



# *Turfgrass and Environmental Research Online*

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...Using Science to Benefit Golf



Although foliar feeding is a common practice among golf course superintendents, research at the University of Illinois shows that the uptake of foliarly applied nitrogen is an inefficient process for creeping bentgrass putting greens.

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## PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 450 projects at a cost of \$31 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

### Editor

Jeff Nus, Ph.D.  
1032 Rogers Place  
Lawrence, KS 66049  
jnus@usga.org  
(785) 832-2300  
(785) 832-9265 (fax)

### Research Director

Michael P. Kenna, Ph.D.  
P.O. Box 2227  
Stillwater, OK 74076  
mkenna@usga.org  
(405) 743-3900  
(405) 743-3910 (fax)

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# Optimization of Foliar Nitrogen Nutrition to Improve Turfgrass Performance under Shade or Mowing Stress

Bruce Branham, Shelby Henning, and Richard Mulvaney

## SUMMARY

Foliar fertilization can be used to apply low amounts of nitrogen to turf. The name implies that the foliage is being fertilized, but this is an assumption. Our research examined the quantity of nitrogen actually absorbed into the turf foliage as a result of foliar applications. When applying foliar fertilizers, turf managers have the opportunity to choose the form of nitrogen to apply. Applying an ammonium fertilizer offers the potential for uptake of ammonium directly into the plant. Ammonium uptake through roots is somewhat rare since ammonium in the soil solution is rapidly converted to nitrate by heterotrophic soil microorganisms. The second part of our research project was to determine if foliar fertilization with ammonium-containing fertilizers leads to improved plant performance. Plant performance may improve if a significant amount of ammonium is taken up by plants because the plants will not have to use photosynthetic energy to convert nitrate back to ammonium. This extra energy can be used for additional growth, which is limited under low cutting heights used in golf turf management. Our results indicated that:

- Uptake by foliage from foliar-applied fertilizers is low and ranged from 14 to 37% of the applied nitrogen, depending upon environmental conditions and other factors.
- Spray volume has a significant effect on foliar uptake with higher volumes (80 to 100 gallons per acre, GPA) significantly reducing foliar uptake compared to spray volumes of 20 to 40 GPA.
- Spray adjuvants, regardless of type, improved foliar uptake compared to fertilizer applied without adjuvants.
- We were unable to measure any increases in plant performance (i.e. no increases in shoot growth, root growth, or turf quality) from foliar fertilization of creeping bentgrass putting greens compared to traditional soil fertilization.

**G**olf turf management is an exercise in managing plant stress. Grasses are put under significant stress by mowing as low as 0.1", mowing daily, and growing under less than ideal condi-

BRUCE BRANHAM, Ph.D., Professor; SHELBY HENNING, Ph.D. Candidate; Department of Crop Sciences, University of Illinois, Urbana-Champaign, IL; and RICHARD MULVANEY, Ph.D., Department of Natural Resources and Environmental Sciences, University of Illinois, Urbana-Champaign, IL.

tions (e.g. shade, traffic, etc). It is remarkable that any plant can tolerate this kind of intentional damage. But survive they do, although occasionally the combined stresses will lead to plant death, devastating disease outbreaks, or other types of plant injury.

When thinking about plant health, it is useful to consider the energy balance in plants. That is, plants take in light energy and convert it to chemical energy, that we all understand. But, for turfgrasses, energy can often be a limiting factor. For example, consider Kentucky bluegrass mowed at 6", what factors will limit its growth? Generally, water and nutrients will limit additional growth of Kentucky bluegrass under these conditions.

But let's consider a creeping bentgrass putting green mowed daily at 0.125". What limits its growth? The turf manager monitors greens daily, provides water when needed, fertilizes frequently with low doses of nitrogen, phosphorus, potassium, and micronutrients. What can these plants possibly lack? The answer is **energy**. When a plant is only allowed to have 1/8 of an



Research at the University of Illinois demonstrates that only about 10% of the foliarly applied ammonium gets absorbed by creeping bentgrass putting greens.



