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Right Time: In-Season Nitrogen Applications

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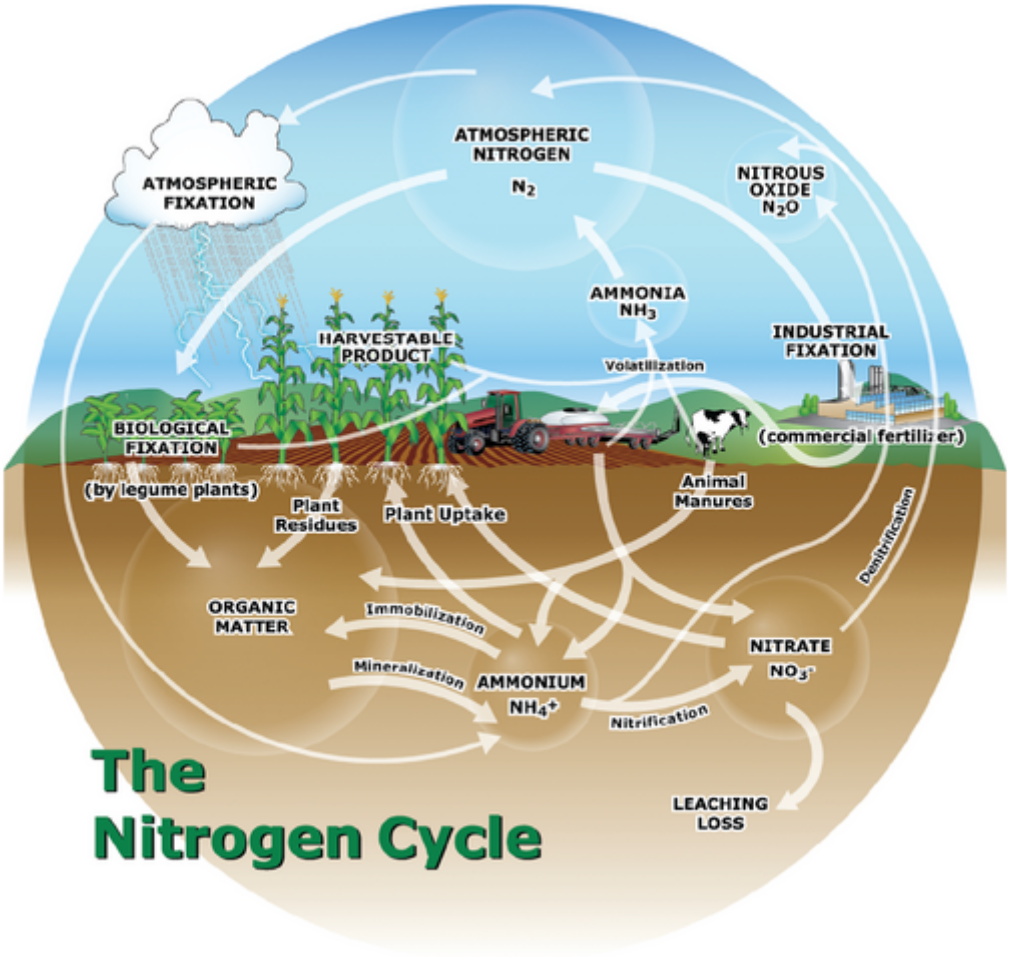
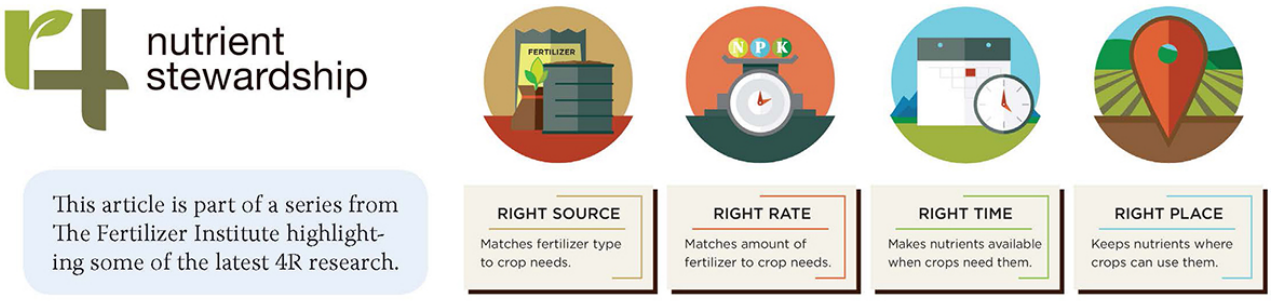


Figure 1. The nitrogen cycle.

