THE MOST IMPORTANT TOOL IN THE NITROGEN MANAGEMENT TOOLBOX

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Nitrogen management continues to be one of the biggest challenges facing crop managers. High fertilizer prices, confusion about fertilizer technologies, and weather uncertainties are just a few of the issues encountered when trying to balance economic and environmental sustainability. The purpose of this paper is to outline how understanding the N cycle is the most important tool that you can use to make profitable N management decisions.

Details of the N cycle are discussed in depth in most soil fertility textbooks. An abbreviated but still very useful discussion is provided in UWEX Publ. no. A3588 "Management of Wisconsin soils" (Schulte et al., 2005). The N cycle is depicted in Figure 1. Several real world scenarios will be used to demonstrate how an intimate knowledge of the N cycle is beneficial to making sound N management decisions.

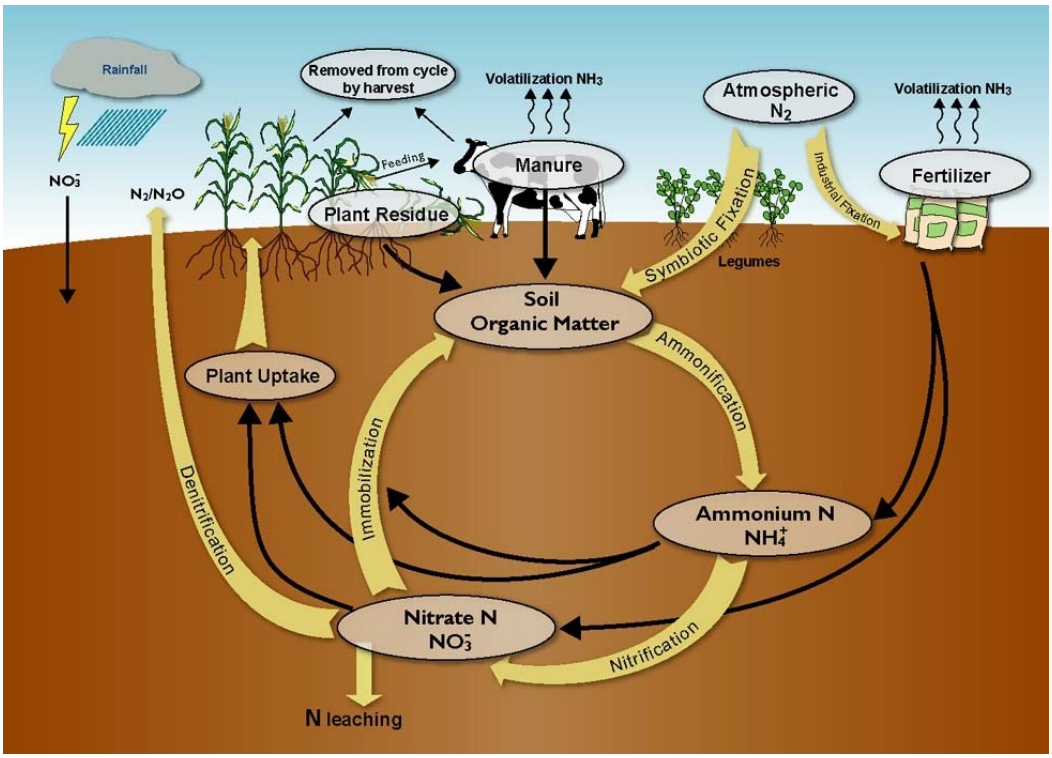

Figure 1. The nitrogen cycle (Schulte et al., 2005).

Situation 1: Sandy soils

Nitrate leaching is the biggest concern on sandy soils. Therefore all efforts should be made to reduce the potential for nitrate leaching. Ammonium containing fertilizers are preferred over nitrate sources. Ammonium is held on the soil's cation exchange capacity and is not leachable. Ammonium is converted to nitrate by soil bacteria in the nitrification process in a relatively short period of time. Preplant applied polymer-coated urea fertilizers, such as ESN, have been shown to

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increase yield over other N sources applied preplant when heavy rainfall occurs after planting. However, split applications of ammonium sulfate have been shown to be superior to preplant polymer-coated urea during years with high rainfall (Bundy and Andraski, 2007). The polymer coating slowly releases urea, which reduces its' leachability. Urea-containing fertilizer should be incorporated within two days of application by tillage or by one-quarter inch of rainfall/irrigation. If urea remains on the soil surface, N volatilization losses will occur. Nitrogen should be applied just before peak demand. Sidedress or split (preplant + sidedress) applications are preferable to spring preplant applications and fall applications should be avoided. Splitting of N applications into three or more application timings has not proven to be superior to sidedress or a single split application. Nitrification inhibitors, such as nitrapyrin (NServe), temporarily stop the conversion of ammonium to nitrate. Thus, they have the ability to reduce the potential for nitrate leaching by holding N in the ammonium form. Nitrification inhibitors applied with preplant N applications can increase yield compared to preplant applications without inhibitor; however past research has shown no yield benefit to sidedress applications with inhibitor.

Be sure to adjust total N application rates to reflect forage legume or manure N credits to reduce potential for N leaching. On sandy soils, water is more limiting than N in most years. Thus, unirrigated sandy soils should have a lower rate of N applied compared to irrigated sands. Any N that is unused is an unnecessary expense and has the potential to leach into ground water. If irrigating, be sure that irrigation amounts do not exceed the soil's water holding capacity. See Wolkowski et al. (1995) for more details.

