Nitrogen in Turfgrass Health and Stress

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Bottom Line: While nitrogen is critical for good turf health and growth, excessive levels in the soil can cause serious and long-lasting damage to turfgrass of all types. While over-fertilization is the major cause of this problem, the release of nitrogen from soil organic matter, the presence of nitrogen in reclaimed water, and the release of nitrogen from clippings left on fairways and roughs can all contribute. Based on analysis of soil samples from around the country, we have developed the guidelines below to assist in fertility management decisions. A new dipstick test can be used for rapid, on-site detection of excessive nitrate levels and should provide superintendents with a good diagnostic tool. However, laboratory analysis of soils should be conducted at least twice yearly to monitor both nitrate and ammonium levels, as well as other soil nutrients.

Figure 1. A ryegrass overseeded bermudagrass collar had areas of severely damaged turf (left photo) that were next to areas of healthy turf (right photo). No diseases, insects or other problems were discovered, but soil nitrogen levels in the damaged area were 77 ppm, and were 22 ppm in the healthy area.

Damage to turfgrass can occur in many ways -- some obvious, like insects, disease or drought -- and some that are less obvious. One unexpected source of stress and damage results when turf is over-fertilized with nitrogen in the form of nitrate or ammonium. This is illustrated in Figure 1, where a ryegrass overseeded bermuda collar had areas of severely damaged turf that were next to areas of healthy turf. When the soil from each area was analyzed, the damaged turf had nitrogen levels almost three times higher than those seen in the healthy turf. The final diagnosis was that excessive levels of soil nitrogen were responsible for the turf loss. To reverse this problem, the superintendent halted all nitrogen applications in the damaged areas and then sent soil samples off for analysis periodically to monitor how rapidly the nitrogen levels were declining. Luckily, the soils in the affected area drained well, and an aggressive leaching program helped to move excess nitrogen down below the root zone. After several weeks, the turf showed slow, but clear signs of recovery.

Turf damage as a result of excess soil nitrogen is a more common problem for turf managers than you might suspect. We see the problem on greens, tees, fairways and roughs from all parts of the country and on all turf varieties -- both warm and cool season. Once nitrogen levels are high, it takes a long time for turf to recover. It's clear that avoiding the build-up of soil nitrogen in the first place should be a key goal in all fertility programs.

Nitrogen sources

Nitrogen is delivered to soils in a variety of forms. Nitrate based fertilizers (ammonium nitrate, calcium nitrate, potassium nitrate, etc.) deliver nitrogen to the plant in the form of nitrate (NO_3^-). On the other hand, ammonium generating fertilizers such as proteinaceous organic fertilizers, urea products (urea, sulfur coated urea, polymer coated urea, ureaformaldehydes, and isobutylidene diurea [IBDU]) and ammonia products (ammonium nitrate, ammonium sulfate, mono and di-ammonium phosphates, etc.) release both ammonium and nitrate following their breakdown by nitrification in the soil.

PACE guidelines for soil plant available nitrogen*

Table 1. ppm = parts per million = mg/kg

Nitrate (NO_3) 3 — 20 ppm
Ammonium (NH_4) less than 7ppm
Total plant available nitrogen less than 20ppm
Nitrate to ammonium ratio greater than 3:1

**Nitrate & exchangeable ammonium measured via potassium chloride extraction & analysis w/a Technicon Autoanalyzer*

The guidelines shown above are based on PACE's database of hundreds of good performing and poor performing green, tee and fairway samples. Staying within these guidelines will help you to avoid one important, and surprisingly common source of turfgrass stress -- nitrogen toxicity.

Defining optimal nitrogen levels

As for many other parameters of turf growth and health, there is no one single nitrogen concentration that will insure healthy turf. Instead, there is a wide range of values that can support good growth. A look at PACE's database of soils from around the country will give you an idea of the broad spectrum of nitrogen concentrations found on good performing greens and fairways (Figure 5).

Figure 2. Aerial photograph showing severe damage to ryegrass overseeded roughs (arrows).

