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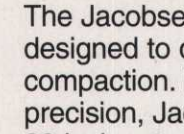

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CIRCLE NO. 142

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.

Can you imagine 20 percent of your applied nitrogen not being available for plant uptake because it was lost as a gas?

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

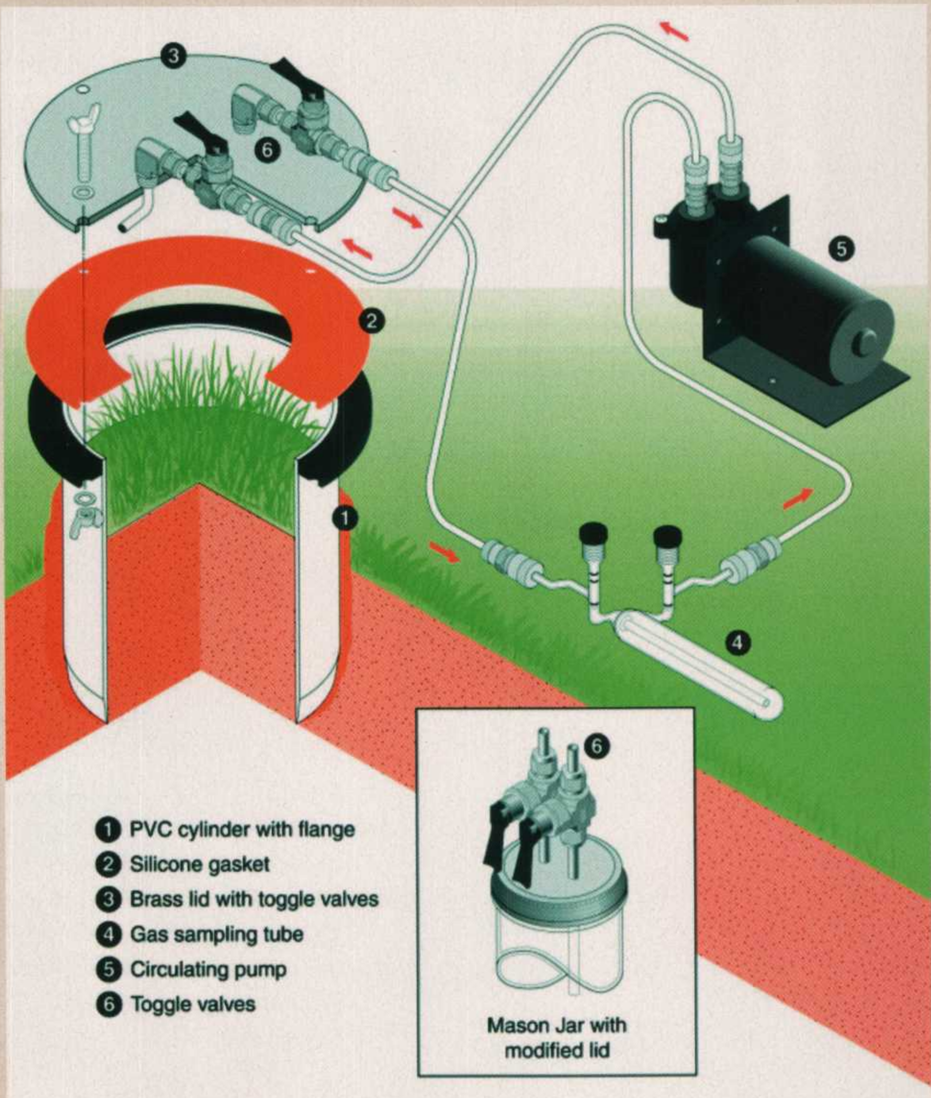
A unique gas sampling system was developed and is illustrated by Figure 1.

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.

