# *Nitrate Fertilization for Improved Root Health*

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Decline of turfgrass roots during the summer months is a common and serious problem throughout the West. Every year we watch turfgrass roots shorten until the greens sometimes appear to have only a thin carpet of foliage covering the soil. Although many factors influence root growth, our observations over the past few years suggest that the type of nitrogen present in the soil (nitrate vs. ammonium) may have greater effects upon root health than previously believed.

Nitrogen fertilization of golf course greens is a controversial topic. Some researchers promote the use of slow release nitrogen products applied infrequently at moderately high rates to provide a constant level of available nitrogen, while others prefer "spoon feeding", the frequent application of small amounts of nitrogen. Still others recommend acidulating fertilizers such as ammonium sulfate, which are believed to help ward off root diseases such as take-all patch of bentgrass greens and summer patch of poa greens. In other words, there are almost as many strategies for summertime nitrogen fertilization programs on greens as there are golf courses. Unfortunately, there is little consensus within the turfgrass research community on the optimum levels for soil nitrogen or an optimum composition of the key plant available nitrogen molecules, ammonium ($NH_4^+$) or nitrate ($NO_3^-$). This ***PACE Insights*** will present our thoughts on this topic, and will discuss how your choice of nitrogen sources during the summer months can either promote or interfere with root growth and root health.

**Cations and Anions**

Cations are positively charged atoms or molecules such as ammonium ($NH4^+$), calcium, magnesium, potassium, sodium, and hydrogen. Anions are negatively charged atoms or molecules such as nitrate ($NO3^-$), sulfate, bicarbonate, hydroxide and chloride. Ammonium and nitrate play a very important role in plant nutrition, with 80% of the total cations and anions taken up by plants represented by these two molecules. Because ammonium and nitrate are so important to the plant, the nature of the nitrogen acquired from the soil may have a dramatic effect upon the basic physiology of the plant. The literature indicates that when both forms of nitrogen are provided, it is easier for the plant to regulate intracellular pH and to store some nitrogen at low energy costs (Marschner, 1995). But what amounts and ratios of nitrate to ammonium are optimum for golf course turf?

**Turf vs. Crop Agriculture -- The Problem with Yields**

Unfortunately, limited research has been performed on the question of the optimum nitrate and ammonium amounts and ratios, and what research has been conducted has focused on crop plants, where high production of seeds or fruits is the farmer's goal. In contrast, for golf courses, the desired outcome is very different. We are not interested in high seed production (far from it!); instead, the ideal golf course green has slow growing, deep green foliage, resistance to wear, rapid recovery from damage, smooth and uniform surfaces, no seed production and a healthy and large root system to acquire nutrients and to resist drought. As a result of the dearth of published data that applies directly to turf, it is hard to answer the question, "what ratio of nitrate to ammonium is optimum for golf course turf?", but we're going to give it a try, based on a few key scientific publications as well as our own experiences and data base on Western turf.

**A Review of the Literature**

*Nitrate to ammonium ratios in root and seed production:* Laboratory studies have been conducted to elucidate the role of nitrate and ammonium nutrition in plants. For ryegrass, Griffith and Streeter found that a nitrate:ammonium ratio of 3:1 was the optimum ratio for promoting high levels of root and leaf soluble carbohydrates (Griffith, S.M., Streeter, D.J. 1994). They also found that production of floral tillers increased with the increase in ammonium content and the fewest tillers were produced when nitrate was the sole nitrogen source. In similar research, Sandoval-Villa et. al. found that wheat grain (seed) production was decreased when nitrogen was supplied exclusively in the form of nitrate fertilizers. When ammonium was added (to produce a nitrate to ammonium ratio of 2.5 to 1), higher grain yields were observed. Sandoval-Villa et. al. also found that root production was greatest when plants were provided nitrate as a sole source of nitrogen (Sandoval-Villa et. al., 1995). Overall, researchers have found that the highest growth rates are achieved with a mixed supply of both nitrate and ammonium (Marschner, 1995). However, when increased root mass and decreased flowering are the desired outcomes, higher nitrate levels, or nitrate as a sole source of nitrogen appears to be the optimum choice.