In-season nitrogen applications, when managed effectively, offer a powerful tool for enhancing crop productivity and environmental sustainability. By aligning nutrient availability with crop needs, optimizing application methods, and mitigating potential risks, farmers can achieve better outcomes for both their crops and the environment.

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This article is part of a series from The Fertilizer Institute, highlighting some of the latest 4R research.



As we enter into harvest season, farmers will have the chance to evaluate what went

right and where they could have improved this past season. Nitrogen management, which is highly impacted by the weather, is a good management practice to look back on and fine-tune based on previous years. To get the most out of N fertilizer applications, growers must consider the 4Rs: applying the right N source in the right place, at the right time, and at the right rate. Split N application is one strategy to optimize the "right time" of the 4Rs. One of the goals of a nutrient management plan is to line up nutrient availability with crop need. In-season and split N applications are one strategy to synchronize nutrient supply with nutrient demand. The end goal is to optimize nitrogen use efficiency (NUE), which is key to reaching the economic, environmental, and social goals of 4R nutrient stewardship.

Soil Water, Crop Uptake, and N Availability

To best manage N, it is essential to understand its dynam ics in the soil. Nitrogen is different from the other two primary macronutrients, phosphorus (P) and potassium (K), in its reactive nature and general mobility in the soil. Nitrogen can easily transform to different chemical forms, making it susceptible to loss (Figure 1). The forms of N that plants can take up are ammonium (NH_4) and nitrate (NO_3), and the best-case scenario is to have N fertilizer in those two forms when the crop need is greatest.

