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Assessing Available Nitrogen from Fall- and Spring-Applied Nitrogen Applications

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Excessive rainfall and the resulting ponding, flooding, or saturated soils have likely caused some loss of applied and soil-derived nitrogen (N). Nitrate-N ($\text{NO}_3\text{-N}$) is the form of N most likely to be lost from the crop root zone, either to tile drainage, groundwater, and/or into the atmosphere (via denitrification). Ammonium-N ($\text{NH}_4\text{-N}$) is not subject to N loss mechanisms when incorporated into the soil.

Most of the fertilizer or manure N added to soil is initially in forms other than nitrate. The exception is liquid N (28-32% N) which is only 25% $\text{NO}_3\text{-N}$, the remainder is $\text{NH}_4\text{-N}$ (25%) and urea-N (50%). Anhydrous ammonia is 100% $\text{NH}_4\text{-N}$ when it reacts with water in the soil. Manure contains mostly organic-N and $\text{NH}_4\text{-N}$ forms.

Unfortunately, no matter what forms of N are added to the soil, all of them eventually convert to $\text{NO}_3\text{-N}$. Time, temperature, soil type, N source, rate, and application method, and other factors determine how rapidly $\text{NO}_3\text{-N}$ appears. It is difficult to estimate the extent of $\text{NO}_3\text{-N}$ formation because of the many factors affecting N conversion, and their interaction. It is even more difficult to then estimate how much of the N converted to $\text{NO}_3\text{-N}$ was subsequently lost from the rootzone.

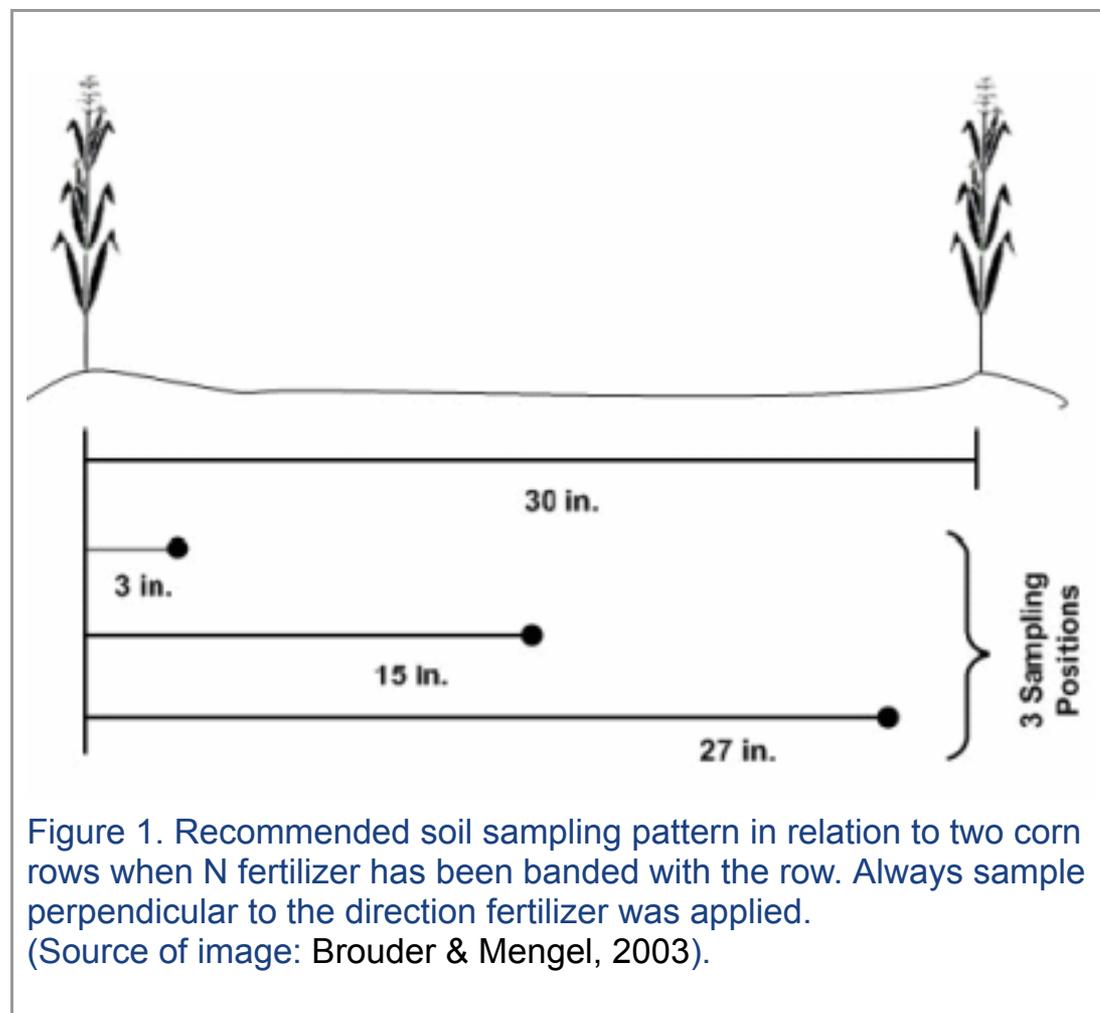
Soil sampling and measuring the concentration of $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ remaining in the rootzone is an alternative to guesstimating how much N was lost.

