Where did my nitrogen fertiliser go?

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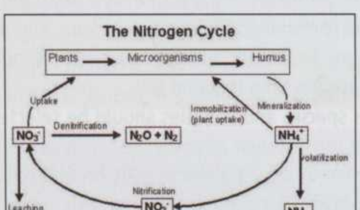
Maintaining a healthy turf-playing surface with high wear tolerance, aesthetic quality and an acceptable rate of growth requires efficient use of fertilisers. When added nitrogen (N) is applied, turfgrass managers expect a response from the turf. Most turfgrass managers apply fertiliser and expect the response from the added N to last a defined period of time. Most turfgrass managers consider fertilisers a major line-item expense in their budgets. But, can you imagine 20-45% of your applied fertiliser-N not being available for plant uptake because it was lost?

Continue to learn

The goal of any fertiliser application is to provide nutrients that are needed to sustain a healthy plant. Knowing that not all of the nutrients are used immediately by the plant, the second goal of any fertiliser application is for the nutrients to remain in the soil so that they are available to the plant when needed. However, this is not always the case.

The N cycle is complex and in recent years, researchers have focused on potential N loss mechanisms not only because of the economics, but because of the environmental implications.

These loss mechanisms include: NO_3^- leaching which can contaminate drinking water, N volatilisation as NH_3, and N denitrified as N_2O or N_2 of which the former is a greenhouse gas that has been implicated in stratospheric ozone destruction.



LEACHING

Nitrate is negatively charged and so is the soil. This is why soils have an ability to bind cations (positively charged ions), often referred to as the cation exchange capacity (CEC). Therefore, the negatively charged NO_3^- and the negatively charged soil repel each other and the nitrate is free to move with soil water.

Leaching of nitrates (NO_3^-) and contamination of groundwater have been studied carefully and are discussed in reviews by Petrovic (1990) and Walker and Branham (1992). The data discussed in these reviews suggest very little NO_3^- leaching occurs from an established turf, as the turf has the ability to take-up large amounts because of an extensive fibrous root system.

However, during establishment of turf on soils that have relatively high percolation rates, leaching can occur and efforts should be made to frequently apply small amounts of N-fertiliser or slow release N sources until root mass is sufficient to reduce downward NO_3^- movement.

VOLATILISATION

Ammonia (NH_3) volatilisation from turf is extremely variable and depends on the source of N, application rate, temperature, thatch thickness, irrigation or rainfall following application, soil moisture, and most importantly, soil pH. In soils with pH greater than 7.0, free hydroxyls (OH^-) are present. When combined with NH_4^+ from fertiliser, NH_3 gas is formed.

$NH_4^+ \; + \; OH^- \qquad NH_3\,(gas) \; + \; H_2O$

In particular, if urea is applied to a soil with a pH greater than 7.0 and not watered in with either irrigation water or rainfall, 36% of the fertiliser N can be lost as a NH_3 (Bowman et al., 1987). This is because as urea hydrolyzes (absorbs water), an OH^- is formed in close proximity to the NH_4 and thus NH_3 gas is formed.

$Urea \; + \; H_2O \qquad NH4^+ \; + \; OH^- \qquad NH_3 \; + \; H_2O$

Therefore, applying sufficient irrigation following the application of urea will help buffer the production of the OH^- and reduce volatilisation of NH_3.

One aspect of a turfgrass system that will dramatically affect volatilisation is the presence of thatch. An enzyme called urease is present in large quantities in the thatch which helps convert the NH_4 to NH_3. In a turf system that contains a larger thatch layer (5 cm), 39% of applied urea was volatilised as opposed to a turf system that contains no thatch, only 5% volatilised (Nelson et al., 1980).

DENITRIFICATION

Recent research has demonstrated that a process called denitrification can be a significant avenue for N loss from a turfgrass system (Horgan et al., 2002). Denitrification is a biologically mediated process that occurs in anaerobic (oxygen limiting) soils. This process does not require complete anaerobicity for N to be lost as a gas. In fact, when turf is watered, through irrigation or from rainfall events, small sites within the soil profile can become oxygen limiting (Sextone et al., 1985) and if nitrate (NO_3^-) is nearby, it will be reduced to N_2O and N_2 gases.

Denitrification is defined as the reduction of NO_3-N to gaseous N.

NO_3 (nitrate) — NO_2 (nitrite) gas — NO (nitric oxide) gas — N_2O (nitrous oxide) — N_2 (dinitrogen)

Let's briefly examine the processes that affect the gaseous N loss:

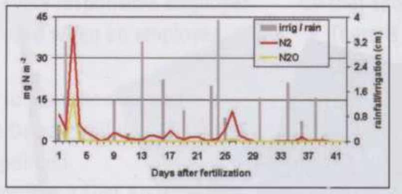
1. Soil temperature – warmer soils stimulate denitrifying bacteria
2. Available NO_3 – from fertilisers or from mineralisation of organic matter
3. Carbon as a source of energy for the denitrifying bacteria – readily available in thatch
4. Some degree of anaerobicity in the rootzone – either from irrigation or rainfall

Highly managed turfgrass represents a system where extensive denitrification could occur as irrigation keeps the soil near field capacity when soil temperatures are high, multiple applications of N fertiliser are common, and large amounts of organic C are present in the thatch and verdure.