Situation 2: Excessive rainfall on silt loams

Excessive rainfall during the growing season has been a troublesome issue over the last several years. On silt loam soils the biggest question is, "how much N have I lost?" In this situation denitrification is the portion of the N cycle that needs to be understood. High rainfall amounts resulting in standing water can cause nitrate to be converted into the gases dinitrogen or nitrous oxide and subsequently released to the atmosphere. Denitrification occurs because soil bacteria are breaking down organic matter under low oxygen conditions and the bacteria use nitrate in a biochemical process. Thus, it is important to understand that several environmental factors determine if denitrification occurs and to what extent. Nitrate must be present. If nitrate is not present or is in low concentrations, denitrification losses will be minimal. Denitrification occurs in wet soils with low oxygen concentrations. Therefore, the longer the time period when soils are saturated, then a larger percentage of nitrate can be denitrified. Denitrifing bacteria work faster in warm soils, particularly when soil temperature is greater than 75°F. Soils with low soluble organic carbon will have less potential for denitrification than soils with high soluble organic carbon. Thus, nitrate that resides deeper in the soil profile (e.g., below 12 inches) where there is less organic matter will have a greatly reduced or minimal probability of being denitrified. Denitrification is negligible in soils with a pH < 5.0. Thus, pH likely doesn't limit denitrification on most of our cropland in Wisconsin.

If denitrification losses are suspected a PSNT sample could be used to assess the N status of the fields. If the concentration of N in this one-foot soil sample is greater than 21 ppm, then there should be adequate N for the crop. There are a couple caveats when using the PSNT in this manner. First, it will work best if N was broadcast rather than band applied. Soil samples collected from fields where N was banded, may not accurately represent the N status of the field. Second, even in medium- and fine-textured soil, nitrate may have moved into the second foot of soil. In this case, the PSNT won't measure all of the N that is in the root zone and available for the crop. Additional details and considerations for heavy rainfall situations can be found in Laboski (2008).

Sidedress N applications reduce the potential for denitrification losses from excessive early season rainfall. However not all producers use sidedress N application. It situations where all of the N is applied preplant to fields that *often* have saturated soil conditions, a nitrification inhibitor, may be a economical choice to help maintain N in the ammonium form that is not subject to denitrification losses. For more information on the economics of using a nitrification inhibitor see Laboski (2006).

Situation 3: Topdressing in no-till corn or grass pasture

In no-till corn production and grass pastures topdressing N is a common practice. Ideally an ammonium form of N, such as ammonium sulfate or ammonium nitrate, would be used because ammonium is not subject to volatilization losses. Because of high price and low availability, ammonium sulfate and ammonium nitrate may not be viable fertilizer materials. Thus, urea-containing fertilizers may be used even though up to 20% of the N may volatilize if the urea is not incorporated with rainfall within two days. Controlling volatilization losses are a key aspect of successfully managing the N cycle in this situation. Volatilization losses are greater in following soil and climatic conditions: no rainfall, high temperatures, high soil pH, intermediate humidity (50-90%), low clay and organic matter content, and crop residues on the soil surface. In these situations, a producer may consider using a urease inhibitor, such as NBPT (ie Agrotain), to halt conversion of urea for 7 to 10 days until adequate rainfall can wash the urea into the soil. Polymer-coated urea is another option to limit N volatilization losses.

Situation 4: Fall N applications

Fall N applications can be troublesome because there are numerous opportunities for N to be lost before the crop can take it up. Fall fertilizer N application should be avoided on sandy soils or other soils that have a high probability of leaching N to ground water with the exception of fall seeded crops. For fall application on silt loam soils, nitrate-containing fertilizers should be avoided because the nitrate can be immediately lost though leaching and denitrification. Ideally fall manure and fertilizer applications will be made once the soil temperature is less than 50° because the nitrification and mineralization processes are dramatically reduced at low soil temperatures. Nitrification inhibitors may be beneficial at reducing the potential for nitrate losses, when N is applied in the fall, particularly the early fall.

Situation 5: Manured fields and forage legumes in the rotation

In 2009 numerous agronomists observed that manured fields ran out of N before the end of the growing season, with some noting lighter green corn in early- to mid-July. An additional observation was that fields with spring applied manure looked worse than fall applied manure. Agronomists questioned why this happened and what could be done about it. Having low manure N availability in a year with a cool spring is not unexpected because the availability of the organic N is dependent upon soil bacteria to mineralize it. When early growing season soil temperatures are cool, mineralization occurs more slowly. If the entire growing season remains cool, as it did in 2009, then it is likely that the actual N availability may be less than expected. Past research in Wisconsin has shown that if July–August temperatures are at or above the average after a cool spring, the total amount of organic N mineralized with be close to expectations.

The pre-sidedress nitrate test (PSNT) can be used to verify manure credits if it is suspected that there is low N availability. Note that when May–June temperatures are more than 1° below

normal, then the PSNT sometimes underestimates the N credit, suggesting that a higher sidedress application rate is needed, when perhaps it is not. If manure credits were determined with book values estimates of total N content, then it may be useful to have manure tested in the future, because the manure from that farm may not be very close to the "average" manure that is used in the book values.

First-year corn after alfalfa needs substantially less N fertilizer than corn following corn. At times agronomists observe that first-year corn appears to need more N than predicted with MRTN and the book value alfalfa credit. If low N availability following alfalfa is suspected, then a PSNT can be used to determine whether or not a sidedress application of fertilizer N is required. The PSNT can also be used to verify second-year forage legume credits.

Additional Materials and References

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