SeedSCOOP

NITROGEN AVAILABILITY IN THE SPRING

- Spring nitrogen (N) availability is affected by many factors such as type of fertilizer and specific nutrient compound applied, use of stabilizers, soil type, and weather conditions.
- Understanding how N loss occurs can help manage N use efficiency.
- Determining the amount of N available for plant uptake in the spring and planning nitrogen management steps needed in season can help maximize crop yield potential.

Sources of Nitrogen

Nitrogen can be supplied for plant growth in several ways.

Atmospheric N is a major component of the N cycle. Legumes such as soybean and alfalfa can use this type of N via N fixation. Decomposing plant material from these legume crops will release N into the soil. Small amounts of atmospheric N are also added to the soil through precipitation.

Mineralization occurs when organic N is converted to nitrate and ammonium and made available to crops. Soil organic matter is composed mainly of humus and is an important source of N for plant growth. Decomposition of humus occurs at a slow rate and can release about 20 pounds of N per acre per year for each percent of organic matter in the soil.[1]

Commercial N fertilizers can also be applied as a primary source of N to enhance plant growth, increase yields, and sustain profits. These products come in various forms, discussed below.

How Nitrogen is Lost in the Soil

Denitrification is the process by which nitrate-N is converted by bacteria into forms of N gas that move up through the soil and can be lost to the atmosphere. The process is initiated by bacteria that are anaerobic, meaning they are active when oxygen levels are low. Therefore, most denitrification occurs under saturated soil conditions. The amount of nitrate-N loss is influenced primarily by the length of time soils are saturated as well as by soil temperature. University of Illinois estimates indicate that when soils are saturated, daily nitrate-N loss by denitrification can be 1 to 2% at soil temperatures less than 55°F, 2 to 3% if soil temperatures are between 55 and 65°F, and 4 to 5% at soil temperatures above 65°F.[2]

Leaching occurs when nitrate-N moves downward in the soil profile and out of the root zone with excessive precipitation. In sandy soils, nitrates may contaminate groundwater but in heavier-textured soils, leached nitrates typically reach tile lines and may eventually reach surface water.

Volatilization, or the loss of N, can occur when urea-based fertilizers are surface-applied and unincorporated. Urease enzymes in soil and plant residue convert urea to free ammonia gas. Volatilization is promoted by excessive plant debris on the soil surface, warm, windy days and high pH (greater than 7) at the soil surface.[3] To minimize N loss by volatilization, incorporation should occur within three to four days after application with tillage, with half an inch of rain or irrigation, or with the use of a urease inhibitor.[4] Under warm, sunny conditions, up to 15 to 20% urea-based N can volatilize within a week of application.[5]

NITROGEN AVAILABILITY IN THE SPRING

Nitrogen Fertilizers

Nitrogen fertilizers contain N in one or more forms: ammonia (NH3), ammonium (NH4), nitrate (NO3), or urea (CO(NH2)2) (Table 1). Ammonia is a compressed gas injected into the soil to minimize N fertilizer loss and can be applied in the fall, spring, or sidedressed. When anhydrous ammonia is applied, the ammonia is converted to ammonium in the soil almost immediately. Ammonium binds to clay and organic matter in the soil, preventing it from leaching. Through nitrification, soil microorganisms convert ammonium to nitrate, the main form of N taken up by plants. Conditions favorable to nitrification are a soil pH of 7, soil moisture at 50% of holding capacity, and a soil temperature of 80°F.[3] Applying anhydrous ammonia to soils that are too wet or too dry can result in loss of N to the atmosphere because of poor sealing of the application slit. To help reduce seed and seedling injury, planting should be delayed three to five days after application of anhydrous ammonia. For preplant applications, consider applying anhydrous at an angle to your corn rows to help minimize seedling injury by minimizing direct contact.

Urea, is converted to ammonia two to four days after application when soil moisture and temperature are favorable. Lower temperatures can slow the process. Urea is first converted to ammonia, then to ammonium, and finally to nitrate, which is readily available to plants. Ammonium applied to the soil originating from urea will also be accessible to microbial conversion to nitrate-N, which is at risk for leaching or denitrification. No matter what form of N fertilizer is used, most of the N will be converted to nitrate in the soil.[6]

Table 1. Characteristics and adaptation of common nitrogen fertilizers.