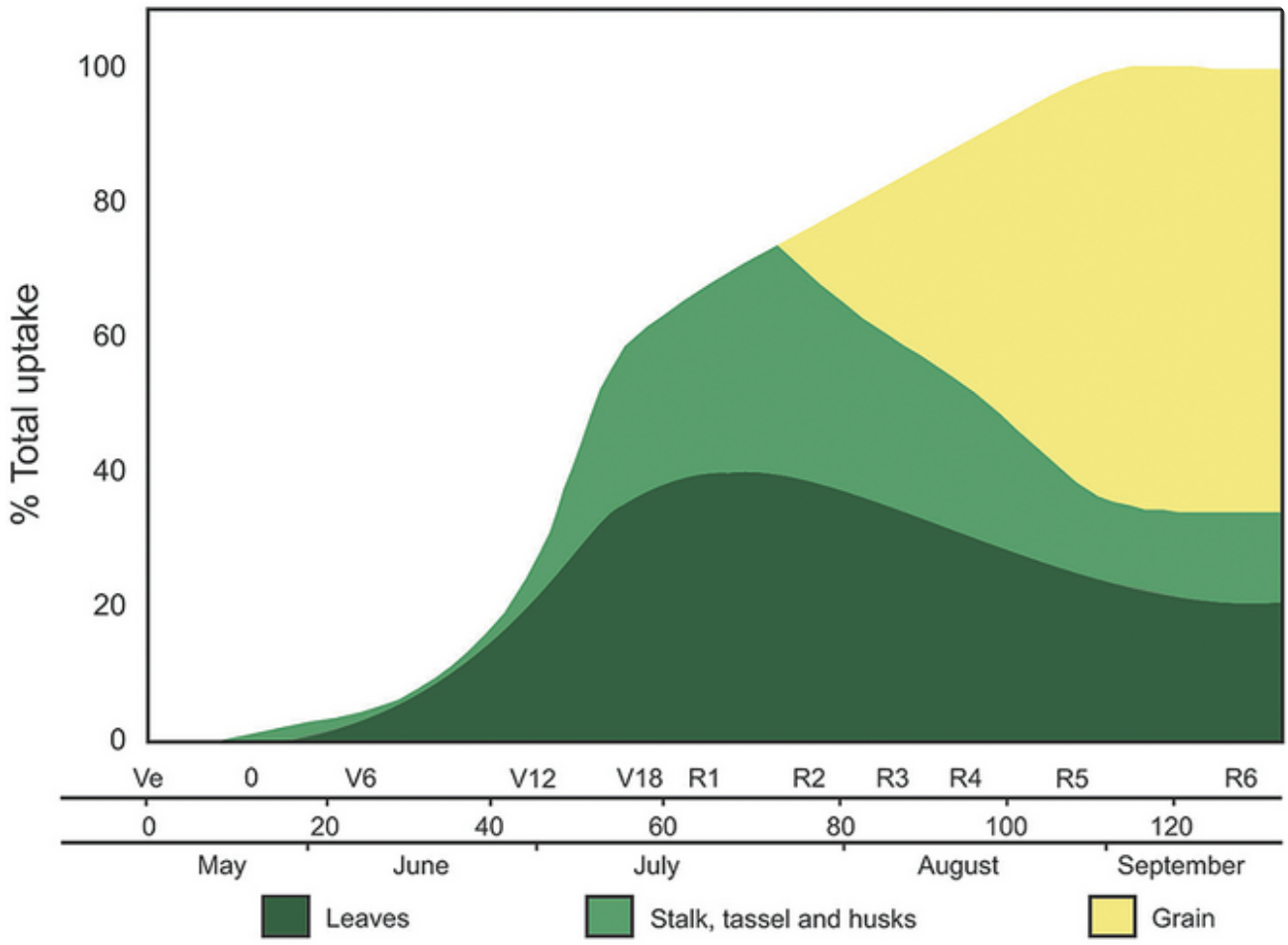


Figure 2. Cumulative corn N uptake divided by plant organ.

For most crops, uptake of N follows a sigmoid or "S"- shaped curve. This characterizes the slower uptake of nutrients in the early spring, followed by a period of rapid growth and uptake that then plateaus as the crop ma tures (Figure 2). In corn, demand for water and nutrients remains low until about V6, and then rapid growth starts and continues until about R3 stage.

Crops take up NO mass flow with soil water and NH4 through diffusion to the plant roots. In general, plants have evolved with a preference for NO3, and the majority of N is taken up in the form of NO3. A negatively charged ion (anion), NO3 is not held on soil cation exchange sites. Because NO3 is not held in soils, it moves easily with soil water through the root zone and is also highly susceptible to leaching outside of the

root zone.

Soil water is one of the most important factors to consider when determining N applications. Water drives many of the N processes in soils: it delivers N to roots, moves N out of the root zone through leaching, drives denitrification, influences mineralization of N, and impacts many other N reactions. Growers are often dealing with conditions where soils are too wet or too dry. Furthermore, growers can experience both extremes in a single growing season: a spring that is too wet and a summer that is too dry. In considering the moisture conditions, we can better understand N availability and movement in the field and use this knowledge to guide N programs.

Two Approaches to In-Season N Applications

There are two basic approaches to in-season N applica tions: preventative and rescue applications. Preventative applications are designed to deliver a substantial or planned amount of N to the crop in season. Rescue appli cations are also in-season N applications that can be ap plied if deficiency appears or if conditions might indicate N deficiency is going to occur (i.e., heavy rains that have washed away N fertilizer). There are benefits and challeng es associated with both types of in-season N applications.

Benefits of Split Nitrogen Applications

There are several reasons why growers and their advisers might want to implement in-season applications in their N programs.

1. Early-season N loss

If the N is not there, it can't be lost. In theory, reducing the amount of NO_3 in the early season by lowering the N rate at pre-plant reduces the potential for N loss in general.

With less N lost, split N applications would allow growers to lower their overall N rates. Applying a portion of N fertilizer in season is generally considered a BMP because of the reduced risk of early-season N loss.

2. Customizing your N rate and N rescue

In-season applications offer the flexibility to adjust nutrient management based on real-time observations and changing conditions. With the crop already growing, there is a chance to evaluate how the growing season is progressing and fold that information into your N application rate.

3. Tight Planting Window

In some areas of the country, the planting window has been tight due to heavy precipitation and a wet spring. Utilizing an in-season application can allow growers to skip the pre-plant N application and apply their first dose of N with the planter. This can help create more time for planting, with a portion of the N application occurring later in the season.

4. Soil and Climate Suitable for In-Season Applications

For some farms, in-season applications work well based on their soil, climate, and general operations. Certain soils and climates can be more prone to N losses, and delaying N application can help mitigate these losses, benefiting both crop yields and the environment.