Soil sampling strategies

Take a good representative soil sample. Collect soil cores to a depth of at least 1 foot. Consider collecting a separate deeper soil sample from between 1 and 2 feet deep for a more complete assessment of plant available N, especially in sandy soils where leaching through the soil profile is the predominant form of N loss.

Each sample should represent no more than 10 acres. Where earlier-applied fertilizer N was

broadcast rather than banded, collect 20 to 30 soil cores per sample. Where earlier-applied fertilizer N was banded (e.g., anhydrous ammonia), collect 15 to 20 soil cores using the sampling scheme illustrated in Figure 1.



Sample handling

Dry or refrigerate the soil samples as soon as possible to stop the soil microbes from altering the N levels. Spread the soil thinly on plastic to air dry and hasten drying with a fan if possible. If you choose to use an oven to dry the soil, keep the temperature below 250F. Alternatively refrigerate the samples and keep them cold through shipping to the laboratory.

A list of certified soil testing laboratories is available at the following Web address. Most should offer soil N test analysis services, but contact them first to confirm.

https://ag.purdue.edu/agry/extension/Pages/soil_testing.aspx.

Soil-test laboratory analyses

Ammonium-N is just as available to plants as nitrate-N, but typically little accumulates in the soil because it is readily converted to nitrate under most conditions. However, if N fertilizer was recently applied, there may well yet be some ammonium N available in the soil for plant use.

Significant levels of soil ammonium are most likely if anhydrous ammonia was the N source, a nitrification inhibitor such as nitrapyrin or dicyandiamide (DCD) was used, and/or soil pH was low (below 5.5). In these situations, low levels of soil nitrate may indicate little conversion of ammonium to nitrate, rather than simply loss of nitrate.

TIP: When you submit the soil samples to the soil-testing laboratory, request analyses for exchangeable ammonium as well as for nitrate, particularly if anhydrous ammonia was applied relatively recently or a nitrification inhibitor was used with the N fertilizer.

If soil test values for ammonium and nitrate are reported as 'ppm' or 'mg/L' nitrogen ($\text{NH}_4\text{-N}$ or $\text{NO}_3\text{-N}$), then calculate pounds per acre of available N by multiplying the test results by 4 when the sample depth was 1 foot. For other sample depths, divide the sample depth (in inches) by 3 and then multiply by the test results.

Example: Soil $\text{NO}_3\text{-N}$ in a 1-foot sample was 30 ppm.

Conversion from ppm to pounds per acre is $(12 \text{ inches} / 3) \times 30 \text{ ppm} = 120 \text{ pounds per acre}$.

If soil test values are reported directly as NH_4 or NO_3 , then these values must be converted to an 'N' basis first. The calculations are: $\text{NH}_4\text{-N} = \text{NH}_4 / 1.2$ and $\text{NO}_3\text{-N} = \text{NO}_3 / 4.5$.

Example: Soil NO_3 was reported to be 90 ppm.

Conversion from NO_3 to $\text{NO}_3\text{-N}$ is $90 \text{ ppm } \text{NO}_3 / 4.5 = 20 \text{ ppm } \text{NO}_3\text{-N}$.

Interpreting soil nitrate and ammonium levels

In our opinion, soil nitrate and ammonium levels can be used to guide additional N applications to fields subjected to saturation and flooding. However, there are admittedly no hard and fast research-based recommendations for this particular situation.

The primary tool for soil N sampling in the Eastern Corn Belt has been the pre-sidedress soil nitrate test (PSNT) which is most applicable as an indicator of N availability in soils where manure had been applied or a legume such as clover or alfalfa had been plowed down (Brouder & Mengel, 2003). For these field situations, the level of soil nitrate found is considered an index of N availability, i.e., an indicator of how much N is currently available AND how much N may become available from the manure or organic matter. When used in this context, soil $\text{NO}_3\text{-N}$ levels greater than 25 ppm are thought to be adequate for optimum corn yield without the addition of more fertilizer N.

