

## *Indiana Soil and Water*



### Authors

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# The Effects of Late-season Nitrogen Applications in Corn

In recent years, high-clearance fertilizer application equipment has become more widely available. Such tools make it feasible to apply nitrogen (N) fertilizer to corn later in the growing season. This option offers corn growers more choices in their N fertilizer program, but what are the potential benefits and risks of late-season N applications?

This publication will explore the potential uses of late-season N applications to corn in Indiana and surrounding states. For the purposes of this publication, we define “late-season” as plants at growth stage V10 (10 visible leaf collars) or later.

Nitrogen fertilizer is one of the most expensive inputs for corn producers. It is also the most difficult nutrient to manage in the soil. Once applied, N fertilizer can be lost through leaching, denitrification, and volatilization. How much N gets lost depends on soil factors (like moisture and temperature), on N fertilizer factors (like source and placement), and on crop factors (like rate and timing of N uptake).

For practical reasons, most producers in the eastern U.S. Corn Belt commonly apply N to the corn crop in the early spring, before or shortly after they plant corn. A less common

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approach is to apply N in fall before planting corn the next spring.

Fall and early spring N applications are attractive options, because they reduce the workload during the busy planting season. But the timing of pre-plant N applications often overlaps poorly with the time when the corn crop actually needs N. Corn accumulates the majority of the N it needs between growth stages V6 (six visible leaf collars) and R1 (silking) (Abendroth et al., 2011). When N is applied before planting, the peak of N availability in the soil occurs well before the crop needs it most.

A goal of managing N should be to have the amount of available N as close to its peak as possible when the crop needs it. Corn producers can influence when and how long N is available by using considering the source of N used, paying attention to when they apply the fertilizer, and using nitrification inhibitors.

There is no one-size-fits-all solution for managing N in corn cropping systems. But there are some things corn producers should consider when considering their N management plans.

## When Does Corn Need N?

Crops specialists generally divide corn development into two categories:

1. The vegetative stages (prior to silking)
2. The reproductive stages (after silking)

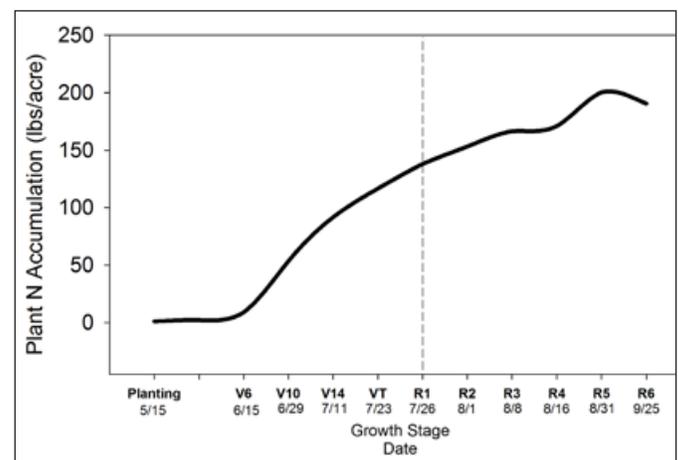
During the vegetative growth stages, the plant's primary goal is to accumulate leaf area, biomass, and N for use during the reproductive stages.

After silking, vegetative growth ceases, but the plants approximately double in dry weight because ears account for about 55 percent of a plant's total dry matter at maturity. Timing of plant N uptake differs from dry weight gains. Generally, a plant accumulates about 70 percent of the total N it will need before silking and accumulates about 30 percent during reproductive growth. These percentages, of course, depend highly on weather and environment.

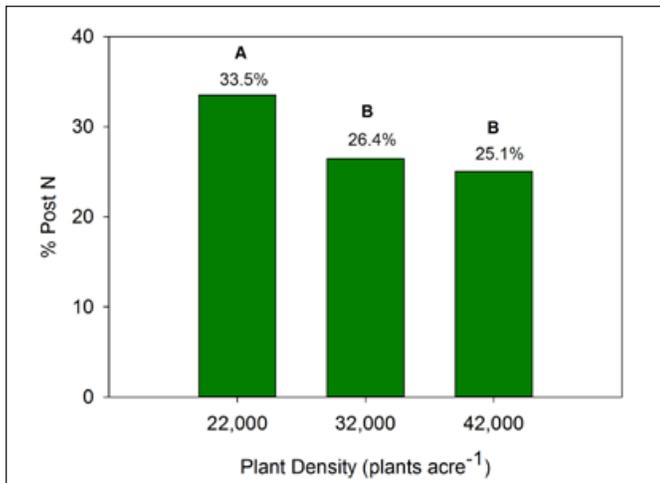
Corn plants cannot meet the N needs of a growing ear from new N uptake alone during reproductive growth. Rather, a plant depends on remobilizing the N from its stems and leaves. At harvest, slightly more than half of the N present in the grain originates from remobilized N. The remainder originates from post-silking N accumulation. Both remobilized N and new N uptake are crucial N sources for the grain.

