Denitrification Impedes Fertilizer Effectiveness

By Brian Horgan

Most turfgrass managers apply fertilizer and expect a response from the added nitrogen. They consider fertilizers a major line-item expense in their budgets. But can you imagine 20 percent of your applied nitrogen not being available for plant uptake because it was lost as a gas?

Recent research has demonstrated that a process called denitrification can be a significant avenue for nitrogen loss from a turfgrass system (Horgan et al., 2002). Denitrification is a biologically mediated process that occurs in oxygen limiting soils. This process doesn't require complete anaerobicity for nitrogen to be lost as a gas. In fact, when turf is watered through irrigation or from rainfall, small sites within the soil profile can become oxygen limiting (Sextone et al., 1985). If nitrate is nearby, it will be reduced to nitrogen dioxide and dinitrogen gases. Denitrification is defined as the reduction of nitrate-nitrogen to gaseous nitrogen.

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Not only do economics and nitrogen use efficiency play into discussions concerning denitrification, but nitrogen dioxide is a greenhouse gas that has been implicated in stratospheric ozone destruction (Prather et al., 1995). So are we throwing money away and not being good stewards of the environment?

Let's briefly examine the processes that affect the rate of gaseous nitrogen loss:

- soil temperature — warmer soils stimulate denitrifying bacteria;
- available nitrate — from fertilizers or from mineralization of organic matter;
- carbon as a source of energy for the denitrifying bacteria — readily available in thatch; and
- 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 nitrogen fertilizer are common, and large amounts of organic carbon are present in the thatch and verdure.

The purpose of this research project was to determine how much fertilizer nitrogen was lost from denitrification. Air is composed of 78 percent dinitrogen and 21 percent dioxide. Other gases comprise less than one percent.

When trying to measure dinitrogen emitted from fertilizer when dinitrogen already makes up 78 percent of the air we breathe, special fertilizers need to be used that contain a nametag. These nametags allow analytical equipment to distinguish between the nitrogen present in the air we breathe and the nitrogen emitted as a gas from the soil.

Sampling procedures, methods

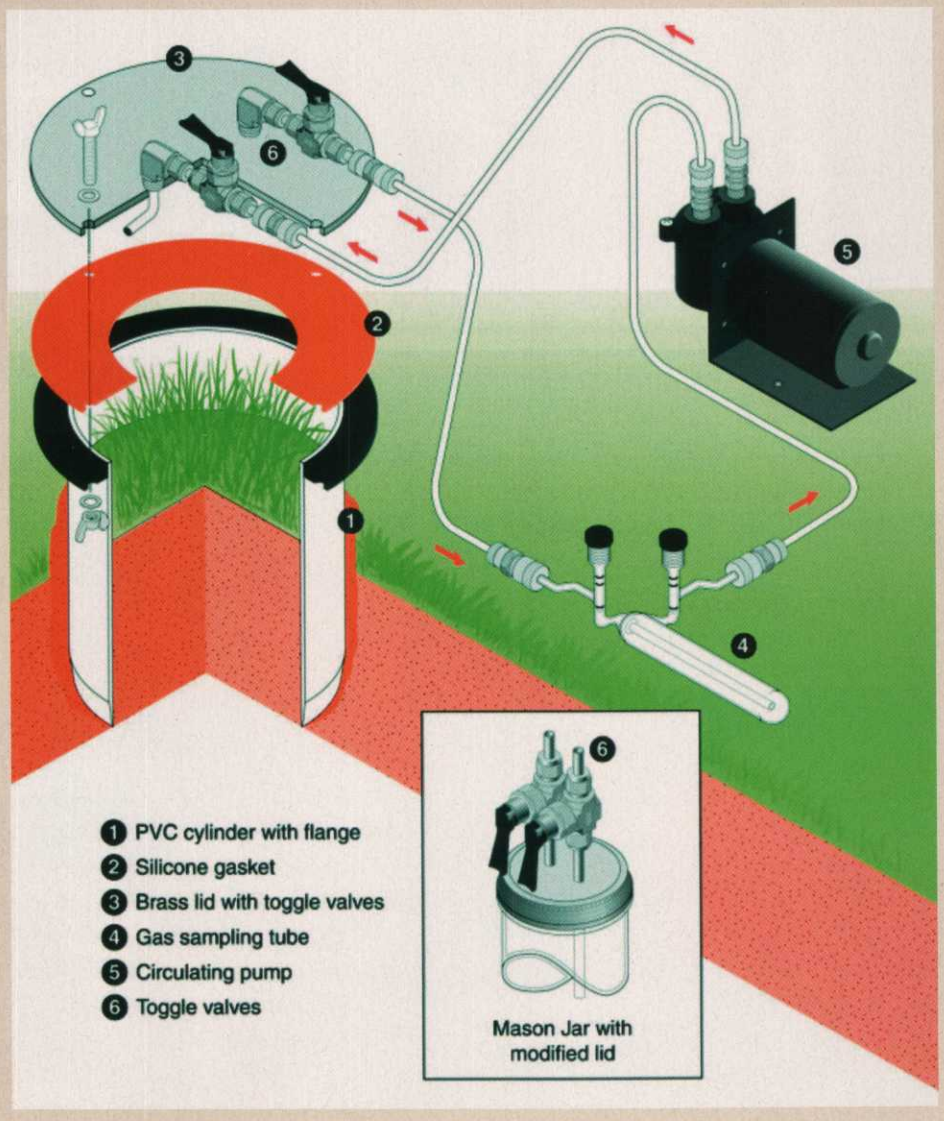
A unique gas sampling system was developed and is illustrated by Figure 1.