During the research that developed this soil test, sampling deeper than 1 foot or analyzing for exchangeable $\text{NH}_4\text{-N}$ did not increase the predictive ability of the PSNT enough to warrant the extra effort. However, when the intent is to assess the loss of N due to rainfall, we suggest that deeper sampling plus analysis for $\text{NH}_4\text{-N}$ content can provide useful information to help growers decide whether additional fertilizer N is merited. It is important to recognize that in this context, measurements of soil nitrate and ammonium following fertilizer N applications indicate current N availability only, because there is no manure- or legume-derived N to be released later in the season. Considering this fact, the commonly accepted 25 ppm $\text{NO}_3\text{-N}$ critical level for manure- or legume-N fertilized soils may be too low for soils that have only received fertilizer N.

Leaching of soil nitrate is expected with ponding, flooding, or soil saturation, but not all of the nitrate will have been moved below the root zone. A shortcoming of the 1-foot sampling depth is that it does not always reflect plant available N deeper in the profile, particularly when abnormal leaching occurs. This is why we suggest also sampling from the 1- to 2-foot depth for assessment of soil N availability, particularly in sandy soils.

In our on-going N rate trials conducted throughout the state, the "normal" background levels of soil N in the upper 1 foot of mineral soils typically range from 5 to 10 ppm $\text{NO}_3\text{-N}$ and 4 to 8 ppm $\text{NH}_4\text{-N}$ for corn grown in rotation with soybean or corn without manure- or legume-derived N. Typically the deeper 1- to 2-foot soil samples would have slightly lower N levels.

Making a decision

We suggest that the 25 ppm $\text{NO}_3\text{-N}$ critical level for manure- or legume-N fertilized soils may be too

low for soils that have only received fertilizer N and where N loss conditions have been severe. Where enough rainfall has occurred to cause substantial N loss, we suggest this level of rain has depleted the lower soil profile as well as the upper foot of soil.

Table 1 lists estimates of expected soil NO₃-N levels with different fertilizer rates assuming “normal” background levels of nitrate and ammonium at the time of fertilization and a “normal” amount of movement below the one foot sampling depth (approximately 1/3 of the fertilizer N is moved below the 1-foot sampling depth but retained within the root zone with normal rainfall). If the corn is healthy and the growing season typical from here on out, we would suggest applying no more than 10 pounds of N for every 2 ppm reduction in soil sample N below the expected levels listed in the table.

Recognize that as a healthy crop moves through the rapid growth phase prior to pollination, soil N levels will naturally decrease in response to rapid N uptake by the plants. However, by the time a healthy crop reaches the V9 leaf stage (about 30 inches tall), only 19 lbs/ac N (equivalent to 5 ppm soil NO₃-N in a 1-foot deep sample) have typically been taken up the plants (Mengel, 1995). But, by the time a healthy crop reaches shoulder-high (~ V15 or 60 inches tall), approximately 116 lbs/ac N (equivalent to 29 ppm soil NO₃-N in a 1-foot deep sample) have been taken up by the plants. With later corn the amount of N in the plant should be considered when evaluating soil N.

The following examples give you an idea of how the tabular information may be used to make this decision.

Example calculation when only NO₃-N is determined:

Fertilizer N was applied at 160 pounds of N per acre in early April as 28% UAN in southern Indiana. Only soil NO₃-N analysis was requested because it was assumed that most of the urea- and ammonium-N had been converted to nitrate since temperatures were warm prior to the April and May rains. The expected NO₃-N level from the table below for a 160-lb N application is 35 ppm. Laboratory results indicated only 20 ppm NO₃-N. The suggested N application rate would be: $((35 \text{ ppm} - 20 \text{ ppm}) / 2) \times 10 = (15 \text{ ppm} / 2) \times 10 = 7.5 \times 10 = 75 \text{ pounds per acre}$.

Example calculation when both NO₃-N and NH₄-N are determined:

Anhydrous ammonia with nitrapyrin was applied at 160 pounds of N per acre in late April in northern Indiana. Since the N application was relatively recent and a nitrification inhibitor was used, both NO₃-N and NH₄-N analysis of soil samples were requested. The

Table 1. Expected soil analysis levels of nitrate or nitrate plus ammonium in the upper 1 foot of soil for different rates of applied N fertilizer.

