing Nitrogen Losses in Corn

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## Summary

- Extremely wet springs with major rain events in late May and June resulted in some degree of nitrogen (N) loss from many corn fields in both 2008 and 2009.
- Understanding nitrogen reactions in the soil and movement of nitrogen forms in various soil types is important to manage nitrogen deficiency.
- Use of soil tests, chlorophyll meters and aerial photographs can all help growers assess additional N fertilizer needs.
- Sidedress applications, when possible, are the ideal way to remediate nitrogen deficiency and reduce further losses by providing nitrogen close to the time of maximum corn uptake.
- For larger corn, nitrogen may be applied by high-clearance spray equipment (dribbling UAN solution) or even by airplane (broadcasting granular sources of N).
- Research studies have shown that "rescue" N applications can be very beneficial for maintaining corn yield. These applications are most effective prior to silking (R1).
- Choosing the right nitrogen source to match the method of application is important in achieving safe and effective remediation of nitrogen deficiency.
- Among granular sources of N, urea is usually the best choice. Although subject to volatilization losses on the soil surface, it is less likely to cause leaf burn and yield loss in large corn.


In both the 2008 and 2009 growing seasons, excessive spring rainfall across the Corn Belt and other areas of North America created concerns that much of the nitrogen (N) applied in the fall and spring may have been lost. Not only does lost N reduce grower profits, but wet weather also presents challenges for re-supplying a deficient crop. This *Crop Insights* will discuss assessing and managing nitrogen losses in corn due to excess rainfall.

## How is Nitrogen Lost?

### Nitrate Form at Risk of Loss

Nitrate ($NO3^-$) is the form of nitrogen most readily taken up by the plant, but it is also the form with the greatest risk for loss. In fact, with heavy rainfall and highly saturated soils, N loss potential is directly related to the amount of nitrogen in the nitrate form. In such situations, nitrate may be lost from the soil either by leaching or denitrification, depending primarily on soil characteristics. Coarse-textured soils allow water and nitrates to move readily downward through the soil profile. When this leaching places nitrates below the root zone, they are of no use to the plant and are essentially lost (Figure 1). Fine-textured soils, on the other hand, have capillary pores that hold water tightly, restricting its downward movement. In this situation, saturated soils and anaerobic conditions may result in nitrate being lost upward to the atmosphere through denitrification (Figure 1).

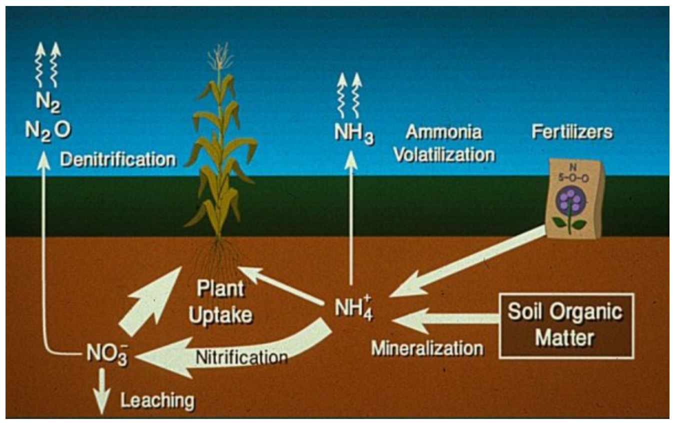


**Figure 1**. The "nitrogen cycle", showing movement and fate of soil nitrogen.

### Nitrogen Reactions in Soil Determine Losses

When nitrogen is applied to a field in the ammonia ($NH_3$) or ammonium ($NH_4^+$) form, it is temporarily protected from water-induced losses. This is because it binds to soil particles, which are negatively charged. Denitrification and leaching are not a risk until the ammonium is converted to nitrate in a bacteria-mediated transformation called nitrification. This occurs in a two-step process – in the first step, the bacterium *Nitrosomonas* converts $NH4^+$ into nitrite ($NO2^-$) and in the second step, *Nitrobacter* bacteria convert $NO2^-$ to $NO3^-$.