Fertilizer material	Percent nitrogen	Form of nitrogen in fertilizer	Adaptation for			
			Fall plow-down for corn	Spring pre-plant	Side-dressing corn	Top-dressing small grains and grasses
Dry Solid Forms						
Ammonium nitrate	33.50%	1/2 ammonium 1/2 nitrate	Unadapted	Good*	Excellent	Excellent*
Ammonium sulfate	20.50%	Ammonium	Excellent	Excellent*	Excellent	Good*
Calcium nitrate	15.50%	Nitrate	Unadapted	Good*	Excellent	Excellent*
Cal-nitro (ammonium nitrate + limestone)	26%	1/2 ammonium 1/2 nitrate	Unadapted	Good*	Excellent	Excellent*
Diammonium phosphate	18%	Ammonium	Excellent	Excellent	Excellent	Excellent
Urea	45%	Ammonium-forming	Excellent	Excellent*	Excellent	Good-winter Poor-summer
Liquid Forms						
Anhydrous ammonia[1] (liquid under pressure)	82%	Ammonium-forming	Excellent	Good*	Excellent	Unadapted
Aqua ammonia[1] (anhydrous ammonia + water)	20-24.60%	Ammonium-forming	Excellent	Good*	Excellent	Unadapted
Low-pressure N solutions[1] (ammonium nitrate-urea-ammonia-water)	37-41%	2/3 ammonia[2] 1/4-1/3 nitrate	Poor	Good*	Excellent	Unadapted
Non-pressure N solutions (urea-ammonium nitrate-water or UAN)	28-32%	1/4 nitrate[2] 3/4 ammonium	Poor	Excellent	Excellent	Excellent-spring Poor-summer

* If fertilizer is used for the purpose indicated at the top of the column, certain limitations or caution are involved. These are spelled out in the section discussing that fertilizer, see: Mengel, D.B. 2014. Types and uses of nitrogen fertilizers for crop production. AY-204. Agronomy Guide. Purdue University Cooperative Extension.

[1] Must be injected into the ground when applied to avoid N loss to the air as gas.

[2] Approximate proportions.

Table adapted from: Mengel, D.B. 2014. Types and uses of nitrogen fertilizers for crop production. Purdue University Cooperative Extension. AY-204. Agronomy Guide. https://www.extension.purdue.edu/extmedia/ay/ay-204.html.

NITROGEN AVAILABILITY IN THE SPRING

Nitrogen Stabilizers

Nitrogen additives can be used to delay N transformations and prolong N availability. If N stabilizers are used with N fertilizer applications, the amount of N loss may be reduced, even if weather conditions are not ideal. There are two categories of N stabilizers generally used: nitrification inhibitors and urease inhibitors. Nitrification inhibitors inhibit soil bacteria responsible for denitrification, slowing the conversion of ammonium to nitrate.[7] Urea can be treated with an urease inhibitor to reduce N loss by ammonia volatilization.[7] Additional nitrogen stabilizers can include polymer-coated urea for slow release of N and products that contain urea, an urease inhibitor, and a nitrification inhibitor.[8]

For more specific information on nitrogen and corn, please read this article, Benefits of Nitrogen for Corn Production.

Determining Nitrogen Availability

Determining available N in fields during spring can be challenging because N availability is influenced by several factors including type of N fertilizer applied, timing and method of application, soil type, previous crop, use of a N stabilizer, and weather conditions. Soil testing to determine the level of nitrate and ammonium forms of N can help estimate the amount of N loss due to rainfall or flooding. Soil cores should be collected to a depth of at least one foot. In sandy soils prone to leaching, sampling at a greater depth may help to identify plant-available N deeper in the soil profile.[9] If fertilizer was broadcast in the fall or early spring, collect 20 to 30 cores per sample. If previously applied fertilizer was banded, samples should contain 15 to 20 soil cores. Samples should be collected perpendicular to the direction that fertilizer was applied. Each sample should represent no more than 10 acres.[5] Samples should be dried or refrigerated as soon as possible to stop soil microbial activity from changing N levels. Results indicating substantial levels of soil ammonium are more likely if anhydrous ammonia was recently applied, nitrogen stabilizers were used, or soil pH is 5.5 or less. In such cases, low levels of soil nitrate may mean that little conversion of ammonium to nitrate occurred rather than loss of nitrate from the soil due to leaching or denitrification.

Nitrogen Soil Tests

A Preplant Soil Nitrate Test (PPNT) can provide helpful information in early spring to adjust the total amount of spring-applied N by the amount indicated in the soil test. Results obtained by scientists in both Wisconsin and Michigan have shown this procedure to work well, but research in Iowa indicated that the procedure did not accurately predict N needs.[2] Since samples are collected in early spring, the procedure measures mostly N carried over from the previous crop and any N applied in the previous fall season. The procedure has the potential for success in corn that follows corn, especially in fields where dry growing conditions limited yields the previous year and where dry weather has reduced N loss. Heavy rainfall in late spring or after testing may reduce the usefulness of this test because some of the nitrate-N detected earlier in the spring may have been lost to denitrification or leaching before the plant had an opportunity to take it up from the soil.