*Root growth and ammonium:* Ammonium nitrogen utilization by roots requires about double the oxygen, as well as increased use of carbohydrates, compared to roots supplied with nitrate nitrogen. As a result, roots of ammonium fed plants have lower levels of carbohydrates compared to nitrate fed plants. When temperatures are high and the demand for carbohydrates for root growth increases, root growth is even poorer in ammonium fed plants as a result of the low carbohydrate content of the roots. The negative effects of ammonium fertilization are more distinct in low potassium conditions. Moreover, when the soil pH is above 7, free ammonia (NH3) may be formed in the soil leading to ammonia toxicity (Marschner, 1995). What impact does this have on us in the West? We know that during the summer months, our soil temperatures are high, oxygen levels are low due to poor soil aeration and increased microbial activity, potassium is frequently low due to leaching programs to reduce soil salinity and soil pH is typically above 7. In other words, during the summer months, we meet most, if not all of the requirements for reduced root development due to accumulation of ammonium and ammonia.

*Nitrification*: Under normal aerobic soil conditions, the process known as nitrification converts ammonium into nitrate in two fast steps, thus circumventing the types of problems described above. However, the nitrification process requires oxygen and at least two genera of soil microbes (including *Nitrosomonas* and *Nitrobacter*). Unfortunately, under the low oxygen conditions and elevated pHs we see in the summer, nitrification may be slowed or stopped. As a result, the breakdown of ammonium to nitrate does not occur, and ammonium and ammonia may accumulate, causing root damage.

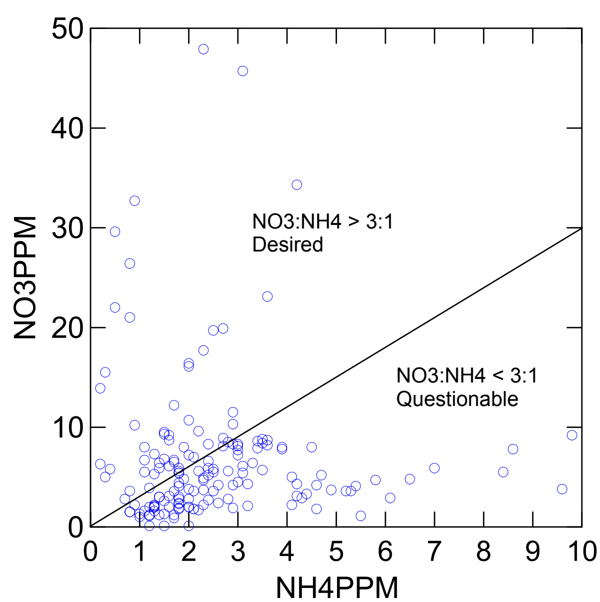
**Nitrogen Sources**

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 nitrification in the soil. The potential problems caused by ammonium generating fertilizers are two-fold. First, when plants take up the ammonium break-down product, reduced root growth can result, especially in the summer, as described above. Secondly, when the conversion of ammonium to nitrate (nitrification) is inhibited due to low oxygen, more ammonium accumulation can result. Some of the advantages and disadvantages of nitrate based fertilizers and ammonium generating fertilizers are summarized in Tables 1 and 2.

**PACE Turfgrass Research Institute (PTRI) Soil Nitrogen Survey results**

During the course of the last few years, PTRI has gathered soil nitrate and ammonium values from 160 samples collected from Western golf course greens. We have found that the average nitrate to ammonium ratio is almost 5 to 1, which jives well with the desired ratio of 3 to 1 nitrate to ammonium or higher that Griffith and Streeter have identified (see above). Our average values for the absolute amount of ammonium were 2.5 ppm and for nitrate they were 6.7 ppm. Figure 1 illustrates the ammonium and nitrate values for each sample evaluated by PTRI. Note that only a few samples report high levels of either ammonium or nitrate.