In short, a PVC cylinder was inserted into Kentucky bluegrass turf mowed at 2 inches. Plots were fertilized with potassium nitrate at 1 pound nitrogen/1,000 square feet and .2 inches of irrigation water was applied. Gas sampling began immediately following fertilization and irrigation. Subsequent sampling occurred daily from 8 a.m. to 11 a.m., 11 a.m. to 2 p.m., and 2 p.m. to 5 p.m. for a six-week experiment period starting in May 1999 and for a four-week experiment starting in August 1999.

Plots were irrigated twice a week to replace 80 percent of the potential evapotranspiration (PET) taking into account rainfall totals. Gas samples were analyzed using a mass spectrometer that can distinguish between nitrogen that contains the nametag and nitrogen that does not.

FIGURE 1

Gas sampling apparatus used to measure denitrification losses from Kentucky bluegrass



The findings

Reviewing Fig. 2 and 3, there are some key points that must be noted:

- Immediately following fertilization and irrigation (day 1), gaseous nitrogen losses occurred.
- Denitrification is a process that can lead to significant amounts of nitrogen lost from the system.
- Nitrogen dioxide losses are minor compared to dinitrogen, which is reassuring considering the effect of nitrogen dioxide on atmospheric ozone destruction.
- Dinitrogen losses occur even after small rainfall/irrigation.

Denitrification of applied nitrogen can cause it to be limiting for turfgrass growth and development.

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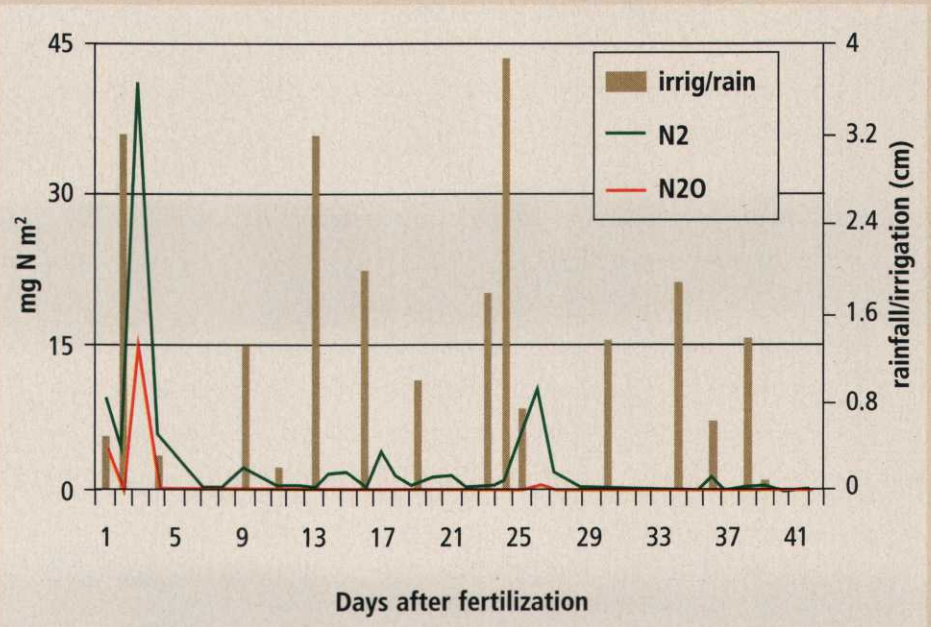
FIGURE 2

Spring denitrification losses from Kentucky bluegrass



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■ Large dinitrogen losses are a possibility when large rainfalls occur immediately following fertilization (Fig. 3).