A Pre-Sidedress Nitrate Test (PSNT) is useful for fields where manure or other organic fertilizers have been applied recently or where legume crops have been grown with high N content, such as alfalfa. Also, farmers may want to consider using this tool for fields that had fall-applied N and suspected N loss from leaching and denitrification. The test provides a measure of the amount of N mineralized from organic N plus the amount of carryover N still present in the soil. Mineralization is the process by which organic N is converted to ammonium-N and nitrate-N, which is then available for plant uptake. Adequate soil moisture and warm temperatures are beneficial for mineralization. However, if late spring temperatures are below normal, the test

may underestimate soil N (lower soil test values) because of slower mineralization rates. Sampling for the PSNT should be done when corn is 6 to 12 inches tall or from late May to early June.[2] Soil cores should be taken at a depth of one foot, with one sample containing 15 to 20 cores. Although some differences exist in University recommendations for interpreting PSNT results, a general rule of thumb is that if soil test results are over 23 to 25 ppm, additional nitrogen is probably not needed.[10]

The following articles are available for more information on soil testing-- Soil Testing 101 and Reading and Interpreting a Soil Test.

In-Season Nitrogen Estimation

Additionally, there are other available tools, such as chlorophyll leaf meters (SPAD meters), crop sensors, and remote sensing/aerial imagery to detect N deficiencies in season.[2] Remote sensing requires good canopy development mid-season and can be accomplished effectively using NDVI (normalized difference vegetative index) cameras on aerial drones or sensors fitted to high clearance N application equipment. The NDVI or NDRE (normalized difference red edge) index for any part of the field is compared to the highest readings in the field (considered the "high N reference") and variable rate N adjustments can be made to areas of the field N deficient.[11] These tools may provide information to aid in determining late-season nitrogen application rates.

For more information on estimating in-season nitrogen sufficiency, please see the article from University of Nebraska-Lincoln, https://cropwatch.unl.edu/2020/tips-season-nitrogen-management-corn.

For more information on estimating nitrogen loss and a corn nitrogen recommendation calculator, please see the calculator available from the University of Nebraska-Lincoln, https://cropwatch.unl.edu/soils/software.

Sources

[1] Lamb, J.A., Fernandez, F.G., and Kaiser, D.E. 2014. Understanding nitrogen in soils. University of Minnesota Extension. AG-FO-3770-B. Nutrient Management. www.extension.umn.edu.

[2] Fernandez, F.G., Nafziger, E.D., Ebelhar S.A., and Hoeft, R.G. 2009. Managing nitrogen, Chapter 9. Illinois Agronomy Handbook. http://extension.cropsci.illinois.edu/handbook/.

[3] Mengel, D.B. 2014. Types and uses of nitrogen fertilizers for crop production. Purdue University Cooperative Extension. AY-204. Agronomy Guide. https://www.extension.purdue.edu/extmedia/ay/ay-204.html.

[4] Scharf, P. and Lory, J. 2006. Best management practices for nitrogen fertilizer in Missouri. University of Missouri Extension. IPM 1027. University of Missouri Extension. https://extension.missouri.edu/publications/ipm1027.

[5] Camberato, J., and Nielsen, R.L. 2017. Soil sampling to assess current soil N availability. Purdue University Extension. Agriculture Agronomy. Chat'n Chew Café. Corny News. https://www.agry.purdue.edu/ext/corn/news/timeless/AssessAvailableN.html.

[6] Nitrogen management. Iowa Soybean Association On-Farm Network. www.isafarmnet.com.

[7] Ferguson, R., Maharjan, B., Wortmann, C., and Krienke, B. 2019. Nitrogen inhibitors for improved fertilizer use efficiency. University of Nebraska-Lincoln. CropWatch. https://cropwatch.unl.edu/2019/nitrogen-inhibitors-improved-fertilizer-use-efficiency.

[8] Franzen, D.W. 2017. Nitrogen extenders and additives for field crops. North Dakota State University Extension Service. SF1581. https://www.ag.ndsu.edu/publications/crops/nitrogen-extenders-and-additives-for-field-crops.

[9] Fernandez, F.G., Hoeft, R.G., and Randall, G.W. 2011. How much nitrogen is there in the spring from fall-applied MAP, DAP, and ammonium sulfate? Proc. of the 2011 Wisconsin Crop Management Conference. 50:127-135.

[10] Shapiro, C., Hergert, G., and Ferguson, R. 2012. Using the PSNT for spring testing of nitrogen availability. University of Nebraska-Lincoln. CropWatch. https://cropwatch.unl.edu/using-psnt-spring-testing-nitrogen-availability-unl-cropwatch-may-23-2012.

[11] Iqbal, J., Wortmann, C., Maharjan, B., and Puntel, L. 2020. Tips for in-season nitrogen management in corn. University of Nebraska-Lincoln. CropWatch. https://cropwatch.unl.edu/2020/tips-season-nitrogen-management-corn.

Legal Statements