Figure 1. Relationship between soil ammonium and nitrate nitrogen for 160 individual samples from Western golf course greens. Samples were extracted with 2 M KCl and analyzed using a nitrogen Autoanalyzer by Brookside Laboratories.



**High Soil Ammonium Levels: A Red Flag?**

During 1997, we received some soil samples from turfgrasses that were severely damaged but had no apparent diseases. Some of these samples had ammonium levels greater than 10 ppm (higher than any of our 160 samples) and in other cases, nitrate:ammonium ratios were less than 1:1 (as compared to the average 5:1 ratio we saw in most samples). Although we are speculating, we believe that soil nitrification may have been hindered in these samples by high pH, low oxygen, or a combination of both. The result was therefore probably an accumulation of ammonia or ammonium that damaged plant roots, but we were not able to confirm this. In 1998, we hope to look further into this area by asking the following questions:

- Is the nitrate:ammonium ratio or accumulation of ammonium the direct cause of some turfgrass declines we see during the summer?
- If reduced nitrification by *Nitrosomonas* and *Nitrobacter* is possibly the problem, is there a method of assaying for these microbes to detect a potential problem? (Note: The nitrifying bacteria are difficult to culture and are slower growing than most bacteria that live in the soil, making the quantification of numbers and activity difficult. We are nevertheless investigating methods to assess nitrification).
- What management practices can we put in place to modify the soil environment, thus preventing ammonium accumulation and ammonia toxicity?
- Will these practices improve root health and growth during the summer?
- Would nitrate as the sole nitrogen source help prevent exhaustion of oxygen from the root zone and the negative effects of ammonium and ammonia?

**Planning for the Summer of '98**

Although preliminary, the evidence so far indicates that increased soil aeration and the use of nitrate fertilizers during the summer months may improve root health during these stressful months. While we plan to conduct research to further investigate our observations, there are some low risk changes you may want to consider as we wait for research results to be generated:

- Increase soil aeration on greens during the summer months. Hollow core aerification using 1/4 inch tines, on a monthly basis (June - November) will increase oxygen levels in the soil, thus contributing to root health, salinity management and disease management, as well as to decreasing the accumulation of ammonium.
- Try using nitrate based fertilizers as your sole source of nitrogen in a few areas that have performed poorly in past summers. 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.

Table 1. Advantages and disadvantages of ammonium generating fertilizers

| Advantages | Disadvantages |
|---|---|
| • Lowered root pH, resulting in increased availability of iron, manganese, zinc and copper | • Increased oxygen requirement by roots |
| • Low soil pH may induce the suppression of take-all patch of bentgrass and summer patch of poa greens | • Possible competition with potassium for root absorption |
| | • Increased root carbohydrate utilization |
| | • Reduced root growth |
| | • Possibility for induction of ammonia toxicity if nitrification is inhibited by low soil oxygen, high pH, or nitrification inhibitors |

Table 2. Advantages and disadvantages of nitrate fertilizers

| Advantages | Disadvantages |
|---|---|
| • Increased root growth | • Possibly elevated root zone pH may reduce availability of iron, manganese, zinc and copper |
| • Lower carbohydrate demand by roots resulting in elevated root carbohydrate levels | • May require use of chelated minor nutrients and iron to counter elevated root zone pH |
| • Reduced demand for oxygen by roots | |
| • Reduced tillering and lower seed production | |
| • Eliminates the possibility of ammonia toxicity if nitrification ceases to function | |

**References:**

Marschner, H., 1995. Mineral nutrition of higher plants. Academic Press.

Griffith, S.M., Streeter, D.J. 1994. Nitrate and ammonium nutrition in ryegrass: Changes in growth and chemical composition under hydroponic conditions. J. Plant Nutrition 17:71-81.

Sandoval-Villa, M., Alcantar-Gonzales, G., and Tirado-Tores, J.L. 1995. Use of ammonium in nutrient solutions. J. Plant Nutrition 18:1449-1457.

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