The most appropriate N application strategy for a producer will depend on location (soil types), equipment, labor availability, and weather during the growing season. In order to make an informed decision about how to best manage N, consider these factors that influence when the crop accumulates N:

1. **Crop growth.** The period of most rapid N accumulation in corn occurs from about V6 to R1 under average conditions (Figure 1).
2. **Precipitation.** Very wet conditions can prevent timely N applications altogether, or may cause severe N loss through leaching or denitrification. On the other hand, very dry conditions also prevent plants from being able to take up soil N.
3. **Soil N availability.** Corn prefers to take up most of its N during the vegetative stages and then remobilize much of that N to the growing ear during grain fill. However, if soil N availability is limited during the vegetative stages, but becomes available around silking, corn can compensate for early-season N stress by increasing the amount of N it accumulates after silking.
4. **Plant population.** The more plants there are, the more N they accumulate before silking and the less they accumulate after silking. This occurs because corn planted at higher plant densities have proportionally more leaf biomass at silking, and leaves have much higher concentrations of N than stems (Figure 2).
5. **Hybrid.** Some hybrids may be more likely to respond to late-season N applications.



**Figure 1.** This graph shows how much a N a corn plant accumulates over the growing season. Dates are included for reference. **Source:** Woli et al., 2017.



**Figure 2.** This graph shows the relationship between corn plant density and the amount of N plants accumulate after silking. The denser the plant population, the less N the plants take up after silking. Averages represent two sites in Indiana, two N rates, and four hybrids. Averages with different letters are significantly different from each other. **Source:** Chen et al., 2015.

### Late-season N Application Methods

As with other methods of N application, corn producers have several options for making late-season N applications. Remember, we define late-season as applications that occur at growth stage V10 or later. By V10, healthy corn plants should have highly developed root systems. If soil moisture is sufficient these roots should be capable of reaching newly available N regardless of their proximity to where N was placed.

There are high-clearance equipment options that growers can use to apply N in late-vegetative stage corn



**Figure 3.** This grower is making a late-season N application using coulter-injection. Photo provided by Mike Shuter.

as broadcast urea, coulter-injected urea ammonium nitrate (UAN) and surface-banded UAN (Figure 3). Although each method has its pros and cons, our research has focused on coulter-injected and surface-banded UAN.

Purdue research has found that coulter-injection of UAN may prevent volatilization of ammonium from UAN; however, even when surface-banded, UAN volatilization risk is estimated to be only 5 percent in canopied corn. But the form of N fertilizer a grower may apply is important. Broadcast urea is a greater volatilization concern than UAN, because urea volatilization may range from 15 to 30 percent of the applied N (depending on rainfall and temperature shortly after application). Growers who broadcast urea should consider using a urease inhibitor to reduce volatilization losses.

The late-season N application research we discuss has largely focused on applying about 25 percent of the full N rate at the V12-V14 growth stages. To test the effect of this supplemental, split N application strategy, Purdue researchers conducted studies from 2014 to 2016. The studies compared multiple total N rates across Indiana — ranging from 100-250 pounds of N per acre in 10 experiments (both on-farm trials and small-plot studies on Purdue University Research farms with multiple hybrids). In addition, there were two experiments in Arizona in conjunction with drought-tolerant hybrid research.

### The Effects of Late-season Applications

Researchers wanted to find out how late-season N applications affected four factors in corn:

1. **Grain yield.** So far, researchers have found no evidence that split, late-season N applications (applied at V10-V16) provided significant yield benefits over the same N rate applied in a single application at early sidedress or at planting.
2. **Whole-plant N accumulation.** In several cases, using a split-N application strategy increased the whole-plant N accumulation at maturity. However, the greater total N accumulation did not increase grain yield. In the responsive experiments, split N applications resulted in higher N content at maturity in both grain and stover.
3. **Grain N concentration.** Late, split N applications only increased grain N concentration in two 2016 experiments. In the responsive experiments, grain N concentration was only increased at the moderate N rates of

150 or 170 pounds of N per acre. At higher N rates in the same studies, there was no significant difference in grain N concentration due to N timing.