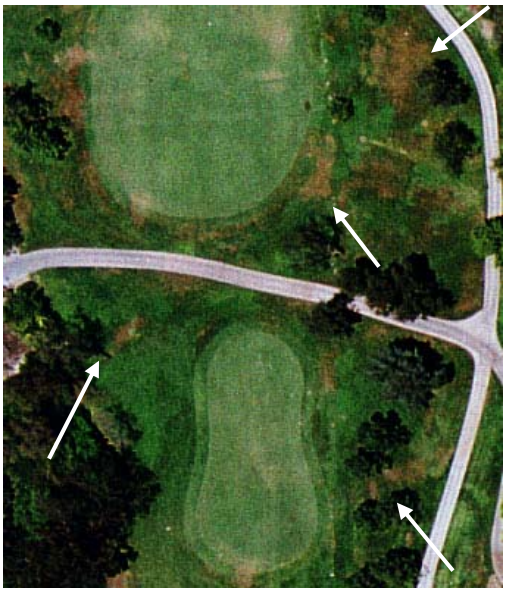


Figure 3. To determine what was causing the damage seen above, samples were taken from the ryegrass rough in areas ranging from very poor turf (quality rating of 1) to relatively healthy turf (quality rating of 5).

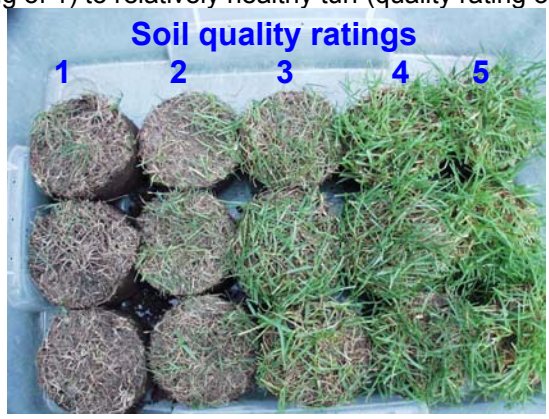


Figure 4. Analysis of the soils in Fig. 3 revealed that turf damage was related to high levels of total nitrogen in the soil (r^2 = 0.88; p<0.001). The highest quality turf had the lowest levels of nitrogen (20 ppm), and the worst quality turf had the highest levels of total soil nitrogen (over 150 ppm).

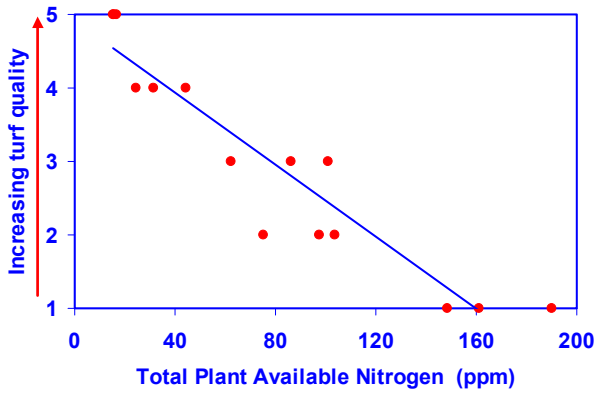
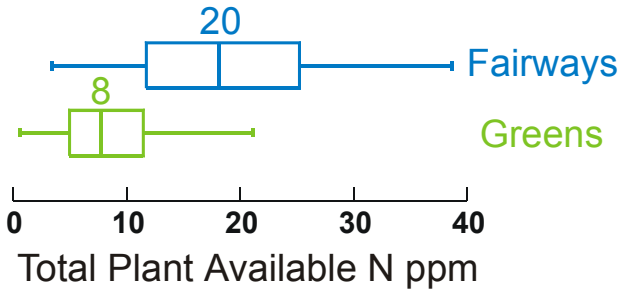


Figure 5. Box plots summarizing total plant available soil nitrogen values (the sum of nitrate and ammonium forms of nitrogen) from 199 good performing fairways and 556 good performing greens.



The box plots above are a convenient way to represent data from several hundred different samples. The values represented by the boxes are the nitrogen levels most likely to support healthy turf -- roughly 12 - 25 ppm nitrogen for fairways, and 6 - 12 ppm for greens. The vertical line inside the box represents the median -- the value at which half the samples were higher and half were lower. For example, in the greens samples, the median was 8 ppm of total plant available N, which means that half of the samples had values below 8, and half had values higher than 8. Some helpful insights can be gained by studying the box plots:

- The majority of good performing turf samples had 20ppm or less of total plant available N.
- Nitrogen levels that are too low (less than 3 ppm) can also compromise turf health.
- Fairways had higher levels of nitrogen than greens; in our opinion, fairways are consistently over-fertilized (see more in "Fairways" below) and should be managed to have less than 20 ppm total nitrogen in the soil.
- A small number of good performing greens and fairways had high levels of total nitrogen -- up to 40 ppm. So yes, it is possible to have high quality turf at high nitrogen levels, but your odds of creating a problem are much, much higher under these conditions.