NOTE: Use the NO₃-N column if this is the only form of N measured in your sample. Add NO₃-N and NH₄-N levels together if both forms of N are measured in the soil sample and use the last column to assess N availability.

Fertilizer N applied prior to rains	Nitrogen analysis	
	NO ₃ -N	NO ₃ -N + NH ₄ -N
lbs/acre	ppm or mg/L N	
130	30	36
140	31	37
150	33	39
160	35	41
170	36	42
180	38	44
190	40	46
200	41	47
210	43	49
220	45	51
	*	**

NO₃-N = Nitrate nitrogen; NH₄-N = Ammonium nitrogen

* Assumes background level of ammonium at 6 ppm and "normal" levels of soil N below the 1-foot sampling depth.

** Assumes "normal" levels of soil N below the 1-foot sampling depth.

expected NO₃-N plus NH₄-N levels listed in the table for a 160-lb N application is 41 ppm. Laboratory results indicated 15 ppm NO₃-N and 20 ppm NH₄-N for a total measured N level of 35 ppm. The suggested N application rate would be: $((41 \text{ ppm} - 35 \text{ ppm}) / 2) \times 10 = (6 \text{ ppm} / 2) \times 10 = 3 \times 10 = 30$ pounds per acre.

Application Methods

A number of application methods are available for N application in tall corn; including urea broadcast with airplane, helicopter or high-clearance box spreader and liquid N dribbled on the soil surface or injected into the soil with high-clearance applicators. Surface-applied urea or liquid N (50% urea) can lose some ammonia to the air but the canopy and banding (for liquid N) reduce the magnitude of potential loss. In either case N loss is likely less than 10% of the urea applied.

All the N sources will "burn" tissue that they contact or dissolve on, but generally the damage is considered cosmetic. And the various methods will cause different levels of collateral damage on end rows and during the application process. Although these methods of application are clearly different there are no clear best or worst options. If the crop needs nitrogen and more than one of these methods is available consider the cost, the amount of N that can be applied versus the amount of N that is needed, and the ancillary effects of the application process.

Sidedress N application rates

If no fertilizer N has been applied this season or soil N measurements suggest little N remains from fall- and spring-applied N, consider using our current N rate guidelines based on results of field trials conducted since 2006 throughout the state using efficient methods and timings of N fertilizer application. This information is summarized at:
<http://www.kingcorn.org/news/timeless/NitrogenMgmt.pdf>

The average Agronomic Optimum N Rate (AONR) for 38 trials conducted on medium- and fine-textured soils in westcentral and southwest Indiana was 183 lbs N / ac. The average AONR for 26 trials conducted on medium- and fine-textured soils in northwest and northcentral Indiana was 191 lbs N / ac. The average AONR for trials conducted on medium- and fine-textured soils in other regions of the state were 196, 221, 226, and 233 lbs N / ac for southeast (11 trials), central (23 trials), northeast (10 trials), and eastcentral (25 trials) Indiana, respectively. The average AONR for 14 trials on non-irrigated sandy soils was 184 lbs N / ac.

At the five Purdue locations where we conducted paired trials of corn/soy and corn following corn (corn/corn) in 2007-2010, the average AONR for corn/corn was 44 lbs greater than for corn/soy while average corn/corn yields were 18 bu/ac less than the corn/soy yields. Economic optimum N rates for various combinations of N cost and grain price can be obtained from the web site noted above.

Evaluating Your Decisions

Loss of N due to excessive rainfall and the potential response of corn stressed by N deficiency AND excess water are difficult to predict. Unfortunately we frequently find ourselves in this same situation asking how much N is needed and what will be the yield increase. Although we have conducted some planned experiments that apply N late to N-deficient corn, it is difficult to plan experiments to evaluate N application to N-deficient corn that is also stressed by excessive rainfall. But now we have another opportunity.

If you decide to apply late N to corn stressed by N deficiency AND waterlogging, consider leaving 3 non-fertilized applicator-wide strips down the length of the field to help evaluate the response to the additional N. The non-fertilized strips should be distributed across the field, not lumped together. Compare the eventual grain yield from these unfertilized strips with that of adjacent fertilized strips to determine the change in yield and profit due to fertilization. Collecting this data will help in making future decisions related to N loss and potential profit from supplemental N fertilization. For assistance in planning an evaluation of supplemental N consult one of us or adapt our Purdue On-Farm Nitrogen Rate Trial Protocol, available online at:

<http://www.agry.purdue.edu/ext/ofr/protocols/PurdueNTrialProtocol.pdf>.

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