Foliar fertilization, applying small amount of nutrients to the foliage (leaf surface) of putting greens has become a common practice for golf course superintendents.

inch of leaf surface, and what little growth the plant can muster is mown off each day, you can readily see that what these plants lack is enough energy from photosynthesis. The lack of energy is manifested in several ways: root growth is restricted, shoot growth is diminished, and the plant lacks overall vigor. What management practices can be instituted under these conditions to improve plant performance and energy balance?

### **Nitrogen Energy Dynamics**

Nitrogen is the mineral element used in the greatest amount by plants. On a dry weight basis, nitrogen content can range from 2-5%. While other nutritional elements are important, none are used in the quantity of nitrogen. A complicating factor when discussing nitrogen is its frequent transformations in soil and plants. Nitrogen is a very labile element that can be utilized by bacteria and converted into a number of different compounds.

A key nitrogen transformation in soil is the

conversion of ammonium ion,  $\text{NH}_4^+$ , to nitrate,  $\text{NO}_3^-$ . The oxidation of ammonium generates energy for bacteria, in essence, this is their food supply. The waste product of this process is nitrate. One can readily see the similarity between this process and the oxidation of reduced carbon [carbohydrate ( $\text{CH}_2\text{R}_2$ ) to oxidized carbon ( $\text{CO}_2$ )]. Both steps yield energy from the process and leave an energy-depleted substrate (nitrate or carbon dioxide), molecules that require energy inputs to again be useful in biological processes.

Plants take up nitrate not because they want to, but because they are beaten to the ammonium by bacteria. In order to be useful in plant biochemistry, nitrate must be reduced to ammoniacal N for incorporation into amino acids, proteins, enzymes, etc. How much energy does this process require? Estimates in the literature go as high as 20% of plant energy is used in the process of reducing nitrate to ammonium (6). If this number is accurate, then a significant portion of plant energy could be saved for other purposes if a way

could be found for plants to take up ammonium instead of nitrate.

Root uptake of ammonium instead of nitrate by roots is problematic since soil bacteria are present in vast numbers and ammonium is their food. Several commercial products have been developed to inhibit the breakdown of fertilizer urea, and these are the basis of products by Agrotain (Uflexx and Umax) and Nutrisphere. In addition, Dow AgroSciences has marketed N-Serve (common name – dicyandiamide or DCD) for application with anhydrous ammonia for many years. However, the effects of these products are transient, so they generally have to be applied concurrently with each nitrogen application in order to have any effect. Finally, it is difficult to determine how effective these products are because it is very challenging for plant scientists to measure plant uptake of ammonium versus nitrate. However, it is not trivial to discern whether the nitrogen in a plant comes from nitrate or ammonium.

One way to get ammonium directly into the plant is to bypass the root system altogether and apply ammonium directly to the leaf surface. This approach, termed foliar feeding, has become the preferred way to fertilize at low rates of N application. When granules are applied at low rates of N application, say less than 0.75 lbs N per 1000 ft<sup>2</sup>, the spotty distribution of granules often leads to a green-speckled turf. Spraying N gives a much more uniform response at these lower N application rates. Spraying N also provides turf managers a chance to get a significant amount of the applied N absorbed directly by the leaf. However, leaves are not necessarily absorbing organs like roots, so getting the applied N to be absorbed by the leaf may be more difficult than simply spraying the turf with liquid N.

## **Our Research**

To determine if foliar feeding results in energy savings for plants, we conducted two experiments. The first set of experiments was designed to optimize foliar N uptake by turfgrasses. That is, what factors can be managed to max-

imize foliar N uptake? Once those factors were determined, we compared foliar N nutrition to root applications of N at three different cutting heights. We used cutting heights as a factor for energy stress. The lower the height, the more the turf will benefit from any extra energy derived from foliar feeding of N.

