CROP INSIGHTS

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Nitrogen Application Timing in Corn Production

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Summary

- Corn takes up half its N supply between V8 and VT, a period that may comprise only 30 days. Providing adequate N for this period is a key goal of N management.
- Spreading N applications is a good way to spread risks and reduce costs, but the extent to which this is practical depends largely on prevailing weather conditions.
- Fall-applied N is at highest risk of loss. In all instances of fall application, only ammonium sources of N should be used, as well as a nitrification inhibitor such as N-Serve®.
- Preplant N application may be considered in areas where growers are able to complete this practice without delaying planting beyond the optimum window.
- Planter N applications are sure to occur, unlike preplant or sidedress applications that may be disrupted by weather.
- In-season (sidedress) N applications allow for adjustments to planned N supply based on weather variations.
- If weather interferes with the originally planned in-season application, a quickly implemented backup plan can help avert significant N deficiency and yield loss.

The goal of timing nitrogen (N) applications to corn is to supply adequate N when the crop needs it, without supplying excess that can potentially be lost. Because N reactions in the soil are closely linked to both temperature and moisture conditions, this goal is often hard to achieve. Its importance, however, cannot be overstated. If corn is deficient in N during its rapid vegetative growth phase, yield losses are inevitable. On the other hand, oversupply of this expensive crop input reduces profits and harms the environment. Applying N at multiple times, including the time of maximum crop uptake, can spread the risk of N loss and crop deficiency, improve profitability by reducing N rates, and benefit the environment.

This *Crop Insights*, the second in a series on N management, will discuss timing N applications to corn. A previous article addressed optimum N rate decisions (Shanahan, 2011), and the final article will discuss rescue N applications.

Corn Needs for Nitrogen

Because N is a constituent of all protein within the corn plant, it is needed in high quantities. When deficient, normal growth and development is thwarted. In fact, N stress at any time during a corn plant's life will subtract from yield, much like drought, insect feeding, disease pressure or other stresses. The following chart shows the approximate amount of N removed in corn grain and stover (i.e., the minimum amount of N required to grow the crop.)

Table 1. N removed by corn crop.

Corn yield (bu/acre)	N removed in grain	N removed in stover	Total N removed*
	- - - - - - *pounds of actual N* - - - - - -		
150	102	51	**153**
200	136	68	**204**
250	170	85	**255**

*Adapted from Sawyer and Malarino, 2007.

Corn requires only a fraction of this nitrogen during the seedling stage, but its needs escalate rapidly once corn reaches the V8 growth stage (8 leaf collar stage). This knee-high corn can grow to shoulder height (approximately V12 to V14) in about two weeks, and reach the tassel/silking stage (VT/R1) in about two more weeks if conditions are favorable. Such rapid growth is equaled by few other crops, and requires a large supply of nitrogen to fulfill the demands of prolific green tissue development (Figure 1).

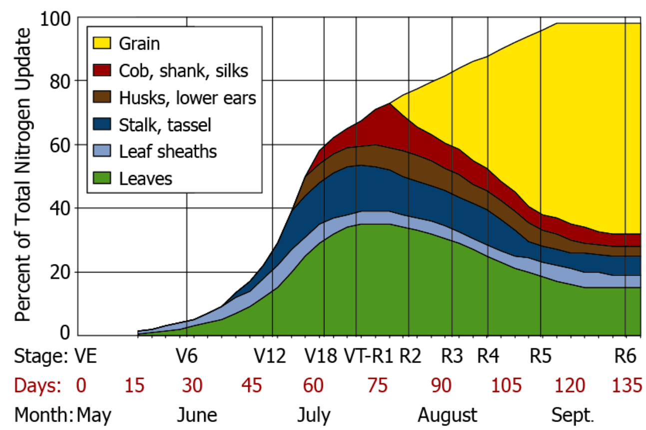

Figure 1. N uptake by corn. Adapted from Richie, et.al, 2005 (*How a Corn Plant Develops*).