Why turf managers should care

Turfgrass managers need to understand that denitrification losses are real. For the spring experiment (Fig. 2), dinitrogen and nitrogen dioxide losses totaled 4.4 percent and 2.9 percent respectively of the 1 pound nitrogen per 1,000 square feet applied. This experiment was conducted when soil temperatures were low during the spring.

In contrast, for the summer experiment (Fig. 3), dinitrogen and nitrogen dioxide losses totaled 13.1 percent and 5.9 percent, respectively.

Therefore, if soil temperatures are warm, nitrate is available from fertilizer and oxygen is limiting because of a large rainfall, a large amount of the applied nitrogen can be lost. But there are several factors which can be modified to reduce nitrogen losses.

Aerification is typically done to decrease compaction in 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.

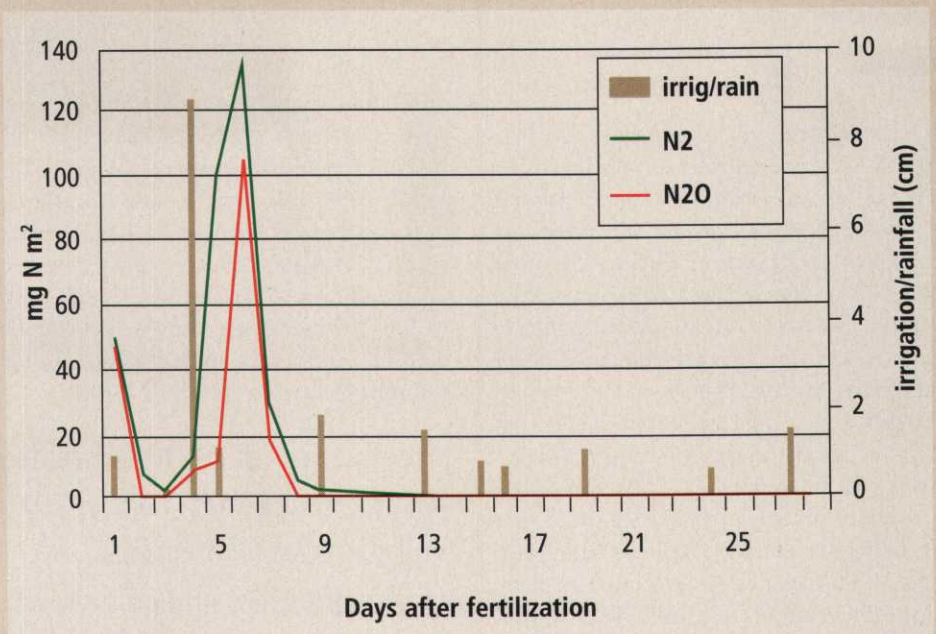
When trying to measure dinitrogen emitted from fertilizer when dinitrogen already makes up 78 percent of the air we breathe, special fertilizers need to be used that contain a "name-tag."

Irrigation is necessary to grow high maintenance turf. However, apply a sensible amount of irrigation water following fertilization so that oxygen doesn't become limiting when a large amount of nitrate-nitrogen is present.

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

FIGURE 3

Summer denitrification losses from Kentucky bluegrass



The source of nitrogen applied can also be a major factor when determining denitrification potentials. If an ammonium nitrate-based fertilizer or a slow-release fertilize is used, the nitrogen must undergo nitrification (conversion of NH4 to nitrate) before the substrate (nitrate) is present for denitrification to occur. In contrast, if a nitrate-based fertilizer is applied, the substrate is present and if oxygen-limiting conditions exists, gaseous losses will occur.

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 nitrate-based fertilizers can be moved out of the root zone through leaching.

Conclusion

Denitrification of applied nitrogen can cause it to be limiting for turfgrass growth and development. Consider the soil type, source of fertilizer and ability of the soil to drain excess water when planning a fertility program to minimize potential gaseous losses of nitrogen.

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REFERENCES

Horgan, B.P., B.E. Branham and R.L. Mulvaney. 2002. "Direct measurement of denitrification using 15N-labeled fertilizer applied to turfgrass." *Crop Sci.* 42:1602-1610.

Prather, M., R. Derwent, D. Ehhalr, P. Fraser, E. Sanhueza and X. Zhou. 1995. "Other trace gases and atmospheric chemistry." *Intergovernmental Panel on Climate Change.* Climate change 1994: Radiative forcing of climate change. Cambridge Univ. Press, Cambridge.

Sexstone, A.J., T.B. Parking, and J.M. Tiedje. 1985. "Temporal response of soil denitrification rates to rainfall and irrigation." *Soil Sci. Soc. Am. J.* 49:99-103.