Defining damaging nitrogen levels

To make our guidelines as useful as possible, it was necessary to identify the nitrogen levels not only on good performing turf, but also on turf that is performing poorly. In the course of a year, we receive several turf samples for diagnosis where the presence of a disease pathogen is suspected, but no fungus or bacteria can be found. In these cases, excessive soil nitrogen levels (greater than 20 ppm) are frequently the culprit, as illustrated in Figures 1 - 3).

The role of ammonium-based nitrogen

As we've described above, levels of total nitrogen (a sum of nitrate and ammonium nitrogen) that are above 20 ppm can cause damage to turf. But sometimes, even when total nitrogen readings are less than 20 ppm, we see problems that are related to the presence of **ammonium** in the soil. We have found that even relatively low concentrations of ammonium -- 7ppm or more -- are related to turf damage. Thus, you could have a soil with 15 ppm total nitrogen -- 5 ppm nitrate, and 10 ppm ammonium. This would be a problem soil, even though the total values are below 20 ppm.

Under normal conditions, ammonia-based fertilizers should break down in the soil to nitrate, a form of nitrogen that is less toxic to plants than ammonia. However, this break-down process, known as **nitrification**, can be inhibited if the soil is low in oxygen (due to compaction, black layer, poor drainage, high microbial populations, etc). Accumulation of toxic levels of ammonium are more likely to occur during the summer, when soils are typically more oxygen depleted than usual.

Healthy turf also appears to be correlated with a specific balance between nitrate and ammonium levels. Keeping this balance at 3 or more times more nitrate than ammonium appears to be optimal for turf health. For example, if nitrate levels are 9 ppm, then ammonium levels shouldn't be higher than 3 ppm.

For these reasons, we have developed the following guidelines for ammonium:

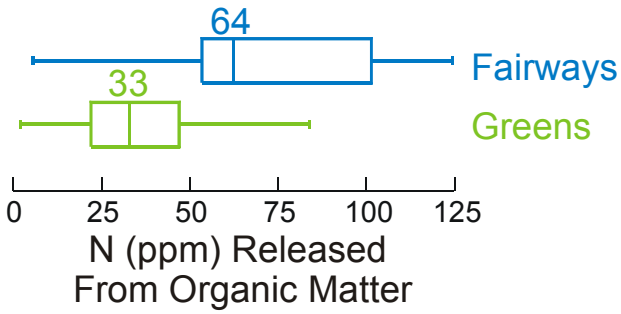
- Keep soil ammonium levels below 7ppm
- Keep nitrate to ammonium ratio greater than 3:1

- If you have areas of turf that are typically weak, especially in the summertime, try using nitrate based fertilizers (such as calcium nitrate or potassium nitrate) as your sole source of nitrogen. Remember, always try out a new strategy like this in small areas where you have the ability to compare the new treatment (nitrate based fertilizers) side-by-side with your current practices. Have soils tested at an analytical lab so that you can monitor results.
- Aerify, especially immediately before and during hot weather, to allow enough oxygen into the soil system to promote nitrification. This will help prevent a build-up of ammonia in the soil.

Special problems on fairways and roughs: When 1 + 1 = more than 2

Fairway and rough turf typically has higher soil nitrogen levels than greens or tees, even when they are all fertilized similarly. How is this possible? There are a few reasons that we can propose. First of all, there are higher levels of organic matter (in the form of thatch, dead roots or other plant material, clippings) in these areas (Figure 6). As the organic matter decays, carbon, nitrogen and water are released into the soil, thus contributing to the total nitrogen concentrations.

Figure 6. Amount of nitrogen released from organic matter in fairways vs. greens (based upon 185 fairway samples and 537 greens samples). Note that the higher level of organic matter in fairways can result in roughly twice the concentration of nitrogen released into the soil, when compared to greens.



In addition to the role of organic matter in higher nitrogen levels, reclaimed water can also play a role.

Although the absolute nitrogen concentrations in reclaimed water are not excessive, they are higher than for most well or domestic waters. And because reclaimed water is delivered continuously to the turf, even small concentrations in the water can build up to high levels in the soil over time.