As the figure shows, corn generally requires over half its total N supply between V8 and tasseling (VT), a period that may comprise only 30 days, depending on temperature and moisture conditions. Recommendations to sidedress N by V4 to V6 are to provide some margin of safety in case weather and soil conditions delay N application or N movement to the roots. The figure also shows that the plant's needs for nitrogen do not end at tasseling – about one-third of plant N requirements must still be met by uptake during the reproductive (ear-fill) period.

Importance of Adequate N During Ear Fill

In addition to its function in green tissue formation, nitrogen plays a crucial role in ear and kernel development. A recent study of nitrogen translocation within the plant indicates that N moves to the ear from other plant tissues even prior to silking, apparently for the nitrogen-intense process of kernel embryo formation (Ciampitti and Vyn, 2010). This study also reported that continued ear growth and yield accumulation from R1 to R6 is closely associated with N content in the above-ground plant tissues.

Perhaps most importantly, the study showed that continued N uptake during the ear-fill period can minimize the remobilization of N from vegetative to reproductive tissues. This means that the plant does not have to cannibalize the leaves to provide N for kernel development when it can take up N from the soil during this period. This allows the plant to retain more green leaf area in late summer and early fall, which increases the duration of photosynthesis, carbohydrate production and grain yield.

Meeting Corn Needs for N

In order to meet corn needs for adequate nitrogen at V8, growers must often contend with aberrant weather patterns that impact N management goals. Excessive rainfall can threaten soil nitrogen reserves as well as hinder resupply by ground equipment. Excessively dry conditions can prevent applied N from moving from the point of application to the root zone of plants. Temperature and moisture conditions also impact the amount of N mineralized from the organic matter fraction of soils.

To help avoid weather-related pitfalls to corn N supply, **growers can spread their risk by applying N at multiple times**, or using products that help protect specific N fertilizers from rainfall-related losses. This is especially important on soils subject to N loss, such as sandy soils that are prone to N leaching, or heavier soils in high rainfall areas that may become saturated and subject to denitrification losses. This approach to N management can also increase the bottom line by decreasing the total amount of N applied.

Nitrogen may be applied by growers at several times during the year: in the fall, early spring (preplant), at planting, and in-season (sidedress).

Figure 2. Severe nitrogen deficiency symptoms are evident in this field that remained saturated due to excessive rainfall.

Fall-application: Fall application of N is practiced in areas where soil temperatures usually remain below 50°F from late fall to spring. These cool soil temperatures reduce the activity of nitrifying soil bacteria that convert ammonium to nitrate forms of N. However, if soil temperatures rise above 50°F, this N is at risk of loss through leaching or denitrification. Because of the extended period of time that this N is at risk of loss, fall application, if practiced, should be carefully managed. In all instances of fall application, only ammonium sources of N should be used (Murrell and Snyder, 2006). A nitrification inhibitor such as N-Serve® should also be considered to help keep N in the stable NH_4^+ form.

Early spring (preplant) application: Preplant N application is commonly used in areas where growers are able to complete this practice without delaying planting beyond the optimum window. Because this N is applied well ahead of major crop uptake, it too is at risk of loss if warm soil temperatures and excessive rainfall occur. Application of ammonium forms of N can reduce loss potential. Depending on the time of application relative to planting, as well as expected weather conditions (determined by climate history) a nitrification inhibitor may also be advantageous.

At planting application: Though many planters are not equipped to apply fertilizer at planting, this method of application has certain advantages. When the field is fit to plant, planter N applications are sure to occur, unlike preplant or sidedress applications that may be disrupted by weather. However, there are limits on how much N can be applied at planting, due to concerns over effects on seed germination, as well as how much material can be reasonably carried on the planter. In addition, applying fertilizer at planting slows the planting process to some degree.

Liquid forms of N, such as UAN solution, are preferred for planter application. UAN solution can be combined with liquid starter or other liquid fertilizers to supply multiple nutrients to the crop.