5. Tailored Applications with Technological Advancement

As technology has improved, growers now have greater ability to tailor in-season N

applications. This includes site-specific N applications within the growing season and even variable-rate applications. Access to advanced application equipment and precision technology allows growers to apply the 4Rs more effectively by optimizing the timing, placement, and rate of in-season N applications.

6. Alignment with Crop Need

Synchronizing maximum nutrient availability with maximum crop need is a logical approach. In-season applications allow farmers to provide N when plants need it most. By timing nitrogen applications to key growth stages, farmers can ensure that crops receive N at the "right time," which can help improve nitrogen use efficiency (NUE) in certain situations.

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Figure 3. Application of UAN through knife injection in 20-inch corn rows using GPS guidance.

Overall, there are several positive reasons for growers and crop advisers to implement in-season N applications, but there are also some challenges:

1. Knowing When to Apply

One of the biggest challenges with in-season applications is timing them correctly. The goal is to apply late enough to match the crop's increased uptake and growth with an increased N supply. However, if application is delayed and deficiency symptoms appear, yield potential may already be reduced. While a rescue application can help boost yield when deficiencies are visible, it rarely results in full yield recovery. Most extension research recommends applying before a deficiency is visible, which should occur no later than V8 in corn (Fernandez & Carlson, 2024).

2. Weather Delaying N Application

Being unable to get into the field before the crop starts showing deficiencies is a risk with in-season applications. Rainy weather in the spring can create significant challenges, delaying growers from applying N on every acre. The optimal window for application is V4–V6, though it can be applied as late as V8 without a yield penalty—assuming adequate N was applied with the planter to get the crop started. To avoid being delayed by rain, it is better to apply too early than too late.

3. Insufficient Rainfall

While excessive rain can delay fieldwork, too little rain can be problematic for N movement. Without sufficient rainfall, N fertilizer is not moved into the soil profile and root zone, raising concerns about N availability and volatilization loss. Knifing in urea ammonium nitrate (UAN) can be an effective strategy to improve soil contact and reduce volatilization loss (Figure 3).

What Does the Research Say?

Looking at the research, the benefits of split N applications are not always straightforward. Studies have found mixed results when comparing yield, optimal N rates, and NO losses between in-season and pre-plant applications.

Although there is not always a clear yield improvement with split N applications, there is typically no yield penalty either (Fernandez et al., 2020; Nasielski et al., 2020). The positive impacts of split N applications are often dependent on growing conditions, particularly soil type and weather. A 49-site-year study across eight Midwestern states found that split applications resulted in greater yields in locations where rainfall was evenly distributed around the time of in-season application and in coarse-textured soils. However, in soils with higher total N, greater cation exchange capacity (CEC), or higher silt and clay content, a single N application resulted in greater yields (Clark et al., 2020).

Split applications typically reduce NO leaching (Bakhsh et al., 2002; Mitchell et al., 2000; Waring et al., 2022), but this is not always the case (Jaynes & Colvin, 2006). In general, NO leaching reductions are more likely when less N is applied in wetter springs. Researchers have found clear benefits to using split N applications to reduce NO losses in cover crop systems (Preza-Fontes et al., 2021; Gentry et al., 2024). One study in Illinois showed that using a split N application in cover crop systems led to a 43% reduction in NO loss while maintaining crop yields (Gentry et al., 2024).


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7
5
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Figure 4. When sidedressing in corn, typically the optimal timing is between V4 and V6, but if getting "rained out" is a concern, getting the N on should be a bigger priority than timing it perfectly in the V4–V6 window.

Best Practices for In-Season Nitrogen Applications

If you are considering implementing in-season applications in your N program, there are several best practices to follow that align with the 4Rs of nutrient stewardship: source, timing, and placement.

First, determine the N source for the in-season application, as this will influence the equipment needed and vice versa. Each N source has benefits and drawbacks. Urea is widely accessible and can be quickly applied as a topdress, though this may require hiring a custom applicator. Alternatively, growers may choose sidedressing with UAN (28–32%), which is often applied using their own equipment. Both urea and UAN have the potential to cause leaf burn, so applications should be avoided when leaves are wet or before the corn whorl is large enough to capture urea granules (Carlson, 2023).

Second, the rate of in-season N application should be considered within the context of the entire N program. Typically, a planter or pre-plant N application supplements in-season applications (or vice versa). When planning the in-season application, factor in the N already applied at planting and ensure that the final in-season application meets the target N rate, whether based on the Maximum Return to Nitrogen (MRTN) or Economic Optimum Nitrogen Rate (EONR). If using variable rate application, in-season N is an excellent tool to fine-tune the total N applied.