The activity of nitrifying bacteria is minimal at temperatures below 50 °F. The bacteria also need aerobic (unsaturated soil water) conditions to nitrify ammonium. Thus, the amount of nitrification that occurs in the soil depends largely on soil temperature and the time elapsed from application until the soil becomes saturated with water. Further, the nitrification process can be reduced with the use of inhibitors that will lower the activity of these bacteria and allow N to stay in the ammonium form for a longer period. The use of nitrification inhibitors is most important in fall since the time elapsed between application and crop uptake is longest for fall applications.

It is important to note that only the portion of the applied N that is in nitrate form is subject to denitrification or leaching. The fact that N is in the nitrate form does not mean that N is lost; rather, it means it is susceptible to loss.

## Early Season Corrective Measures

Sidedress N application allows for more efficient fertilizer use since the nitrogen is applied close to the period of maximum nitrogen uptake for corn (Figure 2).

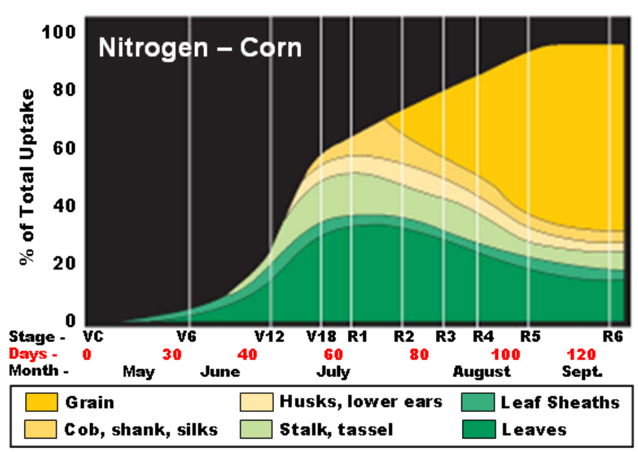


**Figure 2.** Timing of nitrogen uptake in corn. Source: Iowa State University Extension.

As Figure 2 demonstrates, maximum N uptake in corn occurs in periods of maximum growth – roughly from growth stages V9 to V18 (the "exponential growth" stages of vegetative development). The risk of N loss is lowest during this period.

All common N fertilizers can be used for sidedress applications. Dr. Fabian Fernandez at the University of Illinois ranks N fertilizers from most to least desirable for sidedress application (Fernandez, 2008):

**1)** injected anhydrous ammonia or UAN solution between rows

**2)** broadcast of solid ammonium-containing fertilizers such as ammonium nitrate or ammonium sulfate

**3)** broadcast urea

**4)** dribble UAN solution between row

**5)** broadcast UAN solution

## Mid-Season Nitrogen Deficiency

Determining whether or not additional nitrogen is needed can be difficult, but several methods that can be used for this determination.

**Nitrogen soil tests** can help provide an estimate of nitrogen needs. In fields where a high nitrogen loss potential exists, a nitrate soil test can be done. Some labs prefer to do a total nitrogen test assessing both ammonium and nitrate levels. Soil sample depth should be at least 12 inches, but this test is best conducted with two sample depths – 0 to 12 inches and 12 to 24 inches.

**Chlorophyll meters** allow farmers to fine-tune N management by detecting developing deficiencies early enough that they can be corrected before they reduce grain yields. The Minolta chlorophyll meter model SPAD 502 enables users to quickly and easily measure leaf greenness which is affected by leaf chlorophyll content (Figure 3).

**Figure 3**. A chlorophyll meter is used to collect readings in corn. Source: John Sawyer, Iowa State University.

The advantage of using a meter to evaluate N status is that the meter is fast, non-destructive, repeatable, and can detect a deficiency long before it is visual to human eyes.

**Aerial images** are another way to assess the potential nitrogen needs of a corn crop, allowing growers to quickly assess many fields in a short period of time (Figure 4).

**Figure 4.** Excess rainfall can lead to nitrogen loss that can severely limit corn yield, as in this Holt County, Missouri aerial photograph taken August, 2008.

Aerial photographs as a tool for diagnosing deficiency work best if taken when the corn is waist high or taller, so that soil color is not an issue. However, this limits rescue N application options to high-clearance equipment or airplanes. Aerial photographs also work best after the field is no longer saturated and the corn has time to take up whatever nitrogen is left. Corn will appear nitrogen-deficient (and will actually be nitrogen-deficient) in saturated soils even if the soil nitrogen has not been lost.