In-season (sidedress) application: In-season N applications allow for adjustments to planned N supply based on weather variations. If wet spring conditions result in N losses, sidedress rates can be increased. If warm temperatures and moderate rainfall result in high N mineralization and an N-sufficient crop, sidedress rates can be reduced. This process of determining crop sufficiency or need can be aided by various methods of soil testing or plant sensing (Shanahan, 2011).

In-season N applications can supply N to the crop near the time of maximum plant uptake. However, if wet conditions develop, sidedress applications may be delayed beyond the optimum application date. Extremely dry conditions can result in a delay in availability of sidedressed N to the plant.

Because of the risks associated with in-season N application, this practice must be carefully managed to reap its potential rewards. Soil fertility specialists often recommend that only one-third of total crop supply should be targeted for sidedress application. In addition, growers should be well-prepared to apply sidedress N as quickly as possible when the window of opportunity arises. **Finally, a backup plan should be in place for in-season application.** If weather interferes with the originally planned application, a quickly implemented backup plan can help avert significant N deficiency and yield loss.

N-timing Research Results Vary

The effect on yield of N application timing has been widely studied for decades. Common types of nitrogen timing studies include applications in the fall vs. spring (preplant), preplant vs. split between preplant and sidedress, and different types of N fertilizers applied at various timings. Results of several studies are summarized below.

Table 2. Summary of studies on the effect of N application timing on corn grain yield. Adapted from Bundy, 2006.

Test Sites	IA[1]	MN[2]	WI[3]
No. of Years	5	4	5
Total Test Sites	65	32	39
Responsive Sites	25	28	20
Sites with Preplant = Split[4]	15	16	17
Sites with Preplant > Split[4]	8	4	3
Sites with Preplant < Split[4]	2	8	0

[1]Killorn, et al, 1995. [2]Randall and Schmitt. 2004. [3]Bundy, 2006.

[4] Split=Total applied N split between preplant and sidedress.

As Table 2 shows, the most common result of the N timing studies was no difference in corn grain yield between preplant and split application times. In Iowa and Wisconsin, preplant applications were equal or superior to split timings

Figure 3. Sidedress application of anhydrous ammonia at the V5 to V6 corn growth stage. *Photo courtesy of John Deere.*

at most sites. In the Minnesota studies where split applications outyielded preplant applications, excessive rainfall had occurred or sites had coarse soils.

Another study compared various rates and timings of N application in two consecutive years in Minnesota (Table 3). In this study, split applications showed an advantage in year 1 when rainfall was well above average, but a disadvantage in year 2 when rainfall was close to the average.

Table 3. Corn yield as affected by method of N application on fine-textured glacial-till soils (Randall and Schmitt. 2004).

Time of Application		Environment	
Preplant	**12-inch corn**	**Year 1**	**Year 2**
Pounds Actual N/Acre		*Grain Yield (bu/acre)*	
0	0	84	107
30	0	129	132
60	0	143	144
30	30	161	141
90	0	158	156
30	60	157	137
120	0	165	164
30	90	182	153
Average advantage for split		**+11**	**-11**

Year 1 - 56% above average rainfall.
Year 2 - 16% above average rainfall.

Other studies also tested N application timing, multiple rates of N, and different proportions of total N applied at various times. These studies show a wide range of results that often **vary according to the weather conditions** encountered during the study. For this reason, understanding the relationship between N supply, weather conditions, and corn needs is more important to developing successful N management strategies than research results per se.

Ammonium Forms of N More Stable

The most common nitrogen fertilizers are anhydrous ammonia, urea-ammonium nitrate (UAN) solutions, and granular urea. Other forms include ammonium nitrate and ammonium sulfate. Ammonium (NH_4^+) forms of N bind to negatively charged soil particles and are not subject to leaching or denitrification losses. Applying N fertilizers that include more ammonium and less nitrate forms of N reduces their potential for loss in the short term. However, over time, soil bacteria convert ammonium to nitrate (NO_3^-), a form which is readily lost when excessive rainfall leaches or saturates soils. Nitrifying bacteria have minimal activity when soil temperatures are below 50°F, so cool or cold temperatures naturally help protect ammonium forms of N from losses.