When sidedressing in corn, the optimal timing is generally between V4 and V6, with a final cutoff no later than V8 (Figure 4). Growers often want to complete applications as soon as possible, but while the V4–V6 window is ideal, applying earlier than ideal is better than missing the opportunity due to rain delays. For those new to in-season

applications, it is common for some corn plants to be run over by equipment, especially in headlands. However, young corn plants are resilient and can typically recover well, especially while the growing point remains below the soil surface (before V5).

Along with selecting an appropriate N source, equipment plays a crucial role in determining placement. UAN is best applied directly to the soil, either as a dribble or injected between rows. lf available, use precision guidance systems to ensure accurate in-season N applications and to center the application between rows. To minimize root damage when knifing in UAN, apply it in the center of rows before V6. When topdressing urea, much like spraying, aim to apply on dry, calm days when plants are dry and wind speeds are low. Avoid applying topdress urea when the soil surface is moist or when relative humidity is high, as these conditions increase volatilization loss.

A final consideration is whether to use a nitrogen stabilizer or inhibitor. When applying topdress urea or surface-applied UAN, a urease inhibitor can be a good investment if rainfall is not expected soon, if the soil surface is moist, or if humidity is high. Urease inhibitors typically provide protection for about a week if rainfall is not expected within a few days. At least a quarter inch of rainfall is needed to fully incorporate N and reduce the risk of volatilization loss.

Conclusion

ln-season nitrogen applications, when managed effectively, offer a powerful tool for enhancing crop productivity and environmental sustainability. By aligning nutrient availability with crop needs, optimizing application methods, and mitigating potential risks, farmers can achieve better outcomes for both their crops and the environment.

The key to success lies in adopting best practices, leveraging technology when appropriate, and staying informed about challenges and risks. As agriculture continues to evolve, effective in-season nitrogen management will remain crucial for achieving sustainable and productive farming systems. Keeping in mind the “right time” of the 4R nutrient stewardship framework will be essential as growers consider in-season N applications.

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1. **Which form of nitrogen do plants primarily prefer for uptake?**
   a. Ammonium (NH_4^+).
   b. Nitrate (NO_3^-).
   c. Urea.
   d. Nitrite (NO_2^-).

2. **Why is nitrate (NO_3^-) more susceptible to leaching than ammonium (NH_4^+)?**
   a. Nitrate is a positively charged ion.
   b. Nitrate is not held on soil cation exchange sites.
   c. Nitrate binds strongly to soil particles.
   d. Nitrate is absorbed rapidly by plant roots.

3. **Plants take up NO_3^- through _____ and NH_4^+ through _____.**
   a. diffusion; mass flow
   b. mass flow; diffusion
   c. root interception; mass flow
   d. soil water; mass flow

4. **Uptake of nitrogen by crops follows a curve over time whose shape is**

a. sigmoid.
b. linear.
c. spherical.
d. exponential.

5. **What are the two basic strategies to in-season nitrogen applications?**
   a. Pre-plant and post-plant.
   b. Preventative and rescue.
   c. Early and late.
   d. Broadcast and banding.

6. **In a study across eight Midwestern states, what factor contributed to greater yields with split nitrogen applications?**
   a. High soil organic matter.
   b. Uniform rainfall around the time of application.
   c. High soil pH levels.
   d. High P levels.

7. **When is the optimal timing for sidedressing corn with nitrogen?**
   a. V2–V4.
   b. V4–V6.
   c. V6–V8.
   d. V8–R1.

8. **How does too little rainfall impact in-season nitrogen applications?**
   a. It enhances nitrogen uptake by plants.

b. It helps move nitrogen into the soil profile.
c. It prevents nitrogen from moving into the soil profile.
d. It increases the efficiency of nitrogen fertilizers.

9. **What is a potential benefit of using a urease inhibitor with top-dressed urea?**
   a. It reduces leaching of NO
   b. It provides protection against volatilization losses.
   c. It enhances the solubility of nitrogen in water.
   d. It helps in reducing soil compaction.

10. **As evidenced by a study in Illinois, split N applications in cover crop systems led to a _____ reduction in NO losses.**
    a. 16%
    b. 24%
    c. 43%
    d. 62%

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