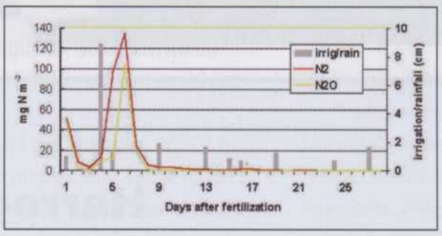
Dr. Brian Horgan, Assistant Professor and Turfgrass Extension Specialist at the University of Minnesota, explains the role of nitrogen in soil, its effect and how to minimise its loss.

Reviewing Figures 1 and 2, there are some key points that must be noted:

- Immediately following fertilisation and irrigation (day 1), gaseous N losses occurred.
- Denitrification is a process that can lead to significant amounts of N lost from the system. Figure 1, right, Spring Denitrification Losses from Kentucky Bluegrass, was an experiment conducted in the spring when soil temperatures were low and only 7% of applied fertiliser N was lost from denitrification.



- In contrast, Figure 2 was an experiment conducted when soil temperatures were high and soil microbes were more active, in these conditions, 19% of applied fertiliser N was lost from denitrification.
- N_2O losses are minor compared to N_2 which is reassuring considering the effect of N_2O on atmospheric ozone destruction.
- N_2 losses occur even after small rainfall/irrigation events.
- Large N_2 losses are a possibility when large rainfall events occur immediately following fertilisation. Figure 2, right, shows Summer Denitrification Losses from Kentucky Bluegrass.



WHAT FACTORS CAN BE MODIFIED TO REDUCE N LOSSES?

Aerification is typically done to decrease compaction in a soil and improve gas exchange.

By reducing compaction, the soil is able to drain excess water more rapidly which will directly affect the length of time soil oxygen may be limiting.

This same principal holds true for correcting drainage problems in the soil by installing drain-tile. This will help reduce denitrification losses.

Irrigation is necessary to grow high maintenance turf. However, apply a sensible amount of irrigation water following fertilisation so that oxygen does not become limiting when a large amount of NO_3-N is present.

Also, irrigate when plants show signs of wilt, subscribe to deficit irrigation practices, and use improved varieties of turfgrass that are drought resistant.

The source of N applied can also be a major factor when determining denitrification potentials. If an ammonium (NH_4) based fertiliser is used or a slow release fertiliser, the N must undergo nitrification (conversion of NH_4 to NO_3) before the substrate (NO_3) is present for denitrification or leaching to occur.

Also, if an NH_4 based fertiliser is used, or urea, and soil pH is greater than 7.0, you can reduce the potential volatilisation losses by watering in the fertilizer and managing the thatch layer.

In contrast, if a NO_3-based fertiliser is applied, the substrate is present and if oxygen limiting conditions exists, gaseous losses will occur and the leaching potential increases.

Sandy soils typically have higher percolation rates than finer textured soils. Therefore, we would not expect high rates of denitrification to occur on sandy soils because oxygen would not be a limiting factor.

However, under these conditions, application of NO_3-based fertilisers can be moved out of the root zone through leaching.

TAKE HOME MESSAGE

Nitrogen losses and potential contamination of the environment can be minimised by subscribing to best management practices. Nitrate (NO_3) is more readily leached during grow-in when plant roots are not established and/or in a sandy soil with high percolation rates and a low cation exchange capacity.

Volatilisation of NH_4 is more likely in soils with a pH greater than 7.0 and/or with turfgrasses that form large thatch layers. Proper selection of fertilisers in high pH soils and managing thatch through topdressing, aerficiation and proper mowing will reduce NH_3 losses.

Lastly, denitrification of applied fertiliser N can cause N to be limiting for turfgrass growth and development. Consider the soil type, source of fertiliser and ability of the soil to drain excess water when planning a fertility program to minimise denitrification losses.

NITROGEN LOSS GAME

You read the scenario and determine what the potential N loss mechanisms are. Correct answers will earn you a "pat-on-the-back". Answers are listed below.

- Scenario 1. Sandy soils, high N fertilizer rates, infrequent application of N.
- Scenario 2. High pH soil, granular urea applied, no irrigation present.
- Scenario 3. Nitrate fertilizer applied, only apply N once a year to my golf course rough, silt loam soil, 4 cm of rainfall just after fertilization.
- Scenario 4. Sand profile, newly seeded turf, soluble N applied weekly at very low rates.
- Scenario 5. Poa/bentgrass putting green, native soil, frequent light application of N, high soil temperatures, summer thunderstorms are common.

Answers: (1) NO3 leaching, (2) NH3 volatilization, (3) denitrification, (4) plant uptake, (5) denitrification and/or plant uptake.

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