Urea-containing fertilizers have yet another mechanism of loss: they are subject to volatilization when surface applied. However, once urea is taken into the soil by rainfall, irrigation, or tillage, volatilization potential ceases.

Nitrogen Stabilizers

To help reduce N losses, nitrogen "stabilizers" or "additives" can be applied along with N fertilizers. These products must be matched with specific N fertilizers in order to be effective. Several common products include Instinct®, N-Serve®, Agrotain®, Agrotain Plus® and ESN®. For these products, read and follow all label instructions carefully.

Instinct and N-Serve contain the chemical nitrapyrin (2-chloro-6-(trichloromethyl) pyridine. These products are nitrification inhibitors that act against bacteria responsible for nitrification, thus slowing the conversion from ammonium to nitrate and reducing the risk of loss.

According to the manufacturer, N-Serve is an oil-soluble product that may be used with anhydrous ammonia, dry ammonium and urea fertilizers. Research studies over many years have proven the effectiveness of N-serve when used with anhydrous ammonia.

Instinct is a new encapsulated formulation of nitrapyrin that, according to the manufacturer, is intended for preplant, preemergence, at-plant row or band injection application with urea ammonium nitrate (UAN). Instinct can be applied in the spring with liquid fertilizer or tank-mixed with a herbicide or insecticide application prior to or at planting. It is also tank-mix compatible with fungicides, according to the manufacturer.

Agrotain, the compound NBPT [N-(n-butyl) thiophosphoric triamide] is used primarily with urea and secondarily with urea-ammonium nitrate solutions. Agrotain inhibits urease, a naturally occurring soil enzyme involved in the conversion of urea to ammonia. This allows more time for rainfall to occur and incorporate the urea into the soil. Agrotain Ultra is a more concentrated formulation of Agrotain.

Figure 4. Application of anhydrous ammonia to field previously in soybeans. A nitrification inhibitor can be added to reduce N losses, especially for fall application. *Photo courtesy of Case-IH.*

Agrotain and Agrotain Ultra are useful when urea is broadcast and not incorporated into the soil with tillage or irrigation. When broadcast in contact with crop residue, high losses may result, as the urease enzyme is abundant in plant material. Research shows that N loss from surface-applied urea can range from 0 to 50 percent. The amount of loss depends on weather conditions; loss is greatest with warm, windy weather and a moist soil surface.

Agrotain® Plus is an additive specifically for UAN solution, according to the product label. Agrotain Plus contains both N-(n-butyl) thiophosphoric triamide, a urease inhibitor that prevents nitrogen loss by ammonia volatilization from synthetic or organic urea, and dicyandiamide, an organic nitrogen material which retards nitrification. Thus, it acts against both the volatilization and nitrification processes that lead to N losses from urea, but does not protect the nitrate portion of UAN solution.

ESN®, Environmentally Smart Nitrogen is another type of nitrogen stabilizer. According to the manufacturer, ESN contains a urea granule within a micro-thin polymer coating, which releases the N as soil warms. This time release method is an alternative way to help reduce nitrogen losses due to volatility.

Using Historical Weather Data in Developing Your N-Supply Strategy

Spreading N applications is a good way to spread risks and reduce costs, but the extent to which this is practical depends largely on prevailing weather conditions in your area.

Historical weather data can be used to determine how much applied N may be lost in typical months, and also to indicate how many days may be available for fieldwork when sidedress applications need to be made.

Growers should use historic weather information to develop a nitrogen timing strategy that has a high probability of being implemented most years. Such strategies should be weighted heavily for soil type and topography, which impact retention of applied N and the ability to apply additional N. Regions and individual fields vary in those properties, so many growers should have multiple nitrogen management strategies in their farming operation.

Growers must also be ready to implement a "plan B" when excessive or prolonged rainfall or other weather anomalies prevent implementation of original nitrogen programs. A quick and effective response to N stress can impact crop yields by at least 10 to 15% (Look for the upcoming *Crop Insights* on Rescue Nitrogen Applications to Corn).

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