Continued on page 56

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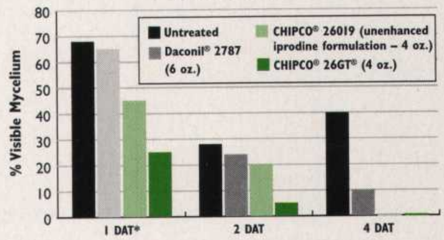

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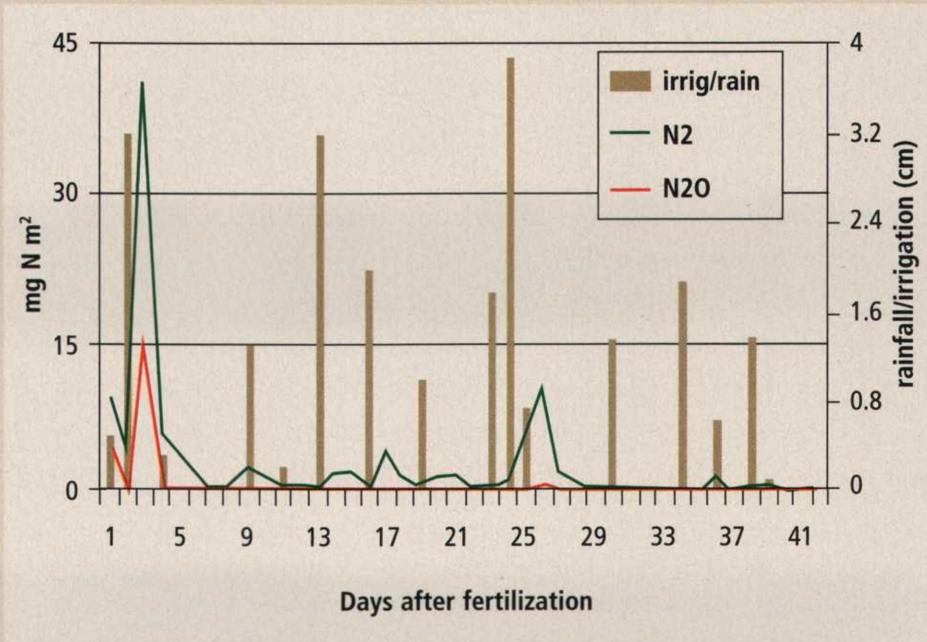
FIGURE 2

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.

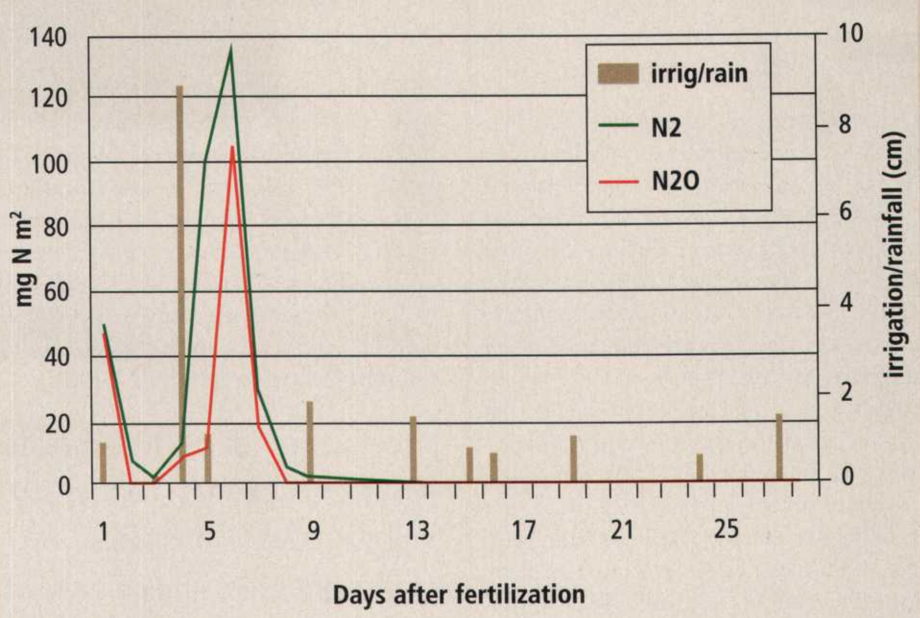
> When trying to measure dinitrogen emitted from fertilizer when dinitrogen already makes up 78 percent of the air we breathe, special fertilizers need to be used that contain a "name-tag."

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.

Horgan is an assistant professor and turfgrass extension specialist at the University of Minnesota.