4. **Post-silking N uptake.** Modern hybrids have the flexibility to increase post-silking N accumulation if early-season N is limited. However, if post-silking N accounts for more than 40 percent of the total N accumulation at maturity, it is likely that yields will still be reduced from the vegetative-stage stress because of reduced kernel set.

In these experiments, there was often little grain yield response to N rates greater than 150 pounds of N per acre. This indicates that when N is not a yield-limiting factor, the corn crop is not sensitive to the timing of N application, and the crop will preferentially accumulate N prior to silking (if possible).

It should be noted that in N management programs where N is applied pre-plant or in the fall, there is more time for early-season N losses. That means there is potentially more benefit from making supplemental late-season N applications.

All but one of these experiments were conducted in a corn-soybean rotation. Positive yield responses to late-season N applications may be different in continuous corn when early-season soil N availability is reduced because of immobilization and when total N requirements are higher relative to corn after soybean.

### 'Rescue' N Applications

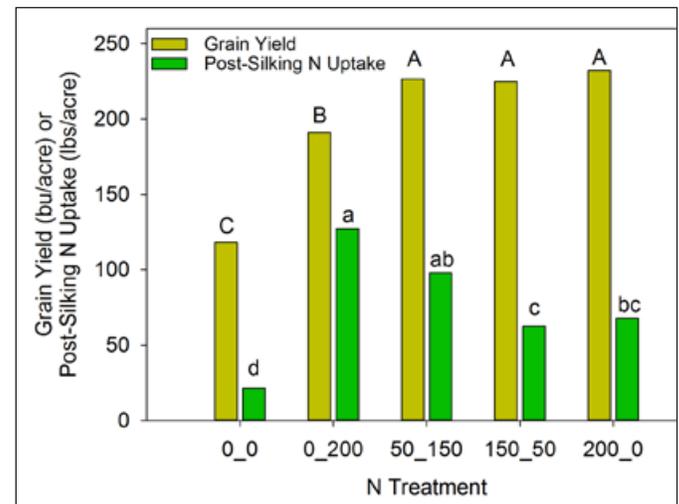
The Purdue experiments provide insight into the usefulness of late-season N applications as "rescue" applications. In growing seasons with excessive spring rainfall, high soil N loss due to leaching and denitrification may be a problem — or the rains may prevent timely spring N applications altogether. Research shows that even greatly delayed N applications can still result in yields that are not significantly different from single, early sidedress applications. Therefore, rescue N applications may be a feasible option when necessary.

A 2016 experiment demonstrates this point well. This study compared a total of 200 pounds of N:

- Applied with the full rate at V5
- Applied with the full rate at silking (R1)
- Split with 50 pounds applied at V5 plus 150 pounds applied at R1
- Split with 150 pounds applied at V5 plus 50 pounds applied at R1

The surprising result was that the treatment with only 50 pounds of N applied before silking and 150 pounds at R1, yielded the same amount of grain as the N treatments with either 150 or 200 pounds of N applied at V5 (Figure 4).

The maintenance of high grain yields was made possible partly by the increased post-silking N accumulation in the treatments that received little early-season N. This example speaks to the utility of late-season N application to minimize yield losses when inclement weather delays planned N applications.



**Figure 4.** Response of grain yield and post-silking N uptake to the timing of N application. N treatments include: a control with no applied N (0\_0); 200 lbs. of N applied at R1 (0\_200); 50 lbs. of N applied at V5 plus 150 lbs. of N applied at R1 (50\_150); 150 lbs. of N applied at V5 plus 50 lbs. of N applied at R1 (150\_50); and 200 lbs. of N applied at V5 (200\_0). The averages represent two hybrids. Averages that share the same letter are not significantly different from each other. **Source:** Mueller and Vyn, unpublished data.

## Conclusions

New technology makes it feasible to apply N later in the corn growing season. But our research comparing early sidedress with the last 25 percent of the total N rate delayed until V12 has shown that there was no evidence that late-season N applications will improve corn yields.

However, corn yield advantages with late-split N may be more likely in N management programs in which the majority of the N fertilizer is applied in the fall or very early spring, because of the much greater opportunity for soil N losses. Other potential uses for planned, late-season N applications may be in environments where N loss is of greater concern, such as very sandy fields, fields that are frequently water-logged, or where fertigation is used. Late-season N applications are a useful option in the case of unforeseen weather or equipment difficulties that prevent timely N applications. Even N application delayed as late as silking can prevent severe yield loss from N deficiency during the reproductive stages.

## Acknowledgments

The authors thank the Indiana Corn Marketing Council, DuPont Pioneer, The Climate Corporation, and The Howard G. Buffet Foundation for their financial support of these field experiments.

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Aug 2017

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