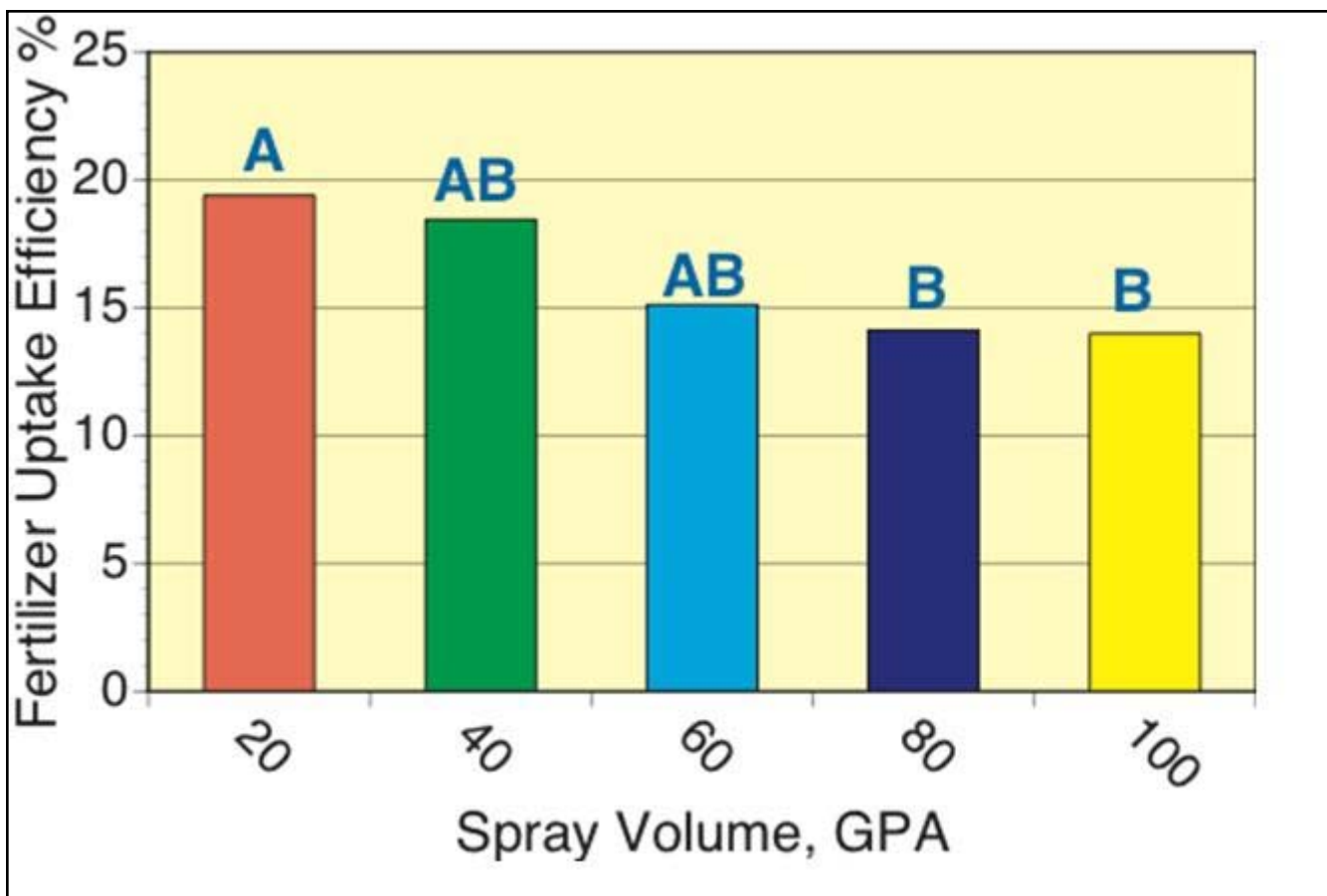
What did we learn? Our foliar feeding trials compared three different nitrogen sources: urea, ammonium sulfate, and calcium nitrate. These are all soluble N sources that can be dissolved in water and sprayed on the turf. The nitrogen in these trials was labeled with <sup>15</sup>N, a method that allows us to distinguish fertilizer-nitrogen from soil-derived nitrogen in plants.

Urea was applied at various spray volumes using an even flat fan spray nozzle. The results showed that the lower the spray volume, the more urea was recovered inside the leaf (Figure 1). Higher spray volumes, 80-100 gallons per acre (GPA), resulted in nearly 25% less uptake than was observed with lower spray volumes (20 GPA). The take-home message is simple - using lower spray volumes results in higher levels of foliar N uptake, presumably by increasing spray retention on the leaf surface.