## Rescue Options

Once corn is too big to pass through with a tractor and sidedress applicator, nitrogen application options are somewhat restricted due to machinery limitations, nitrogen source options, and dependency on rain to move the nitrogen into the soil profile. UAN solution dribbled between rows with high clearance equipment is an effective rescue N treatment, but broadcast UAN solution causes severe yield loss due to leaf burn.

Another option is a broadcast application of granular N (ammonium nitrate or urea) by airplane, with urea being the far better choice when corn is two feet or taller in height. Ammonium nitrate has one advantage over urea – it will not be subject to volatilization losses on the soil surface like urea. However, ammonium nitrate can cause much greater leaf burn to large corn, especially to plants that are wet from rain or dew. This occurs as moisture on the leaves allows some of the nitrogen fertilizer to stick to the leaves, resulting in tissue burn (Figure 5). With aerial application, it is safest to keep rates below 125 lb N/acre.

**Figure 5.** Leaf burn to margins of plants receiving aerial broadcast nitrogen fertilization.

In research at the University of Missouri, Dr. Peter Scharf found broadcast urea causes almost no yield loss due to leaf burn. In his studies, 150 lb N/acre as urea was applied on corn up to four feet tall, and the yield difference between broadcast and in-row placement of urea was measured. The difference was generally less than 4 bu/acre in favor of in-row placement. Ammonium nitrate, on the other hand, caused substantial leaf burn and yield losses of almost 20 bu/acre when broadcast over 3- or 4-foot corn, 8 bu/acre when broadcast over 2-foot corn, and no yield loss when broadcast over 1-foot corn. This work showed urea was clearly a better N source than ammonium nitrate for aerial application on all but the smallest corn. University of Missouri studies have also shown that full or nearly full yield can be achieved if rescue N is applied by the time the corn tassels.

The disadvantage of urea broadcast on the soil surface is that it reacts with the urease enzyme present in plant material. The reaction releases the ammonia in urea, which may then be partially lost to the air. Rainfall is needed to move the urea into the soil to prevent these losses. Urease inhibitors, such as Agrotain, can be used with urea to slow the conversion to ammonia. However, even with use of Agrotain, rainfall is still needed to move the urea into the soil for plant uptake.

## Post-Pollination N Corrections?

In most dryland areas, there is less likelihood that corrections to deficiencies can be successfully made after pollination. Nitrogen could be aerially applied but rainfall is necessary to move the applied N into the soil profile for root uptake. Root systems are also starting to decline in size and activity once ears reach the R3 stage. This combination of factors makes it much less likely that application of a foliar-safe form of N will remediate a late-season nitrogen deficiency.

## References

Fernandez, Fabian. 2009. Have I Lost My Nitrogen This Spring. *the Bulletin* No. 7, May 8. University of Illinois – Urbana. http://ipm.illinois.edu/bulletin/article.php?id=1116

Larson, Erick. 2008. Emergency Corn Nitrogen Topdress. MSU Grain Crops Update, May 29. Mississippi State Univ. http://msucares.com/newsletters/grain/2008/may29_2008.pdf

Nafziger, Emerson. 2008. Nitrogen Deficiency In Corn After Pollination. *the Bulletin* No. 20, August 8. University of Illinois – Urbana. http://ipm.illinois.edu/bulletin/article.php?id=1013

Sawyer, John. 2007. Measuring the nitrogen status -- 2007 Iowa State University Integrated Crop Management Newsletter, May 14, 2007 http://www.ipm.iastate.edu/ipm/icm/2007/5-14/measuren.html

Scharf, Peter. 2008. Nitrogen Loss in 2008. Integrated Pest and Crop Management Newsletter. Vol. 19 No 1, January 15, 2009. University of Missouri. http://ppp.missouri.edu/newsletters/ipcm/archives/v19n1/a2.pdf

Scharf, Peter. 2008. Nitrogen Loss Again??!! Integrated Pest and Crop Management Newsletter. Vol. 19 No 13, June 1, 2009. University of Missouri. http://ppp.missouri.edu/newsletters/ipcm/archives/v19n13/a1.pdf