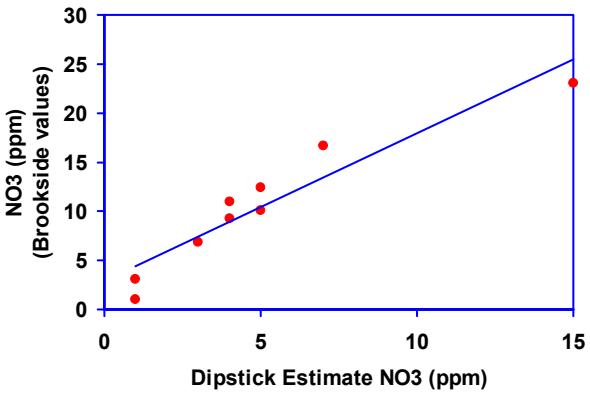
For these reasons, fairways and roughs may require very little additional nitrogen in the form of fertilizers. To avoid excessive levels of ammonium or total nitrogen, monitor soils and avoid fertilizing with nitrogen if levels approach the limits shown in Table 1.

Testing for soil nitrogen

Regular monitoring (twice yearly is usually recommended) of soil nutrients is the foundation for many management decisions, and can be carried out by a variety of analytical labs across the country. To make sure that you receive enough information about your soils, be sure to request analysis (in parts per million) for nitrate and ammonium forms of nitrogen. From these values, you can calculate total plant available nitrogen (nitrate plus ammonium) and nitrate to ammonium ratios (nitrate divided by ammonium values).

We have also developed a quick, easy, on-site test for soil nitrates that can detect excessive levels of soil nitrates. Although this test does not replace the analytical testing described above, it provides values that are rough estimates (Figure 7) of nitrate levels, and should be a useful and rapid diagnostic tool.

Figure 7. A simple dipstick test provided a good estimate of soil nitrate (NO_3) values. Nine different soil samples were tested with the dipstick and these values were compared to those generated by Brookside Laboratories, New Knoxville, OH using potassium chloride extraction and a Technicon Autoanalyzer.



Quick dipstick test for soil nitrate

Materials needed:

- Hach water test strips for nitrate/nitrite (Cat. # 27454-25, Hach Company, PO Box 389, Loveland, CO 80539. Phone: 800-227-4224. Website: www.hach.com). A bottle of 25 strips is $14.95.
- Small beaker or container
- Tablespoon
- Soil from problem area and from nearby area of healthy turf
- Notebook for recording data

Procedure:

1. Mix equal volumes of soil and tap water (for example, 1 tablespoon of each) in a small container and stir thoroughly. Allow the soil to settle for 1 minute
2. Dip the test strip into the soil suspension.
3. Allow the strip to develop for 1 minute
4. Lightly rinse the strip with water to remove soil
5. Compare the color on the tip of the strip to the nitrate nitrogen color chart on the test strip container as shown in Figure 8. Write down the ppm value that you think is closest to the color you see on the strip.
6. This value must be converted to obtain the nitrate concentration (in parts per million) of your soil.

(Dipstick value X 1.5) + 2.9 =
Soil nitrate concentration (ppm)

Example: In Figure 8, the dipstick color was estimated to be 15 because it fell in between the 10 and 20 ppm squares on the nitrate color chart. The soil nitrate concentration is therefore = (15 X 1.5) + 2.9 = 24.9.

7. If the final value is over 20 ppm as it is in the example to the right, nitrogen applications of all types should be halted until levels are well below 20 ppm. If possible, leach the area to help bring nitrogen levels down more rapidly.

We still have work to do to validate this test, but we encourage you to try it out, and let us know what you think. Keep in mind that the dipstick test has several limitations, including:

- It does not test for ammonium levels -- only for nitrate levels. Therefore, even If you have high ammonium levels in your soils, you will get a low reading from the dipstick.
- The test is designed to detect an excess of nitrogen, but it will not detect nitrogen deficits. To determine whether your soils are lacking in nitrogen, the soils should be sent to an analytical laboratory.

Avoiding high nitrogen levels

- Don't fertilize unhealthy turf unless you know that low nitrogen is the problem.
- To avoid a build-up of nitrogen in soil, apply fertilizers frequently at low rates, rather than infrequently at high rates.
- Base fertility programs on measurements of total plant available nitrogen from soil tests. The data is generally more reliable than data obtained from turf tissue samples.
- Slow release fertilizers, though theoretically the ideal vehicle for delivering small amounts of nitrogen continuously, can present some problems because many variables can control their rate of release. For example very hot or very wet weather can cause certain fertilizers to release the majority of their nitrogen, thus potentially raising levels high enough to cause damage. Be extra careful when using these products.
- Increase soil aeration to promote higher oxygen levels and improved nitrification in soil.