An important point to note is the relatively low level of foliar uptake. Even at 20 GPA, less than 20 % of the applied urea was taken into the leaf. Much of the urea remains on the leaf surface and can be washed onto the soil/thatch with irrigation and rainfall. One can also see the value of returning clippings since a portion of the applied N is undoubtedly removed by mowing.

## **The Effect of Foliar Nitrogen Nutrition on Putting Green Performance**

The next step in our research project was to determine whether foliar N nutrition, that is, applying ammoniacal forms of N directly to the leaf for uptake, could increase turfgrass performance. Again, our thinking was to use decreasing mowing heights as a means of imposing energy stress on the bentgrass. If our hypothesis is correct, we should see better turf quality from the foliarly fed turf, with this improvement in quality



**Figure 1.** Effect of various spray gallonages (GPA, gallons per acre) on foliar uptake of urea into turfgrass leaf tissue.

becoming more apparent at lower heights of cut.

We maintained ‘L-93’ creeping bentgrass at heights of 0.125”, 0.110”, and 0.095”. The fertility treatments were (1) no nitrogen (control), (2) 0.1 lbs N/1,000 ft<sup>2</sup>/wk as a foliar spray, and (3) the same foliar spray rate but followed immediately with irrigation applied with a hand-held nozzle (to serve as a soil application). Additionally, to further assess whether application of ammoniacal-N results in significant energy savings over that of nitrate-N, we applied nitrogen as urea or calcium nitrate.

We monitored visual turf quality, clipping weights, and root mass for a two-year period. And despite our hopes, we saw no statistically significant differences. Upon some reflection, this may not be unexpected. First, there have been a number of studies of fertilizer uptake by turfgrasses (2, 3, 4, 5, 7). If the studies are done with <sup>15</sup>N-labeled fertilizer, the only way to accurately measure fertilizer usage, most of these studies have

shown that about 1/3 of the nitrogen recovered within the turf comes from the applied fertilizer (1, 4, 7). The bulk (2/3) of the nitrogen used by plants comes from the soil. This is a fact ignored by many turf managers, fertilizer salesmen, and others who work with plants. The soil is the key supplier of nutrients, and what nutrients we add supplements the soil.

In addition, our foliar uptake work indicates that only about 1/3 of the foliarly-applied N gets absorbed by the leaf. The rest of the applied N stays on the leaf surface or reaches the soil/thatch surface where microbes will transform it. So, by these calculations (1/3 from fertilizer x 1/3 efficiency) only a little more than 10 % of the N in the plant might come from foliar absorption. The potential energy savings are not so great when such a small fraction of the N in the plant is coming from foliar uptake.

Foliar N fertilization may be more effective on sandy, USGA-type rootzones. Our trial

was conducted on a native soil green, which has plenty of N-supplying power. Sandy soils, particularly new putting greens, have significantly less ability to supply N, and the fraction of N coming from foliar feeding could be higher under these conditions. However, as these greens age, sandy soils increase in organic matter and become more fertile and capable of supplying a higher level of N. To save plant energy by utilizing ammonium over nitrate, a significant portion of the nitrogen supplied to the turf must come from foliarly applied N. But the problem, as demonstrated in our foliar uptake studies, is that well under 50 % of the foliarly applied N actually gets into the plants. This should not be surprising, as the leaf is not the main absorbing organ of a plant.

We also studied the effects of adjuvants and tank-mixing on the uptake of nitrogen into plants, and while there was some improvement in uptake, it was not dramatic. We examined the effects of four different adjuvant products, each representing a common adjuvant class, on the absorption of applied nitrogen by the foliage. All of the adjuvants increased N uptake compared to urea applied without adjuvants, but none of the adjuvants were significantly better than the others (data not shown).

Environmental conditions also can affect foliar N uptake. As long as the spray droplet remains liquid on the leaf surface, foliar uptake can continue. Once the droplet dries, uptake slows significantly. Thus, applications made early in the morning under humid conditions will achieve better foliar uptake than applications made at mid-day. Applications made in arid climates, like most of the western U.S., will see limited foliar uptake because drying is so rapid.

While the idea of improving plant energy status through foliar feeding with ammonium is biochemically valid, the practical limitations imposed by nature make it difficult for turf managers to achieve significant benefits with this approach. Future research should examine ways to improve the foliar and root uptake of ammonium.

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