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Ubiquitous Chlorine Performs Vital Tasks In Turf

By Richard J. Hull

Although chlorine (Cl) is the most abundant micronutrient in most plant tissues, Turner and Hummel (1992) reported that "deficiency symptoms or beneficial responses of turfgrasses to Cl have not been reported." This apparent inconsistency reflects the simple fact that Cl is ubiquitous in nature, and deficiency symptoms are never observed in turfgrasses or any other plants.

It was not until 1954 that Broyer and his colleagues reported the general requirement of plants for Cl (Broyer et al. 1954). They were able to demonstrate Cl deficiency symptoms in plants only after filtering the air entering their Berkeley, Calif., greenhouses and growing plants on nutrient solutions prepared with doubly recrystallized salts to remove all Cl.

While the Cl content of plant tissues normally ranges between 2 to 20 milligrams per gram dry matter (parts per thousand), the Cl content required for optimum growth is in the range of 0.2-0.4 mg/g (Marschner, 1995). Apparently there are no data on the specific Cl requirements of turfgrasses, but it is unlikely their needs are different from those of most other plants.

Since a Cl insufficiency is not likely, the turf manager need be little concerned about supplying this nutrient, but that does not mean it is unimportant.

Cl uptake by roots

Cl is present in soils and water as the monovalent anion chloride (Cl^-). Most salts of chloride are soluble, making Cl^- highly mobile in soils and easily leached below the root zone when rainfall or irrigation exceed evapotranspiration. Cl would become insufficient for plant needs were it not supplied continuously through atmospheric deposition.

Wave action causes sea water to be thrown into the air, and that introduces Cl^- ions into the atmosphere. Marschner (1995) estimates that the annual crop requirement for Cl of 4 pounds to 8 pounds per acre is supplied by rain even at inland locations. In oceanic climates, the supply of Cl in rainfall is about 10 times the amount removed by crops.

Cl is absorbed by roots from the soil solution as Cl^- ions, but the membrane transporter involved apparently is not very efficient. A nutrient solution containing .1 mM Cl^- was shown to satisfy the Cl needs of white clover, but reducing that to 0.01 mM Cl^- caused a 50- percent decline in shoot dry weight (Chisholm and Blair, 1981).

Cl deficiency has yet to be reported for turfgrasses. That is not to say that turf never experiences insufficient Cl for optimum growth.

By comparison, plants can satisfy a much greater phosphorus need from a solution phosphate concentration substantially less than .01 mM. While Cl^- uptake by roots is likely an active process, it may occur through transporters involved in the absorption of other anions (e.g. nitrate, phosphate or sulfate).

Cl functions in plants

Although Cl is often the most abundant micronutrient, its exact functions in plants are not well understood. Nevertheless, several Cl functions are generally recognized (Table 1).

Oxygen evolution in photosynthesis: Four electrons are drawn from the oxygen atoms of two water molecules to initiate the electron transport in photosynthesis that eventually leads to the reduction of CO_2 and the production of sugars (Fig. 1). The oxidized oxygen from the two waters forms a molecule of O_2 that is released to the atmosphere.

The four electrons reduce four manganese atoms ($4Mn^{3+} + 4e^- \longrightarrow 4Mn^{2+}$) as we described in an earlier article on manganese in turf (Hull, 2001). When these four Mn atoms surrender their electrons to photosynthetic electron transport, they acquire four positive charges.

Continued on page 60

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- 14-0-28 with Turf Enhancer
- Turf Enhancer 2SC

The active ingredient in all these products is paclobutrazol, a systemic mode of action growth inhibiter. It inhibits gibberellic acid biosynthesis in the plant that results in a reduction in cellular elongation. The key benefits from the TGR products are clipping reduction, increased density, enhanced turf quality, decreased water usage and *Poa annua* reduction.

The Andersons TGR products are the best available growth regulator products for a *Poa annua*-reduction program. The company's years of experience along with University testing illustrates the strength of TGR products for *Poa annua* reduction. Spring and fall applications of either the 31-3-7 Fertilizer with TGR and the 14-0-29 High K Fertilizer along with the spray applications of Turf Enhancer 2SC or granular 14-0-28 with Turf Enhancer through the summer months provide the best programs for accelerated *Poa annua* reduction programs. The key to success with a *Poa annua* reduction program is to continue with the program until the *Poa* population is reduced to the desired level. To determine the best timing recommendation for your area, we advise consulting with your Andersons distributor or Andersons territory manager.

For a clipping-reduction program, applications of either the granular 14-0-28 with Turf Enhancer or the Turf Enhancer 2SC sprayable programs work best. Both can be applied at the 21-30 day intervals throughout the growing season to reduce clipping yield. The other benefits to this program are enhanced greening and a tighter, denser turf stand that requires less water that will handle environmental stress better than turf that is nonregulated. The turf manager can use a combination of the granular product and sprayable products that suits his program the best.

The Andersons TGR products can be used to enhance grow in and establishment of new turf. Usage on turf should begin after the third or fourth mowing and continued on a 14 to 21 day interval. This will force the young turf to grow horizontally – in lieu of vertical growth.

All of The Andersons granular TGR products are 100 SGN size so they can be used on all turf areas including bentgrass greens. The granular products have excellent flowability out of the bag and the spreader. Properly calibrated equipment is a must, whether the turf manager is using a sprayable or granular formulation. Check with your Andersons distributor or Andersons Territory Manager for the rates and formulations which best suit your area.

Article contributed by Dave Louttit, Andersons Territory Manager

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TABLE 1

Functions of chlorine in plants

- Stabilizes the protein components of the oxygen evolving complex of Photosystem II in photosynthetic electron transport.
- Stimulates the hydrogen-pumping ATPase of tonoplast that energizes ion transport and accumulation in vacuoles.
- In some plants, Cl- is counter ion for K+ influx during stomate opening.
- Serves as an osmotic solute in maintaining proper water relations between plant and soil solution.
- Is essential for cell division and cell enlargement possibly by interacting with auxin activity.
- Stimulates asparagine synthetase thereby contributing to nitrogen transport in some plants.

SOURCE: BASED IN CARROW ET AL. 2001

Continued from page 58

The protein configuration in Photosystem II, where this process occurs, would be destabilized by the additional 4+ charges were they not balanced by 4- charges contributed by four soluble Cl^- ions. In this way, free Cl- ions in the chloroplasts balance the transient + charges within the O_2 evolving complex so it can oxidize water efficiently. This function of Cl is essential for photosynthesis, and chloroplasts are the last to lose their Cl when that element is withheld.

Ion concentration in vacuoles: When turf is fertilized, many of the ions absorbed by roots from the soil are stored in the large vacuoles of root cells. From there, these nutrient ions will be used as they are needed. However, for ions to be concentrated in vacuoles, an electrical gradient must be created across the vacuole membrane — the tonoplast. This electrical gradient (positive inside the vacuole) is achieved by a positive hydrogen atom (H^+) pumping ATPase in the tonoplast that uses ATP to transport H^+ (protons) into the vacuole making the inside positive.

There is a similar H^+ pumping ATPase in the cells' plasma membrane that is activated by positive potassium (K^+) ions but the one in the tonoplast is activated by Cl^- ions. It appears that for plants to use nutrients efficiently, temporary accumulation in vacuoles is required and that requires Cl.

Stomate functioning: For CO_2 to enter leaves while O_2 and H_2O vapor exits, pairs of epidermal guard cells must become turgid and open the stomates. This occurs during periods of light when the solute content of guard cells increases and water flows in making the cells turgid.

The solutes involved are mostly K^+ ions that are pumped into guard cells from surrounding cells. The influx of K^+ must be electrically balanced by anions that, in most plants, are organic acids made from starch through photosynthesis. Guard cells are the only epidermal cells that have chloroplasts and are capable of photosynthesis. However, some plants have few if any chloroplasts in their guard cells, so they must import Cl^- ions to balance the influx of K^+.

> At this time, there is no clear explanation for the role of Cl in cell division and expansion.

Osmotic adjustment: In order to maintain proper water status, plants must be able to adjust the solute content of their cells in response to changes in soil water availability.

As with guard cells, organic molecules partly serve this function, but when osmotic changes are rapid or severe, inorganic ions must be imported from the soil solution.

This role is often played by K^+ ions, but in many situations Cl^- also is utilized. Plant adjustment to salinity stress frequently